Feasibility Study on the Cellulosic Ethanol Market Potential in Belize

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The Organization of American States (OAS) is a multi-national institution that via its Department of Sustainable Development (DSD), Energy and Climate Change Division, in collaboration with the industry, academia, and NGOs, assists OAS Member States to advance sustainable energy in the Americas. This Belize Cellulosic Ethanol Project is part of the effort to facilitate the transition of the Latin American and Caribbean region's energy mix to increased sustainable use of renewable and abundant biomass resources for the production of cost competitive high performance biofuels, bioproducts and biopower.

In 2008, the government of Canada through its Department of Foreign Affairs and International Trade (DFAIT) requested the assistance of the OAS/DSD to address the goal to reduce gasoline consumption through efficiency and adoption of alternative fuels in the Latin American and Caribbean region. This assessment is a response to this request and is prepared by the OAS/DSD Energy and Climate Change Division under supervision of Mark Lambrides (Chief of the Energy and Climate Change Division) to indentify market challenges and further develop opportunities for cellulosic ethanol market penetration in the transport sector of Belize.

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Abbreviations

ABNT	Abengoa Bioenergy New Technologies, Inc.
BDT	Bone Dry Ton
BEJ	Bio Ethanol Japan
BEL	Belize Electricity Limited
BIOCARD	Global Process to Improve Cynara cardunculus Exploitation for Energy Applications
BSI	Belize Sugar Industries
Bu	Bushels
CAFTA	Central American Free Trade Agreement
Caricom	Caribbean Community
CBI	Caribbean Basin Initiative
CE	Cellulosic Ethanol
CIDAUT	Spanish Center for Automotive Research and Development
Cm	Centimeter
CO_2	Carbon Dioxide
DFAIT	Canadian Department of Foreign Affairs and International Trade
DOE	U.S. Department of Energy
DSO	Department of Sustainable Development
DT	Dry Ton
DWB	Dead Wood Biomass
E.U.	European Union
EIA	Environmental Impact Assessment
EISA	Energy Independence and Security Act
EPA	Economic Partnership Agreement
Etho	Ethanol
FAO	UN Food and Agricultural Organization
GHG	Green House Gases
GM	General Motors
GST	Goods and Services Tax
ha	Hectares
METI	Japan Ministry of Economy, Trade and Industry
MMT	Million Metric Ton
MSW	Municipal Solid Waste
MTBE	Methyl Tertiary-Butyl Ether
MW	Megawatt
NILE	New Improvements for Lignocellulosic Ethanol
NOx	Nitrogen Oxide
NREL	U.S. National Renewable Energy Laboratory
OAS	Organization of American States
PSI	Pounds per square inch
R&D	Research and Development
RD&D	Research, Development, and Deployment
RDD	Revenue Replacement Duty
RFG	Reformulated Gasoline
RVP	Reid Vapor Pressure
U.S.	United States
UNFCCC	United National Framework Convention on Climate Change
USD	United States Dollars
USDA	U.S. Department of Agriculture
VEETEC	Volumetric Ethanol Excise Tax Credit
VOC	Volatile Organics

Executive Summary

Background

The Canadian Department of Foreign Affairs and International Trade (DFAIT) commissioned this study to evaluate the near-term potential for the development of a cellulosic ethanol (CE) market in Belize. The principle objective of this study is to assess the potential for the development of cellulosic ethanol based on the available biomass feedstocks, considering their likely costs and the related transportation and infrastructure requirements for their use. Further, the study reviews the status of suitable technologies that may be deployed for the conversion of biomass to ethanol via cellulosic processes in an effort to determine the likely costs of ethanol when such technologies become readily available.

At present, most commercially available ethanol is produced by fermenting plant derived sugars. These sugars are typically derived from sugarcane, corn, wheat, sweet sorghum, and sugar beats. Their use presents several challenges including the fact that these feedstocks are also used as foods. Also, extracting the sugars for use in the fermentation process requires considerable inputs and, therefore, is relatively expensive. Alternatively, second generation biomass conversion technologies, including cellulosic ethanol, proposes to utilize agricultural, forestry, and municipal wastes, as well as dedicated feedstocks that do not compete with food products as feedstocks for conversion to ethanol.

This study considers a variety of potential cellulosic biomass feedstocks that are widely present in Belize including those originating as residues or waste from activities within the agricultural, forestry and waste management sectors. It also describes a number of likely obstacles that may affect the potential development of cellulosic ethanol production in Belize and it addresses possible strategies to overcome these obstacles through public policy initiatives market development tools. A primary goal of this study is to characterize the likely potential for cellulosic ethanol production and to provide broad recommendations for enabling this market in Belize.

Methodology

An expert team comprised of OAS staff and consultants was assembled to conduct this analysis. The primary activities completed to generate this report included extensive technical research (desk study) into the available cellulosic technologies and their feedstock requirements, field research conducted on a mission to Belize, and consultations with key energy and agricultural sector stakeholders conducted in Belize and by telephone interview from OAS headquarters in Washington, DC. The initial findings as presented in this draft report will be presented in a stakeholder consultation in Belize on the occasion of the project's second field mission, and the findings will be refined/modified based on feedback from local experts.

To ensure that cellulosic ethanol would be produced in a sustainable manner for the long-term, the OAS assessment was based on the "5E" evaluation approach (Schuetzle, 2007). This methodology was developed and applied specifically to evaluate the potential viability of different technologies and approaches for the production of cellulosic ethanol. The components of this 5E assessment methodology are: E1 – validation of technical performance and stage of development; E2 – estimation of energy efficiency; E3 – environmental impact assessment; E4 – economic analysis; and E5 – appraisal of socio-political effectiveness. Results of the 5E assessment are provided generically for bio- and thermo-chemical technology categories where available data was found to be adequate to perform such an assessment. The report's recommendations include further study needs in those cases where sufficient data are unavailable.

Assessment
According to the findings presented in the first draft report, ethanol is a clean-burning, renewable and biodegradable fuel that may be produced from biomass resources in nearly every region of Belize. Its widespread timber and agricultural industries generate substantial quantities of biomass residues and by-products, which, together with municipal solid waste (MSW), offer the potential for a significant biomass production industry in Belize.

Our research indicates that Belize has an abundance of cellulose feedstocks, which could potentially be used for ethanol production. Preliminary results from the resource assessment completed as part of this study indicate that more than 1.3 million tons of cellulose feedstocks were produced in 2004 and a similar amount in 2005. If it were possible to economically collect and use all of the available materials, Belize would have the potential to produce in the range of 85.6 – 89.6 million gallons per year from cellulosic biomass feedstocks when considering the application of thermo-chemical and biochemical conversion processes. However, there are a number of technical and economic factors, described herein, that affect the economics and sustainability of biomass collection and use that reduce the overall availability of the feedstocks.

In spite of Belize’s large forested areas (near to 79 percent of the total land is covered by natural vegetation), the most readily available biomass feedstocks are agricultural residues. Agricultural residues comprise about 81 percent of the total resources, followed by municipal solid waste at 12 percent and forest residues at 7 percent. The feedstocks were reviewed for current market demand, cost, collection potential, qualities and geographic concentrations.

Industry experts predict that commercially competitive, readily available cellulosic ethanol conversion technologies will be available at a scale appropriate for Belize around the year 2012. Included in this study is a complete description and quantitative assessment of several potential cellulosic feedstocks in Belize along with a calculation of the potential ethanol yields based on the emerging technologies (biochemical and thermo-chemical). The study applies critical sustainability criteria for the use of key feedstocks.

At present there are no ethanol production facilities in Belize. As such there is no policy framework to treat the potential industry for its production and use. It is recommended that a comprehensive ethanol production and consumption law and implementing regulations be developed in anticipation of this emerging market.

While Belize’s forest, agricultural residues and MSW have the potential to be used for ethanol production, near-term economic feasibility depends largely on what happens to the price of gasoline and the potential demand for ethanol. In addition, proof of economic viability of the cellulose-to-ethanol technology in a successful commercial facility would substantially improve the position for the development of cellulose-ethanol production in Belize and other countries in the region.

Recent technical publications indicate that the current cost of producing ethanol from cellulosic biomass ranges from US$ 1.85 to 2.65 per gallon. However, advances in feedstock processing and biotechnology could reduce cellulose-ethanol costs to US$ 0.74 – 1.07 per gallon by 2012. The comparable prices for gasoline depend largely on the prevalent price of oil on the international markets. With considerable variations in oil prices over the past four years, the gasoline price (at the port; without taxes; all grades average) has been US$ 1.10 to 1.35 in April 1998, US$ 2.00 to 2.55 in April 2005, US$ 2.82 to 3.08 in April 2008 and US$ 1.80 to 1.95 in October 2008. In addition to the base price for gasoline, the government of Belize added taxes and other fees to its price before it is sole to the public. As a result, the final price at the pump in April of 2008 ranged from US$ 5.06 – 5.22 per gallon. It will be up to the government to determine whether ethanol produced locally pays similar taxes. If it is exempted this may make ethanol more competitive vis-à-vis gasoline at a wider range of prices. For the purposes of this study the prevailing price of gasoline per gallon on the international markets shall be most relevant for comparison.

Conclusions

The broad conclusion of this assessment suggests that Belize has the potential to be an attractive market for the development and use of ethanol derived from second generation, cellulosic ethanol production processes. There are many benefits that may be derived for a country like Belize in the development of a local cellulosic ethanol production industry. These benefits, further outlined in this report, include:

- Creates value in the use of waste and residues
- Addresses local and global environmental challenges
- Creates new employment opportunities
- Enhances local energy resource base
- Attracts international financial investments

However, the fact remains that the technology for cellulosic ethanol production is pre-commercial, and a number of additional factors limit its near-term deployment. These obstacles include the absence of a suitable biofuels policy, the absence of an overall energy policy, and the lack of experience in Belize with the development and use of ethanol due to the fact that there is no domestic production at this time.

Based on our assessment, it is concluded that the thermo-chemical conversion technology has the best potential for cellulosic ethanol production in Belize. This conclusion is based on the type and quantity of feedstocks found in Belize and the current cost of this technology, expecting in the near future (2012) further reductions in cost.

In reviewing the likely conversion technologies, the study indicates that biochemical conversion processes that utilize enzymatic hydrolysis of lignocelluloses, followed by fermentation of the simple sugars, would currently have the potential for producing ethanol in Belize at approximately US$1.96 - $2.89 per gallon. In the case of such an approach, the amount of feedstock for a typical plant exceeds the current amount of feedstock available in Belize (over 2000 dry tons/day). Based on this information, a biochemical approach appears most applicable where large volumes of a biomass feedstock of consistent quality are available. Examples include current corn and sugarcane ethanol and where conventional ethanol facilities already exist and using biochemical technologies.

However, the assessment indicates that current state-of-the-art thermo-chemical technology will be capable of producing ethanol from the cellulosic biomass of Belize using 1,400-1,700 dry tons (DT) per day of biomass at a production cost of about US$0.34 – 0.87 per gallon and the ethanol cost based on cellulosic feedstock is approximately US$1.64 – $2.17 per gallon in the near term with further cost reductions of US$0.15 – 1.14 per gallon expected as the technology matures by 2012 and beyond.

The OAS assessment team applied the relevant sustainability criteria to the possible scenario wherein agricultural, timber, and municipal wastes were utilized in a thermo-chemical processing plant to create ethanol. Based on our initial assessment it is estimated that approximately 46 million gallons of ethanol could be produced annually given the state of the technology today.

With expected technological improvements, that number may increase to 72 million gallons per year.

Belize currently consumes about 12.5 million gallons of gasoline per year for transportation. Thus, if one assumes that ethanol is blended with gasoline at 10%, approximately 1.2 million gallons would be required per year. Even if flex fuel vehicles replaced the entire vehicle fleet, no more than 12 million gallons of ethanol would be required locally. Therefore, it is clear that Belize has the potential to meet all of its domestic demand for ethanol and export considerably more than this amount, based on its available feedstocks for cellulosic ethanol production. The competitiveness of such development will depend on the continued improvements in production technology and the prevailing price of gasoline. But, even at today's relatively low cost of gasoline (US$1.80 to 1.95/gallon) and the immature status of the technology (producing ethanol at US$1.64 to 2.17/gallon) cellulosic ethanol offers great promise for production in Belize.

This report highlights significant potential for Belize to develop cellulosic ethanol from a variety of feedstocks at such time as the technology becomes commercially available. Despite the fact that the commercial opportunity for cellulosic ethanol may be three to five years away this does not suggest that there is no need to begin, immediately, efforts that will create the pathway for its development. A number of suggestions have been outlined in the conclusion to this report (Chapter 9) that describe the interventions that may be considered by the Government of Belize to accelerate the transition to a more sustainable energy future, that is inclusive of ethanol – including second generation ethanol as it becomes available.

1 Introduction

1.1 Background

Cellulosic ethanol is increasingly being recognized by the global community as one of the great promises and alternatives for the sustainable production of ethanol. Cellulosic ethanol can be used to reduce a nation's dependency on volatile imported fossil fuels and bring about socio-economic development with reduced negative impact to the environment and reduced contribution to climate change.

The critical difference of this technology to the currently established biomass-to-fuel systems, as for instance the corn-based ethanol production system, is that cellulosic ethanol can be produced from a wide variety of biomass waste feedstocks. These include agricultural plant wastes (e.g. corn stover, cereal straws, and sugarcane bagasse), forest industry wastes, organic wastes from industrial processes (e.g. sawdust and paper pulp), the organic fraction of municipal solid and liquid waste and a wider range of alternative energy crops (non-food crops) grown specifically for fuel production, such as switchgrass.[1]

Belize (Annex 11.1) its location in the sub-tropics with a large forestry sector, adequate climate and soil conditions and available cultivable lands allow for both sustainable forestry and agricultural development to satisfy food demand and the sustainable production of renewable biofuels. Large amounts of waste that are produced by these sectors are given added value as feedstock when using cellulosic ethanol production systems. Feedstock is not limited to these wastes from these sectors; also the municipal solid and liquid waste generated in the high density urban areas is of interest.

As per 2007, Belize imported about 71% of its primary energy to cover the power and transport sector energy demand.[2, 3] All of the imported transport fuel consists of fossil origin. And as many other countries in the world, Belize has been confronted with the rise and increased volatility of international fossil fuel prices. This is putting considerable pressure on the economy and ultimately the purchasing power of the 300,000 inhabitants of Belize.[4] Having a small population and an economy that relies heavily on international trade require Belize to improve the security of energy supply by developing indigenous renewable energy.[5,6]

Within the agricultural sector, the only significant renewable energy initiative being implemented for the development of agro-energy in Belize is the launch of a project under the cooperation of the Belize Sugar Industries Ltd (BSI) and BEL (Belize Electricity Limited) to establish a 25 MW co-generation power plant by 2009. That plant will use bagasse to generate excess electricity to sell to the national grid. The project is expected to reduce electricity imports from Mexico by at least 50%.

The transport sector on the other hand is coping with continuously increasing retail prices of gasoline at the pump. In 2001, the vehicle fleet consisted of approximately 40,000 units[7] and consumed

[1] Greer, Diane. 2005. "Creating Cellulosic Ethanol: Spinning Straw into Fuel." BioCycle.; source: Greer, Diane. 2005. "Creating Cellulosic Ethanol: Spinning Straw into Fuel." BioCycle.
[2] Energy for Sustainable Development Toward a National Energy Strategy for Belize Energy Sector Diagnostic, prepared by: Launchpad Consulting Belize, C.A in collaboration with Dr. Ivan Azurdia-Bravo, Fundación Solar, Guatemala. For Formulation of a National Energy Plan; November 5, 2003.
[3] Energy Information Administration (EIA), International Energy Annual http://tonto.eia.doe.gov/country/country_energy_data.cfm?fips=BH; visited 15 June 2008.
[4] Ibid 2.
[5] Central Statistical Office, "2005 Labor Force Survey." (Belmopan: Ministry of National Development, 2005).
[6] Small Island Developing States Network, "Who are the SIDS." UN DESA, 2003, 28 Mar. 2008 <http://www.sidsnet.org/2.html>.
[7] Launchpad Consulting Belize, CA & Azurdia I. (2003). Energy Sustainable Development Toward a National Energy Strategy for Belize Energy Sector Diagnostic, Public Utilities Commission of Belize

approximately 24.4 million gallons of gasoline in 2002.[8] Belize imported US$ 26 million in transportation fuel during 2002 when oil prices hovered between US$ 20-30 per barrel.[9] As of October 2008, the price of the gasoline at the pump in Belize was approximately US$ 5 per gallon for super and regular gas. This price is among the highest in the Caribbean region.

1.2 Why cellulosic ethanol?

The difference between cellulosic ethanol (CE) and corn- and sugarcane-based ethanol systems lies in the type of feedstock used and the process applied to produce the ethanol. Although cellulosic ethanol is currently more expensive to produce compared to corn or sugarcane ethanol, the cellulosic ethanol process is based on two critically different premises with great improvement potential.

First, cellulosic biomass feedstock (organic waste or residue) is in principal considerably lower in cost since it is a waste product. Nevertheless, the final cost for the cellulosic biomass feedstock depends on the critical mass and its collection and transportation costs, but plenty of room is available for improvements and increased cost-effectiveness. The second premise is that there is a great potential to reduce the conversion cost within the cellulosic ethanol production process that relies in part on enzymes and bacteria. At the international level, significant resources are being injected into research and development (R&D) programs supporting synthetic biology research to improve the cellulosic ethanol process.[10, 11] According to experts in the field, the evolution of this technology will benefit the final prices of cellulosic ethanol, becoming more and more accessible and cost-competitive.

The net energy balance for the cellulosic ethanol system has the potential to be five times better compared with the corn-based ethanol system.[12] Another advantage over corn- and sugarcane-based ethanol is that production of a perennial cellulosic biomass crop such as switchgrass, requires lower inputs of energy, fertilizer, pesticide, and herbicide -- which reduces erosion and improves soil fertility.[13,14]

The cellulosic ethanol system is in essence an upgrade of existing biomass-to-ethanol systems, and therefore it is necessary to mention that the ethanol produced from corn[15], sugar cane and cellulosic biomass have identical chemical composition. The ethanol is mainly used to replace either methyl tertiary-butyl ether (MTBE)[16] or other additives and as replacement to gasoline. Therefore it is important to highlight the comparative advantages of using ethanol as replacement for gasoline. Table 1.1 summarizes some of the key advantages of ethanol compared to gasoline.

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[8] Ibid.

[9] U.S. Energy Information Administration, EIA website: http://tonto.eia.doe.gov/dnav/pet/hist/wtotworldw.htm (visited November 2008)

[10] An Introduction to Synthetic Biology, January 2007, ETC Group; www.etcgroup.org/upload/publication/pdf_file/602

[11] The Berkeley Daily Planet; http://www.berkeleydailyplanet.com/issue/2007-02-06/article/26282?headline=News-Analysis-UC-s-Biotech-Benefactors-&status=301

[12] Demain A., Newcomb M. , Wu D. (March 2005). "Cellulase, Clostridia, and Ethanol. Microbiology". Molecular Biology Reviews (69): 124–154.

[13] The numbers behind ethanol, cellulosic ethanol, and biodiesel in the U.S.; By Maywa Montenegro 04 Dec 2006; http://grist.org/news/maindish/2006/12/04/montenegro/

[14] Creating Cellulosic Ethanol: Spinning Straw into Fuel; by Diane Greer, April, 2005; http://www.harvestcleanenergy.org/enews/enews_0505/enews_0505_Cellulosic_Ethanol.htm

[15] "corn" here concerns corn kernels, which are currently used for ethanol production and represent about half the above-ground dry matter of a corn plant at harvest time

[16] Eliminating MTBE in Gasoline in 2006, energy information administration, 2006; http://www.eia.doe.gov/pub/oil_gas/petroleum/feature_articles/2006/mtbe2006/mtbe2006.pdf

Table 1.1 Ethanol advantages to gasoline as transport fuel[17,18,19]

Factor	Description
Octane	Although the octane (RON) of pure ethanol is only 112, ethanol exhibits a much higher blending octane value – in the range of 130-132 RON (~115 (R+M)/2). Higher octane gives more power to vehicles.
Vapor pressure	The Reid Vapor Pressure (RVP) of pure ethanol is not particularly high – about 2.4 psi, but the blended RVP is much higher – about 18 to 22 RVP, depending on volume of ethanol blended[20]
Oxygen content	35% of ethanol's weight is oxygen (C_2H_6O), which enables the complete combustion of compounds such as carbon monoxide and volatile organics (VOCs), resulting in lower emissions of these compounds
Fuel economy	Although ethanol has 35% lower energy content per liter than gasoline, the more complete combustion of abovementioned compounds combined with other combustion effects results in a much lower reduction in fuel efficiency than anticipated by the differential in energy content; this lower reduction in fuel efficiency has been observed to be more pronounced in older vehicles
Material compatibility	Some materials used in fuel systems, such as elastomers used to make hoses and valves, tend to degrade over time. Some older elastomers were found to deteriorate more rapidly in the presence of aromatics (found in higher concentrations in unleaded gasoline) and alcohols. However, since the early-1980s, all vehicles have used materials that are specifically designed to handle all modern gasoline, including ethanol/gasoline blends
Exhaust emissions	Ethanol/gasoline blends reduce CO_2, VOC, and particulate emissions; although Nitrogen Oxide (NO_x) emissions may increase depending on the vehicle and the driving conditions. Ethanol reduces particulate emissions, especially fine particulates that pose a health threat to individuals suffering from respiratory ailments
Greenhouse gas emissions (GHG)	Considering the full crop production and fuel consumption cycle there is a net reduction in carbon dioxide emission compared to gasoline lifecycle

An important environmental consideration when promoting renewable fuels is the greenhouse gas (GHG) emissions reduction potential to mitigate global climate change. The production and utilization of a short-cycle non-food crop derived biomass removes, in theory, the same amount of CO_2 from the atmosphere that is returned upon conversion and utilization, given that crop and land use remains the same. By using biomass or organic waste as feedstock for cellulosic ethanol production there is great

[17] http://www.drivingethanol.org/motorsports/racing_fuel_characteristics.aspx
[18] Alcohol fueled Vehicles & Flex Fuel Vehicles, presentation by Henry Joseph Jr. http://www.unfoundation.org/files/misc/biofuels_presentations/Joseph%20Session%205%20FINAL.pps#256,1,Alcohol Fueled Vehicles & Flex Fuel Vehicles
[19] Ethanol Motor Fuel Storage Overview, Program letter Revised September 2005 http://commerce.wi.gov/ERpdf/bst/ProgramLetters_PL/ER-BST-PL-EthanolMotorFuelStorageOverview.pdf
[20] Note: Ethanol exhibits a high vapor pressure when blended with the hydrocarbons of gasoline. The RVP impact of the ethanol is quite non-linear. RVP rises by about 7kPa with 3-10vol% of ethanol blending; this phenomenon is due to decline in strength of hydrogen bond and azeotrope effect. (Source: http://www.pecj.or.jp/japanese/division/division09/asia_symp_5th/pdf_5th/16-HaruyaTanaka.pdf)

potential to curb greenhouse gas emissions originating from landfills or open dumps, thereby lowering net emissions.

The extent to which this ideal of a sustainable carbon cycle (with zero net greenhouse gas emissions) is achieved for both crop residues or biomass waste scenarios depends on the fossil energy inputs in the feedstock cultivation or production, the harvesting or collection, the conversion or production, the delivery or distribution and the utilization cycle of ethanol (also known as the well-to-wheel cycle analysis). Any processes currently used to produce cellulosic ethanol require some level of fossil fuel use and generate GHG emissions. Thus, use of cellulosic ethanol to displace gasoline does not result in a 100% reduction of GHG emissions.

Nevertheless, the GHG emission reductions potential by corn- and cellulosic ethanol relative to reformulated gasoline (RFG)[21] (on a well-to-wheels basis) is higher.[22] Figure 1.1 shows that between corn- and cellulosic ethanol use –in either E10 or E85 blends- there is a clear differential in GHG emissions reduction potential. For cellulosic ethanol, the use of a gallon helps to reduce GHG emissions by more than 85% relative to GHG emissions from use of RFG.

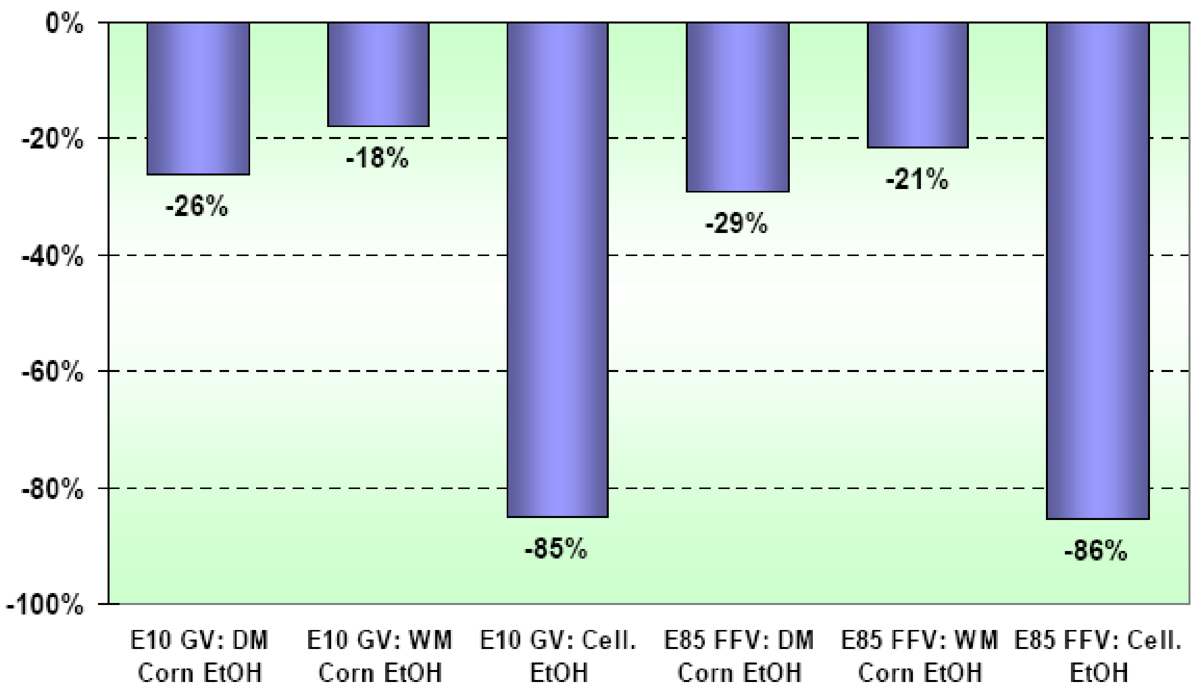

Figure 1.1 GHG emissions reductions per gallon of ethanol to displace an energy-equivalent amount of reformulated gasoline[23]

Another important factor to consider is the energy balance. This is defined as the energy content of a unit of fuel product minus the (fossil) energy inputs used to make it. According to this, calculations of fossil energy inputs include all key activities used in the production of the energy product (a well-to-wheel analysis). This energy content evaluation was calculated for cellulosic ethanol, corn ethanol, coal and gasoline by the Argonne National Laboratory and is depicted in Figure 1.2. Of the four energy carriers,

[21] Reformulated gasoline (known as "RFG") is gas blended to burn cleaner by reducing smog-forming and toxic pollutants in the air we breathe. The Clean Air Act requires that RFG be used in cities with the worst smog pollution to reduce harmful emissions that cause ground-level ozone.
[22] Wang M. (2005). Updated Energy and Greenhouse Gas Emission Results of Fuel Ethanol. The 15th International Symposium on Alcohol Fuels, September 26-28, 2005, San Diego. USA. Retrieved on September 2008; http://www.eri.ucr.edu/ISAFXVCD/ISAFXVAF/UGEEERF.pdf
[23] Estimated used GREEK, http://www.transportation.anl.gov/modeling_simulation/GREET/greet_1-8b_beta.html

only cellulosic and corn ethanol have positive energy balances, because both fuels depend on direct solar energy that produces short-cycle feedstocks for ethanol production. But the huge positive energy balance for CE is due to the small amount of fertilizer used during farming of grasses and trees. Cellulosic biomass feedstock (if compared with corn) has a better balance between energy production and internal energy use.

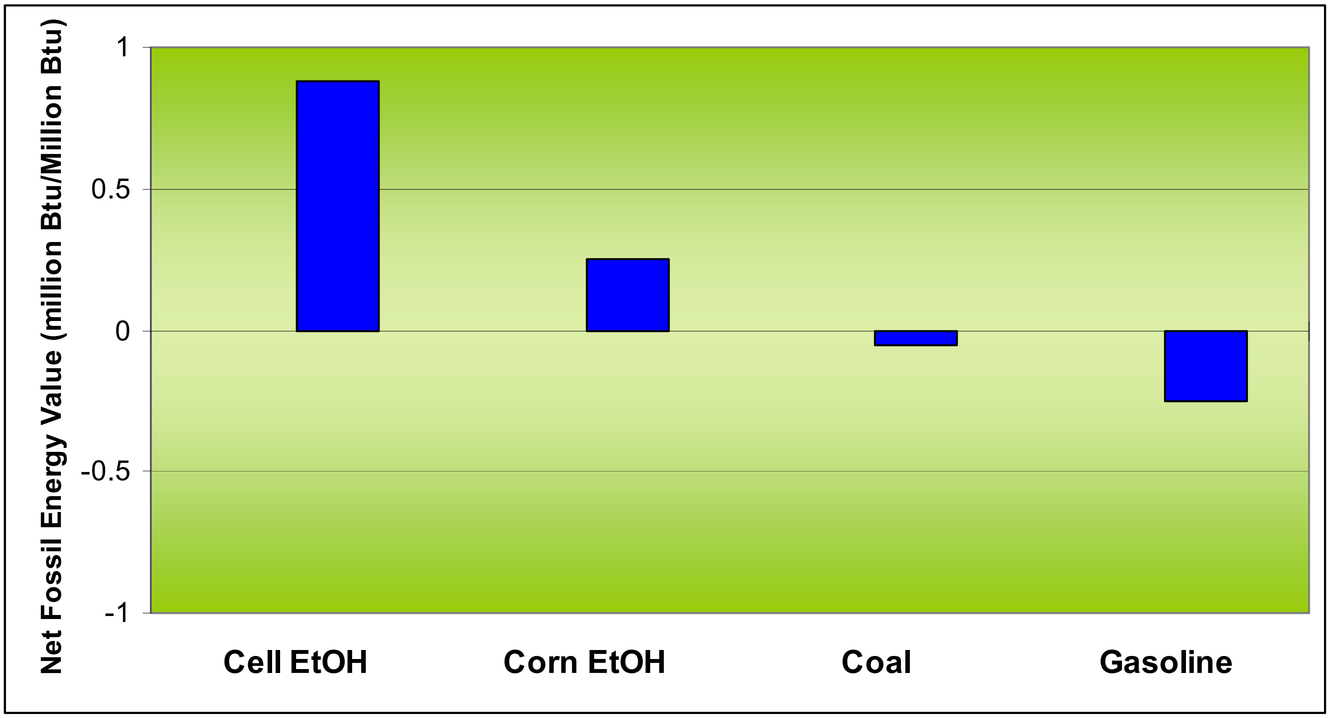

Figure 1.2 Quantitative synthesis comparisons in net fossil fuel energy of four principal energy carriers[24]

The results show that CE has a high energy output ratio and that high levels of GHG emission reduction can be reached. This amounts to similar reductions when compared with sugarcane based ethanol, using the same assumptions. In brief, cellulosic ethanol is seen as the optimal alternative that can replace a significant portion of the current gasoline consumption, diminish the dependency on imported fuels and reduce greenhouse gas emissions generated by the transport sector of Belize.

Being a novel and emerging technology, it is understandable that concerns are raised when considering cellulosic ethanol introduction and use in Belize. Its market potential is highly dependent on the price of the ethanol, the regulatory framework in place and the competitive environment. Therefore it is essential to assess the feedstock availability, technology development pathway, costs for the short- and medium term, and its accessibility for implementation in Belize. Also it is important to identify challenges to CE development in the context of Belize and recommend solutions to enable the optimal extraction of the benefits it offers for sustainable development. The results of this study will enable decision-makers in Belize to asses the potential for implementing CE, once the technology is mature or commercially available within the next five years, according to the leading cellulosic ethanol companies and research institutes such as NREL.[25,26,27,28]

[24] Estimated using GREEK, http://www.transportation.anl.gov/modeling_simulation/GREET/greet_1-8b_beta.html
[25] Moresco J. (2008) Cellulosic Ethanol: In Search of the Perfect Match. http://www.redherring.com/blogs/23874
[26] National Renewable Energy Laboratory, Lignocellulosic Biomass to
Ethanol Process Design and Economics Utilizing Co-Current Dilute Acid Prehydrolysis and

1.3 Objective of Study

The objective of this report is to assess the cellulosic ethanol market potential by 2012 in Belize through:

- the use of agricultural and forestry residues and municipal solid waste (MSW) as primary sources of feedstock;
- the evaluation of present and potential future feedstock supply volume and its costs;
- the identification and description of suitable cellulosic ethanol sub-technologies;
- the determination of present and future cellulosic ethanol production cost range (economics);
- the assessment of the regulatory framework for cellulosic ethanol introduction and technology transfer potential (market drivers); and
- the establishment of sustainability criteria for the implementation of cellulosic ethanol technology and market development (competitive environment).

The market potential is determined by focusing on the main market drivers identified as the cost of production of the cellulosic ethanol, the regulatory framework, and the competitive environment. Ethanol consumption as a transport fuel is driven by a combination of government policies and techno-economics.

To complete this report the research team relied on various resources including:

- Reports, articles and other published literature
- Summary or notes from several meetings and workshops related to biofuels
- Interviews with several energy, agricultural/forestry and transport sectors stakeholders in Belize
- Electronic information from the internet

Enzymatic Hydrolysis for Corn Stover; http://www.nrel.gov/docs/fy02osti/32438.pdf

[27] National Renewable Energy Laboratory, Thermochemical Ethanol via Indirect Gasification and Mixed Alcohol Synthesis of Lignocellulosic Biomass; http://www.nrel.gov/docs/fy07osti/41168.pdf

[28] U.S. Department of Energy, News release, website: http://www.energy.gov/news/5903.htm (visited January 2009)

2 Methodology

The assessment is executed using the following methodology:

2.1 Demarcation

This study is limited to the assessment of cellulosic ethanol production volume and cost competitiveness potential in Belize by assessing the feedstock and technology development and applicable regulatory and sustainability divers for the time frame 2008 to 2012. The domestic gasoline market is assessed as the principal target for the introduction of cellulosic ethanol as transport fuel.

It is not intended to be a detailed and comprehensive well-to-wheel lifecycle assessment of the cellulosic ethanol. Nor can it be considered a comprehensive market assessment since it has the purpose of initiating the discussions around the potential for cellulosic ethanol development in Belize. It is anticipated that once serious commitments are made to the development of cellulosic ethanol a more comprehensive study will be required to refine the preliminary estimates made here.

The following approach is deemed practical and suitable to the Belizean context, where there is limited data or information available to execute a more in-depth analysis. It is also meant to provide a basic idea of the potential to introduce cellulosic ethanol in Belize and identify the expected gaps in data and other market challenges. Also the aim is to provide recommendations to improve the monitoring or assessment of essential factors that influence cellulosic ethanol development.

For the purposes of simplification, life-cycle of cellulosic ethanol can be divided in five main topics, for this study three of them are explored (see Figure 2.1).

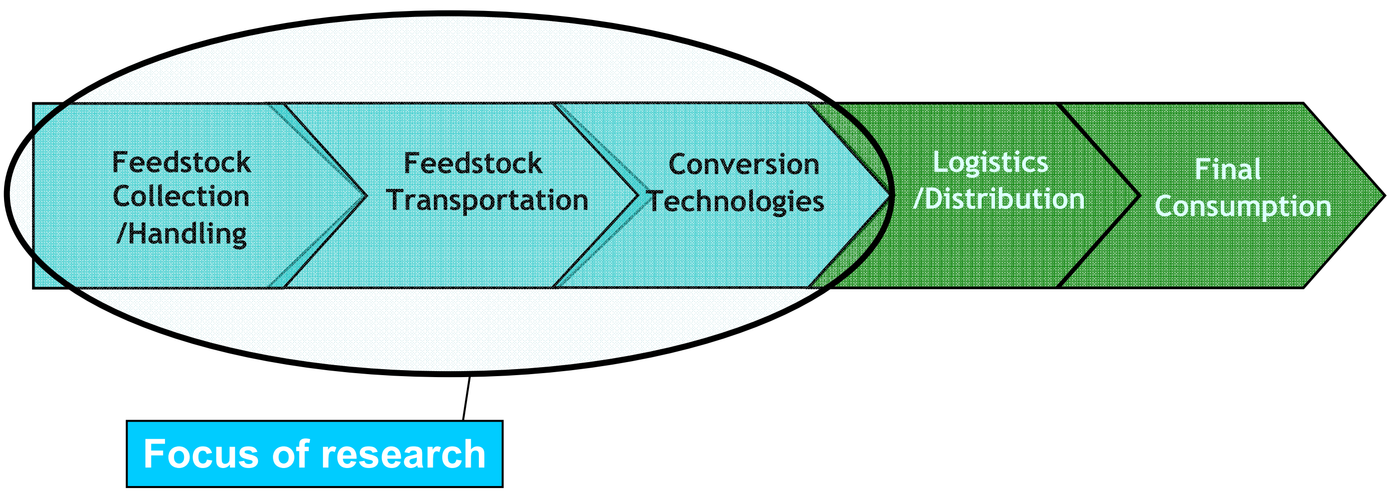

Figure 2.1 Life-cycle of cellulosic ethanol

The topics of interest have been divided into four major segments:

1. Technology Analysis: Cellulosic Ethanol Conversion or Production Technologies Development and Cost Assessment
2. Feedstock Analysis: Cellulosic Biomass Feedstock Availability and Cost Assessment
3. Regulatory Framework: Energy, Transport, Agricultural, Forestry and Waste Management Policy Analysis

4. Competitive Environment: Assessment of Established and Future Cellulosic Ethanol Competitors and Creation of Sustainability Criteria for CE Development

The segments related to Logistics and Distribution (that includes blending & storage) depicted in Figure 2.1 are not included in this research. This is deemed beyond the scope of this study, firstly since there is no available data to assess the logistical and infrastructural requirements for blending and retail; and secondly the objective is to provide a quick scan of available feedstock and technology applicability to determine the current and future potential cost range of cellulosic ethanol production in Belize.

Optimally the price of ethanol at the pump is determined to compare it with the retail gasoline price, but this is deemed unfeasible at this stage. Nevertheless, with current technology, cellulosic ethanol (CE) cost includes much higher processing costs than corn- or sugar-based ethanol, while on the other hand the CE feedstock costs are generally lower. If targeted reductions in conversion costs can be achieved, the total costs of producing cellulosic ethanol could be less than that of 1st generation ethanol (corn- or sugar-based ethanol) and gasoline. That is the principal reason to estimate the cost of the CE feedstock in Belize (to confirm whether the feedstock is indeed cheaper) and assess the international conversion technology costs. In this study, the remainder of the costs of the production chain as blending and distribution costs are not the principal focus since both ethanol and gasoline use the same distribution logistics and infrastructure when looking at the domestic transport market. This study sets a target of 2012, based on general literature and electronic information that describes the commercialization of cellulosic ethanol.[29,30]

2.2 Macro assessment

The CE market potential is assessed by focusing on:

1. Cost of CE production
- Identifying and quantifying the cellulosic biomass feedstock
- Determining the current potential CE production volume and cost
- Assessing the potential CE cost reduction by 2012

2. Market drivers (regulations)
- Describing gasoline sector in Belize
- Estimating the annual fuel consumption rate (gasoline demand)
- Describing current and future regulatory considerations
- Providing projections of future CE consumption

3. Competitive environment
- Comparing the performance, operating factors and economics of CE with other fuels
- Creating a competitive playing field and introducing a sustainability criteria

The assessment will focus on the **feedstock** analysis, where three main sectors, agricultural, forestry and waste management, are pre-identified as sources for the supply of cellulosic biomass feedstock. Due to the varying characteristics of these sectors, different methodologies are applied to each sector to identify and quantify waste materials or residues. Via a simplistic biomass-to-ethanol conversion rate, the gross potential volume of ethanol is calculated to provide an initial picture of the scale of ethanol yield potential.

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[29] National Renewable Energy Laboratory, Lignocellulosic Biomass to Ethanol Process Design and Economics Utilizing Co-Current Dilute Acid Prehydrolysis and Enzymatic Hydrolysis for Corn Stover; http://www.nrel.gov/docs/fy02osti/32438.pdf

[30] National Renewable Energy Laboratory, Thermochemical Ethanol via Indirect Gasification and Mixed Alcohol Synthesis of Lignocellulosic Biomass; http://www.nrel.gov/docs/fy07osti/41168.pdf

As a second step, the cost of collection and transportation of the identified feedstock is assessed to provide the potential cost range per feedstock in the Belizean context. And once the cost range of feedstock is determined, the focus is set on the conversion phase to cellulosic ethanol. In the technology analysis, all the currently available or existing CE conversion technologies are assessed (based on a literature/internet desk study). And based on both international research and development (R&D) prospective, cost per unit of ethanol, and local techno-economic and sustainability criteria, the sub-technologies with the highest probability of introduction and implementation in Belize within the coming five years are identified.

The following methodology is used as part of the technology analysis in an attempt to clarify the potential use of this technology in Belize and its costs.

Step 1: A brief description is provided of the existing biomass-to-cellulosic ethanol conversion sub-technologies. The main conversion steps are highlighted and the difference between the sub-technologies is explained.

Step 2: A macro assessment is made to determine the current CE production cost range per gallon of ethanol by sub-technologies based on the international R&D and pre-commercialization data (which are at the pilot scale or pre-commercial stage).

Step 3: Next a compilation of the current costs for the feedstock generated in Belize and the current capital cost for the sub-technology is made to project the potential present cost range of cellulosic ethanol production within the context of Belize.

Step 4: Three assessments are made to determine the future cost reduction potential for sustainable Belizean cellulosic ethanol production within a period of five years. .

1. First an assessment is made of feedstock expansion or improvement potential taking in mind sustainability criteria and other limiting factors (for instance the limits to available cultivable lands or the un-controllable deforestation).
2. In addition a macro assessment is made of the international research and development (R&D) funding and activities for the existing cellulosic ethanol sub-technologies (e.g. bio-chemical, thermo-chemical or hybrid systems).
3. A comprehensive evaluation method is applied to identify the most sustainable sub-technology in the context of Belize using the 5E methodology which is introduced by Schuetzle, et.al. 2007[31]. This "5E" assessment approach includes the following components: technology evaluation (E1); energy efficiency (E2); environmental impacts (E3); economic viability (E4); and socio-political and human resource effectiveness (E5).

A summary is provided on the results of the feedstock and technology analysis for both current and future conditions. The total volumes of cellulosic ethanol and the cost range by feedstock and sub-technology used is provided.

In addition an assessment is made of the present regulatory framework in place and its suitability to promote cellulosic ethanol in Belize. And although cellulosic ethanol is marketed as an alternative to MBTE and as a gasoline replacement, this study will focus only on the use of cellulosic ethanol to produce E-10 (a gasoline-ethanol blend containing 10% of tank volume of dehydrated ethanol, where current used vehicles need no retrofitting). As a final step, the competitive environment is assessed to take in mind possible alternative fuel developments that may restrict or incentivize the cellulosic ethanol market

[31] Dennis Schuetzle, Gregory Tamblyn and Frederick Tornatore, TSS Consultants, 2007. Alcohol Fuels from Biomass – Assessment of Production Technologies. www.westgov.org/wga/initiatives/biomass/ASSESSMENT-BIOALCOHOL-tech.pdf

penetration. This overall approach will enable decision-makers in Belize to asses the potential for implementing cellulosic ethanol, once the technology is mature or commercially available.

3 Cellulosic Ethanol Sub-Technology

Taking in mind that the cellulosic ethanol production technology is emerging and is not widely commercially applied for the time being, it is challenging to provide information about production costs, investment costs or a realistic timeframe of when this technology will become commercially viable and accessible for introduction in Belize. In this chapter an attempt is made to assess the potential R&D developments and costs reductions.

3.1 Cellulosic ethanol sub-technologies

According to Schuetzle et al (2007)[32], an estimated 450 organizations worldwide have developed technologies for the conversion of biomass to bio-power and/or biofuels. The most relevant technologies designed for bio-alcohol production are technologies based on either the thermo-chemical or the bio-chemical processes.

The thermo-chemical process is the production of a synthetic gas (syngas) via gasification or pyrolysis of the feedstock, which can then be used to produce alcohols in a catalytic process. The biochemical processes for producing fuels from biomass can be categorized by four processes. These processes employ anaerobic digestion to produce methane; chemical and physical methods to produce sugars from cellulosic materials; enzymes to produce sugars from cellulosic materials; or a variety of microbiological processes to produce methane, alcohols and hydrogen from biomass. Of these, the main technologies relevant to produce cellulosic ethanol are acid hydrolysis and enzymatic hydrolysis, which produce alcohols by breaking down cellulose into component sugars that are then fermented.

The principal thermo-chemical and biochemical processes for ethanol production are described in more detail in the following section. It is estimated that 50 or more organizations worldwide have concentrated their efforts on the research and development and deployment of sub-technologies employing such processes.

The next section provides an overview of the principal technologies under development used to convert cellulosic biomass feedstock into ethanol, the technology platforms are: the biochemical platform, thermo-chemical platform and a hybrid version of these processes.

Biochemical Process

The biochemical process consists of hydrolysis on pretreated lignocelluloses materials, using enzymes to break complex cellulose into simple sugars such as glucose and followed by fermentation and distillation. The most important stages to produce ethanol from cellulose, using the biochemical approach are:

a) Pretreatment

Cellulose is one of the most abundant vegetal material resources, but unfortunately its availability is reduced by its rigid structure. To make it more accessible it is necessary to use an effective pretreatment to separate and make the principal components of biomass (cellulose, hemicellulose, lignin, and extractives) more soluble and finally make them more accessible to further chemical or biological treatment or a subsequent hydrolysis step.

The pretreatments are done through physical or chemical means. The most common chemical pretreatment methods used for cellulosic feedstocks are dilute acid, alkaline, organic solvent, ammonia,

[32] Dennis Schuetzle, Gregory Tamblyn and Frederick Tornatore, TSS Consultants, 2007. Alcohol Fuels from Biomass – Assessment of Production Technologies. www.westgov.org/wga/initiatives/biomass/ASSESSMENT-BIOALCOHOL-tech.pdf

sulfur dioxide, carbon dioxide and ozone pretreatment, to make the biomass more digestible by the enzymes. Biological pretreatments are sometimes used in combination with chemical treatments to solubilize the biomass components in order to make cellulose more accessible to hydrolysis and fermentation.

Any particular feedstock needs to undergo a specific pretreatment to minimize the formation of degraded products to maximize the sugar yield on subsequent hydrolysis and fermentation processes.

b) Hydrolysis

Hydrolysis is the process where long chains of sugar molecules that have cellulose molecules are broken down to free the sugar before it is fermented for alcohol production. The hydrolysis (Cellulolysis) processes most commonly used are: the chemical reaction using acids or an enzymatic reaction.

- Chemical hydrolysis

There are two main approaches when using acids for the hydrolysis process. Dilute acid may be used under high heat and high pressure, or more concentrated acid can be used at lower temperatures and atmospheric pressure.

Dilute and concentrate acid processes have several disadvantages, because in the case of the dilute acid, during the process it tends to produce large amounts of derivates and secondary products. By the other hand, concentrated acid produces smaller amounts of derivates, but the critical factors needed to make this process economically viable are dependant on the optimization of sugar recovery and the cost of effectively recovering the acid for recycling. In this regard, the process to recover the acid adds more complication to the process.

The National Renewable Energy Laboratory (NREL) estimates that the cumulative impact of improvements in acid recovery and sugar yield for the concentrated acid process could provide savings of up to 14 cents per gallon, whereas process improvements for the dilute acid technology could save around 19 cents per gallon (Schuetzle, et. al, 2007).

- Enzymatic hydrolysis

Cellulose chains can be broken into glucose molecules, replacing acid in the hydrolysis process by cellulase enzymes. This kind of reaction occurs at body temperature in the stomach of ruminants such as cows and sheep, where the enzymes are produced by bacteria. Currently there are two technical-methods: enzymatic and direct microbial conversion. NREL estimates that future cost reductions could be four times greater for the enzyme process than for the concentrated acid process and three times greater than the dilute acid process (Schuetzle, et. al, 2007).

This process uses several enzymes at various stages of the conversion. Using a similar enzymatic system, lignocellulosic materials can be enzymatically hydrolyzed at a relatively mild condition (50˚C and pH5), thus enabling effective cellulose breakdown without the formation of byproducts that would otherwise inhibit enzyme activity. All major pretreatment methods, including dilute acid pretreatment, require enzymatic hydrolysis steps to achieve high sugar yield for ethanol fermentation.[33] Various enzyme companies have also contributed to significant technological breakthroughs in cellulosic ethanol through the mass production of enzymes for hydrolysis at competitive prices.

[33] Lynd LR (1996) Overview and evaluation of fuel ethanol from cellulosic biomass: technology, economics, the environment, and policy. Ann. Rev. Energy Environ. 21:403–465.

c) Microbial fermentation

Fermentation is the process of deriving energy from the oxidation of organic compounds, such as carbohydrates, using an endogenous electron acceptor, which is usually an organic compound.[34]

In the case of ethanol, fermentation is the last step to produce ethanol from biomass feedstock converting the sugars of the feedstock (glucose, fructose, and sucrose) into cellular energy and thereby producing ethanol and carbon dioxide as metabolic waste products.

For many years, the traditional brewery industry used the *Saccharomyces cerevisiae* yeast of the fungi kingdom to produce ethanol from *hexoses (6-carbon sugar)*[35] but this kind of yeast does not work with more complex structure present in the biomass feedstock impeding the complete use of material available to produce ethanol. For example, only about 50-60% of the sugar derived from cellulose-rich plant materials is glucose. The remaining 40-50% is largely a sugar called “xylose,” which naturally occurring yeast cannot ferment to ethanol. Biotechnology has been used to genetically modify yeast[36] and some bacteria[37] to allow them to produce ethanol from both glucose and xylose. These advances increase the amount of ethanol than can be produced from a ton of cellulosic material by as much as 50%. Additional improvements, based upon understanding the basic metabolism and genetics of microorganisms, are underway to increase the efficiency and rates that the microorganisms convert xylose to ethanol (Bro et al., 2006). As a result, the ability of the fermenting microorganisms to utilize the whole range of sugars available from the hydrolysate is vital to increase the economic competitiveness of cellulosic ethanol and potentially bio-based chemicals.

d) Combined hydrolysis and fermentation

Researchers have identified how genes responsible for biomass breakdown are turned on in a microorganism that produces valuable ethanol from materials like grass and cornstalks. These microorganisms are bacteria capable of direct conversion of a cellulose substrate into ethanol. For example, *Clostridium thermocellum* utilizes a complex cellulosome to break down cellulose and synthesize ethanol. However, it also produces other products during cellulose metabolism, including acetate and lactate, in addition to ethanol, lowering the efficiency of the process. Researchers are working to optimize ethanol production by genetically engineering bacteria that focus on the ethanol-producing pathway.[38]

The biochemical approach-processing and current technical barriers are resumed in Figure 3.1;

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[34] Prescott, L. M., Harley, J. P., & Klein, D. A. (2005), Microbiology. New York: McGraw-Hill, 6th Edition

[35] http://www.microbiologybytes.com/video/Scerevisiae.html

[36] Miroslav Sedlak and Nancy W. Y. Ho, 2004, Production of ethanol from cellulosic biomass hydrolysates using genetically engineered saccharomyces yeast capable of cofermenting glucose and xylose. Journal Applied Biochemistry and Biotechnology, Humana Press Inc. Volume 114, Numbers 1-3 / March, 2004, Pages 403-416

[37] L. O. Ingram *, P. F. Gomez, X. Lai, M. Moniruzzaman, B. E. Wood, L. P. Yomano, S. W. York, 1997, Metabolic engineering of bacteria for ethanol production. Biotechnology and Bioengineering, Volume 58 Issue 2-3, Pages 204 - 214

[38] University of Rochester, 2007. http://www.rochester.edu/news/show.php?id=2803

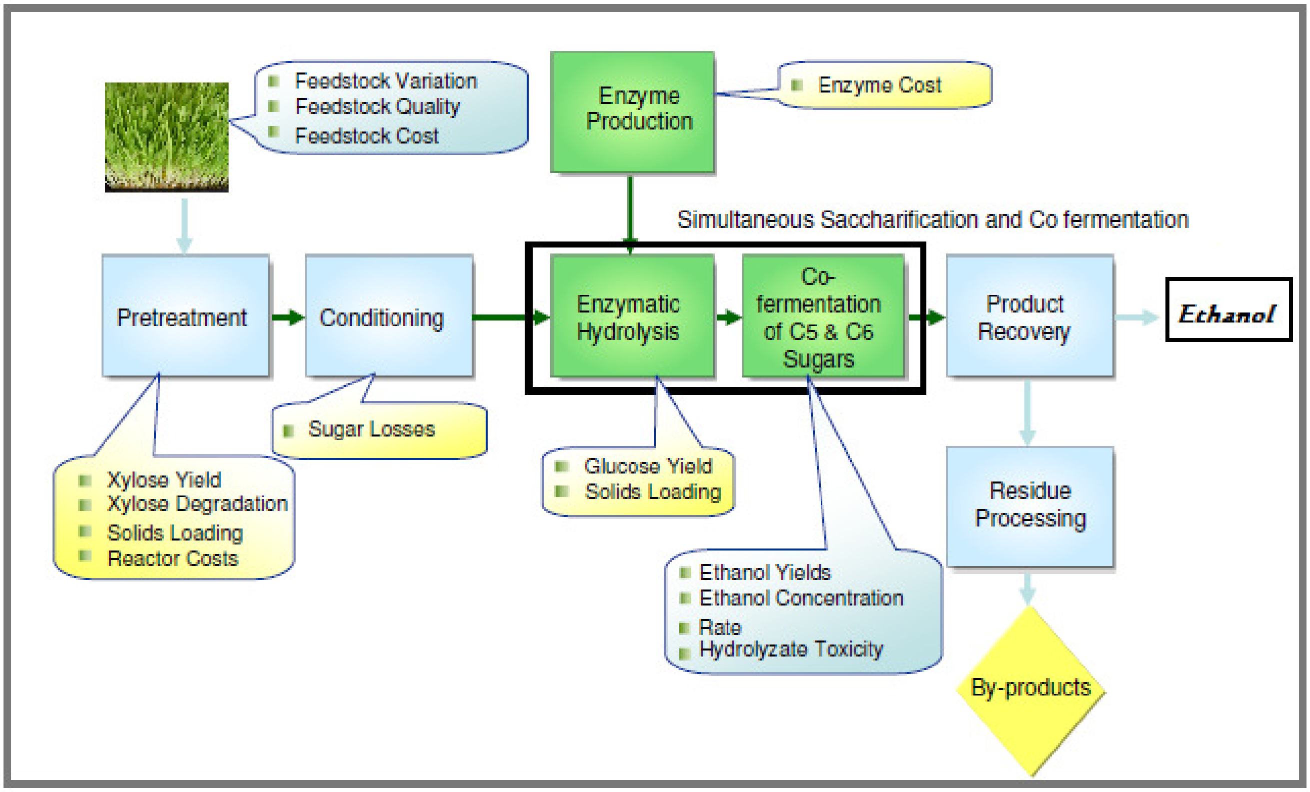

Figure 3.1 Biochemical approach-processing[39]

Thermo-chemical Process

The thermo-chemical approach like the biochemical involves breaking down biomass into its elemental components by using heat and chemical synthesis. The principal thermo-chemical technologies include pyrolysis and gasification, which are followed by a chemical synthesis process. Currently, the most relevant emerging technology is gasification, followed by catalytic conversion of the synthesis gas to ethanol or other high-value products.

Basically, instead of breaking the cellulose into sugar molecules, the carbon in the raw material is converted into synthesis gas (Syngas). The syngas is converted either through a catalytic reaction or by bacteria into various products such as ethanol or butanol.
The process can be resumed into three steps:

1. Gasification: Complex carbon based molecules are broken apart to access the carbon in the form of carbon monoxide, carbon dioxide and hydrogen that are produced.

2. Fermentation: Convert the carbon monoxide, carbon dioxide and hydrogen into ethanol using bacteria like the *Clostridium ljungdahlii* or a catalytic reactor where the synthesis gas is used to produce ethanol and other higher alcohols.

3. Distillation; Ethanol is separated from water

[39] DD Hsu, 2008. Cellulose-Based Ethanol Production. National Bioenergy Center. EDF-EBI-ERG Workshop, Berkley, CA. Retrieved from: http://www.edf.org/documents/8120_Microsoft%20PowerPoint%20-%20Session%203%20Hsu%20David%202008%20EDF%20LCA%20workshop%20Berkeley.pdf

The process is very flexible towards different biomass sources and can produce a variety of products. Chevron Texaco, Conoco Phillips (Global Energy) and Shell (Lurgi) have developed economically viable biomass-to-syngas production systems for the production of electricity in the 100-1,000 MW output range. However, these technologies have not proven to be economical for small scale power generation applications (1-25 MW). During the past several years approximately 110 organizations have focused their efforts on the development of small (1-25 MW), economical systems for generation of electricity from waste materials. However, very few of these companies have successfully demonstrated their technologies by building and systematically testing full scale operating systems.[40]

The thermo-chemical approach-processing and currently technical barriers are resumed in Figure 3.2;

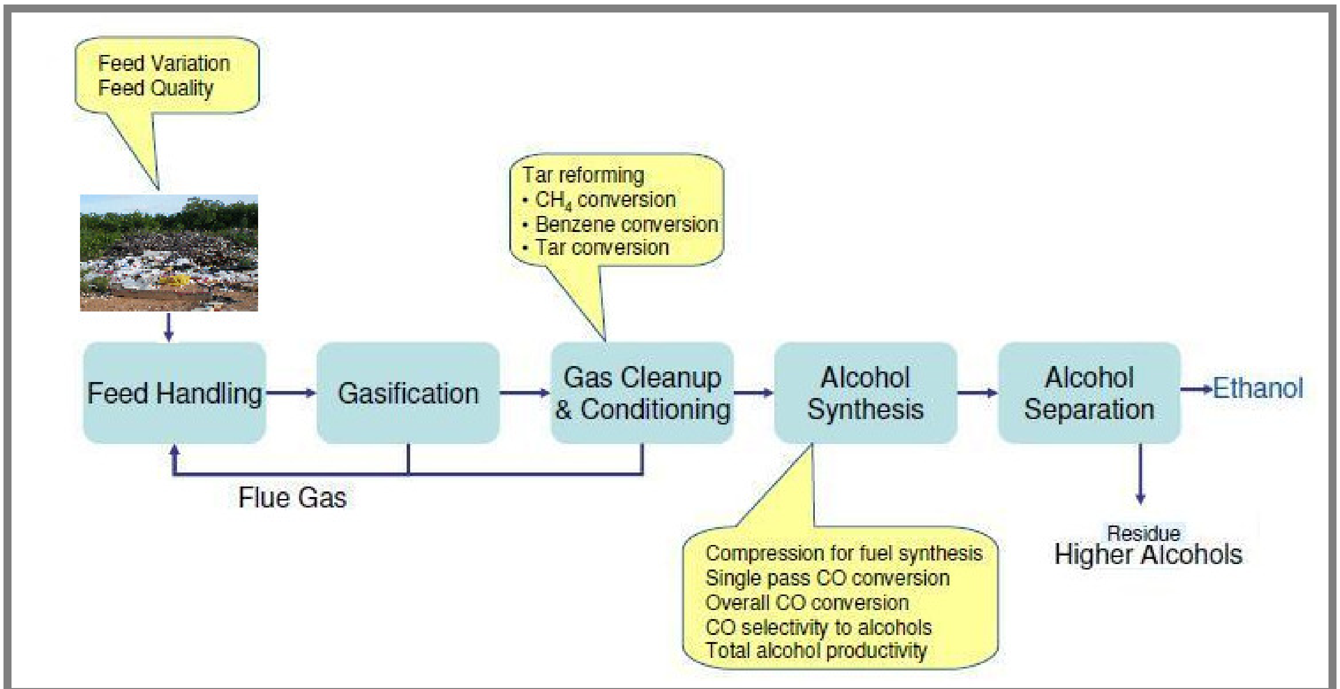

Figure 3.2 Thermo-chemical approach-processing[41]

Integrated approaches of Biochemical and Thermo-chemical Processes

New approaches try to integrate the biochemical and thermo-chemical processes to improve cellulosic ethanol production. New technologies introduced syngas into an aqueous solution containing nutrients and specific microorganisms. The studies show the potential capability of producing ethanol and acetate from the syngas in 2 minutes or less, with a reported yield of 70-85 gallons of ethanol per dry ton of carbohydrates. Nevertheless, technical issues need to be addressed and further scientific validation carried out before using it.

Furthermore, many new projects continue to be developed in different countries to produce ethanol from corn and sugarcane. Some of the earliest and best prospects for cellulosic ethanol production will undoubtedly occur via incorporation of the above discussed processes into these conventional facilities. In

[40] Dennis Schuetzle, Gregory Tamblyn and Frederick Tornatore, TSS Consultants, 2007. Alcohol Fuels from Biomass – Assessment of Production Technologies. www.westgov.org/wga/initiatives/biomass/ASSESSMENT-BIOALCOHOL-tech.pdf

[41] DD Hsu, 2008. Cellulose-Based Ethanol Production. National Bioenergy Center. EDF-EBI-ERG Workshop, Berkley, CA. Retrieved from: http://www.edf.org/documents/8120_Microsoft%20PowerPoint%20-%20Session%203%20Hsu%20David%202008%20EDF%20LCA%20workshop%20Berkeley.pdf

fact, some of the approaches currently being pursued by cellulosic process developers involve initial project plans at existing or new corn-to-ethanol plants.[42] See next section for more information about cellulosic ethanol development projects.

3.2 International Cellulosic Ethanol RD&D initiatives and projects

United States

The U.S. Department of Energy (DOE) is investing up to US$ 385 million for six biorefinery projects over the period of 2007-2010. When fully operational, the biorefineries are expected to produce more than 130 million gallons of cellulosic ethanol per year.[43] The following six projects were selected and are under development:

Abengoa Bioenergy Biomass of Kansas, LLC of Chesterfield, Missouri, up to $76 million
The proposed plant will be located in Houghton, Kansas. The plant will produce 11.4 million gallons of ethanol annually and enough energy to power the facility, with any excess energy that will be used to power the adjacent corn dry grind mill. The plant will use 700 tons per day of corn stover, wheat straw, milo stubble, switchgrass, and other feedstocks. Abengoa Bioenergy Biomass investors/participants include: Abengoa Bioenergy R&D, Inc.; Abengoa Engineering and Construction, LLC; Antares Corp.; and Taylor Engineering.

ALICO, Inc. of LaBelle, Florida, up to $33 million
Alico is no longer developing a cellulosic ethanol plant. On June 3, 2008, New Planet Energy took over the sight. At this time, Bioengineering Resources Incorporated is the technology provider.

BlueFire Ethanol, Inc. of Irvine, California, up to $40 million
The proposed plant will be in Southern California. The plant will be sited on an existing landfill and produce about 17 million gallons of ethanol a year. As feedstock, the plant will use 700 tons per day of sorted green waste and wood waste from landfills. Currently, the company is setting up a demonstration plant in Lancaster, California. The company hopes to build modular units to lower the capital costs for companies planning to utilize MSW as a feedstock for cellulosic ethanol production. BlueFire Ethanol, Inc. investors/participants include: Waste Management, Inc.; JGC Corporation; MECS Inc.; NAES; and PetroDiamond.

Broin (POET) Companies of Sioux Falls, South Dakota, up to $80 million
The plant is in Emmetsburg (Palo Alto County), Iowa, and after expansion, it will produce 125 million gallons of ethanol per year, of which roughly 20% will be cellulosic ethanol. For feedstock in the production of cellulosic ethanol, the plant expects to use 842 tons per day of corn fiber, cobs, and stalks. With the involvement of POET there is the aim to increase ethanol yield at its dry-mill facility in Emmetsburg, Iowa by processing the fiber that comes from its fractionation process. The fiber will provide 40% of the cellulosic feedstock from the corn kernels that POET is already processing in its facility, the remainder will come from corn cobs. With the process, POET says it will be able to produce 11% more ethanol from a bushel of corn and 27% more from an acre, while almost completely eliminating fossil fuel consumption and decreasing water usage by 24%.[44] Broin Companies (POET, LLC[45]) participants include: E.I. du Pont de Nemours and Company; Novozymes North America, Inc.; and DOE's National Renewable Energy Laboratory.

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[42] Ibid.
[43] U.S. Department of Energy (DOE), DOE Selects Six Cellulosic Ethanol Plants for Up to $385 Million in Federal Funding, February 2007, website: http://www.energy.gov/news/4827.htm (visited January 2009)
[44] Ethanol Statistics, Issue Focus: Plant construction and process equipment, June 2008 Monthly Market review, Volume 1, Issue 2.
[45] POET Energy, website: http://www.poet.com/about/showDivision.asp?ir=&id=6 (visited January 2009)

Iogen Biorefinery Partners, LLC, of Arlington, Virginia, up to $80 million
The company scrapped plans for the cellulosic plant in Shelley, Idaho. Instead, Iogen is investigating sites in Canada and Florida. Shell also increased its investment to 50% of the company by virtue of an additional US$ 70 million investment. Iogen Biorefinery Partners, LLC investors/partners include: Iogen Energy Corporation; Iogen Corporation; Goldman Sachs; and The Royal Dutch/Shell Group.

Range Fuels (formerly Kergy Inc.) of Broomfield, Colorado, up to $76 million
The company broke ground at their proposed plant in Soperton (Treutlen County), Georgia on March 14, 2008. The plant will produce about 20 million gallons of ethanol per year and 9 million gallons per year of methanol. As feedstock, the plant will use 1,200 tons per day of wood residues and wood based energy crops. The company also raised an additional US$ 100 million in the capital markets during the summer of 2008. Range Fuels investors/participants include: Merrick and Company; PRAJ Industries Ltd.; Western Research Institute; Georgia Forestry Commission; Yeomans Wood and Timber; Truetlen County Development Authority; BioConversion Technology; Khosla Ventures; CH2MHill; Gillis Ag and Timber.

The U.S. Department of Energy and Abengoa Bioenergy New Technologies (ABNT) signed a 4-year, $35.5 million (U.S.) contract in 2003 to develop the technology for Advanced Biorefining of Distillers Grain and Corn Stover Blends: Pre-Commercialization of Biomass-derived Process Technologies. Abengoa Bioenergy New Technologies, in collaboration with the National Renewable Energy Laboratory (NREL), and Stake Technology, lead the research team to develop a novel biomass-derived process technology that utilizes advanced bio-refined Distiller's Grain and Corn Stover blends to achieve significantly higher ethanol yields while maintaining the protein feed value.[46]

The U.S. Government is also putting massive resources into a program called Genomes to Life (GTL), which is supporting synthetic biology research to this end as part of the U.S. aim to develop alternatives to its dependence on fossil fuels.[47] In the same approach, British Petroleum (BP) has offered 500 million U.S. dollars to the University of Berkeley, California for research into fuels. A major component of the work will be genetic engineering research into lignocellulosic fuels, which will include the use of synthetic biology.[48] 'Synthetic biology' is the name given to a new area of work that combines Genetic Engineering with nanotechnology and computing. As more genomes of different organisms are mapped, providing the raw material, researchers are aiming not only to redesigning existing organisms, but of building completely new organisms that are more precisely designed to do a specific function.

Just to mention some recent private sector investments, DuPont Danisco Cellulosic Ethanol LLC., a global joint venture between DuPont and Genencor (a division of Danisco A/S) established in 2008 that they are investing US$140 million over a 3-year period initially targeting sugarcane bagasse and corn stover, but with targets to include multiple lingo-cellulosic feedstocks including wheat straw.[49]

Partly as a result of the above mentioned U.S. government initiatives but mainly due to private sector engagement, there are currently at least 24 Cellulosic Ethanol projects under development in the U.S. See Table 3.1 for an overview of cellulosic ethanol projects under development in the U.S., and Annex 11.2 provides an overview of the companies involved and the location of these cellulosic ethanol projects.

[46] Abengoa Energy, website: http://www.abengoabioenergy.com/sites/bioenergy/en/nuevas_tecnologias/proyectos/doe/index.html (visited January 2009)
[47] An Introduction to Synthetic Biology, January 2007, ETC Group; www.etcgroup.org/upload/publication/pdf_file/602
[48] The Berkeley Daily Planet; http://www.berkeleydailyplanet.com/issue/2007-02-06/article/26282?headline=News-Analysis-UC-s-Biotech-Benefactors-&status=301
[49] Ethanol Statistics, Issue Focus: Plant construction and process equipment, June 2008 Monthly Market review, Volume 1, Issue 2.

Table 3.1 Cellulosic Ethanol Projects under development and construction in the U.S. (as per Dec 2008)[50]

	Company	Location	Technology	Production capacity (M gallons)	Feedstock
1	Bluefire	Corona, CA	Arkenol Process Technology (Concentrated Acid hydrolysis process)	17	Green waste, wood waste, and other cellulosic urban wastes (post sorted urban waste)
2	California Ethanol + Power, LLC (CE+P)	Brawley, CA		55	Local imperial valley grown sugarcane; facility powered by sugarcane bagasse
3	Bluefire	Lancaster, CA	Arkenol Process Technology (Concentrated Acid hydrolysis process)	3.1	Green waste, wood waste, and other cellulosic urban wastes (post sorted urban waste)
4	Lignol Innovations	Grand Junction, CO	Biochem-organisolve	2.5	Woody biomass, agricultural residues, hardwood and soft wood
5	New Plant Energy	Vero Beach, FL	INEOS Bio Ethanol Process (gasification fermentation and distillation)	8	Municipal Solid Waste (MSW); unrecyclable paper; construction and demolition waste; tree, yard and vegetative waste; and energy crops
6	ALICO, Inc.	LaBelle, FL		13.9	Yard, wood, and vegetative wastes and eventually energy cane
7	Range Fuels	Soperton, GA	Two-step thermo-chemical process (K2)	20	Wood residues and wood based energy crops, grasses and corn stover
8	Iogen Corp.	Shelley, ID	Enzyme Technology	18	Agricultural residues including wheat straw, barley straw, corn stover, switch grass and rice straw
9	POET	Emmetsburg, IA	BFRAC™ separates the corn starch from the corn germ and corn fiber, the cellulosic casing that protects the corn kernel	25	Corn fiber, corn cobs and corn stalks
10	Abengoa	Hugoton, KS		11.6	Corn stover, wheat straw, switchgrass and other biomass
11	Ecofin, LLC	Washington County, KY	Solid state fermentation process developed by Alltech	1.3	Corn cobs
12	Verenium	Jennings, LA	C5 and C6 fermentations	1.4	Sugarcane bagasse and specially-bred energy cane
13	RSE Pulp & Chemical, LLC	Old Towne, ME	University of Maine proprietary process for pre-extracting hemicelluloses during the pulping process	2.2	Woodchips (mixed hard wood)
14	ICM, Inc.	St. Joseph, MO	Biochemical and thermo-chemical processing	1.5	Switchgrass, forage, sorghum and stover
15	AE Biofuels	Butte, MT	Ambient Temperature Cellulose Starch Hydrolysis	Small scale	Switchgrass, grass seed, grass straw and corn stalks
16	Abengoa	York, NE		11.6	Corn stover, wheat straw, milo stubble, switchgrass and other biomass
17	Mascoma (New York State Energy R&D Authority)	Rome, NY		5.0	Lignocellulosic biomass, including switchgrass, paper sludge and wood chips
18	Pacific Ethanol	Boardman, OR	BioGasol	2.7	Wheat straw, stover and poplar residues
19	ZeaChem	Boardman, OR		1.5	Poplar trees, sugar and wood chips
20	Coskata	Madison, PA	Biological fermentation technology; proprietary microorganisms and efficient bioreactor designs in three-step conversion process that can turn most carbon-based feedstock into ethanol	0.4	Any carbon-based feedstock; including biomass, municipal solid waste (MSW), bagasse, and other agricultural waste
21	POET	Scotland, SD	BFRAC™ separates the corn starch from the corn germ and corn fiber, the cellulosic casing that protects the corn kernel	0.2	Corn fiber, corn cobs and corn stalks
22	DuPont Danisco Cellulosic Ethanol, LLC	Vonore, TN	Enzymatic Hydrolysis Technology	0.25	Switchgrass, corn stover and corn cobs
	NewPage Corp.	Wisconsin Rapids, WI		5.5	Woody biomass and mill residues
23	Flambeau River Biofuels, LLC	Park Falls, WI	Thermo-chemical conversion of biomass using advanced gasification technologies followed by Fischer-Tropsch catalytic conversion into renewable liquid fuels and waxes ("Thermal 1" process)	6.0	Softwood chips, wood and forest residues
24	KL Process	Upton, WY	Thermal-mechanical process	1.5	Softwood, waste wood, including cardboard and paper

[50] U.S. Renewable Fuels Association, website: http://www.ethanolrfa.org/resource/cellulosic/documents/RFACellulosicPlantHandout.pdf (visited January 2009). Some other companies included in the table with sources from Vandershield Research website: http://www.investincellulosicethanol.com/ (visited January 2009)

Japan[51]

Japan is currently the third largest oil consumer in the world and is almost completely dependant on imported fossil fuels. In 2007, Japan's Ministry of Economy, Trade and Industry (METI) set a target to introduce a new cost-efficient technology for producing cellulosic ethanol to help reduce the country's gasoline demand by 2015. One of the main objectives for METI is to cut the cost of producing ethanol from cellulosic biomass such as waste wood and wood chips to 100 yen (91 cents) per liter ($3.45 per gallon) from more than 2,000 yen at present.

Another objective is to develop further-reaching technology that would turn soft cellulose such as silver grass, a common grass in Japan, into ethanol at a cost of 40 yen per liter (1.38US$ per gallon). The 40 yen target was set after taking into consideration a U.S. plan to cut costs to around 30-40 yen per liter in 2012.

A task force of academics and staff from companies such as oil refiners Nippon Oil Corp and Idemitsu Kosan Co Ltd, and automaker Toyota Motor Corp will work on the project. The Japanese Farm Ministry's target is to produce 50,000 kilo liters a year of biomass ethanol by fiscal year 2011/12, a challenging plan in a country where costly farm produce has kept usage of green fuels largely at bay.

In July 2008, the Ministry of Economy approved two new cellulosic ethanol plants by two joint ventures, one in the northern island of Hokkaido by general contractor Taisei Corp (1801.T) and beer company Sapporo Holdings (2501.T), and another one in Hyogo prefecture, western Japan, by Mitsubishi Heavy Industries Ltd (7011.T) and a group led by the Hyogo prefectural government. During November 2008, according to the Agriculture ministry, Japan has approved a third test project to make ethanol from farm waste with subsidies to pay for building and running of plants totaling about $32 million over 5 years. The latest project in Japan is a joint venture by a unit of Kawasaki Heavy Industries Ltd (7012.T) and an agricultural public corporation led by the prefectural government of Akita in northern Japan. The ministry set aside 3.2 billion yen (approx. US$ 33 million) in 2009 to support projects to run a small test plant with daily output of up to 1,000 liters (1 kilolitre) at costs possibly low enough for commercial production.

The ministry has said it will shoulder 50 percent of estimated costs to build a cellulosic ethanol plant and 100 percent of a plant's running costs during a research and development period. For the next fiscal year, the ministry has requested a budget of 3.7 billion yen to keep supporting similar projects in the cellulosic ethanol field. The construction cost of the plant in Akita, with projected annual ethanol output of up to 22.5 kilolitres, is estimated at 1.03 billion yen and its running costs for the five-year project at 900 million yen.[52,53]

Brazil

Even though that Brazil is one of the largest ethanol producers and the main exporter in the world, there has been limited RD&D investment into cellulosic ethanol process improvements. Brazil's ethanol production is mainly based on sugarcane, which has a much higher energy efficiency or positive net energy balance compared to the U.S. corn-based ethanol. The available lands for dedicated energy crop (sugarcane) production are plentiful and the cost of labor is low in Brazil. Brazilians have managed to improve the cane-ethanol plants via optimized use of bagasse as fuel source for process heat and electricity requirements, with limited power exported to the national grid. This is a different

[51] Reporting by Osamu Tsukimori, Reuters, November 21, 2007 05:54 AM; http://www.reuters.com/article/environmentNews/idUST27706620071121
[52] Reporting by Risa Maeda, Reuters, Nov 18, 2008 6:30am EST; http://www.reuters.com/article/rbssIndustryMaterialsUtilitiesNews/idUST30138220081118
[53] 1US$ is approx. 96.70 Yen

configuration of an ethanol production system. Therefore no high incentives are currently present in Brazil to research and invest in optimizing the cellulosic biomass (bagasse).

European Union

Directly relevant EU initiatives for the promotion and development of cellulosic ethanol are among others, the RENEW Project, which is a 10M€ project launched in 2004 and funded by 6th Framework Program of the European Commission over 4 years to develop, compare, (partially) demonstrate and train on a range of fuel production chains for motor vehicles.[54]

This project is coordinated by Volkswagen AG (Germany) and Abengoa Bioenergy is one of the key participating partners. Abengoa is an international bioenergy company with headquarters based in Spain. Abengoa's contribution to the RENEW project is to optimize ethanol production. In the first step, an assessment of the enzyme pathway will be undertaken to integrate the information generated by current R&D projects being developed by Abengoa. Then the thermo chemical pathway for ethanol production will be deeply investigated, including the analysis of each process stage: 1) biomass gasification; 2) gas cleaning and gas conditioning; and 3) the catalytic conversion of syngas to ethanol. Abengoa will identify the best technologies to produce ethanol using the thermo-chemical pathway, and optimize the entire process thereafter, such as the integration of different subsystems through species and energy recycle.

The NILE (New Improvements for Lignocellulosic Ethanol) project is a 7.7M€ launched in 2005 for a period of 4 years. The objective is to develop cost effective production of clean ethanol from lignocellulosic biomass via non-thermal pathways. Key issues are decreasing costs of enzymatic hydrolysis, removing limitations in the conversion of fermentable sugars and validating engineered enzyme systems. These technologies will be verified using a unique and fully integrated pilot plant.

BIOCARD the acronym for the Global Process to Improve Cynara Cardunculus Exploitation for Energy Applications Project is a 2.5 M€ project that was launched in 2005 for 3.5 years. The project aims at demonstrating technical and economical feasibility of a global process for Cynara Cardunculus exploitation for energy applications. This energy crop is suited for the Mediterranean area where problems of water insufficiency exist. A combined process to produce liquid biofuel from seeds and energy from the lignocellulosic part will be studied. Different technologies for biomass energy conversion will be compared.

Thanks to a project funded by the Spanish Ministry of Education and Science (FIT-120000-2004-108), Abengoa Bioenergy has evaluated the optimal blend formulation, material compatibility and engine performance in a Spanish automotive research and development centre (Cidaut), testing both off-road and LDV engines with E-diesel. E-diesel is an ethanol and diesel blend containing between 5 and 15% ethanol, and an additive that ensures the stability of the mixture. It can be used in conventional diesel engines with slight or no modifications at all.[55]

The 7th Framework Program of the European Commission for research and technology development is the European Union's chief instrument for funding research over the period 2007 to 2013. Under this cycle the following initiatives were identified related to cellulosic ethanol R&D.

There is the existence of the HYPE project, which focuses on lignocellulosic ethanol using a combined approach to develop a novel integrated concept for hydrolysis and fermentation of lignocellulosic

[54] European Commission Energy Research, website: http://ec.europa.eu/research/energy/nn/nn_rt/nn_rt_bm/article_2820_en.htm (visited January 2009)
[55] Abengoa Bioenergy, website: http://www.abengoabioenergy.com/sites/bioenergy/en/nuevas_tecnologias/proyectos/ediesel/index.html (visited January 2009)

feedstocks. Improved enzymatic hydrolysis, fermentation of all carbohydrates, process development as well as high flexibility to feedstocks and technical robustness are among the goals of HYPE. The technologies included in HYPE will be combined into a one unit continuous consolidated bioprocessing reactor including hydrolysis, fermentation and ethanol recovery. The consolidated bioprocessing developed in the HYPE project is expected to significantly improve the overall process economy through a reduced process time, improved enzyme efficiency and high yield of all carbohydrates.[56]

In the EU, 4 cellulosic ethanol plants have been identified, two of which use C-starch as feedstock and are already in operation. See Table 3.2 for an overview of these projects. Note that this only based on the membership of the European Bioethanol Fuel Association, and therefore the number of CE projects in the EU should not be considered as exhausted. See Annex 11.3 for and overview of the ethanol capacity installed in the EU and Annex 11.4 for and overview of the Ethanol Projects under development in the EU during 2008.

Table 3.2 EU Cellulosic Ethanol Projects under development and construction (As per Dec 2008)[57]

	Company	Location	Production capacity (million liters)	Feedstock
1	Royal Nedalco	Bergen op Zoom, NL	35	C-starch
2	Cargill	Wroclaw, PL	36	C-starch
3	Wabio Bioenergie	Bad Kostritz, GER	8.4	Waste
4	Biocarburantes Castilla & Leon	Salamanca, SP	5.0	Lignocellulose

The above projects are part of a group of 23 ethanol production plant projects under development and construction in the European Union.

In review, it can be concluded that the RD&D path ways of the thermo-chemical and the biochemical processes are different and independent from each other. Most of the recent RD&D initiatives are focused on high-yield feedstocks and on more efficient enzymes for improving the bio-chemical process to handle a wider variety of feedstock including agricultural waste residues and to some extent organic municipal waste.[58] RD&D investments are to a lesser extent spend on improving thermo-chemical processes, but are on the other hand composed of several mature process technologies due to application in the petrochemical industry and have in general a wider tolerance for feedstock varieties including agricultural, forestry and municipal organic waste.

Current and future international Cellulosic Ethanol production costs

In 2007, Bio Ethanol Japan (BEJ)[59] opened the world's first CE plant in Osaka. It is also the first commercial cellulosic-ethanol plant in the world. The process is based on a licensed technology by Verenium, a U.S. based cellulosic ethanol company. The plant takes wood based waste materials (construction industry waste, waste from industrial wood product manufacturing, agricultural waste, tree cuttings, etc). Moreover, Verenium, operates one of the U.S.'s first CE demonstration plant at an R&D facility, in Jennings, Louisiana. The company terminated mechanical completion of a 1.4 million gallon-per-year by mid 2008.[60,61] Verenium's goal is to demonstrate that cellulosic ethanol could be produced in

[56] http://cordis.europa.eu/fetch?CALLER=FP7_PROJ_EN&ACTION=D&DOC=47&CAT=PROJ&QUERY=011efaefcdf8:67c6:541c3e12&RCN=88489
[57] European Bioethanol Fuel Association, website: http://www.ebio.org/statistics.php?id=6 (visited January 2009)
[58] U.S. Department of Energy, Bioenergy Program, Energy Efficiency and Renewable Energy Division, website: http://www1.eere.energy.gov/biomass/field-to-plant.html (visited January 2009)
[59] Bio Ethanol Japan (BEJ), http://www.bio-ethanol.co.jp/about/index.html?PHPSESSID=2ec40d1a81e63a8d36dc8fe929db6b18
[60] http://www.technologyreview.com/Energy/20828/?nlid=1099&a=f
[61] Verenium Web-Page; http://www.verenium.com/

the range of US$ 2 per gallon by 2009.[62] Even though the plant in Jennings is a demonstration-scale facility, both this plant and the Japanese plant demonstrate that cellulosic-ethanol is an economically and technologically attractive investment and experience gained from these plants will contribute in making these technologies viable.

In May 2008, General Motors (GM) entered into a strategic relationship with Mascoma Corp., a biofuel company with technology to produce cellulosic ethanol from non-food sources via a single-step biochemical conversion. The agreement is based on joint research and development, technology exchange, and rapid commercialization of CE technology and infrastructure. Mascoma is building a pilot facility in Rome, New York, and hopes to have it operating soon. The company announced that their first demonstration plant will be located in Chippewa County, Michigan. The company is looking at 2010 or beyond before commercial scale facilities are operating.[63]

GM also has a partnership with Coskata, a renewable energy company with the means to produce low-cost ethanol from virtually any carbon-containing feedstock including biomass, MSW, and even used car tires. In November 2008, U.S. Sugar Corp. and Coskata, Inc. signed an agreement to explore building a 100-million gallon per year cellulosic ethanol facility in Clewiston, Florida. The facility, which would be the world's largest second-generation ethanol facility, would convert left-over sugar cane materials and residues into cellulosic ethanol. Coskata uses a thermo-chemical process to gasify biomass feedstock or waste into syngas, which is then fermented to ethanol. With this approach, Coskata estimates that ethanol production costs less than US$ 1.00 per gallon[64] (manufacturing cost), which could be replicated almost anywhere in the world.

Based on estimations from the U.S. Department of Agriculture (USDA), the current and future production costs for cellulosic ethanol may be around US$ 2.65 per gallon in 2007 and US$ 1.10 per gallon by 2012.[65]

Looking at the ongoing R&D activities described above, the future market for CE seems to be promising, even taking in mind the current economic crisis. Table 3.3 summarizes the current and future potential cost of production based on different sources. The values are compared to the corn-based ethanol production cost. According to this table, the future CE cost of production may range from US $0.74 – 1.07 per U.S. gallon by 2012.

[62] http://www.treehugger.com/files/2008/06/celulose-cellulosic-ethanol-plant-verenium.php
[63] Gas 2.0 biofuels, oil, and revolution. http://gas2.org/2008/05/01/gm-announces-new-cellulosic-ethanol-partnership-with-mascoma-corp
[64] Washington Times; http://washingtontimes.com/news/2008/nov/18/drop-expected-in-durum-wheat-in-southwestern-us-1/
[65] Keith Collins, Chief Economist, USDA, The New World of Biofuels: Implications for Agriculture and Energy, EIA Energy Outlook, Modeling, and Data Conference, March 28, 2007.

Table 3.3 Cost comparison of current and future CE production costs according to different assessments

	Corn-based ethanol (2007)	CE Biochemical (2007)[66]	CE Biochemical (2012)[67]	CE Biochemical (2007)[68]	CE Biochemical (2012)[69]	CE Biochemical (2007)[70]	CE Biochemical (2012)[71]	CE Thermo-chemical (2007)[72]	CE Thermo-chemical (2007)[73]	CE Thermo-chemical (2012)[74]	CE Thermo-chemical (2007)[75]	CE Thermo-chemical (2012)[76]
Feedstock	US$ 1.17	-	-	US$ 1.00	US$ 0.33	US$ 0.32	US$ 0.10	-	-	-	US$ 0.55	US$ 0.27
	@US$ 3.22/bu	-	-	@US$ 60/DT	@ US$ 30/DT	@ US$ 53/DT	@ US$ 46/DT	-	-	@ US$ 35/DT	-	-
	2.75 g/bu	@ 2,200 BDT/day	@ ≥ 2,000 BDT/day	60 g/DT	90 g/DT	-	-	@ 250 DT/day	@ 500 DT/day	@ 500 DT/day	-	-
By-product	- US$ 0.38	-	-	- US$ 0.10	- US$ 0.09	-	-	-	-	-	-	-
Enzymes	US$ 0.04	-	-	US$ 0.40	US$ 0.10	US$ 0.74	US$ 0.10	-	-	-	-	-
Other costs**	US$ 0.62	-	-	US$ 0.80	US$ 0.22	-	-	-	-	-	-	-
Capital costs	US$ 0.20	-	-	US$ 0.55	US$ 0.54	-	-	-	-	-	-	-
Conversion costs	-	-	-	-	-	US$ 1.34	US$ 0.54	-	-	-	US$ 1.30	US$ 0.80
Total	**US$ 1.65**	**US$ 2.24**	**US$ 1.50**	**US$ 2.65**	**US$ 1.10**	**US$ 2.40**	**US$ 0.74**	**≤ US$ 1.50**	**US$ 1.12**	**≤ US$ 1.00**	**US$ 1.85**	**US$ 1.07**

g = gallon, (B)DT = (bed) dry ton, ** = includes pre-processing, fermentation, labor and capital costs

[66] Scheutzle et al., Alcohol Fuels from Biomass - Assessment of Production Technologies, TSS Consultants, USA, 2007, website: http://www.westgov.org/wga/initiatives/biomass/ASSESSMENT-BIOALCOHOL-tech.pdf (visited January 2009)
[67] Scheutzle et al., Alcohol Fuels from Biomass - Assessment of Production Technologies, TSS Consultants, USA, 2007, website: http://www.westgov.org/wga/initiatives/biomass/ASSESSMENT-BIOALCOHOL-tech.pdf (visited January 2009)
[68] Keith Collins, Chief Economist, USDA, The New World of Biofuels: Implications for Agriculture and Energy, EIA Energy Outlook, Modeling, and Data Conference, March 28, 2007.
[69] Keith Collins, Chief Economist, USDA, The New World of Biofuels: Implications for Agriculture and Energy, EIA Energy Outlook, Modeling, and Data Conference, March 28, 2007.
[70] Gil Jackson (2007), Office of the Biomass Program. Retrieved September 20, 2008 from; www.sener.gob.mx/webSener/res/345/3.%20DOE%20Gil%20JACKSON.pdf
[71] Gil Jackson (2007), Office of the Biomass Program. Retrieved September 20, 2008 from; www.sener.gob.mx/webSener/res/345/3.%20DOE%20Gil%20JACKSON.pdf
[72] Scheutzle et al., Alcohol Fuels from Biomass - Assessment of Production Technologies, TSS Consultants, USA, 2007, website: http://www.westgov.org/wga/initiatives/biomass/ASSESSMENT-BIOALCOHOL-tech.pdf (visited January 2009)
[73] Scheutzle et al., Alcohol Fuels from Biomass - Assessment of Production Technologies, TSS Consultants, USA, 2007, website: http://www.westgov.org/wga/initiatives/biomass/ASSESSMENT-BIOALCOHOL-tech.pdf (visited January 2009)
[74] Scheutzle et al., Alcohol Fuels from Biomass - Assessment of Production Technologies, TSS Consultants, USA, 2007, website: http://www.westgov.org/wga/initiatives/biomass/ASSESSMENT-BIOALCOHOL-tech.pdf (visited January 2009)
[75] Thermo-chemical Conversion Roadmap Workshop, January 9 - 10, 2007 Marriott at Metro Center. Retrieved October 13, 2008 from; http://www.thermochem.biomass.govtools.us/documents/TC_R&D_Plan.pdf
[76] Thermo-chemical Conversion Roadmap Workshop, January 9 - 10, 2007 Marriott at Metro Center. Retrieved October 13, 2008 from; ttp://www.thermochem.biomass.govtools.us/documents/TC_R&D_Plan.pdf

4 Theoretical Cellulosic Ethanol Yield

The currently relevant feedstocks to produce cellulosic ethanol are agricultural and forestry residues, and municipal solid waste (MSW). The range of CE yield mainly varies by technology and feedstock. Table 4.1 shows the theoretical CE yield based on a range of feedstock.

Table 4.1 Theoretical yields per dry ton for some commonly considered biomass feedstocks in 2000

Feedstock	Theoretical Yield in gallons per dry ton of feedstock
Forest residues	66
Mixed waste paper	54
Agricultural residues	50
Wheat straw	60
Paper mill sludge	66.6
Grass straw	60.6
Wheat straw	60

Source: Government of Oregon Biomass Energy[77]

Technical research results of NREL[78] provided in Table 4.2, suggest that it is important to take into account the timeframe of technology R&D and the expected improvements in biomass-to-ethanol conversion efficiency. The current and future average theoretical cellulosic ethanol yields by the two principal sub-technologies (bio-chemical and thermo-chemical) are provided for the years 2007, 2009 and 2012.

Table 4.2 Projected theoretical average yields per dry ton and technology

Conversion Technology	2007 Technology Ethanol Yield (gal/dry metric ton)	2009 Technology Ethanol Yield (gal/dry metric ton)	2012 Technology Ethanol Yield (gal/dry metric ton)
Biochemical Conversion	65.3	74.3	89.8
Thermo-chemical Conversion	63.2	67.0	80.1

Source: U.S. National Renewable Energy Laboratory

[77] Oregon Cellulose Ethanol Study: www.oregon.gov/energy/renew/biomass/study.shtml
[78] United States National Renewable Energy Laboratory, see for more information: www.nrel.gov David D. Hsu, July 1, 2008

In order to assess the cellulosic ethanol yield potential (in gallons per year), the above collected data or parameters are used. Two scenarios are composed describing a conservative and an optimal projection using parameters that range from the ethanol yield per sub-technology and the timeframe. Two basic scenarios are described:

a. **Conservative ethanol yield scenario**: an average of the low ethanol yield values found in the literature is used to represent the lower-end current and future (2012) ethanol yield scenario.

b. **Optimal ethanol yield scenario**: an average of the high ethanol yield values found in the literature is used to represent the optimal current and future (2012) ethanol yield scenario. Table 4.3 below contains the ethanol yield factor per ton by sub-technology.

Table 4.3 Theoretical ethanol yields for the Conservative and Optimal Scenarios

Conversion Technology	**2008 Technology Ethanol Yield (gal/dry metric ton)**	**2012 Technology a. Theoretical *Conservative* Ethanol Yield Scenario (gal/dry metric ton)**	**2012 Technology b. Theoretical *Optimal* Ethanol Yield Scenario (gal/dry metric ton)**
Biochemical Conversion	70.0	90.0	105.3
Thermo-chemical Conversion	65.0	75.0	100.6

5 Finding the feedstock

In this study, the current amounts of organic waste, forest and crops residues available are estimated in order to present a general picture of the potential available feedstock for cellulosic ethanol production.

5.1 Feedstock from the Agricultural Sector

Method applied

Step 1: A selection of the most important agricultural commodities was made. To do that, the database from the national crop statistics published in the United Nations Food and Agricultural Organization (FAO) Production Year Book and the Agro-MAPS Global Spatial Database of Agricultural Land-use Statistics were used. The information from these sources was combined with the information gathered in Belize from interviews with several authorities and stakeholders related with the agricultural sector. The assumed multiplication factors for the types of crops are explained below.

Step 2: The aim was to find a gross indication of dry matter quantities of the various residues by crop type within the agricultural sector in Belize to produce cellulosic ethanol. The following steps were made:

1. Assessment of the total agricultural production per year: The data was based on production years in 2004 and 2005. The amount of production was derived from the annual report of the Ministry of Agriculture & Fisheries 2005 (acquired during the in-country assessment mission in Belize, August 2008);
2. Determination of the cultivation activities per crop by district: The areas' location and sizes were determined based on the FAO Agro-maps v.2.5;[79, 80]
3. Application of the Residue to Product Ratio (RPR) available from the literature to determine the yield of crop residue from the agricultural products, as well as composition, lower moisture content and ash content. The RPR converts directly wet weight of agricultural and forestry residues to dry weight feedstock: An overview of all values found in literature is shown in Annex 11.5. These are highly variable and one should be very careful in applying RPR ratios, because using different RPR ratio can have a tremendous influence on the amounts of residues theoretically generated. It should be stressed here that large variations in RPR ratios can lead to false expectations. Therefore it is decided to only use the most conservative RPR ratio for this study, presented in Table 5.1. In the future, the RPR should be determined at more detailed level taking in mind agronomical conditions and other measures in the field.

It is also important to distinguish between residues generated in the field and those generated during the processing phase. The reason for this is that it may be assumed that in the latter case, residues are more easily concentrated, which will make it easier for disposal or collection. On the other hand, residues spread over large areas, in such cases as straw, stalks and leaves are concentrated generally in smaller quantities. It may be noted that, agricultural production has been changing with time. This is due to usage of different farming techniques and the lasting impacts of natural disasters. In this research the latest information available corresponds to the agricultural average production data from years 2004 and 2005.

[79] FAO Agro-Maps; http://www.fao.org/landandwater/agll/agromaps/interactive/page.jspx
[80] http://www.fao.org/countryprofiles/index.asp?lang=en&iso3=BLZ&subj=4

Based on the methodology resumed above, the total amount of residues per crop (R_{fpc}) can be derived via
Equation 5.1:

$$R_{fpc} = \left(\frac{A_{c2004} + A_{c2005}}{2} \right) \times C_{fr} \qquad \text{Equation 5.1}$$

Where A_c is the amount of total crops production (ton) and C_{fr} is the residue factor per crop or Residue to Product Ratio (see Table 5.1 for used values) (a-dimensional).

Table 5.1 Potential harvestable agricultural residues in Belize (selected RPR values)

Agricultural Residue in Field	Coefficient	Agricultural Residue during a Industrial Process	Coefficient
Oranges (leaves and steam)	0.37	Oranges (skin and pulp)	0.50
Sugarcane (top and leaves)	0.17	Sugarcane (Bagasse)	0.40
Bananas (Leaves and branches)	1.50	Maize Husks	0.40
Papayas (Leaves and branches)	0.30	Rice Husks	0.29
Maize Stalks	2.10	Grapefruit and Pomelos (Skin and pulp)	0.50
Rice Straw	1.80		
Sorghum Straw	1.81		
Peas (leaves, green matter)	0.43		
Grapefruit and Pomelos (leaves and steam)	0.37		
Beans (leaves and green matter)	0.43		
Vegetables (residues)	0.50		

Step 3: The gross volume of ethanol production is calculated using the theoretical yield per dry ton for some commonly considered biomass feedstock as described in Table 4.3 (page 19).

Results
Table 5.2 summarizes the agricultural industry production per product in Belize for the year 2004 and 2005. Sugarcane is the most abundant agricultural product in Belize and represents the primary source for cellulosic biomass feedstock. However, other products as sorghum, rice, maize, fruits and vegetables also have a great agro-residues potential.[81]

[81] The forage demand is not included in this study.

Table 5.2 Major agricultural production in Belize in 2004[82] and 2005[83]

Agricultural product	Production in 2004 (metric tons wet weight)	Production in 2005 (metric tons wet weight)
Oranges	205,000	265,350
Sugarcane	1,149,475	929,392
Bananas	79,000	76,000
Papayas	26,664	26,384
Maize	30,530	34,643
Rice, paddy	10,680	17,692
Sorghum	8,146	6,759
Peas, dry	3,137	2,700
Grapefruit and Pomelos	53,660	55,966
Beans, Dry	4,063	5,317
Vegetables Fresh	3,450	3,500
TOTAL	**1,573,805**	**1,423,703**

Agriculture still continues to form the foundation of the productive sector and the rural economy of Belize. The production amounts shown in Table 5.2, represent, at least, 35% of GDP ($338 million at constant prices) and 41% of total employment is directly dependent on agriculture, fisheries & forestry. Agriculture is vulnerable to climate change impacts and being a main economic pillar, it is evermore important to consider sustainability criteria for the reliable supply of residues. In recent years, natural disasters (e.g. hurricanes and tropical storms) have contributed to a reduction in agricultural production and exports, leading to short-term increases in food imports.[84] According to the Ministry of Agriculture and Fisheries a drought affected the country from the last trimester of 2004 and extended into first semester of 2005 affecting the production of some agriculture products. Some sectors with stronger economical and infrastructural support (e.g. irrigation systems) were less affected and even managed to increase their production.

Farming in Belize is uniquely distinct from the rest of countries in the region, taking in account its major farming systems, the Milpa and the Mennonite farming systems. The Milpa system is one of shifting cultivation on a rotational basis for each production cycle. Small farmers, primarily of indigenous origin grow corn and beans in sparsely populated areas, traditionally for their own consumption. However, this is changing somewhat with more export-oriented commodities in the production basket. Alternatively the Mennonites use a farming system which is more cooperative / community-driven in scope. Major commodities grown by the Mennonites include poultry, dairy-based products, corn and other grains, vegetables and beans.[85] According to the data provided above, the potential amount of residues is considered adequate for a sustained feedstock supply for the production of cellulosic ethanol.

Residue availability

Agricultural residues are not available throughout the year; the amount available depends upon the harvesting time and the storage requirements. According to Mr. Arturo Hernandez (Member of the Management Committee of the Belize Cane Farmers Association) it has been observed that for the majority of the agricultural crops, residues are available for a maximum period of 5 months on the lands. In general cereals residues remain on the lands for a period of 4 months from August to December and

[82] FAO Statistical Yearbook, visited 10 June, 2008
[83] Ministry of Agriculture and Fisheries in 2005
[84] Belize European Union ACP Partnership, Annex VIII – Agricultural Sector Performance http://www.deljam.ec.europa.eu/en/belize/annualrep/2002/Annexes/ANNEX%20VIII.pdf
[85] SINGH, R.H, RANKINE, L.B., SEEPERSAD, G., 2005. A Review of Agricultural Policies: CASE STUDY OF BELIZE. REPORT PREPARED FOR THE CARICOM SECRETARIAT by THE DEPARTMENT OF AGRICULTURAL ECONOMICS AND EXTENSION THE UNIVERSITY OF THE WEST INDIES ST. AUGUSTINE, TRINIDAD W.I. source: http://www.caricom.org/jsp/community/agribusiness_forum/agri_policy_belize.pdf

sugar cane residues for about 7 to 10 months per year. Residues availability thus depends highly on crop-production, which depends upon the agronomical conditions. An indication of the areas available with all potential residues (feedstock) in Belize is depicted in map included in Annex 11.6.

Potential harvestable Agro-Residues and Potential Cellulosic Ethanol Production

The total amount of residues potentially harvestable in an area of 35,000 ha of permanent crops in a year in Belize is over 500,000 ton per year (2004-2005), see Table 5.3. Based on this amount it is possible to estimate the potential amount of cellulosic ethanol production with the theoretical yield based on current technology efficiency.

Table 5.3 Potential harvestable agricultural residues in Belize

Agricultural Residue in Field	**Potential Amount of Residues harvestable *in the field (MT dry weight (dw))***	**Agricultural Residue *during a Industrial Process***	**Potential Amount of Residues Harvestable during *a Industrial Process(MT dry weight)***
Oranges (leaves and steam)	87,015	Oranges (skin and pulp)	117,588
Sugarcane (top and leaves)	181,901	Sugarcane (Bagasse)	417,506
Bananas (Leaves and branches)	116,250	Maize Husks	13,035
Papayas (Leaves and branches)	7,957	Rice Husks	4,057
Maize Stalks	68,411	Grapefruit and Pomelos (Skin and pulp)	27,407
Rice Straw	25,593	Maize Cob	15,817
Sorghum Straw	13,528		
Peas (leaves, green matter)	1,255		
Grapefruit and Pomelos (leaves and branches)	20,281		
Beans (leaves and green matter)	2,017		
Vegetables (residues)	1,738		
Total Potential Harvestable feedstock from the field	**525,945**	**Total Potential Harvestable feedstock during a industrial process**	**595,408**

Table 5.3 shows that a total amount of approximately 1,121,353 metric ton of cellulosic biomass residues is available in Belize.[86] Based on this potential amount of biomass available from the agricultural sector, it is possible to estimate the potential amount of cellulosic ethanol yield, see the results in Table 5.4.

[86] Take in account that the basic data used was for the years 2004 and 2005.

Table 5.4 Theoretical cellulosic ethanol yield from agricultural residues in Belize

Conversion Technology	Potential Amount of Biomass feedstock (MT dw)	2008 Ethanol Yield (gal/y)	2012 Theoretical *Conservative* Ethanol Yield Scenario (gal/y)	2012 Theoretical *Optimal* Ethanol Yield Scenario (gal/y)
Biochemical Conversion	1,121,353	78,494,704	100,921,762	118,078,462
Thermo-chemical Conversion	1,121,353	72,887,940	84,101,469	112,808,103

5.2 Feedstock from the Forestry Sector

According to the Belize Forest Department, 79% of Belize's 2.3 million hectare of land is covered by natural vegetation, but only 55% can be considered substantial forest. Between 1990 and 2000, this number diminished by 21%, for this reason the Belizean government has the remaining 43.6 % of the forest protected.

According to the country report prepared as part of the Global Forest Resources Assessment 2005 (FRA 2005) [87], which is currently the most comprehensive assessment to date, the amount of Dead Wood Biomass (DWB) in the forest of Belize in 2005 was approximately 18 million metric tons of oven-dry weight. DWB is defined as all non-living woody biomass not contained in the litter, which is either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps larger than or equal to 10 cm in diameter or any other diameter used or specified by the country. The logistics to attempt to collect this feedstock to produce CE is highly complex, for this reason this amount of biomass is not considered in the following calculations.

As of 2004, 319,000 ha of forest were available for sustainable harvesting. Assuming a deforestation rate calculated by the Forestry Department of Belize of 2.3% annually[88], the current (2008) remaining forest is estimated to be covering an area of 172,266 ha. Extrapolating the amount logged back in 2004 to present time, an amount of 188,000 m^3 of round wood can be identified.

With this panorama in mind it is possible to assume that the current state of forest health in Belize is a result of both human and natural influences (e.g. Hurricane, Tropical storms, Forest-industry, among others). Recognizing the importance of the protected areas, the Ministry of Natural Resources appointed a Task Force in October 2003 to develop a policy and plan for Belize's protected areas system.

There are 45 sawmills in Belize with an established annual capacity of 200,000 m^3.[89] However, with timber resources exhausted in public lands there has been a change in the silvicultural practices in concessions to access private and public land to exploit forest reserves that represent the last remaining timber stocks, according to the last national inventory. Studies in the past showed that only about 14 percent of forested land are suitable for sustainable timber production; of these, 4.4 percent are within

[87] Global Forest Resources Assessment, Belize Country Report 2005; http://www.fao.org/forestry/media/8859/0/171/
88 Belize Forest Department and FAO. 2004. National report Belize. Latin American Forestry Sector Outlook Study Working Paper - ESFAL/N/17, Belize Forest Department and FAO, Rome, 70 pp. Available at: http://www.fao.org/docrep/007/j4051b/j4051b00.htm
[89] Latin American Forestry Sector Outlook Study, Working Paper, National Report Belize, 2004. http://www.fao.org/docrep/007/j4051b/j4051b00.htm

public land and the remaining 9.6 percent are in protected areas and private land.[90] Figure 5.1 shows the lumber production (including main lumber industries and their production).

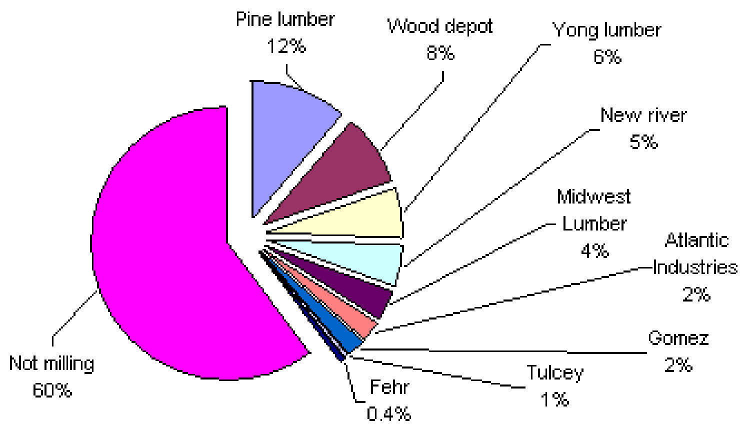

Figure 5.1 Relative contributions to the Belizean lumber production by industries[91]

It is difficult to estimate the resource potential from thinning because it depends on a wide range of factors, as among others planting density, species, age and location. Therefore the residues vary considerably per region. However, the national forestry statistics published in the FAO Production Year Book in combination with the information gathered from an interview with Mr. Wilber Sabido, Chief Forest Officer of Forestry Department were used to estimate the current amount of forestry residues available for cellulosic ethanol production. In 2008, the forest resources equaled 14-17% of the natural territory of Belize.

Logging Residues recovery rates; Logging residues consist of branches, leaves, lops, tops, damaged or unwanted stem wood, such residues are often left in the forests. Recovery rates vary considerable by local conditions, usually a 50/50 ratio is often found in the literature e.g. for every cubic meter of log removed, a cubic meter of waste remains in the forest (including the less commercial species). In case logging is carried out for export purposes, values of up to 2 cubic meters of residues for every cubic meter of log extracted may apply.[92]

A range of 30-40% logging wastes have been reported by FAO[93] indicating a recovery rate of 66% with 34% being residues, consisting of stumps, branches, leaves, defect logs, off-cuts and sawdust. This figure may be higher if unwanted species that are felled intentionally or accidentally are considered as well. In order to calculate the amount of logging residues an average conservative recovery factor of 40% has been used.

Saw-milling; Sawmill residues are used for various purposes but much depends on local conditions such as demand centers nearby. However, the recovery rates vary with local practices as well as species. According to FAO[94], after receiving the logs, about 12% is waste in the form of bark. Slabs, edgings and trimmings amount to nearly 34% while sawdust constitutes another 12% of the log input. After kiln-drying

[90] National Report Belize, Prepared by the Belize Forest Department and FAO, available at: http://www.fao.org/docrep/007/j4051b/j4051b00.htm
[91] Ibid 43
[92] Adams, M. (1995), Technical Report: Forest Products, Harvesting and Utilization Component, Paper presented to a Project Formulation Workshop on Sustainable Conservation, Management and Utilization of Tropical Rainforests in Asia, GCP/RAS/148/AUL, Bangkok, 6-8 February 1995.
[93] Trash or treasure? Logging and mill residues in Asia and the Pacific (2001), available at: http://www.fao.org/docrep/003/X6966E/X6966E00.htm#TOC
[94] Energy conservation in the mechanical forest industries (1990), FAO Forestry Paper 93. http://www.fao.org/docrep/T0269e/T0269e00.htm

the wood, further processing may take place resulting in another 8% waste (of log input) in the form of sawdust and trim end (2%) and planer shavings (6%). In order to calculate the residues, a yield factor of 50% has been used in this research (composed of 38% solid wood waste and 12% sawdust).

To calculate the potential amount of harvestable forestry residues in tons, the following steps were taken:

Step 1: It is estimated that from the 100 percent of logging wood available, during the cutting of trees, the 'round wood' volume is equivalent to 60 percent of this total volume and that 40 percent remains as residues on-site and count as the first order source of CE feedstock. To estimate this total volume of residues in tons, it is necessary to determine the total amount of 'round wood' which is the sum of 'Fuel wood' and 'Industrial round wood'. To do this, a balance of volume of production by species was used to calculate the total amount of logged wood. [95] See Figure 5.2 for a schematic overview of the methodology.[96]

Step 2: The total volume of 'round wood', identified for the year 2004[97] was the sum of 62,000 cubic meters of 'Industrial round wood'[98] and 126,000 cubic meters as 'Fuel wood'. During the milling process about 50 percent of the 'Industrial round wood' remains as a residue. This sawmill residue matches a total volume of 31,000 cubic meters.

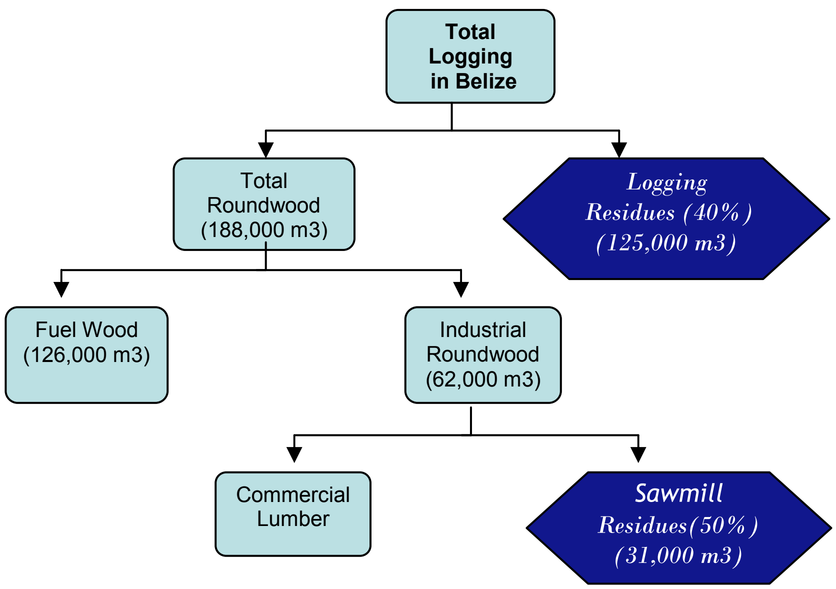

Figure 5.2 Flow chart of the wood volumes from logging to wood product in Belize

Step 3: Once the relative residues from general logging activities is determined, the relative contribution to the overall wood production is assessed. Figure 5.3 provides an overview of the relative contribution to the total wood production by species.

[95] Conversion factor, sources; http://www.simetric.co.uk/si_wood.htm
[96] Latin American Forestry Sector Outlook Study, Working Paper, National Report Belize, 2004. http://www.fao.org/docrep/007/j4051b/j4051b00.htm
[97] This was the only available reported data.
[98] Industrial round wood, as defined in FAO Forest Products Yearbook, includes all industrial wood in the rough (saw logs and veneer logs, pulpwood and other industrial round wood).

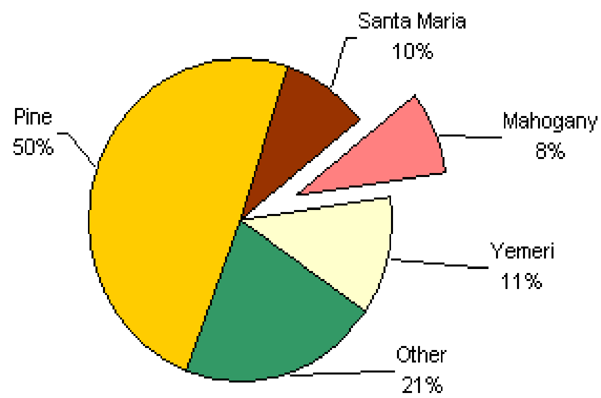

Figure 5.3 Production by species in the Belize forestry sector[99]

Table 5.5 summarizes the factors used to convert the volume of wood into mass by species logged in Belize.

Table 5.5 Density per wood species[100]

Wood (Seasoned and dry)	Density (kg/m3)
Caribbean/Ocote Pine[101]	737
Santa Maria[102]	641
Mahogany[103]	657
Yemeri[104]	569
Others[105]	500

Step 4: The known residue volumes of wood produced per species are converted into dry mass (ton) to facilitate the estimation of the ethanol yield. The conversion factors used are summarized in Table 4.1.

The results obtained with this methodology are summarized in Table 5.6 and Table 5.7 showing the "potential harvestable forestry residues" from wood logging and industrial round wood processing.

Table 5.6 Potential harvestable forestry residues from logging activities in Belize

Logging	Residues Potentially Harvestable (MT dw)
Caribbean/ Ocote Pine	46,062
Santa Maria (Calophyllum antillanum)	8,012
Mahogany (Swietenia macrophylla)	6,570
Yemeri (Vochysia hondurensis Sprague)	7,837
Others	1,3125
Total from Logging	**81,607**

99 Ibid 43
100 Kukachka, F. (1969), Properties of Imported Tropical Woods, US Forest Service; http://www2.fpl.fs.fed.us/publications/fplrp125.pdf
101 Ibid 52.
102 Center for Wood Anatomy Research, Calophyllum brasiliense; http://www2.fpl.fs.fed.us/techsheets/Chudnoff/TropAmerican/pdf_files/caloph1new.pdf
103 Center for Wood Anatomy Research, Swietenia macrophylla; http://www2.fpl.fs.fed.us/TechSheets/Chudnoff/TropAmerican/html_files/swiete1new.html
104 Center for Wood Anatomy Research, Vochysia spp; http://www2.fpl.fs.fed.us/TechSheets/Chudnoff/TropAmerican/pdf_files/vochys1new.pdf
105 An average density ratio of the species less commercial in Belize was used.

Table 5.7 Potential harvestable forestry residues from industrial round wood processing in Belize

Sawmill	Residues Potentially Harvestable (MT dw)
Pine	11,423
Santa Maria (Calophyllum brasiliense)	1,987
Mahogany (Swietenia macrophylla)	1,629
Yemeri (Vochysia hondurensis Sprague)	1,943
Others	3255
Total from Sawmill	**20,239**

The total amount of biomass from forestry is about 101,846 MT/year. It should also be noted that the information provided here only shows the gross amount of residues, which are generated in theory. In practice this amount is not expected to be more, this is due to a variety of reasons, e.g. the use as raw material for non-energy purposes like feed for cattle.

Step 5: The gross volume of ethanol production is calculated using the theoretical yield per dry ton for some commonly considered biomass feedstock. This conversion yield is between 70-110 gallons per dry ton of feedstock for cellulosic ethanol conversion systems[106], potential CE yield from forestry activities can be seen in Table 5.8.

Table 5.8 Theoretical potential cellulosic ethanol yield of forestry residues from current forestry activities in Belize

Conversion Technology	**Total Potential Amount of sustainable-harvestable Biomass (MT dw)**	**2008 Technology Ethanol Yield (gal/y)**	**2012 Theoretical *Conservative* Ethanol Yield Scenario (gal/y)**	**2012 Theoretical *Optimal* Ethanol Yield Scenario (gal/y)**
Biochemical Conversion	101,846	7,129,220	9,166,140	10,724,384
Thermo-chemical Conversion	101,846	6,619,990	7,638,450	10,245,708

5.3 *Feedstock from the Waste Management Sector*

Solid waste management in Belize remains one of the great challenges to the Government of Belize. In the 1990s Belize had a total lack of waste management services. Reasons for prior in-action are among others:

- Lower demographic pressure
- No or limited organization of the civil society to pressure the government
- Lack of technical and financial resources
- No waste management policies or regulations

[106] National Renewable Energy Laboratories (NREL), http://www1.eere.energy.gov/biomass/pdfs/32438.pdf and http://www1.eere.energy.gov/biomass/for_researchers.html

However, today numerous municipalities have contracts with private companies for the collection and disposal of waste. Still, the waste is just deposited in open dumps or in not adequately sited and designed landfills, generating environmental damage and causing other contamination issues.

Currently, the majority of landfills do not meet the technical qualifications required for a sanitary landfill and the waste is just disposed of on the lands.[107] Using Google-Earth, it is possible to take a view of the current conditions of landfills in Belize City (see Figure 5.4 and Figure 5.5). The images show the critical situation at a landfill near Belize City. Large amounts of organic waste materials can be observed that can be considered potential cellulosic ethanol feedstock.

Figure 5.4 Bird-view picture of the landfill near Belize City (March, 2006)

[107] National Assessment Report for Barbados +10, Government of Belize 2003. http://www.sidsnet.org/docshare/other/20041117154915_Belize_NAR_2004.doc

Figure 5.5 Pictures of the landfill near Belize City (August, 2008)

The total amount of organic waste as feedstock for the cellulosic ethanol system is difficult to measure in the Belizean context. This is because there has been limited monitoring of generated Municipal Solid Waste (MSW) in cities and other urban settings. To estimate the available amount of solid organic waste, it is essential to determine the waste quantity and composition. As an ad-hoc solution to the limited information available, the following method was used:

Step 1: Waste statistics data was collected from the National Solid Waste Management Project and the Central Statistical Office of Belize (CSO)[108] for the year 1999. This report highlighted that the average production of was around 1.69 kg/person/day. Current research[109] verified this average amount of waste per capita/day.

Step 2: Interviews were held with officials from the Ministry of Natural Resources and Environment that include Waste Management as one of their mandates. The objective was to collect updated information on waste generation and composition. The preferred data is waste generation at the domestic, commercial and industrial level.

According to Mr. Martin Alegria (Chief Environmental Officer, Department of Environment, Ministry of Natural Resources and the Environment, Belize)[110], it is estimated that Belize in 2006 produced over 200,000 tons of solid waste annually from domestic households and commercial establishments. There is no data on the quantity or composition of tourism generated waste. Municipal wastes are not separated by domestic and industrial sources. The average collection cost of waste in Belize City is about US$ 14.76 per ton; however in other cities the cost of collection easily surpasses the amount of US$ 30 per ton. Currently, Belize has no regulations regarding the siting, design, operation, management, monitoring, closure and post closure care for landfills.

Step 3: Since no updated information exists concerning the composition of the waste, the following waste composition data dated from 1997 was used. The composition of the solid waste was dominated by papers and organic waste (see Figure 5.6). The amount of plastic has probably increased in the last decade, due to changes in imported products and in consumption patterns triggered by economic development. But as an initial attempt to identify the potential feedstock, the waste composition data for 1997 in Belize is used, unless more updated info is provided within this project's timeframe.

[108] National Solid Waste Management Project, 199 and the Central Statistical Office of Belize (CSO) in 2002; source: NATIONAL ASSESSMENT REPORT for Barbados +10, Government of Belize September 2003. visited 09 June 2008
[109] Lewis, G. (2008), Analyzing the potential of utilizing the Methane emissions from the Western Corridor Waste Landfill sites for electrical energy generation; http://www.hydromet.gov.bz/Microsoft%20Word%20-%20LEWIS%20Methane%20Abatement%20PROGRESS-Report%20.pdf
[110] Albert Roches, 2007. Solid Waste Management Present State in Belize. http://www.epa.gov/landfill/conf/ca_workshop/SolidWasteBelize.pdf

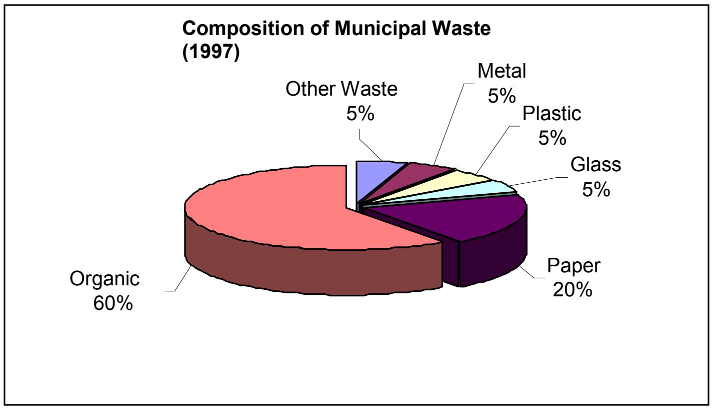

Figure 5.6 Waste composition for Belize in 1997 (Ratified, 2008)[111]

Figure 5.6 shows that the organic waste fraction amounted to about 80% of the total waste generated. This is a phenomenon that is common in economies with high dependency on the agricultural sector. The agricultural sector is currently the second most import sector in the Belizean economy and therefore we can expect that the organic waste is equal to or greater than 50% or more of the total generated waste. In 2003, a study confirmed that organic waste accounts for 30 to 60 percent of the MSW in most Caribbean and Latin American countries.[112]

Step 4: In the Belizean context, it was decided to rely on more conservative assumptions. For instance, gypsum board does not contain cellulose material among the paper fraction of the waste. In the total amount of waste (200,000 tons), approximately 20 percent corresponds to paper and 60 percent is organic waste. From this total of waste, there is nearly 80 percent, or about 160,000 MT, of potential feedstock available to produce cellulosic ethanol. According to a recent research the amount of organic waste is 83%.[113] Yet for our calculations, 80% is used.

Step 5: Once the range of potential organic waste is defined and the total amount of waste generated per year is estimated, a conversion is made to determine cellulosic ethanol production from organic waste. Currently, when assessing the available sub-technologies, the thermo-chemical technology is the only process that is capable of converting this type of feedstock into cellulosic ethanol.[114] The range of ethanol yields provided in chapter 4 are used for these calculations.

Based on this potential amount of organic waste available from the MSW, it is possible to estimate the potential amount of cellulosic ethanol yield, see Table 5.9 for results.

[111] Ratified by Lewis, G. (2008), Analyzing the potential of utilizing the Methane emissions from the Western Corridor Waste Landfill sites for electrical energy generation; http://www.hydromet.gov.bz/Microsoft%20Word%20-%20LEWIS%20Methane%20Abatement%20PROGRESS-Report%20.pdf
[112] International Development Research Centre, 2003, Recycling Organic. Wastes. http://www.idrc.ca/uploads/user-S/10530123150E5.pdf
[113] Ibid. 69
[114] CIFAR Conference XXIV A Global Eye on California's Biorefinery Industry UC- Davis June 12, 2007,

Table 5.9 Theoretical potential cellulosic ethanol yield from organic waste in Belizean MSW

Conversion Technology	Total Potential Amount of Sustainable-harvestable Biomass from MSW (MT)	2008 Technology Ethanol Yield (gal/y)	2012 Theoretical *Conservative* Ethanol Yield Scenario (gal/y)	2012 Theoretical *Optimal* Ethanol Yield Scenario (gal/y)
Thermo-chemical Conversion	160,000	10,400,000	12,000,000	16,096,000

The total gross theoretical yield under 2008 conditions from 160,000 ton of organic municipal waste is 10.4 million gallons per year of cellulosic ethanol. The 2012 forecast indicate a yield range of 12 – 16.1 million gallons of ethanol from organic waste.

5.4 Overall CE feedstock available in Belize

Based on the analysis made in previous sections, the overall gross feedstock and cellulosic ethanol yield potential for Belize are 1.2 - 1.4 million metric tons and 85.6 - 89.6 million gallons of ethanol respectively. The feedstock is supplied from the agricultural, forestry and waste management sectors of Belize, see Table 5.10 for specific quantities per sector. Note that in chapter 7 this gross amount of feedstock is scrutinized and adapted to sustainable supply rates.

Table 5.10 Potential feedstock availability in Belize under 2008 conditions per sector (metric tons)

Agriculture	Forestry	MSW
1,121,353	101,846	160,000

The gross cellulosic ethanol yield potential for 2008 conditions and 2012 forecast are shown for both the biochemical as the thermo-chemical process technologies, see Table 5.11 for more detail.

Table 5.11 Theoretical potential cellulosic ethanol yield in Belize with feedstock originating from the agricultural, forestry and waste management sectors

Conversion Technology	Total Potential Amount of harvestable Biomass from Agriculture, Forestry and MSW (MT)	2008 Technology Ethanol Yield (gal/y)	2012 Theoretical *Conservative* Scenario, *Total* Ethanol Yield (gal/y)	2012 Theoretical *Optimal* Scenario, Total Ethanol Yield (gal/y)
Biochemical Conversion	1,223,199	85,623,924	110,087,902	128,802,846
Thermo-chemical Conversion	1,383,199	89,907,930	103,739,919	139,149,811

6 Assessing the Cellulosic Ethanol Feedstock Cost

Usually, agriculture residues are assumed to be available at "no-cost" to the user by the nature of them. However, this assumption is clearly not valid. When agricultural residues are used by the owner, the costs of the residues are not clearly determined and depend on the type of crop and the level of agro-chemicals used in the process.

In the Belize context, the classic econometric tools are not useful for estimating the supply cost of residues because currently there is no existing formal market for the residues materials or products. Principally, price data is not available. However, as a first approximation, it could be assumed that the cost of crop harvesting, collection and transportation of the residue would be the primary contributors towards the cost of residues. Data from Ministry of Agriculture & Fisheries and FAO 2004 are used as a baseline. For this study, an attempt to estimate the cost of potential harvestable residues has also been made.

In this research, the costs are influenced by; first, the cost of harvesting residue and second, the transport rate and density of available residues to be delivered to the processing plant.

6.1 Feedstock Distribution and Critical distance between feedstock and processing plant

Using the maps developed by the Food and Agriculture Organization of the United Nations (FAO) [115] and a map of the principal roads of Belize, Annex 11.7, it is possible to estimate the distance between the principal roads and location of permanent crops.[116]

In order to asses the potential total cost of residues, the next procedure was followed:

Step 1: Critical Distance
The transportation costs of the feedstock increases with factory capacity because greater distances are to be traveled to guarantee supplies. Based on this assumption, the relationship between distance from the cellulosic ethanol plant (d) and available residues supplies (S_{ra}) of one crop can be defined by:

$$S_{ra} = (\pi d^2) R_y C_d \qquad \text{Equation 6.1}$$

Equation 6.1 represents the product of the area of a circle or radius d, and the density of residue by the product of $R_y \times C_d$. Residue density is the product of the residue yield (R_y) and the density of planted crops in the total area (C_d). For example, in a region that produces rice, the amount of planted hectares per km^2 is C_d = 130 Ha of crop per km^2. Based in the RPR, it is possible to know the amount of residue per Ha of crop, where in this example is, R_y = 4 tons of residue per Ha, then the product of R_y and C_d give the density of residue, i.e. $R_y C_d$ =520 tons/ km^2. The density of residue is calculated only for the feedstock that is generated in the field or is deposed in a land/field.

[115] FAO Country Profiles and Mapping Information System; http://www.fao.org/countryprofiles/maps.asp?iso3=BLZ&lang=en, visited 12 June 2008
[116] This is necessary because it is generally less expensive to produce ethanol close to the feedstock supply.

If $\widetilde{S}_a$ is established as the potential capacity of a processing plant, the maximum distance between feedstock and plant required can be obtained by rearranging Equation 6.2 as follows:

$$d_{\max} = \sqrt{\widetilde{S}_{ra}/(\pi R_y C_d)} \qquad \text{Equation 6.2}$$

The relationship between the cost of feedstock transportation and distance from the processing plant to the feedstock is defined by the radius of the circle; this radius represents the distance between the crop and the plant. Also, the production capacity of the plant depends on the density of residues. For this study, the transport cost estimates are specified using plausible biomass plant capacities ($\widetilde{S}_{ra}$ =600.000 tons of residue per year (which could be considered a medium size CE plant)) and the density conditions for all available feedstock ($(R_y C_d)_i$, where i refers to different types of crop residues in Belize).

Step 2: Harvesting Cost

Assuming that the harvesting of the residue is done manually (highly true in Belize's case), the harvesting cost of residues (H_c) is estimated by dividing the daily remuneration rate of labor *(R)* (expressed in US $ per day), by the harvesting capacity (H_{cap}) (in tons per day).

In this research, the harvesting cost has been calculated for maize stalks, husk and cob only, because the other residues do not require a separate harvesting. The expression is:

$$H_c = \frac{R}{H_{cap}} \qquad \text{Equation 6.3}$$

Step 3: Collection Cost

The residues are required to be collected from different points on the farm before transportation. The cost of collection is related with the wage rate and time used in the collection. The Collection Cost (C_c) could be calculated by dividing the daily wage cost or remuneration (*R*) by the carrying capacity in tons per trip ($C_{cap.}$) and the numbers of trips made by a person per day (*n*).

$$C_c = \frac{R}{(C_{cap} \times n)} \qquad \text{Equation 6.4}$$

Step 4: Transportation Cost

The main factors influencing the distribution between farm costs and delivered plant costs are the density of residue, the capacity of processing plants, and local truck-hauling rates. It is important to account for local variation of transport costs.

The transportation cost (T_c) can be estimated, based on the fuel consumption (F_{cons}) of the truck per hour of operation, the cost of fuel (C_{fuel}), the driver's remuneration per hour (R_d), the distance of transportation (d), the carrying capacity of the tractor (Tr_{cap}) and the transportation speed in km/h (S_t). In this research, the assumptions are made for a standard dump truck.

$$T_c = d_{\max} \frac{(F_{cons} \times C_{fuel} + R_d)}{(Tr_{cap} \times S_t)}$$ Equation 6.5

Step 5: Total Cost

The total cost of the agricultural residues ($TT_{\cos t}$) is the sum of the equations described above:

$$TT_{\cos t} = H_c + C_c + T_c$$ Equation 6.6

The storage cost could be considered as part of the first capital invested, to prevent cost generated by a rental of a space or cost to cover the feedstock to protect from rain. In this preliminary analysis, the contribution of storage cost to the total cost could be assumed negligible.

Key Assumptions

In Table 6.1 the input parameters used for calculations of the total cost are provided. Manual harvesting is considered for estimating the harvesting cost, which is representative for the main agro-activities in Belize (observation made during the first technical visit was that a limited amount of agro-machinery is used in Belize).

The collection of residues is assumed done manually, a farm worker usually can carry 25-40 kg of collected residues in each trip and an average distance in each trip is about 0.1-0.2 km. A worker is assumed to make a maximum of 50-55 trips per day (assuming a day as 8 hours of labor). This variable was assumed for the forestry residues too. A detailed resume of the assumptions in this regard is explained in the table below.

The transport system assumed in this research is a tractor trolley, so the distances between plant and feedstock have a crucial role in the final cost. Four distance rates were used, the $d_{\max}$, 25, 45 and 85 km (12.5, 25 and 50 mi). The maximum distance of 85 km has been considered, because the average distance between the centre of Belize and surrounding borders of Belize are, to the north and south approx. 80-90 km and between the west and east approximately 20-30 km. That means that the raw material for a single plant in the centre of Belize would be available within an 85 km distance from the final use point.

Land availability and opportunities for CE plant location across Belize are vast. The following is a sample of a possible industrial site for an ethanol facility in Belize based on the distance between the feedstock and the potential centralized processing plant. The critical distance between the crop residues sources and principal roads of Belize was analyzed using the land use information, biodiversity map of Belize[117], and FAO satellite maps with the principal roads of Belize (See Figure 6.1 red lines).

According to this information, the crop locations and densities comply effortlessly with the minimum distance required to achieve reasonable transportation cost. In Figure 6.1 it is possible to observe that the average distance between the potential feedstock (in green) is within a distance of about 5 – 85 km from the potential CE facility (red dotted point). Compared with the average $d_{\max}$ (150-300km), the distances calculated in the map (see yellow straight line into the circle, calculated with satellite information) are shorter and the transportation costs are therefore presumed to be cost effective. Figure 6.1 shows the radius of 85km (red circle) that represents the area where more than 90% of the available feedstock is present.

[117] Biological Biodiversity Info.; http://biological-diversity.info/about-belize.htm

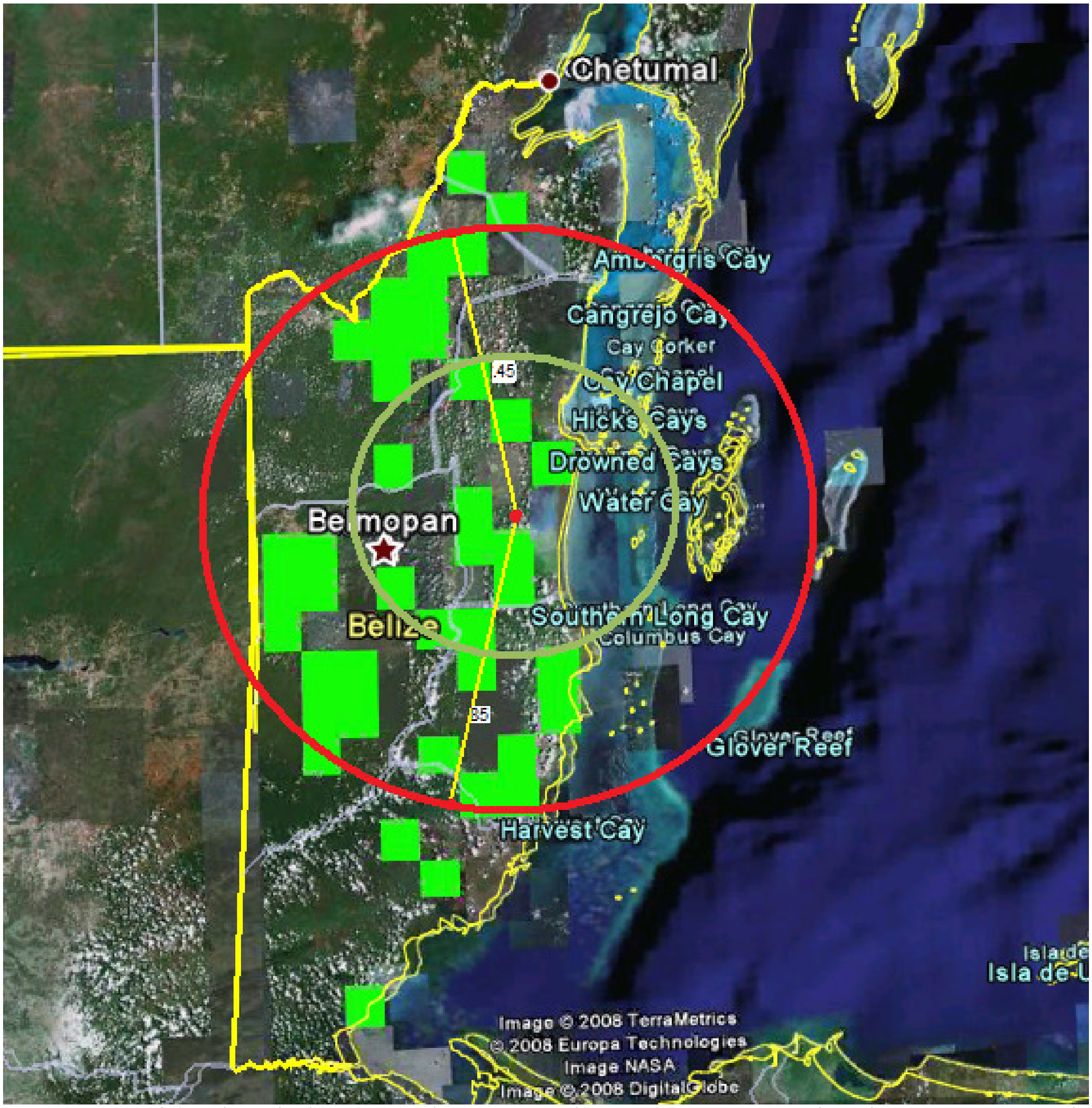

Figure 6.1 Critical feedstock density and transport distances to a centralized CE processing plant in Belize (Source: Google Earth)

A complete overview of gathered and assumed input parameters is provided in Table 6.1. The information is categorized by harvesting costs, collection costs and the transportation costs. Most of the information is gathered from interviews with representatives of the relevant sectors or industries.

Table 6.1 Input parameters for estimating the total cost of Feedstock

Variables	Units	Value
HARVESTING COSTS		
-Average Manual Harvesting capacity	Tons/person	1.0 – 1.3
- Average Remuneration[118] for worker in sugar top-leaves	US$/worker-day	12 – 15
- Average Remuneration for worker in Citrus residues	US$/worker-day	12 - 15
- Average Remuneration for worker in Banana residues	US$/worker-day	12 - 15
- Average Remuneration for worker in Cereals Stalks-Straw	US$/worker-day	12 - 15
- Average Remuneration for worker in roots/tubers residues	US$/worker-day	12 - 15
- Average Remuneration for worker in Vegetables residues	US$/worker-day	12 - 15
- Average Remuneration for worker in Fruits leaves and green matter	US$/worker-day	12 - 15
- Average Remuneration for worker in Forest	US$/worker-day	12 - 15
- Average Remuneration for worker in MSW	US$/worker-day	12 - 15
COLLECTION COSTS		
-Carrying capacity (manually)	Tons/trips	0.025-0.0400
-Avg. distance pull to collect residues from the field to the truck	Kilometers	0.10-0.20
-Avg. Trips per day	Number of trips	50-55
TRANSPORTATION COSTS (Tractor Trolley[119])		
-Average loading capacity per trip	Tons	1.7
-Average speed of transportation	Km/hr	25
-Fuel consumption[120] (60 PTO[121]- hp)	Liter/hour	10-19[122]
-Average Cost fuels[123]	US$/liter	0.95
-Remuneration of Tractor driver	US$/hour	1.5

Results

Critical distance, permanent crops, and principal roads

Based on Equation 6.2, the critical distance ($d_{\max}$) for a mid-sized CE plant ($\tilde{S}_{ra}$ =600.000 tons), depends on the density ($R_y \times C_d$) of the different feedstock. In this research, the density was calculated at the national level for the potential harvestable feedstock (See Table 6.2). Currently, nobody in Belize knows with certainty the real surface of land covered with MSW, because the number of illegal dumpsite are unknown. To estimate the amount of land covered by waste in Belize, the MSW density was estimated by using research from the study entitled, “Analyzing the potential of utilizing the Methane emissions from the Western Corridor Waste Landfill sites for electrical energy generation,” (2008).[124] According to this study, the average density of the Belizean MSW is about 200 kg/m^3 .

[118] Remuneration or wage according to Government of Belize: http://www.governmentofbelize.gov.bz/press_release_details.php?pr_id=4348
119 HP,PTO@2000 erpm=60;Standard Transmission; 2WD; Avg. Weight=3.500Kg
120 Calculations based in the software by John P. Hewlett, University of Wyoming, Department of Agricultural and Applied Economics, Farm Management Online Software; http://agecon.uwyo.edu/farmmgt/Software/
121 Maximum power takeoff horsepower (PTO-hp); Colorado State University, http://www.cde.state.co.us/artemis/ucsu20/ucsu2062250061998internet.pdf
122 Range between diesel consumption (10) and gasoline consumption (15) with the same HP-PTO
123 Range of fuel price is based in; Price in Belize per gallon, 04 Nov. 2008, Regular Gasoline=3.525US$; Premium Gasoline=3.705US$; Diesel=3.48US$. The average cost is 3,57 US$ and Price in Belize per gallon, 10 Oct. 2008, Regular Gasoline=5.06US$; Premium Gasoline=5.22US$; Diesel=4,52US$. The average cost is 3,57 US$. The average cost is 4.93 US$.
[124] Lewis, G. (2008), Analyzing the potential of utilizing the Methane emissions from the Western Corridor Waste Landfill sites for electrical energy generation; http://www.hydromet.gov.bz/Microsoft%20Word%20-%20LEWIS%20Methane%20Abatement%20PROGRESS-Report%20.pdf

Table 6.2 Cellulosic biomass feedstock density

Feedstock available in the Field	Residues density (ton/km^2)
Oranges (leaves and steam)	12
Sugarcane (top and leaves)	28
Bananas (Leaves and branches)	17
Papayas (Leaves and branches)	1
Maize Stalks	4
Rice Straw	2
Sorghum Straw	1.5
Peas (leaves, green matter)	0.5
Grapefruit and Pomelos (leaves and steam)	3
Beans (leaves and green matter)	0.2
Vegetables (residues)	0.2
Forestry (Logging residues)	5
MSW (paper/organic waste)	7
Oranges (skin and pulp)	515
Sugarcane (Bagasse)	0.85
Maize Husks	0.5
Rice Husks	0.5
Grapefruit and Pomelos (Skin and pulp)	515
Maize Cob	0.9
Sawmill wood	310.5

Potential costs calculations are based on the Equation 6.1 to Equation 6.6 explained above and express the cost of delivering the harvested feedstock from the area of production to the processing plant. See Table 6.3 and Table 6.4 for an overview of the cost results.

Table 6.3 Potential cost of cellulosic biomass feedstock from the fields in Belize

Feedstock residue	Total amount of residues (tons)	Cost of Residues									
		Harvesting cost (US$/ton)	Collection cost (US$/ton)	Transportation cost (US$/ton)				Total cost (US$/ton)			
Residues in the field				25km	45km	85km	Max. Cost(dmax)	25km	45km	85km	Max. Cost(dmax)
Oranges (in field)	52,209	-	6 - 7	6.4 - 11.5	11.6 - 20.7	22.0 - 39.1	32.6 - 58.0	13.3 -17.5	18.5 - 26.7	28.8 - 45.1	39.5 - 64.1
Sugarcane (in field)	109,141	-	6 - 7	6.4 - 11.5	11.6 - 20.7	22.0 - 39.1	21.3 - 38.0	13.3 -17.5	18.5 - 26.7	28.8 - 45.1	28.2 - 44.0
Bananas (in field)	69,750	-	6 - 7	6.4 - 11.5	11.6 - 20.7	22.0 - 39.1	27.4 - 48.7	13.3 -17.5	18.5 - 26.7	28.8 - 45.1	34.3 - 54.8
Papayas (in field)	4,774	-	6 - 7	6.4 - 11.5	11.6 - 20.7	22.0 - 39.1	113.1 - 201.0	13.3 -17.5	18.5 - 26.7	28.8 - 45.1	120.0 - 207.1
Maize Stalks	41,047	10.9 -11.5	6 - 7	6.4 - 11.5	11.6 - 20.7	22.0 - 39.1	56.5 - 100.5	24.2 - 29.1	29.4 - 38.3	39.7 - 56.7	74.3 - 118.1
Rice Straw	15,356	-	6 - 7	6.4 - 11.5	11.6 - 20.7	22.0 - 39.1	80.0 - 142.1	13.3 -17.5	18.5 - 26.7	28.8 - 45.1	86.8 - 148.2
Sorghum Straw	8,117	-	6 - 7	6.4 - 11.5	11.6 - 20.7	22.0 - 39.1	92.3 - 164.1	13.3 -17.5	18.5 - 26.7	28.8 - 45.1	99.2 - 170.2
Peas (in field)	753	-	6 - 7	6.4 - 11.5	11.6 - 20.7	22.0 - 39.1	160.0 - 284.3	13.3 -17.5	18.5 - 26.7	28.8 - 45.1	166.8 - 290.4
Grapefruit and Pomelos (in field)	12,168	-	6 - 7	6.4 - 11.5	11.6 - 20.7	22.0 - 39.1	65.3 - 116.0	13.3 -17.5	18.5 - 26.7	28.8 - 45.1	72.1 - 122.1
Beans (in field)	1,210	-	6 - 7	6.4 - 11.5	11.6 - 20.7	22.0 - 39.1	252.9 - 449.6	13.3 -17.5	18.5 - 26.7	28.8 - 45.1	259.8 - 455.6
Vegetables	1,043	-	6 - 7	6.4 - 11.5	11.6 - 20.7	22.0 - 39.1	252.9 - 449.6	13.3 -17.5	18.5 - 26.7	28.8 - 45.1	259.8 - 455.6
Forestry (Logging residues)	60,083	-	6 - 7	6.4 - 11.5	11.6 - 20.7	22.0 - 39.1	50.6 - 89.9	13.3 -17.5	18.5 - 26.7	28.8 - 45.1	57.4 - 95.9
MSW (paper/org. waste)	160,000	-	6 - 7	6.4 - 11.5	11.6 - 20.7	22.0 - 39.1	42.7 - 76.0	13.3 -17.5	18.5 - 26.7	28.8 - 45.1	49.6 - 82.0

Table 6.4 Potential cost of cellulosic biomass feedstock from industrial processing in Belize

Feedstock residue	Total amount of residues (tons)	Harvesting cost (US$/tons)	Cost of Residues			
			Total cost (US$/ton)			
Residues of industrial Process			25km	45km	85km	Max. Cost(dmax)
Oranges (skin and pulp)	117,588		6.4 - 11.5	11.6 - 20.7	22.0 - 39.1	5.0 - 8.8
Sugarcane (Bagasse)	-		6.4 - 11.5	11.6 - 20.7	22.0 - 39.1	146.0 - 259.4
Maize Husks	13,035	10.9 -11.5	17.3 - 23.0	22.5 - 23.0	32.9 - 50.6	170.9 - 295.9
Rice Husks	4,057		6.4 - 11.5	11.6 - 20.7	22.0 - 39.1	160.0 - 284.3
Grapefruit and Pomelos (Skin and pulp)	27,407		6.4 - 11.5	11.6 - 20.7	22.0 - 39.1	5.0 - 8.8
Maize Cob	15,817	10.9 -11.5	17.3 - 23.0	22.5 - 23.0	32.9 - 50.6	130.1 - 223.5
Sawmill wood	3,917		6.4 - 11.5	11.6 - 20.7	22.0 - 39.1	6.4 - 11.4

The cost of harvesting/collecting and transporting cellulosic ethanol feedstock has been estimated for residues or waste originating both in the fields and processing plants. In the case of feedstock originating from the fields, the cost per feedstock varies according to the distance between the point of collection and the processing plant. The cost is dependant on the type of residue, the collection method applied, transportation methods, logistic and the distance to the processing plant. Table 6.4 shows that at shorter distances of up to 25km feedstock costs vary between US$ 6.4 – 29.1 per ton. This potential cost range in the case of the cellulosic biomass from the fields in Belize increases to US$ 28.2 – 455.6 per ton when considering the maximal critical distance d_{max}. Among the residue types originating from the fields, sugarcane residues (tops and leaves) represent the lowest cost range of US$ 28.2 – 44.0 per ton.

Among the feedstock costs originating at the processing plants, the orange residues (skin and pulp) are among the least expensive with a cost range of US$ 5.0 – 8.8 per ton when considering the maximal critical distance d_{max} from the point of waste generation to the cellulosic ethanol plant. When taking in account all identified cellulosic ethanol feedstock the cost ranges from US$ 5.0 – 295.9 per ton. This indicates that it is extremely important to focus on the specific type and location of the residue to identify attractive feedstock options.

According to Shahbazi A. and Li Y.[125] the collection radius for an ethanol plant with 900 tons/day feedstock demand are 31 and 46 miles, and for a 1500 tons/day feedstock demand are 46 and 71 miles respectively. According with our estimations, Belize has a range of feedstock production about 1200 to 1600 tons/day. Consequently, the range of collection radius for Belize is about 39 to 68 miles (63-109km). According with our analysis approximately 90% of the feedstock is available in a radius of 52 miles (85 km). Based on the analysis made above, it is possible to estimate a range of US$ 22.0 – 56.7 per ton for feedstock present within the distance of 52 mile radius (85 km), where 90% of all available cellulosic biomass feedstock in Belize is available for harvesting.

[125] Shahbazi A. and Li Y, 2005, Assessment of Crop Residues for Bioethanol Production in North Carolina, Published by the American Society of Agricultural and Biological Engineers, St. Joseph, Michigan www.asabe.org. Paper number 056044, 2005 ASAE Annual Meeting

7 Sustainable Cellulosic Ethanol Production

In the next sections a detailed analysis is provided to explain the calculated sustainable ethanol production cost range. First, each feedstock type that is located within the 52 mi (85km) radius and that is harvested or collected in a sustainable manner is considered further in the analysis. This means that the production potential may decrease once taking in account aspects of land use changes and environmental impacts. Also a qualitative comparative analysis was done between the biochemical and the thermo-chemical processes to identify the best suitable sub-technology based on the criteria used in this study.

The potential production of Cellulosic Ethanol in Belize needs to comply with basic sustainable criteria to guarantee socio-economic and environmental benefits. Since this approach is not institutionalized or part of a standard market potential assessment, it is decided to introduce the 5E evaluation method, for details about it see Annex 11.8. This method is based on the following components: technology and feedstock evaluation (E1); energy efficiency (E2); environmental impacts (E3); economic viability (E4); and socio-political and human resource effectiveness (E5). The environmental impacts category (E3) is not a formal comprehensive EIA, but highlights in qualitative way issues to take in account at the initial evaluation phase of a biofuels project. The principal criteria used as part of the E3 category are:

1. Land Conversion
2. Biodiversity
3. Greenhouse Gas Lifecycle
4. Food displacement
5. Protected Areas
6. Land Tenure

The key factors that influence the CE production cost and therefore the market potential are:

1) feedstock availability and cost
2) sub-technology capacity and costs

7.1 Sustainable Feedstock supply (E1)

Sustainable harvestable agro-residues

It is necessary to consider the rate of removal of agricultural residues from farming lands, because of sustainability concerns, most particularly related to soil erosion and loss of soil tilth and soil moisture. Agricultural residues play a relevant role in controlling erosion and retention of soil carbon, nutrients, tilth, and moisture.

Sustainable removal rates will vary by region and management system, sometimes even with fields and quality of soils. Factors for calculating realistic and sustainable amounts of extractable residues from farm lands to produce CE are numerous and beyond the scope of this study. However, until better data is available, a conservative rate of 60% is used for the total amount of residues sustainably extracted from the agricultural lands. In this regard, according with the U.S. National Resource Conservation Service,[126] a minimum of 30% cover by residues on the field is required for sustainable agricultural practice. Future

[126] U.S National Resource Conservation Service; http://soils.usda.gov/sqi/management/files/sq_atn_19.pdf

detailed analyses will require tools as RUSLE2, WEQ, and the SCI which are likely to be the most practical ways to predict safe removal rates for erosion protection and maintain soil quality.[127]

In addition, it is necessary to mention that the Belize Sugar Industry (BSI) has established the Belize Co-Generation company (BELCOGEN), a company that will produce electricity by burning bagasse. According to Mr. Richard Harris (Director of Business Development, BELCOGEN) BSI is the only sugar mill in Belize, and for the coming crop season (Dec2008-June2009) production of approximately 420,000 tonnes of bagasse is anticipated, all of which will be used by BELCOGEN's cogeneration plant for the production of electricity. As part of their 10-year strategic plan, BSI is considering constructing a distillery for the production of dehydrated ethanol using its molasses. With this panorama in mind, bagasse and molasses may not be available sources to produce CE in Belize.

The more realistic and sustainable amount of potential harvestable residues originating from the agricultural sector for CE production are summarized in Table 7.1.

Table 7.1 Potential sustainable harvestable agro-residues in Belize

Agricultural Residue in Field	**Potential Amount of Residues harvestable *in the field (MT dw)***	**Agricultural Residue *from Industrial Processing***	**Potential Amount of Residues Harvestable from industrial processing (MT wt)**
Oranges (leaves and steam)	52,209	Oranges (skin and pulp)	117,588
Sugarcane (top and leaves)	109,141	Sugarcane (Bagasse)	0
Bananas (Leaves and branches)	69,750	Maize Husks	13,035
Papayas (Leaves and branches)	4,774	Rice Husks	4,057
Maize Stalks	41,047	Grapefruit and Pomelos (Skin and pulp)	27,407
Rice Straw	15,356	Maize Cob	15,817
Sorghum Straw	8,117		
Peas (leaves, green matter)	753		
Grapefruit and Pomelos (leaves and steam)	12,168		
Beans (leaves and green matter)	1,210		
Vegetables (residues)	1,043		
Total Potentially Harvestable in the field	**315,567**	**Total Potentially Harvestable in a industrial process**	**177,902**

Table 7.1 shows that a total amount of approximately 493,469 MT can be sustainably harvested or collected originating from both the lands and at the processing plants. Table 7.2 summarizes the potential cellulosic ethanol yield with residues biomass resources originating from the agricultural sector in Belize.

[127] Ibid. 126

Table 7.2 Theoretical potential cellulosic ethanol yield from sustainable agricultural residues in Belize

Conversion Technology	Total Potential Amount of Sustainable-harvestable Biomass from Agriculture sector (MT dw)	2008 Technology Ethanol Yield (gal/y)	2012 Theoretical *Conservative* Ethanol Yield Scenario (gal/y)	2012 Theoretical *Optimal* Ethanol Yield Scenario (gal/y)
Biochemical Conversion	493,469	34,542,848	44,412,234	51,962,313
Thermo-chemical Conversion	493,469	32,075,502	37,010,195	49,643,008

Sustainable harvestable forestry residues

It is necessary to mention that the latest information on rate of production of industrial round wood, according to FAO and Belize Forestry Department is about 62,000 cubic meters (2004). The National Forestry Report of Belize[128] notes that a sustainable rate of industrial round wood is approximately 10,000 to 12,000 cubic meters per year. With this sustainable criteria and using the methodology explained above, the amount of residues generated by logging activities is about 92,000 cubic meters. According to these sustainable amounts the sustainable potential CE yield was calculated.

The results obtained with this range are summarized in the Table 7.3 and Table 7.4 showing the "Sustainable-potential harvestable forestry residues" from wood logging and industrial round wood processing.

Table 7.3 Potential sustainable-harvestable forestry residues from logging activities in Belize

Logging	Residues Potentially Harvestable (MT)
Pine	33,920
Santa Maria (Calophyllum antillanum)	5,900
Mahogany (Swietenia macrophylla)	4,835
Yemeri (Vochysia hondurensis Sprague)	5,768
Others	9,660
Total from Logging	**60,083**

Table 7.4 Potential sustainable-harvestable forestry residues from industrial round wood processing in Belize

Sawmill	Residues Potentially Harvestable (MT)
Pine	2,211
Santa Maria (Calophyllum brasiliense)	385
Mahogany (Swietenia macrophylla)	315
Yemeri (Vochysia hondurensis Sprague)	376
Others	630
Total from Sawmill	**3,917**

The total amount of biomass from the forestry sector is approximately 64,000 MT. The gross volume of ethanol production based on this sustainable forestry feedstock is summarized in the Table 7.5.

[128] Latin American Forestry Sector Outlook Study, National Report Belize, Prepared by the Belize Forest Department (2004); http://www.fao.org/docrep/007/j4051b/j4051b00.htm#TopOfPage

Table 7.5 Theoretical sustainable-potential cellulosic ethanol yield of forestry residues from current forestry activities in Belize

Conversion Technology	Total Potential Amount of Sustainable-harvestable Biomass from Forestry Sector(MT)	2008 Technology Ethanol Yield (gal/y)	2012 Theoretical *Conservative* Ethanol Yield Scenario (gal/y)	2012 Theoretical *Optimal* Ethanol Yield Scenario (gal/y)
Biochemical Conversion	64,000	4,480,000	5,760,000	6,739,200
Thermo-chemical Conversion	64,000	4,160,000	4,800,000	6,438,400

Sustainable Feedstock from the Waste Management Sector

In this case, it was assumed that the potential amount of organic waste available from the Municipal Solid Waste (MSW) sector could be considered the same estimated amount in section 5.3. The MSW sector allows for a unique opportunity to reuse these residues while protecting the environment. Due to feedstock requirements, only the thermo-chemical process is capable of converting organic MSW into cellulosic ethanol. The potential amount of cellulosic feedstock and ethanol yield is showed in Table 7.6 below.

Table 7.6 Theoretical potential cellulosic ethanol yield from organic waste from MSW in Belize

Conversion Technology	Total Potential Amount of Sustainable-harvestable Biomass from MSW (MT)	2008 Technology Ethanol Yield (gal/y)	2012 Theoretical *Conservative* Ethanol Yield Scenario (gal/y)	2012 Theoretical *Optimal* Ethanol Yield Scenario (gal/y)
Thermo-chemical Conversion	160,000	10,400,000	12,000,000	16,096,000

Overall Sustainable CE feedstock available in Belize

The overall cellulosic ethanol yield potential for Belize is summarized in Table 7.7.

Table 7.7 Theoretical potential sustainable cellulosic ethanol yield in Belize with feedstock originating from the agricultural, forestry and waste management sectors

Conversion Technology	Total Potential Amount of Sustainable- harvestable Biomass from Agriculture, Forestry and MSW (MT)	2008 Technology Ethanol Yield (gal/y)	2012 Theoretical *Conservative* Scenario, *Total* Ethanol Yield (gal/y)	2012 Theoretical *Optimal* Scenario, Total Ethanol Yield (gal/y)
Biochemical Conversion	557,469	39,022,848	50,172,234	58,701,513
Thermo-chemical Conversion	717,469	46,635,502	53,810,195	72,177,408

Potential future sustainable CE feedstock available in Belize in 2012 and beyond

Based on the information available for Belize, it is not possible to make a real estimation of the overall amount of feedstock available by 2012 and beyond. For increasing the amount of production/residues in the agriculture sector it is necessary to make deep changes in technology, management and policy. Forestry resources are currently overexploited; and the amount proposed under the sustainable development criteria further reduces the available amount for CE. As showed in the previous section, MSW is the unique sector where it is possible to make a scientific estimation of the future amount of MSW generated. MSW availability is based on the principle that as long as there is human presence, waste is generated.

Potential Future MSW generation in Belize

According to PAHO[129], solid waste management in Belize lacks resources for proper management as landfills do not meet the technical sanitary requirements. For the future, the amount of MSW produced in Belize will increase and could become a bigger sanitary problem. A sustainable solution to tackle this increasing amount of MSW is using it as feedstock to produce cellulosic ethanol. Currently, the 160.000 MT of MSW potentially produce 10,112,000 gallons of ethanol with current thermo-chemical technology. By 2012, production of 12,816,000 gallons is possible assuming the same 2008 amount of MSW.

To explore the potential yield of CE from MSW in the near future (2010-2015) a linear regression analysis was developed. It was based on data gathered from the Belize National Meteorological Service during the research trip.[130] The data consisted of per capita daily waste generation rate for Belize (1.7 Kg/person/day) and population growth estimates from the Statistical Institute of Belize (the medium variant projection was used).[131]

The results of this analysis are summarized in Figure 7.1. The range of MSW results demonstrates that there will be feedstock potential of 245,563 ton per year by 2010 and 270,273 ton per year by 2015.

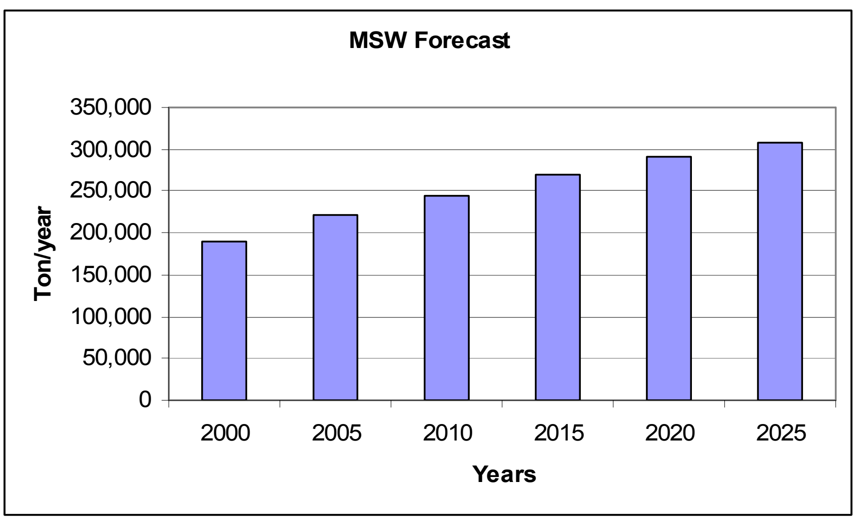

Figure 7.1 MSW Forecast for Belize

[129] Regional Evaluation Municipal Solid Waste Management Services, Belize Report (2002) http://www.bvsde.paho.org/bvsacd/cd65/belize.pdf
[130] Belize National Meteorological Service, Enabling Activities for the Preparation of the Second National Communication to the Conference of the Parties off the United Nations Framework Convention on Climate Change (2008); http://www.hydromet.gov.bz/Microsoft%20Word%20-%20LEWIS%20Methane%20Abatement%20PROGRESS-Report%20.pdf
[131] Statistical Institute of Belize (2007), http://www.statisticsbelize.org.bz/dms20uc/dm_browse.asp?pid=6

Based in the assumption that 80% of the waste is organic, and taking into account the CE conversion efficiency improvements, the potential CE yield from MSW in 2012 will be:

Table 7.8 Potential increased CE yields by MSW volume growth

Thermo-chemical approach / **CE yield Per Year**	**Estimated Gallons of Ethanol Yield for 2010**	**Estimated Gallons of Ethanol Yield for 2015**	**Estimated Gallons of Ethanol Yield for 2020**
Conservative Thermo-chemical Conversion	14,733,780-17,680,536	16,216,380-19,459,656	17,480,100-20,976,120
Optimal Thermo-chemical Conversion	19,762,910-20,686,227	21,751,571-22,767,798	23,446,641-24,542,060

Figure 7.2 depicts a breakdown by feedstock type of sustainable ethanol yield including MSW potential increased yield.

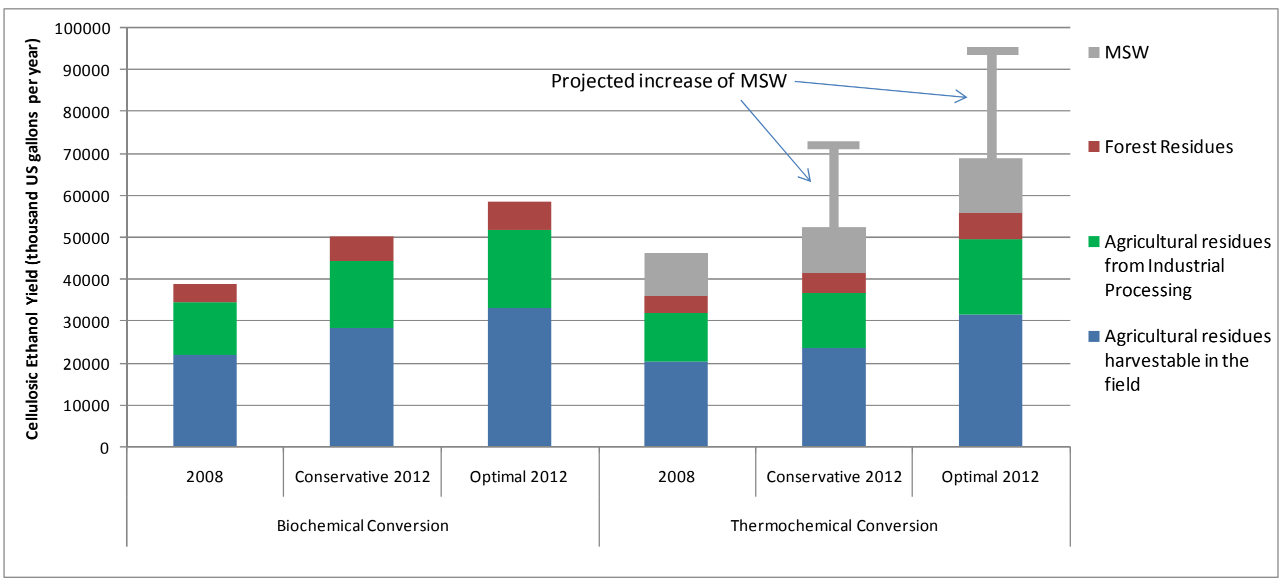

Figure 7.2 Cellulosic ethanol yields through Biochemical and Thermochemical conversions in 2008 and 2012 (conservative and optimal scenarios) by type of feedstock including projected increase of MSW

Sustainable Potential Cellulosic Ethanol production cost in Belize

Based on the analysis made in the previous sections, the theoretical CE production cost can be calculated.

This initial assessment of the potential CE production cost range in Belize is based, first on the sustainable amount of available feedstock estimated in section 7.1. Secondly, the estimated cost for harvesting, collecting and transportation of the feedstock, being in the range of 22.0 to 56.7 US per ton for the identified feedstock in Belize within the distance of 85 km (radius) to a centralized plant. And thirdly, the theoretical CE yield using the identified feedstock.

Table 7.9 shows the production cost by technology, where CE production cost in Belize will range between US$ 1.64 – 2.89 per gallon. The CE production cost via the thermo-chemical process has a range of US$ 1.64 – 2.17 per gallon under Belizean conditions and is the cheapest among the two conversion processes. Note, that the capital and operational costs are kept static in this study, where only the feedstock cost has been adapted to Belizean conditions. The technology development (learning curve via RD&D activities) will determine the rate of increased efficiency, available unit capacity, and potential capital investment cost reductions. The phase of global CE development and available tools and information, this is deemed the best estimation of CE production costs in Belize.

Table 7.9 Cost comparison of Sustainable CE production cost in Belize and current CE production costs according to different assessments

	Belize CE Biochemical A (2008)[132]	Belize CE Biochemical B (2008)[133]	Belize CE Thermo-chemical (2008)[134]	CE Biochemical Literature A (2007)[135]	CE Biochemical Literature B (2007)[136]	CE Thermo-chemical (2007)[137]
Feedstock	US$ 0.31 - 0.81[138]	US$ 0.31 – 0.81[139]	US$ 0.34 – 0.87	US$ 1.00[140]	US$ 0.32[141]	US$ 0.55
By-product	- US$ 0.10	-	-	- US$ 0.10	-	-
Enzymes	US$ 0.40	US$ 0.74	-	US$ 0.40	US$ 0.74	-
Other costs[**]	US$ 0.80	-	-	US$ 0.80	-	-
Capital costs	US$ 0.55	-	-	US$ 0.55	-	-
Conversion costs	-	US$ 1.34	US$ 1.30	-	US$ 1.34	US$ 1.30
Total (US$/Gal)	**US$ 1.96 – 2.46**	**US$ 2.39 – 2.89**	**US$ 1.64 – 2.17**	**US$ 2.65**	**US$ 2.40**	**US$ 1.85**

Figure 7.3 presents an overview of the breakdown costs (US$/gallon) for the production of CE in Belize based on current technologies compared to the average spot market price of gasoline[142] in the last five years (error bar shows the volatility of gasoline prices).

[132] The estimations of By-product, Enzymes, other cost and Capital cost based on Keith Collins, Chief Economist, USDA. Details on footnote No.131.
[133] The estimations of Enzymes and Capital cost based on Gil Jackson, Office of the Biomass Program. Details on footnote No.132
[134] The estimations of Conversion cost based on Thermo-chemical Conversion Roadmap Workshop. Details on footnote No.133
[135] Keith Collins, Chief Economist, USDA, The New World of Biofuels: Implications for Agriculture and Energy, EIA Energy Outlook, Modeling, and Data Conference, March 28, 2007.
[136] Source: Gil Jackson (2007), Office of the Biomass Program. Retrieve September 20, 2008 from; http://www.sener.gob.mx/webSener/res/345/Gil%20JACKSON.pdf
[137] Source: Thermo-chemical Conversion Roadmap Workshop, January 9 - 10, 2007 Marriott at Metro Center. Retrieved October 13, 2008 from; http://www.thermochem.biomass.govtools.us/documents/TC_R&D_Plan.pdf
[138] Calculation of the feedstock cost per gallon is based on a cost of 22 - 56.7 US$/mt and considering a distance of 85km from the CE plant.
[139] Ibid 138
[140] Calculation of the feedstock cost per gallon is based on a cost of 60 US$/mt and considering an output yield of 60 gallons/mt.
[141] Calculation of the feedstock cost per gallon is based on a cost of 53 US$/mt.
[142] Values retrieved in February, 2009 from the Energy International Agency at: http://www.eia.doe.gov/

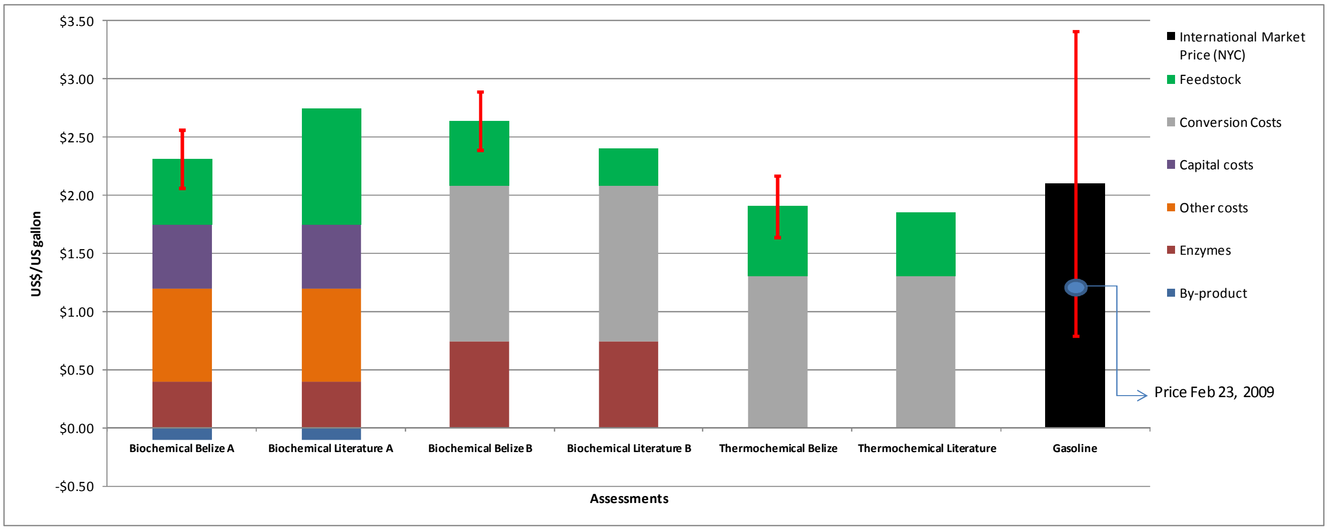

Figure 7.3 Cost breakdown comparison between Belize (error bars for uncertainty in feedstock costs) and literature reported CE production costs vs. Gasoline NYC international spot prices (average value from 2004-2009; uncertainty range represents the lowest and highest values in the market in the last 5 years)

Table 7.10 and Table 7.11 below extend the projections for cellulosic ethanol production until 2012. These estimates should be considered very preliminary as it is extremely difficult to predict the costs for an emerging technology. These figures are offered to given an idea of the possible range of costs for production assuming that the technology development process occurs as predicted.

Table 7.10 Cost comparison of Sustainable CE production cost in Belize and current CE production costs according to different assessments (Conservative Scenario)

CE Biochemical in Belize CONSERVATIVE Scenario (2012)	CE Biochemical in Belize CONSERVATIVE Scenario (2012)	CE Thermo-chemical in Belize CONSERVATIVE Scenario (2012)
US$ 1.014 - 1.40	US$ 0.884 - 1.27	US$ 1.069 - 1.493

Table 7.11 Cost comparison of Sustainable CE production cost in Belize and current CE production costs according to different assessments (Optimal Scenario)

CE Biochemical in Belize OPTIMAL Scenario (2012)[143]	CE Biochemical in Belize OPTIMAL Scenario (2012)[144]	CE Thermo-chemical in Belize OPTIMAL Scenario (2012)[145]
US$ 1.003 - 1.372	US$ 0.873 - 1.242	US$ 1.029 - 1.390

[143] Keith Collins, Chief Economist, USDA, The New World of Biofuels: Implications for Agriculture and Energy, EIA Energy Outlook, Modeling, and Data Conference, March 28, 2007.
[144] Gil Jackson (2007), Office of the Biomass Program. Retrieved September 20, 2008 from; www.sener.gob.mx/webSener/res/345/3.%20DOE%20Gil%20JACKSON.pdf
[145] Thermo-chemical Conversion Roadmap Workshop, January 9 - 10, 2007 Marriott at Metro Center. Retrieved October 13, 2008 from; http://www.thermochem.biomass.govtools.us/documents/TC_R&D_Plan.pdf

According to sources used in this study, the cost for cellulosic ethanol production is expected to fall between 2008 and 2012 by 53% for the biochemical approach and by 35% for the thermo-chemical approach.

Table 7.12 Cost comparison of Sustainable CE production cost in Belize and current CE production costs according to different assessments

	CE Biochemical in Belize CONSERVATIVE Scenario (2012)[146]	CE Biochemical in Belize CONSERVATIVE Scenario (2012)[147]	CE Thermo-chemical in Belize CONSERVATIVE Scenario (2012)[148]	CE Biochemical in Belize OPTIMAL Scenario (2012)[149]	CE Biochemical in Belize OPTIMAL Scenario (2012)[150]	CE Thermo-chemical in Belize OPTIMAL Scenario (2012)[151]	CE Biochemical (2012)[152,153]	CE Biochemical (2012)[154]	CE Thermo-chemical (2012)[155]
Feedstock	US$ 0.244 – 0.63[156]	US$ 0.244 – 0.63[157]	US$ 0.269 – 0.693	US$ 0.233 – 0.602[158]	US$ 0.233 – 0.602[159]	US$ 0.229 – 0.590	-	US$ 0.33[160]	US$ 0.27
By-product	- US$ 0.09	-	-	- US$ 0.09	-	-	-	- US$ 0.09	-
Enzymes	US$ 0.10	US$ 0.10	-	US$ 0.10	US$ 0.10	-	-	US$ 0.10	-
Other costs**	US$ 0.22	-	-	US$ 0.22	-	-	-	US$ 0.22	-
Capital costs	US$ 0.54	-	-	US$ 0.54	-	-	-	US$ 0.54	-
Conversion costs	-	US$ 0.54	US$ 0.80	-	US$ 0.54	US$ 0.80	-	-	US$ 0.80
Total	**US$ 1.014 – 1.40**	**US$ 0.884 – 1.27**	**US$ 1.069 – 1.493**	**US$ 1.003 – 1.372**	**US$ 0.873 – 1.242**	**US$ 1.029 – 1.390**	**US$ 1.50**	**US$ 1.10**	**US$ 1.07**

[146] Keith Collins, Chief Economist, USDA, The New World of Biofuels: Implications for Agriculture and Energy, EIA Energy Outlook, Modeling, and Data Conference, March 28, 2007.
[147] Gil Jackson (2007), Office of the Biomass Program. Retrieved September 20, 2008 from; www.sener.gob.mx/webSener/res/345/3.%20DOE%20Gil%20JACKSON.pdf
[148] Thermo-chemical Conversion Roadmap Workshop, January 9 - 10, 2007 Marriott at Metro Center. Retrieved October 13, 2008 from; http://www.thermochem.biomass.govtools.us/documents/TC_R&D_Plan.pdf
[149] Keith Collins, Chief Economist, USDA, The New World of Biofuels: Implications for Agriculture and Energy, EIA Energy Outlook, Modeling, and Data Conference, March 28, 2007.
[150] Gil Jackson (2007), Office of the Biomass Program. Retrieved September 20, 2008 from; www.sener.gob.mx/webSener/res/345/3.%20DOE%20Gil%20JACKSON.pdf
[151] Thermo-chemical Conversion Roadmap Workshop, January 9 - 10, 2007 Marriott at Metro Center. Retrieved October 13, 2008 from; http://www.thermochem.biomass.govtools.us/documents/TC_R&D_Plan.pdf
[152] Scheutzle et al., Alcohol Fuels from Biomass – Assessment of Production Technologies, TSS Consultants, USA, 2007, website: http://www.westgov.org/wga/initiatives/biomass/ASSESSMENT-BIOALCOHOL-tech.pdf (visited January 2009)
[153] Feed stock at ≥ 2,000 BDT/day
[154] Keith Collins, Chief Economist, USDA, The New World of Biofuels: Implications for Agriculture and Energy, EIA Energy Outlook, Modeling, and Data Conference, March 28, 2007.
[155] Thermo-chemical Conversion Roadmap Workshop, January 9 - 10, 2007 Marriott at Metro Center. Retrieved October 13, 2008 from; http://www.thermochem.biomass.govtools.us/documents/TC_R&D_Plan.pdf
[156] Calculation of the feedstock cost per gallon is based on a cost of 22 - 56.7 US$/mt and considering a distance of 85km from the CE plant.
[157] Ibid 156
[158] Ibid 156
[159] Ibid 156
[160] Calculation of the feedstock cost per gallon based on a 30US$/mt and consider an output yield of 90g/DT

7.2 Sustainable conversion technology

For this Belize CE market potential assessment study it is possible to assess only criteria 1, 3, 4, and 5 as part of the environmental impacts category (E3). Biodiversity (2) assessment is conducted to establish the location and design of the CE plant to study the different impacts on site (landscape and watershed). This is not the aim of this research. In this research biodiversity data is used, but for a different purpose.

Land Tenure (6) is related to the transparency of the negotiations made, compensations provided, and the awareness level of intended land ownership. The idea is that a future site for a CE plant is decided by local community and stakeholders.

> Criteria n.1. Land Conversion: Cellulosic Ethanol (CE) does not require the conversion of natural ecosystems into crops lands or changes in land uses. CE only needs residues from agriculture, forestry, and it is a good tool for reducing the amount of MSW.
>
> Criteria n.3. GHG life cycle assessment: These issues were evaluated and compared with other ethanol feedstock in Figure 1.1. CE is carbon neutral, basically, because the carbon present in feedstock was absorbed from the atmosphere by the plant that produced the biomass. Considering MSW as a feedstock, CE could be considered slightly carbon-negative, because all the GHGs emissions from the MSW are re-used during the CE production process. According to U.S. Department of Energy studies,[161] one of the benefits of CE is that it reduces GHGs by 86% when compared to gasoline.
>
> Criteria n.4. Food Displacement: Only crop residues are used to produce CE. CE is made from the stems, leaves, stalks and trunks of plants, none of which are used for human food consumption. With advantages far above corn-ethanol, CE will reduce the pressure on land resources being used for food and energy cultivation.
>
> Criteria n.5. Protected Areas: CE will not encroach on existing protected areas in Belize because CE's feedstock will come from residues without affecting the proximity areas. On the other hand, it is necessary to assess the potential impacts that a CE plant can have on surrounding areas and watersheds.

The issue related with soil erosion and agriculture residues was evaluated in section 7.1. The forestry and MSW sectors meet the sustainable criteria evaluated above.

Table 7.13 summarizes some general results and conclusions from the 5E assessments of thermo-chemical and biochemical processes for the conversion of renewable biomass to alcohol fuels, with electricity as a secondary product. As well, Table 7.13 shows a comparison of the thermo-chemical and the biochemical processes, applying some of the key parameters of the 5E assessment. The two technologies compared are: (A) a thermo-chemical (pyrolysis/steam reforming) facility producing mixed alcohol fuel and electricity; (B) a biochemical (enzymatic hydrolysis) facility producing ethanol fuel and electricity. The 5E factors applied in this quantitative comparison include: product yields (an E1 factor); net energy efficiency (an E2 factor); emissions of air pollutants including carbon dioxide (E3 factors); and capital, operating and production costs (E4 factors). Socio-political (E5 factors) at this stage are less amenable to quantification and thus are not included in this table.

[161] U.S. Department of Energy, Biomass Program; http://www1.eere.energy.gov/biomass/environmental.html

Table 7.13 Comparison between the Thermo-chemical and the Biochemical process[162],[163]

	A) Thermo-chemical Conversion Mixed Alcohols & Electricity	B) Biochemical Conversion Ethanol & Electricity
Typical Plant Size (E1) BDT/day	500	2,205
Feedstock type tolerance (E1)	Agricultural residues, Forestry residues and MSW	Agricultural residues and lower potential use of Forestry residues
Products (E1)		
Ethanol Fuel (gallons/BDT)	80	59
Electricity (kWh/BDT)	550	205
Total Net Energy Efficiency (E2)	50%	33%
CE Plant Emissions (E3)		
(lb/MMBTU output)		
NO_x	4.69E-03	2.71E-01
SO_x	8.72E-04	5.95E-01
PM	1.77E-02	7.30E-02
CO	2.32E-02	2.71E-01
VOC	1.73E-03	2.30E-02
CO_2	303	481
Economics (E4)		
Capital Cost, US$M	66	205
Operating Cost, $M/yr	14.9	107.0
Electricity Production Cost (U$/kWh)	$0.071	N/A
Belize CE Production Cost (U$/gallon)	$ 1.64 – 2.17	$ 1.96 – 2.89

N/A: Not applicable; E1, E2 and E4 values are given with $\pm$15% uncertainty and E3 values are given with $\pm$20% uncertainty

The reason for the lower capital costs for thermo-chemical process technologies is that several key components of the process are conducted with commercially viable and mature technologies. For instance, the catalyst used for the alcohol synthesis is commonly used in the petrochemical industry to cost-effectively produce methanol from syngas that forms the basis for products such as formaldehyde, acetic acid, MBTE and plastic compounds.

The comparative analysis shows that the thermo-chemical sub-technology[164] seems to be to best suitable cellulosic ethanol process to apply in Belize under the prevailing conditions. The wide tolerance for feedstock types, the higher ethanol yield, the lower capital costs per unit of output due to the accessibility to the technology (off the shelf technology), and the lower potential CE operating costs range are among the main arguments to consider this sub-technology as a viable short- to medium-term (by 2012) technology to produce cellulosic ethanol in Belize.

[162] Ibid 152
[163] Ibid 152 Modified to Belize specific conditions.
[164] This category includes gasification and pyrolysis processes.

8 Envisioning the Ethanol market in Belize

Global ethanol production is currently undergoing exceptional growth. According to British Petroleum, global production of ethanol grew by 27.8% to 920,000 barrels per day in the period 2006-2007.[165] Although this only represents 1.1% of the 81,533,000 barrels per day of petroleum produced in 2007, with a continuation of this growth trend in ethanol production, ethanol will certainly have a substantial impact on the equilibrium of the future global energy markets, in particular in the transport sectors.

The ethanol market potential in Belize is highly dependant on the price comparison between gasoline and ethanol, the regulatory framework in place, and fiscal incentives provided to create a domestic renewable fuels industry.

8.1 Belize Policies

As part of the ethanol market assessment, it is important to take in consideration the legal framework in place that may positively or negatively impact the prospects for sustainable biofuels development in Belize.

Industrial land is currently available in every region throughout Belize. If a company is interested in Belize as a place to develop CE production, it is necessary to provide them with clear and specific overview of requirements. The Ministry of Public Utilities will seek out technical information prior to providing an operational license. The Environmental Impact Assessment (EIA) also needs to be provided to the Department of Environment. See for a more in-depth assessment of project licensing and an overview of the main administrative bodies in Belize, Annex 11.9.

The following section covers the national legal framework concerning the environment, socio-economic development, land use issues, and the transportation sector. All these regulations and mandates have an impact on access to and availability of current and future cellulosic biomass feedstock, the operational conditions and compliance requirements for operating the CE processing facility, and the present and future standards or conditions for the consumption of ethanol in the transport sector.

National Environmental Legal Framework

According to the different authorities interviewed in Belize, when an EIA is needed for a project, the principal legal instrument that deals with environmental protection is the Environmental Protection Act of 1992. This act provides the Department of the Environment the responsibility and authority to implement regulations or instruments for the protection of the environment. Agencies involved in environmental protection include the Department of Environment, the Coastal Zone Management Authority and Institute, the Land Utilization Authority, the Geology and Petroleum Department, the Forestry Department, the Fisheries Department, and the Public Health Department.

The principal legal instruments having a direct or indirect bearing on a cellulosic ethanol project are summarized below:

1. The Environmental Protection Act (No. 22 of 1992 as amended by Act No. 328 of revised editions 2000 and 2003) states;
- *The Belize Environmental Protection Act relates to the preservation, protection and improvement of the environment, the rational use of our natural resources, and the control of pollution. This Act was passed into Legislation in 1992 (No. 22 of 1992). Under this Act and its Subsidiary Regulations several*

[165] http://www.bp.com/sectiongenericarticle.do?categoryId=9023791&contentId=7044194

areas of paramount concern are being addressed. This includes effluent discharge, pollution control, regulation of development through the use of EIA, decrease in use of ozone depleting substances as well as persistent organic pollutant. In the context of our level of development as well as relatively small size, the Act allows government to address the issue of environmental protection in consultation with other sectors including environmental groups, community organizations, developers and investors.

2. Environmental Impact Assessment Regulations No. 107 of 1995;
- These regulations form the basis for determining which projects require an EIA. Its regulations govern the type and size of development that requires an EIA, as well as detailing the EIA process. Under these regulations the National Environmental Appraisal Committee (NEAC) which vets the EIA is established.

National Energy and Transportation Sector Legal Framework

Another principal category of regulation and policies for CE development is related to the energy and transport sectors. In Belize, currently, there is no policy or legislation on renewable energy, agro-energy or biofuels for usage as transport fuel. The government is aware of the need for policy and legislation, and has some basic guidelines governing investments in this area. These guidelines include environmental impact assessment requirements and requesting adequate compensation for alleviating poverty and promoting rural development, but there is no existence of clear compliance mandates.

In October of 2004, the government of Belize authorized the formulation of a National Energy Plan (NEP).[166] Under this initiative, the Project presented a wide range of Energy Policy Recommendations to the Government of Belize.[167] Three of these recommendations are extremely relevant to cellulosic ethanol developments which are the following:[168]

a. Conduct renewable-energy resource assessments for hydro, wind, biomass, geothermal, and solar energy and compile these into a single Renewable Energy Resource Database for use in promoting Belize as a destination for renewable-energy investments. The database should not only identify resources, but should contain potential project proposals. An accompanying investor's information pack should be developed, targeted to local investors as a priority.

b. Any benefits of using ethanol to reduce emissions, increase fuel security, and increase price stability, whilst utilizing and investing in the local agricultural industry should be evaluated against the total cost of producing the ethanol and adapting the existing gasoline infrastructure to accommodate an ethanol blend.

c. The logistics and feasibility of the creation of a dedicated renewable energy fund for renewable energy project feasibility studies and for project investment should be investigated.

A comprehensive National Energy Plan is instrumental to the development of a CE market in Belize and will allow for the identification of key project opportunities and provide clear guidelines that will lead to attracting potential investors.

A summary is provided in Table 8.1 describing the relevant national regulations in place that impact the feedstock availability, technology application and the ethanol consumption in Belize.

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[166] United Nations Development Programme; Formulation of National Energy Plan for Belize (Sector Diagnostic and Policy Recommendations) Project Document UNDP, Energy Thematic Trust Fund (TTF), september 2002 Belize.
[167] Public Utilities Commission, web site; http://www.puc.bz/nep.asp, visited 8 June 2008
[168] Formulation of a National Energy Plan for Belize, Energy Policy Recommendations, December 2003; web: (Sector Diagnostic & Policy Recommendations) Project http://www.puc.bz/publications/Policy%20Recommendations%20INTERNET.pdf, visited June 8, 2008.

Table 8.1 Summary of Regulations impacting the CE development in Belize

Critical CE development aspects	Sector	Regulation	Article and Enactment	Description
Feedstock availability	Agricultural	The Land Utilization Act	(Chapter 188 of revised edition 2000)	-The Land Utilization Act establishes the Land Utilization Authority of the Ministry of Natural Resources, Local Government and the Environment, provides for measures to govern the use and development of land, and introduces measures for the conservation of land and watersheds. This Act governs the subdivision of private lands and the construction of jetties in coastal areas.
		The National Lands Act	(Chapter 191 of revised edition 2000)	-According to the National Lands Act, "National Lands" means all lands and sea bed, other than reserved forest within the meaning of the Forest Act, including cays, and parts thereof not already located or granted, and includes any land which has been, or may hereafter become escheated to or otherwise acquired by Government of Belize. These lands are classified as town lands, suburban lands, rural (including pastoral lands), mineral lands and beach lands. The minister responsible is empowered to appoint a National Lands Advisory Committee to advise him generally on matters relating to land
	Forestry	The Land Utilization Act	(Chapter 188 of revised edition 2000)	See description above
		The National Lands Act	(Chapter 191 of revised edition 2000)	See description above
		The Wildlife Protection Act	(Chapter 220 of revised edition 2000)	-The Wildlife Protection Act controls the conservation and use of protected species and empowers the Forest Department to pass regulations that govern the management of endangered flora and fauna. Under this Act 'Endangered Species' may not be kept in captivity unless so approved by the Forest Department. All species listed as endangered by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) are protected in Belize.
		National Parks Systems Act	(SI No. 5 of 1981 and Chapter 215 of 2000 Revised Edition)	-Under Section 3 of the Act, wildlife sanctuary means 'any area reserved as a nature conservation reserve in accordance with the provision of Section 3 for the protection of nationally significant species, groups of species, biotic communities or physical features of the environment requiring specific human manipulation for their perpetuation.
	Waste Management	Solid Waste Management Authority Act	(SI 224 of 2000)	-Under the Act, the Authority shall devise ways and means for the efficient collection and disposal of solid waste employing modern methods and techniques and exploring the possibility of recycling waste materials. Under the Act 'construction waste material' includes building materials from construction, alteration and remodeling building or structure of any kind, such as lumber, concrete, steel roofing, etc
Technology application		Pollution Regulations	(SI No. 56 of 1996)	- These regulations address issues of air, water and soil pollution, including noise pollution. Part III – 6 (1) deals generally with the emission of contaminants into the air where no person shall cause, allow or permit contaminants to be emitted or discharged either directly or indirectly into the air from any source. Part X 31 (c & d) deals with pollution of land generally that could be harmful, or potentially harmful to animals, birds, wildlife, plants or vegetation. The Department of Environment is responsible for the enforcement of the Regulations.
		The Public Health Act	(No. 40 of 2000)	- The newly revised Public Health Act authorizes the Ministry of Health and Sports to issue regulations to prevent, control, or reduce contamination of the air, soil or water, and prohibits improper disposal of medical and infectious wastes.
		The Land Utilization Act	(Chapter 188 of revised edition 2000)	See description above
		The National Lands Act	(Chapter 191 of revised edition 2000)	See description above
		Belize Tourist Board Act 2000	(SI 275 of 2000)	-The Belize Tourist Board Act establishes the Belize Tourist Board with wide responsibilities for the promotion of tourism in Belize. Apart from being charged with the development of the tourism industry, the Belize Tourist Board also has the responsibility to foster understanding within Belize of the importance of environmental protection and pollution control and the conservation of natural resources.

	Ancient Monuments and Antiquities Act, 1972	(Chapter 330 of 2000 Revised Edition)	- Under section 4 of the Ancient Monuments and Antiquities Act, all ancient monuments and antiquities however situated are vested in the Government of Belize. Under section 12, any person discovering an ancient monument or antiquity has to report their findings to the Minister within fourteen days of the discovery.
	Institute of Culture and History (Amendment)	Act (No. 20 of 2003)	- This act empowers the Institute of Archaeology to carry out research, interpretation and the protection of the archaeological heritage of Belize. The ownership of all ancient monuments and antiquities shall rest in the Institute of Archaeology, Government of Belize.
CE consumption	Belize Tourist Board Act 2000	(SI 275 of 2000)	See description above
	United Nations Framework Convention on Climate Change (UNFCCC)	Signed in 1992 and ratified in 1994	- "Stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system…within a timeframe sufficient to allow eco-systems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner"(UNFCCC).

Climate Change Policy

Human industrial activities from the beginning of the past century have been adding significant levels of greenhouse gases into the atmosphere. Fossil fuels (coal, oil and natural gas) for energy generation are the principal sources of emissions. Gasoline and diesel as fuels are burned to run cars and trucks, heat homes, and in the industrial sector; they are responsible for about 80 percent of global carbon dioxide emissions.

In 1994, Belize ratified the United Nations Framework Convention on Climate Change (UNFCCC) signed in 1992.[169] Based on the UNFCCC, Belize's First Greenhouse Gas Inventory was conducted in 1999, using 1994 as the base year. But, the country has yet to develop programs on climate change launching and sustaining an effective program on that direction.

The Government of Belize has designated its National Meteorological Service (NMS) as the agency responsible for providing technical advices on climate change issues. The Chief Meteorologist of the NMS is the government's chief technical negotiator on matters related to climate change, and he has been appointed as the National Focal Point since signing the UNFCCC.

In 1994 the total greenhouse gases (GHG) emission due to liquid fuels amounted to 597.77 Gg. This has increased to 618.99 and 643.59 Gg in the years 1997 and 2000, respectively. According to the last report[170] (2007), the results show a general increase of 7.6% in carbon dioxide emissions during the period 1994 - 2000. This gives a total increase of 45.82 Gg of carbon dioxide emissions.

Table 8.2 CO_2 emissions (Gg) from transport sector in Belize

Year	1994	1997	2000
Domestic Aviation	11.87	15.65	20.85
Road	263.58	275.94	330.55
Railways	-	-	-
National navigation	35.51	57.03	77.54
Total (Gg)	310.9	348.6	428.9

Emissions from road transportation are clearly the main source of CO_2 emissions in Belize, see Table 8.2. The effects of increased global GHG emissions have been felt in Belize. Changes in global temperatures are affecting Belize with severe hurricanes affecting the availability of arable land, water resources, forest productivity, and the sustainability of human and animal health. Since traffic is concentrated in urban areas, increased urban CO_2 emissions in Belize will deteriorate air quality and possibly create smog.

The Kyoto Protocol was advanced in 1998 to address these problems. It is important to create an adequate legal framework to reduce GHG emissions in Belize and establish a realistic mandatory rate of

[169] United Nations Framework (2005), Convention On Climate Change, National Capacity Self Assessment, Thematic Assessment Report, Belize http://ncsa.undp.org/docs/408.pdf

[170] May, J. (2007), greenhouse gas inventory, of the energy sector in Belize, Belize's second national communication, climate change project; http://www.hydromet.gov.bz/ENERGY%20GHG%20Inv%20Fin%20Rep.pdf

reduction for a period of time. Belize has ratified the Kyoto Protocol, which is a good reason to establish a program of greenhouse gas reductions, but up to now this has not culminated in a mandatory reduction scheme of GHGs. Ethanol has proven to reduce carbon dioxide emissions in a fuel life cycle analysis conducted by numerous studies around the world. And ethanol derived from cellulose biomass decreases CO_2 emissions by about 90 percent compared to gasoline. Therefore taking in account a direct applicable blending ratio of 10% ethanol to gasoline, a considerable GHG emission reduction can be achieved at the national level.

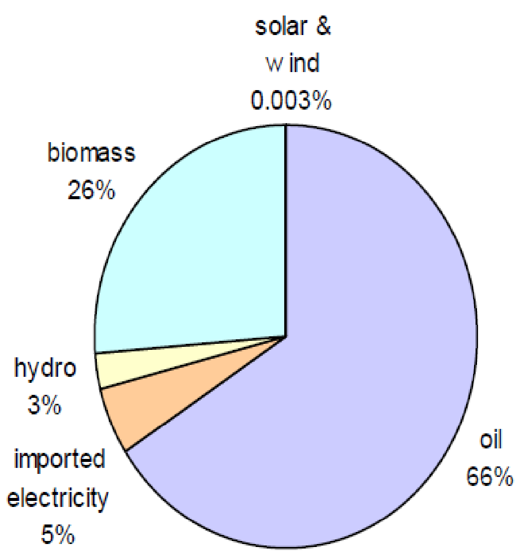
8.2 Belizean Energy and Transport Sector Baseline

Currently there are no refineries in Belize and the country is served primarily by refineries from Netherlands Antilles and to a lesser degree from United States. When the tanker(s) arrive every twenty days with the refined fuels (carrying about 75,000-100,000 barrels per shipment); it is delivered to the service stations by trucks and barges in the case of the small islands or cays located in front of the coast of Belize.

In 2002, about 6,000 barrels of petroleum per day was imported for domestic consumption. During the same year, oil represented 66% of the primary energy sources consumed for both transport and power generation, see figure 8.1. Since 2006 Belize started producing a small amount of oil,[171] about 2,600 barrels per day (2007).[172] The company leading this venture is Belize Natural Energy Ltd. (BNE).[173] BNE manages the exploration activities at the Spanish Lookout site, located to the west of the capital city of Belmopan in the central part of the country, in the Spanish Lacote district of the Corozal Basin. BNE has an early estimate of available reserves for the Spanish Field site set at 10 million barrels (2008).

In 2007, Belize consumed about 7,000 barrels of oil derived products per day. Figure 8.1 shows the oil consumption in Belize over the last decades. There seems to be stagnation in consumption growth since 2005, reasons can be multiple, as for instance weather related disasters impacting the export of agricultural products leading to lower economic activity and therefore demand. In 2007, one of the primary uses of oil derived fuel imports was for transport, comprising 30% of the total imported oil products. This sums to a total consumption of about 2,100 barrels of petroleum derived fuels in 2007.

[171] In the form of 38Þ-gravity API
[172] Energy Information Administration; http://tonto.eia.doe.gov/country/country_energy_data.cfm?fips=BH
[173] New York Times, Touched by Oil and Hope in Belize http://www.nytimes.com/2006/02/21/business/worldbusiness/21belize.html?_r=1



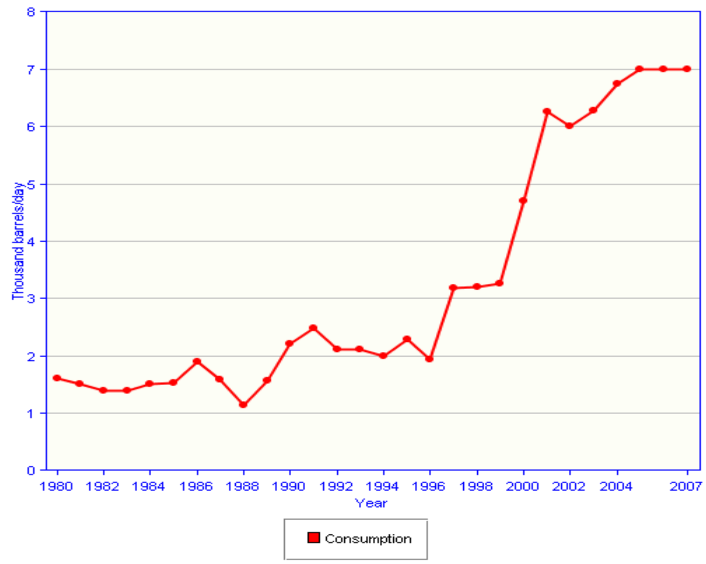


Figure 8.1 Primary Energy Sources in Belize (2002) and oil consumption in Belize (1980-2007)

In the transport sector, all of the fuel consumed originates from imported fossil fuels. This situation makes Belize highly dependant on international fossil fuel prices. The price of a barrel of oil exceeded US$ 148 per barrel in July of 2008.[174] And although oil prices have since fallen to a low of $31/barrel in recent months, there is still concern that prices will rise rapidly once the world economy stabilizes. Consequently, developing new markets for alternative fuels and renewable energy opportunities are essential -- in particular countries, such as Belize, that are highly energy and oil dependant.

Gasoline Consumption

The primary product of interest for this assessment is gasoline, this is because cellulosic ethanol directly competes or co-exists depending on the price of gasoline. Another important facet is the present and future volume of gasoline needed to guarantee sustainable mobility in Belize.

The number of vehicles licensed in Belize has increased in the last years but the volume of imported gasoline remains relatively the same. Clearly, the volume of gasoline imports and number of licensed cars has not a linear correlation because among other reasons, increased butane consumption in the public transportation sector has been observed. According to the Ministry of Transport, in the last years a significant number of buses running on butane (of which a large number is not registered) have been imported mainly for local transportation. Unfortunately, the Department of Transport and the Statistical Institute of Belize do not have data about the number of vehicles licensed to use butane and diesel.

Table 8.3 shows the number of vehicles licensed from 1995 to 2007. According to this data, the transport sector has grown rapidly in the last 6 years (2001-2007).

[174] http://tonto.eia.doe.gov/dnav/pet/hist/wtotworldw.htm

Table 8.3 Number of vehicles licensed in Belize[175]

Category	Vehicle type	1995	1996	1997	1998	1999	2000	2001	2007	Avg. Annual Growth (%) 1995-2001	Growth (%) 2001-2007
Public Service	Passengers Bus	404	435	447	211	640	638	642	710	8	11
	Taxi	1,727	1,765	1,918	1,901	1,927	2,192	2,191	2,759	4	24
Private	Cars	7,250	7,517	8,098	8,028	8,960	8,896	9,939	13,390	5	34
	Pick-up Truck	6,867	7,387	8,847	8,485	9,826	10,198	11,158	14,350	9	28
	Motor Cycles	679	607	670	513	504	527	518	1,546	-3	198
	Van	2,242	2,459	2,761	2,854	3,044	2,992	3,474	4,596	8	32
	Other	1,764	1,782	2,157	2,680	2,575	2,317	4,758	12,130	24	154
Goods Vehicles	Truck	247	284	190	862	283	171	195	220	-3	12
	Dump	302	307	257	252	120	151	264	254	-2	-4
	Tractor	317	304	384	288	245	251	243	391	-3	60
	Other	1,694	1,738	3,348	1,911	2,449	2,286	3,570	3,879	16	9
	TOTAL	23,493	24,585	29,077	27,985	30,573	30,619	36,952	54,225		

There has been a large increase in imports of motorcycles but no information was found to explain this sudden increase in motorcycle use. Nevertheless assumptions can be made about the motorcycle low purchase price and the total amount of gasoline consumption required using a motorcycle in comparison with other type of motor vehicle.

In Belize, gasoline is mainly consumed as fuel in the transportation sector. This fuel is imported as regular (octane 87) and as premium (octane 91) gasoline. Within the transport sector, diesel and butane are direct competitors to gasoline. Table 8.4 below reflects the cost and imports of gasoline, diesel and butane for road transport for the years 2005 to 2007.

Table 8.4 Gasoline, Diesel and Butane imports in Belize (2005-2007)[176]

Imports	2005			2006			2007		
	QTY (Gal)	Cost (US$)	US$/gallon	QTY (Gal)	Cost (US$)	US$/gallon	QTY (Gal)	Cost (US$)	US$/gallon
Gasoline	13,049,547	27,169,774	2.08	12,492,175	31,617,280	2.53	12,589,986	32,135,446	2.55
Diesel	19,827,857	48,942,986	2.47	20,367,853	99,811,689	4.90	23,086,587	94,890,917	4.11
Butane	289,590	714,632	2.47	2,691,671	4,252,961	1.58	1,296,408	5,033,494	3.88

From 2005 to 2007 gasoline imports have been fluctuating between 12.5 to 13.0 million gallons. Gasoline import costs have steadily increased from US$ 27.2 million in 2005 to US$ 32.1 million in 2007. [After July

[175] Information provided by the Statistical Institute of Belize
[176] Ibid. 171

2008, gasoline prices have steadily decreased, and due to lack of data, it is difficult to estimate what the total cost of gasoline imports was for 2008.]

8.3 Market Drivers and Opportunities

Gasoline vs. Cellulosic Ethanol Prices in Belize

There are three major gasoline distribution chains in Belize: Esso Standard Oil (Esso), Shell Belize and Texaco Belize.[177] As mentioned before, they import the gasoline and diesel from refineries located in the Netherlands Antilles and to a lesser extent from the United States and sell petroleum products in a regulated market, where the government regulates the retail prices of the service stations. These prices include a high proportion of taxes, used in part to buffer against the international fluctuations in the petroleum market.

In January 2005, the retail price for regular gasoline was US$ 4.16 per gallon. By April 2008, the retail price rose to US$ 5.00 and US$ 4.95 per gallon for the regular and premium gasoline, respectively. In August of 2008, the retail price was US$ 5.06 and US$ 5.22 per gallon for the regular and premium, respectively.

[177] Belize web site; http://www.belizenorth.com/gasoline.htm

Table 8.5 shows how Belizean retail gasoline prices were affected by the taxes in 2005 and 2008.[178] In the period between 2005 and 2008, a change has occurred in the regular gasoline price structure. In 2005 neither an environmental tax nor a charge on additives were included, also an increase in import duty charges from B$0.41 to B$0.45[179] and the import duty RRD charge from B$0.55 to B$1.45 can be noted. On the other hand the sales tax GST charge was lowered from B$4.18 to B$0.81 per gallon. These gasoline price structure changes resulted in a net decrease in overall tax costs of B$2.32 per gallon for regular gas. Even with this reduction in taxes, an increase of B$1.57 for the retail gasoline price was recorded; this was principally due to the increase of the imported international gasoline price. July 2008 was the month when the highest international petroleum price was recorded, at a level of about US$ 147 per barrel.[180] In 2008, the cost of gasoline import represented about 57% of the retail price. This record clearly shows how much the cost of imported gasoline influences the price at the pump.

[178] Mr. Trevor Vernon. Columnist for Amandala

[179] Currency Conversion in 2008, 1 US$ = 2B$

[180] United States Energy Information Administration (EIA), website: http://tonto.eia.doe.gov/dnav/pet/pet_pri_wco_k_w.htm (visited January, 2009). Note: One has to take in account an average lag-time of 2-3 months for changes in the international petroleum prices to take affect on petroleum derived products as gasoline.

Table 8.5 Example of taxes and final gasoline retail prices (B$) per gallon in Belize in 2005 and 2008

5-Jan-05	Super	Regular
Cost of Fuel	**N.A.**	**$3.12**
Import Duty	N.A.	$0.41
RRD	N.A.	$0.55
Environ Tax	N.A.	-
Freight	N.A.	$0.070
Additive	N.A.	-
GST	N.A.	$4.18
Total Taxes Cost	N.A.	$5.21
B$ at Pump	**N.A.**	**$8.33**
US$ at Pump	**N.A.**	**US$ 4.16**

7-Apr-08	Super	Regular
Cost of Fuel	**$6.166**	**$5.640**
Import Duty	$0.450	$0.450
RRD	$0.994	$1.449
Environ Tax	$0.119	$0.109
Freight	$0.070	$0.070
Additive	$0.002	$0.002
GST	$0.815	$0.807
Total Taxes Cost	$2.45	$2.89
B$ at Pump	**$10.00**	**$9.90**
US$ at Pump	**US$ 5.00**	**US$ 4.95**

From September 2008 on forward the international petroleum price has been decreasing. By November 2008, the Ministry of Finance mandated the decrease of the pump prices to US$ 3.53 per gallon for regular gasoline, US$ 3.71 per gallon for the premium gas, and US$ 3.48 per gallon for diesel. This meant a decrease of cost of transportation fuels in Belize by approximately 30%, but also meant that other public sector resources were being consumed for subsidizing gasoline.

As per the 1st of January 2009, the decrease of the price of gasoline at the pump in Belize continued and reached the level of US$ 2.275 per gallon (regular gas) and US$ 2.43 per gallon (premium gas). This is significantly lower than the previous average gasoline prices over the last 3 years.

The most complicated and uncertain aspect of this assessment is analyzing the long-term comparative cost advantages between ethanol and gasoline prices. Global petroleum prices have become very volatile with highs and lows ranging from US$ 30-148 per barrel over the last 5 years. Meanwhile, the cost of cellulosic ethanol is uncertain because there have been no commercial-scale plants erected to date. Oil prices can be affected by geo-political events, climate change, the global economy, and demand projections due to emerging population growth. The latest price development is in contrast to what several renowned energy experts have predicted or projected a year ago. The volatility is very significant, and makes long-term projections difficult to almost impossible. Therefore one has to consider the independence from imported fossil fuels as a main motivation for the development of indigenous renewable power and fuels.

In 2007, the average annual cost of imported gasoline was US$ 2.55 per gallon (see table 8.3). On April 07 of 2008, the cost of imported gasoline was US$ 2.82 per gallon (B$5.64/gallon, see table 8.4). Although there is a clear relationship between the cost of the international petroleum price and the gasoline spot prices (See Annex 11.10), there is no linear relationship between the gasoline spot prices and the cost of imported gasoline in Belize. This is due to the different intermediate players in the distribution activities and varying costs of delivery of gasoline to Belize.

In order to compare the cost of CE production in Belize with gasoline in an objective manner, the cost of CE was calculated based on the gasoline equivalent. This is because ethanol's energy content is 30% lower to gasoline per tank volume. This is in itself disputable, because studies also indicate that due to the usage of ethanol the overall engine operation and efficiency increases. Therefore one has to consider this conversion as a baseline data with improvement potential.

Table 8.6 resumes the cost of cellulosic ethanol production in Belize and its gasoline equivalent. The range of ethanol production cost is between US$ 2.25 to 3.55 per gallon when expressing it in gasoline equivalents. Note that this is the potential production cost under prevailing conditions in Belize (as per available data in 2008).

Table 8.6 Sustainable CE production cost in Belize based on the gasoline equivalent

Technology	2008 CE production cost (US$/gallon)	2008 CE production cost in gasoline equivalent (US$/gallon)
Biochemical	2.04 – 2.73	2.65 – 3.55
Thermo-chemical	1.64 – 2.17	2.33 – 2.82

Among the two principal conversion technologies, the thermo-chemical technology produces the lowest production cost range of US$ 2.25 – 2.61 per gallon of ethanol (gasoline equivalent). As an initial comparison this ethanol cost range ranges to the same extent to imported gasoline costs of US$ 2.25 – 2.82 per gallon.[181]

The above is an interesting result, since the 2008 production cost of cellulosic ethanol was calculated for feedstock data of 2004/05 adapted to 2008 prevailing conditions in Belize and using 2007 conversion efficiency data for two different sub-technologies (the bio-chemical and thermo-chemical processes). And this cost range is being compared to imported gasoline costs in a time period that the international petroleum and therefore also the gasoline spot prices were increasing in the highly volatile market prices. But without accounting for the additional taxes and charges that on average represent 29% of the retail price. There is about US$ 1.45 per gallon (B$2.89 per gallon, see table 8.4) buffer for developing a comparative cost advantage for the domestically produced cellulosic ethanol.

The estimated cellulosic ethanol production cost range is very robust without including future cost effectiveness due to increased production efficiencies by 2012. There could also be increased cost effectiveness due to improved feedstock harvest, lower collection and transports costs, and reduced logistics costs. If these potential factors are taken in account the production cost may decrease to 0.74 and 1.50 US$ per gallon, and will make cellulosic ethanol development a very interesting endeavor.

Domestic gasoline demand

According to the Statistical Institute of Belize, approximately 13 million gallons of gasoline were imported in 2007. This represents approximately 30% of all oil derived fuel products imported by Belize.

Figure 8.2 shows the potential demand of gasoline in Belize for the period 2005 to 2012. The figure also includes total CE production capacity of 3,000 barrels per day using the current available data on potential sustainable harvested or collected biomass feedstock. In 2007, Belize imported approximately 820 barrels of gasoline per day.[182] Based on this data the country can easily satisfy its domestic market if a 10% ethanol blend level is introduced. The production volume is significant enough to commit to a long

[181] Note: US$2.25 per gallon represents the annual 2007 average cost of gasoline import and US$ 2.82 per gallon the cost of gasoline import on April 7th, 2008. These are not the retail prices at the pump.
[182] Factor conversion: 1 gas barrel represent about 42 gas gallons.

term strategy of shifting the car fleet to flex-fuel vehicles (with higher tolerance for any ethanol blending rate), similar to the cars driven in Brazil. The large ethanol production volume also allows for exploration of ways for export activities.

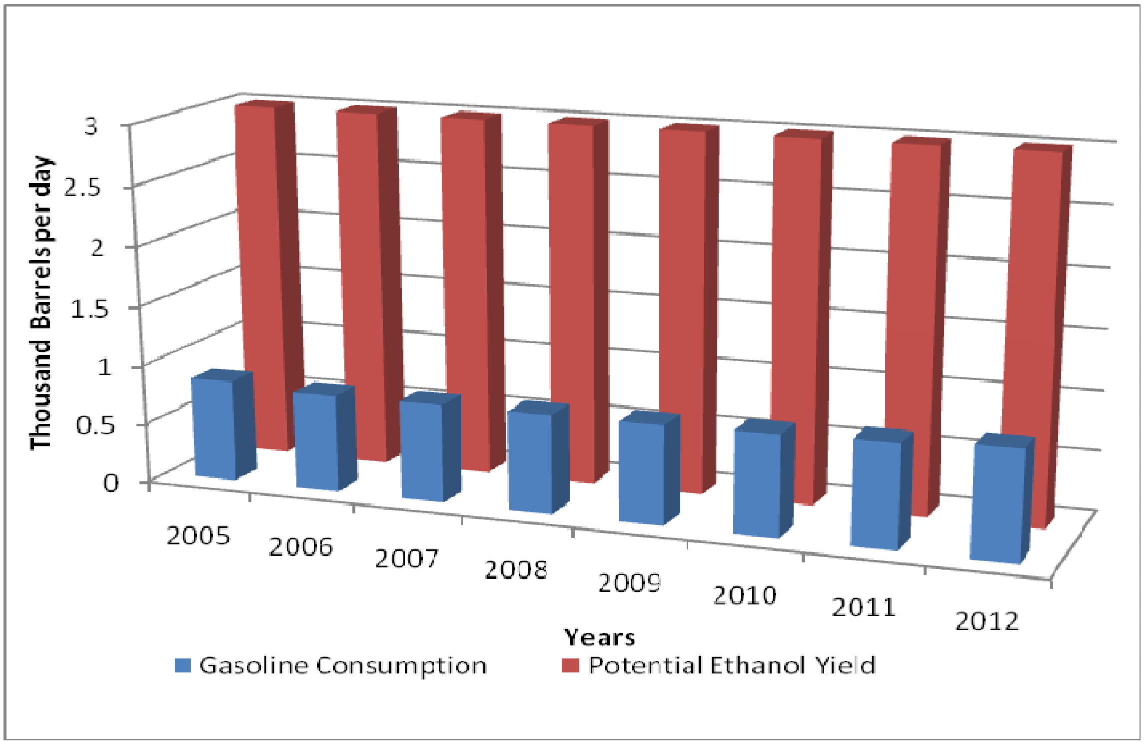


Figure 8.2 Gasoline demand forecast for 2012 compared with potential ethanol yield in Belize

In 2007, Belize imported approximately 12,600,000 gallons of gasoline. The optimal cellulosic ethanol production system, thermo-chemical process, can yield about 46 million gallons of ethanol per year (based on 2008 data). All vehicles manufactured since 1978 can run on E10, but one limiting aspect that was observed in the U.S. is that current warranties for conventional vehicles would be voided if the cars were run on levels of ethanol higher than E10.[183] Assuming a blending rate of 10% of ethanol with gasoline, the volume required of 1,260,000 gallons per year is easily satisfied. This leaves a total of about 44 million gallon of ethanol per year for potential export.

Export potential of Belizean Cellulosic Ethanol[184]

In addition to tourism, Belize's economy has historically relied on preferential trade agreements with the United States, the European Union, and the United Kingdom for the export of agricultural commodities. Recent erosion of trade agreements and the rise of free trade policies among other nations have raised concerns regarding Belize's ability to compete in the global economy. Belize's very high level of public debt during 2006, approximately US$ 1 billion, is nearly equal to its GDP.[185] Since 1990, debt service payments have tripled and were over 20% of GDP in 2005.[186] The nation has limited access to capital, and

[183] U.S. Department of Energy, Bioenergy Program, Energy Efficiency and Renewable Energy Unit, website: http://www1.eere.energy.gov/biomass/markets.html (visited January 2009)
[184] Source of data: IMF and Central Bank of Belize. 2006 International Monetary Fund October 2006 IMF Country Report No. 06/370, Belize: Selected Issues and Statistical Appendix
[185] Ibid. 160
[186] UNDP Human Development Report.

its debt has been downgraded to the lowest possible levels by credit rating agencies.[187] As urged by the IMF and USAID, Belize began a structural adjustment program in the 1980s that continued until 2004. Foreign investment, privatization of public assets and trade liberalization were promoted under this program.[188]

Based on the potential export volume of 44 million gallons of ethanol it is important to assess the potential global ethanol markets. Figure 8.3 depicts the potential market-countries to export cellulosic ethanol, this chart is related to Belize's current major export markets. Exports are defined as total exports minus re-export.

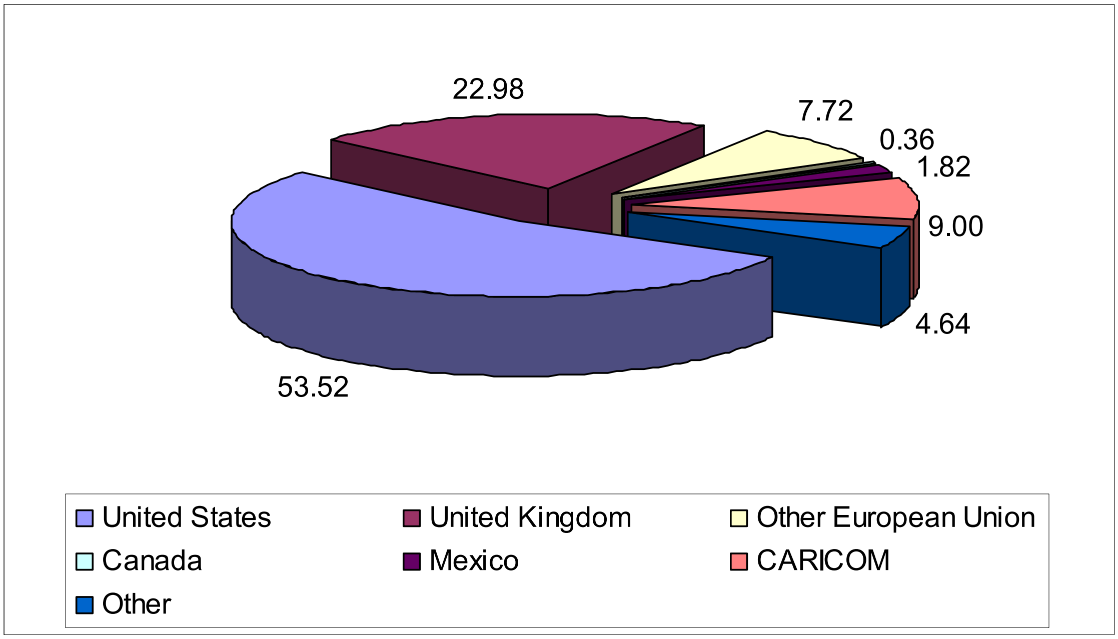


Figure 8.3 Relative shares of Belize's export markets (2001-2005)

The potential countries available to export CE are Canada, United States, United Kingdom, and the European Union and CARICOM countries among others. In the next section a quick analysis is made of ongoing or new mandates or initiatives that may influence the potential for CE export. Among the main markets of interest are the U.S. ethanol market, Canadian biofuels market, and the European market.

U.S. Ethanol Market[189]

Currently about 7 percent of the total U.S. gasoline demand is met with ethanol, and roughly half of U.S. gasoline contains some ethanol.[190] Being one of the largest ethanol markets in the world, the long-term viability of the U.S. market is important for potential ethanol exporting countries. The following is a summary of the principal U.S. mandates that guarantee a long term commitment to developing the biofuels market in the U.S.[191]

[187] Robert Richardson, "Economic Development in Belize: Two Steps Forward, Two Steps Back." Taking Stock: Belize at 25 Years of Independence, ed. Barbara Balboni and Joseph Palacio (Benque Viejo: Cubola Productions, 2007).
[188] Ibid.
[189] Text extracted from: de Cuba, K.H. and Rivera-Ramirez, M.H, Background Discussion Paper on Bio-energy Potential for St. Kitts and Nevis, OAS Department of Sustainable Development (OAS/DSD) and Energy & Security Group (ESG), August 2007.
[190] Yacobucci, B.D., Ethanol Imports and the Caribbean Basin Initiative, CRS Report for Congress, March 2008.
[191] Verenium Cellulosic Ethanol company, website: http://www.verenium.com/ (visited January 2009)

Energy Independence and Security Act 2007

The Energy Independence and Security Act (EISA) of 2007 (H.R. 6), signed into law in December 2007, contains a number of incentives designed to spur cellulosic ethanol production. EISA mandates the use of at least 16 billion gallons of cellulosic ethanol in the U.S. automotive fuel supply by 2022. Currently the gasoline consumption in the U.S. is about 9,286,000 barrels of gasoline per day (390 million gallons per day) or 142.4 billion gallons per year.[192] Taking in account that most vehicles in the U.S. car fleet can run on E-10 blend, this sums to a total of 14.2 billion gallons per year as per 2007. The U.S. ethanol production in 2007 was 6.5 billion gallons[193] and covered thus 46% of the potential E-10 replacement potential. There is therefore a margin of 9.5 billion gallons up to 2022 signifying a required increase in production of 633 million gallons per year.

EISA establishes definitions for the renewable fuels program, including advanced biofuels and cellulosic biofuels. *Advanced biofuels* is defined as renewable fuel derived from renewable biomass, and achieves a 50% greenhouse gas (GHG) emissions reduction requirement. The definition includes two subcategories: cellulose and biomass-based diesel. *Cellulosic biofuels* is defined as renewable fuel derived from any cellulose, hemicellulose, or lignin that is derived from renewable biomass, and achieves a 60% GHG emission reduction requirement. (Cellulosic biofuels that do not meet the 60% threshold, but do meet the 50% threshold, may qualify as an advanced biofuel.)

EISA also authorizes disbursement of US$ 500 million annually for FY08-FY15 for the production of advanced biofuels that have at least an 80% reduction in lifecycle GHG emissions relative to current fuels. The act authorizes $25 million annually for FY08-FY10 for R&D and commercial application of biofuels production in states with low rates of ethanol and cellulosic ethanol production.

Cellulose provisions in the 2008 Farm Bill[194]

The farm bill, the Food, Conservation and Energy Act of 2008 (H.R. 2419) includes a new income tax credit for the producers of cellulosic alcohol and other cellulosic biofuels. The credit is US$ 1.01 per gallon. If the cellulosic biofuel is ethanol, this amount is reduced by the amount of credit available for alcohol fuels generally (now assumed to be $0.45 per gallon in 2009). The value of the credit, plus the existing small ethanol producer credit and VEETC[195], cannot exceed US$ 1.01 per gallon. The credit will apply to fuel produced after 2008 and before 2013. The bill also includes the Bioenergy Program for Advanced Biofuels (Section 9005) that provides payments to producers to support and expand production for advanced biofuels.

The Biomass Crop Assistance Program (BCAP) (Section 9011) establishes the Biomass Crop Assistance Program to encourage biomass production or biomass conversion facility construction with contracts which will enable producers to receive financial assistance for crop establishment costs and annual payments for biomass production. Producers must be within economically practicable distance from a biomass facility. It also provides payments to eligible entities to assist with costs for collection, harvest, storage and transportation to a biomass conversion facility.

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[192] U.S. Energy Information Administration (EIA), Petroleum Basic Statistics for 2007, website: http://www.eia.doe.gov/basics/quickoil.html (visited January 2009)

[193] Renewable Fuels Association, Industry Statistics, website: http://www.ethanolrfa.org/industry/statistics/ (visited January 2009)

[194] http://www.ethanolrfa.org/resource/cellulosic/documents/CellulosicBiofuelProducerCreditBrief.pdf

[195] The Volumetric Ethanol Excise Tax Credit, also known as VEETC, is a Federal tax credit that went into effect on January 1, 2005. This is a credit of US$.51 for every gallon of pure ethanol blended into gasoline. For example, an E10 blend will have a credit available of US$.051/gallon, and E85 will have a credit available of US$.4335/gallon. This credit is identical for both E10 and E85, as are the forms to file for it.

Recent bio-energy developments in the Caribbean and Central America have been mainly focused on producing ethanol for duty free export to the United States using the Caribbean Basin Initiative (CBI) and the DR-CAFTA treaties as legal base. For Belize, only the CBI is of relevance.

The Caribbean Basin Initiative (CBI), initially launched in 1983 and expanded in 2000 until September 2008,[196] is intended to facilitate the economic and export diversification of countries in the Caribbean region. The CBI provides 24 beneficiary countries, including Belize, with duty-free access to U.S. markets for most goods produced in the beneficiary country. The agreement allows countries covered under the CBI to export dehydrated ethanol produced by foreign feedstock (including hydrous ethanol from a third country) into the U.S. duty-free, equaling up to 7% of total U.S. ethanol production, which was about 455 million gallons in 2007.[197] Beyond this, an additional 35 million gallons can be imported into the U.S. duty-free, provided that at least 30% of the ethanol is derived from local feedstock. Anything above the additional 35 million gallons is duty-free if at least 50% of the ethanol is derived from local feedstocks.[198] As for now, there are currently no provisions for 2nd generation ethanol indicating requirements for the feedstock origin to be determined in order to be eligible for duty free imports to the U.S. Thus it can be assumed that all Belizean cellulosic ethanol that is dehydrated is in principal eligible for export to the U.S. up to the point the 7% cap is reached.

In the Caribbean and Central America, currently four countries supply ethanol to the U.S. market (see Table 8.7): Jamaica, Costa Rica, El Salvador, and Trinidad and Tobago. In 2007, the total of imported ethanol originating from countries under the CBI agreement[199] summed to 230.5 million gallons.

Table 8.7 Ethanol Exports to the U.S. 2002-2007 (millions of gallons).[200]

Country	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Brazil	0	0	90.3	31.2	433.7	188.8
Costa Rica	12	14.7	25.4	33.4	35.9	39.3
El Salvador	4.5	6.9	5.7	23.7	38.5	73.3
Jamaica	29	39.3	36.6	36.3	66.8	75.2
Trinidad & Tobago	0	0	0	10	24.8	42.7
Canada	-	-	-	-	-	5.4
China	-	-	-	-	-	4.5
Total	**45.5**	**60.9**	**159.9**	**135.0**	**653.3**	**426.2**

U.S. ethanol imports over the period 1999 to 2007 (see Figure 8.4) show a considerable increase in imports from Brazil in 2006, while in 2007 a sudden decrease in imports can be observed. U.S. ethanol imports from the Caribbean Basin (Central America and Caribbean islands) in 2007 represented about 54% of the country's total ethanol imports (about 426.2 million gallons). Even with the existing US$ 0.54 per gallon import tariff, Brazil exported about 369 million gallons of dehydrated ethanol directly to the U.S. in 2008. The total of hydrated ethanol originating from Brazil that enters the U.S. via one of the CBI countries is estimated to be about 227.8 million gallons in 2007 and 287.5 million gallons in 2008.[201,202]

[196] Caribbean Basin Initiative website: http://www.mac.doc.gov/CBI/FAQs/faqcbi-all.htm#Five.
[197] Hunt, S. and Forster, E., "Biofuels for transportation: global potential and implications for sustainable agriculture and energy in the 21st century", online at http://www.renewable-energy-world.com/display_article/271573/121/ARCHI/none/none/Biofuels-for-transportation:-Global-potential-and-implications-for-sustainable-agriculture-and-energy-in-the-21st-century/ , value updated for 2007 via Renewable Fuels Association website: http://www.ethanolrfa.org/industry/statistics/#A (visited January 2009)
[198] *Ethanol Today*, "Ethanol Import Debate Looms." April 2005.
[199] CBI countries are Costa Rica, Jamaica, El Salvador and Trinidad & Tobago
[200] Renewable Fuels Association. 'Industry Statistics', website: http://www.ethanolrfa.org/industry/statistics/ (visited January 2009)
[201] Ministerio do Desenvolvimento, Industria e Comercio Exterior, Destino das exportacoes Brasileiras de Álcool Etílico, website: http://www.desenvolvimento.gov.br/arquivos/dwnl_1229517244.xls (visisted January 2009)

The last amount represents about 38% of the total U.S. imported ethanol from Brazil (directly and indirectly), thus the CBI countries have significantly increased in importance as ethanol hubs to enter the U.S. ethanol market. An interesting phenomenon is that since 2007 new players have entered the U.S. ethanol market, namely ethanol originating from Canada and China.

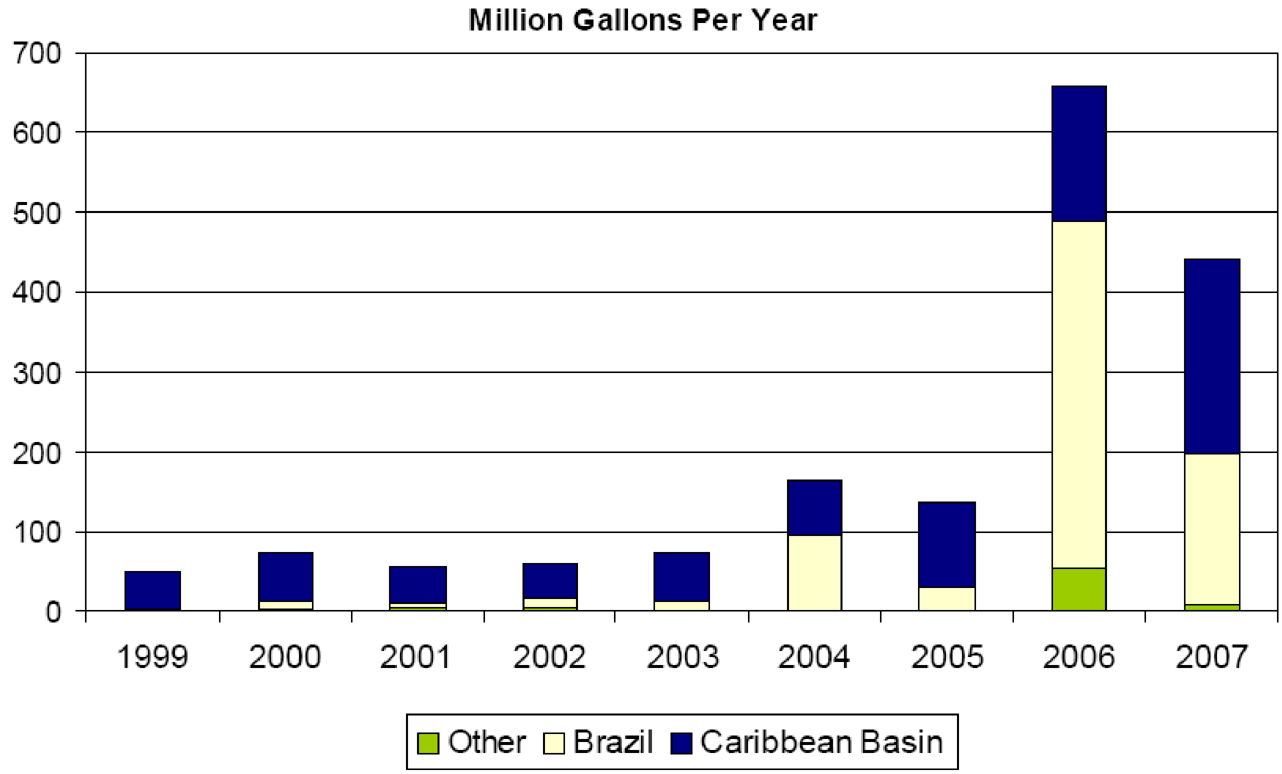

Figure 8.4 Annual Ethanol Imports to the United States (Million Gallons per Year)[203]

In 2007 the amount of ethanol allowed to be imported duty free under the CBI was up to the 7% quota defined under the agreement that summed to 455 million gallons. In that same year the total amount of imported ethanol originating from the CBI countries summed to 227.8 million gallons, thus leaving a margin of 227.2 million gallons of duty free export to the U.S. As stated in the CBI agreement, beyond the 7% of U.S. ethanol production, an additional 35 million gallons can be imported into the U.S. duty-free, provided that at least 30% of the ethanol is derived from local feedstock. Anything above the additional 35 million gallons is duty-free if at least 50% of the ethanol is derived from local feedstocks.[204]

Up to 2005, all the dehydrated ethanol produced in CBI countries was made of imported hydrous ethanol from Brazil. However, sugarcane is abundantly grown in El Salvador and Jamaica; and the governments have launched initiatives to promote domestic ethanol use and production of domestic ethanol, which could benefit from the schedules under the CBI agreement. Other countries under the CBI that lack significant sugarcane production potential could assess their 2nd generation ethanol production potential using other biomass waste residues as feedstock. Although the CBI quota of 7% of U.S. ethanol production is a limiting factor, currently only half of the quota is used or satisfied with ethanol coming from El Salvador, Costa Rica, Jamaica and Trinidad & Tobago and therefore future export potential for Belizean

[202] Ministerio do Desenvolvimento, Industria e Comercio Exterior, website: http://www.desenvolvimento.gov.br/sitio/interna/interna.php?area=2&menu=999 (visited January 2009)
[203] Yacobucci, B.D., Ethanol Imports and the Caribbean Basin Initiative, CRS Report for Congress, March 2008.
[204] *Ethanol Today*, "Ethanol Import Debate Looms." April 2005.

cellulosic ethanol to the U.S. would still be allowed under the CBI quota and would not depend on the U.S. ethanol production growth rate generating a large enough demand margin to allow Belize to become a market player.

E.U. Ethanol Market[205]

Europe's fuel ethanol sector was a slow starter. It took almost 10 years to grow production from 60 million liters in 1993 to 525 in 2004. In the following 2 years however, there were double-digit growth levels of over 70%. Yet, it was not a sustainable growth; in 2007 production increased by 'only' 11%.

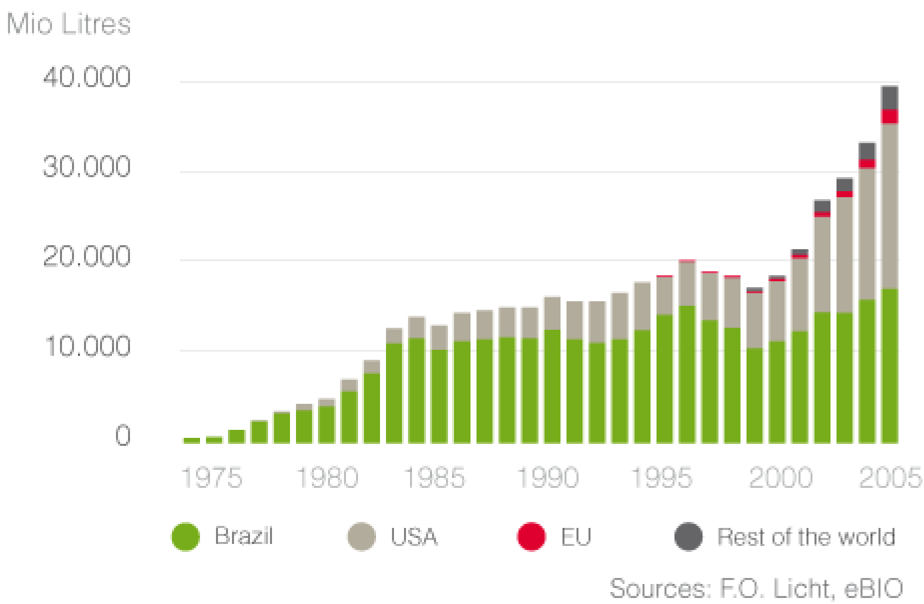

Figure 8.5 Global Ethanol Production (1975-2005)[206]

In 2005 EU ethanol production was estimated to be 950 million liters (251 million gallons) and increased to 1.25 MMT (418.4 million gallons) and 1.35 MMT (451.9 million gallons) by 2006 and 2007 respectively.[207] The EU production capacity is projected to increase to 7.0 MMT (2.34 billion gallons) by 2010 whereby most of this growth is anticipated to occur in the Netherlands and Belgium, since they have seaports that can receive biomass from a wide variety of international suppliers. Currently all the ethanol is produced via 1st generation ethanol process plants, with Abengoa as the leading market player.[208] A large percentage of this ethanol originates from Germany, Poland, France and Spain; and is mainly derived from corn, wheat and sugarcane. The 2007 EU ethanol consumption was 2.1 MMT (702.9 million gallons), thus resulting in a supply-demand gap margin of 251 million gallons of ethanol. This gap was filled with imports from mainly from Brazil and to lesser extent from Guatemala, Argentina, Costa Rica, Peru and the U.S.

The EU ethanol market is wide open to a number of countries with no limitations imposed to volumes. One issue that has been of concern by member states is that the classification of ethanol is unclear and allows large quantities of ethanol to be imported under other CN customs codes with much lesser import

[205] E.U. represents the current EU-27 member states, thus values adapted after inclusion of Bulgaria and Romania in 2007.
[206] European Bioethanol Fuel Association, website: http://www.ebio.org/EUmarket.php (visited January 2009)
[207] USDA Foreign Agricultural Service, EU-27 Biofuels Annual 2008, Global Agricultural Information Network (GAIN) Report, May 2008, website: http://www.fas.usda.gov/gainfiles/200806/146294845.pdf (visited January 2009)
[208] Abengoa Bioenergy, website: http://www.abengoabioenergy.com/sites/bioenergy/en/acerca_de/oficinas_e_instalaciones/bioetanol/europa/index.html (visited January 2009)

duties. These quantities are difficult to track because the CN codes encompass many different products which are not classifiable anywhere else.[209]

Ethanol only accounted for 1.1% of the total EU motor gasoline consumption of 104.7 million tons (37.1 billion gallons) in 2006.[210] Over the course of the last decade, the EU has established very aggressive targets for increasing the use of biofuels in general. The EU is motivated by multiple goals including improving domestic energy security, improving the overall CO_2 balance, complying with the Kyoto Protocol, and sustaining economic competitiveness.[211] Bio-diesel production has been dominant over ethanol (representing 80% of biofuels in 2005), despite that fact the EU has recognized ethanol "as a leading contender to complement and replace gasoline as an energy source.[212]"

One of the EU's objectives is to displace oil consumption of member countries with biofuels by 5.75% in transport by 2010, and 25% by 2030. However, objectives aside, local producers face high costs to produce ethanol; and insufficient domestic production to reach the EU biofuels initiative goals has been forecasted.[213] Even with existing EU import taxes of US$ 0.24/liter (US$ 0.91 per gallon) for non denatured or hydrated ethanol and US$ 0.13/liter (US$ 0.49 per gallon) for denatured or de-hydrated liquor and ethanol, in 2008 the EU imported about 1.5 billion liters (396 million gallons) from Brazil.[214] An uncompetitive ethanol production capability and a large gasoline consumption rate present a challenge for the EU to achieve its targets, which in the future will certainly need to continue importing ethanol. In April 2008, the Dutch and the Brazilian governments signed a Memorandum of Understanding (MoU) in recognizing and using the strategic location of the Rotterdam port for the transit of biofuels to the EU.

The EU's bio-fuel strategy also includes enhancing trade opportunities with ethanol-producing countries. Among trade alternatives that may be of interest to Belize is the recently signed Economic Partnership Agreement (EPA). In October 2008, the CARIFORUM and the EC signed an Economic Partnership Agreement (EPA).[215] The EU exempts African, Caribbean, and Pacific (ACP) countries from import duties on ethanol (and other goods), whereas other regions have to pay US$ 0.10/liter (US$ 0.38 per gallon) tariff. Further, for those countries in the ACP that were negatively affected by the EU sugar reform, a special Biofuels Assistance Package has been established. This package makes available financial assistance for redevelopment of domestic sugar production by enabling eligible countries, as Belize, to redeploy those national productive assets for biofuel production.[216]

The EU ethanol market is an interesting option for Belizean cellulosic ethanol exports, since long-term EU targets are set: 5.75% in the transport sector by 2010, and 25% by 2030. Although Brazil is currently the main supplier of ethanol, with future cost reduction potentials for Belizean ethanol, Belize will be able to compete on the cost of ethanol while still having a large enough EU demand in place. This scenario is based on a first serve first earn principle.

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[209] Ethanol Statistics, Issue Focus: Plant construction and process equipment, June 2008 Monthly Market review, Volume 1, Issue 2.
[210] International Energy Agency (IEA), Oil in European Union – 27 in 2006, IEA Statistics website: http://www.iea.org/Textbase/stats/oildata.asp?COUNTRY_CODE=30 (visited January 2009).
[211] Biofuels in the European Union: A Vision 2030 and Beyond. Final draft report of the Biofuels Research Advisory Council. 03/14/2006.
[212] United Nations Conference on Trade and Development (UNCTAD).
[213] Biofuels in the European Union: A Vision 2030 and Beyond. Final draft report of the Biofuels Research Advisory Council. 03/14/2006.
[214] Ministerio do Desenvolvimento, Industria e Comercio Exterior, website: http://www.desenvolvimento.gov.br/sitio/interna/interna.php?area=2&menu=999 (visited January 2009)
[215] Caribbean Community (CARICOM) Secretariat, website: http://www.caricom.org/jsp/pressreleases/pres309_08.jsp (visited January 2009)
[216] "Commission urges new drive to boost production of biofuels." Brussels, 8 February 2006. European Commission Web site.

Canadian ethanol market[217,218]

In 2007 Canada produced 211.3 million gallons of ethanol of which 5.7 million gallons were exported to the U.S.[219] This ethanol production accounted for 1.9% of the total 2007 motor gasoline consumption (42.4 million m^3 or 11.2 billion gallons) in Canada.[220] In May 2008, the Canadian House of Commons passed the national biofuels bill including a Renewable Fuel Standard (RFS).[221] In the next month, the Senate passed Bill C-33, which mandates 5% renewable content in gasoline by 2010, and 2% renewable content in diesel fuel by no later than 2012.

In December 2008, Canada produced more than 1 billion liters per year (264 million gallons per year) of ethanol production.[222] All the ethanol is produced with 1st generation ethanol plants, using wheat and corn as primary feedstock.[223] In the near future, the first 2nd generation MSW ethanol plant will be commissioned with a planned capacity of 36 million liter per year using non-recyclable organic waste as main feedstock.

As of May 2008, the Canadian House of Commons passed the national biofuels bill including a Renewable Fuel Standard (RFS).[224] Consequently in June of 2008, the Senate passed the Bill C-33, that mandates 5% renewable content in gasoline by 2010, and 2% renewable content in diesel fuel by no later than 2012. This means that if we consider the 2007 values, the total amount of ethanol required to comply with the E-5 mandate would sum to 560 million gallons. Consequently, 296 million gallons of ethanol production should be added over the period 2009-2010, which requires more than doubling the current ethanol production capacity or importing ethanol from abroad.

Given the historical connections to Canada, Belize has an opportunity to establish a trade regime with Canada. As a member state of CARICOM, it is in a good position to benefit from the ongoing CARICOM-Canada trade negotiations. Negotiations are planned to start during the first months of 2009.[225]

Other global ethanol markets

Ethanol markets for the potential export of Belizean cellulosic ethanol are Japan, India, and other countries in Latin America. In mid-2008, India decided to withdraw all state-level taxes and levies on ethanol. The reason is that domestic ethanol prices have been high due to a complex system of taxes on levies (e.g. import permit fees, license fees, administration fees, state excise fees, etc.) imposed by each state. For instance in Goa the sales tax was 19% while in Tamil Nadu it was 8%, but with 5% surcharge on sales taxes. The policy change will allow oil companies to implement a 5% blend mandate under the Ethanol Blend Petrol (EBP) scheme. From October 2008, the 5% mandate will be increased to a 10% blending requirement (about 1.2 billion liters in volume), which is not anticipated to be fulfilled by domestic production in the medium term.[226]

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[217] http://www.bahamas.gov.bs/bahamasweb2/home.nsf/vImagesW/Canada+Caricom+Consultation+Document/$FILE/caricomcanadaconsultationdocument.pdf
[218] http://www.kaieteurnews.com/2008/12/06/canada-caricom-trade-agreement-%E2%80%98sideswiped-by-epa%E2%80%99/
[219] Renewable Fuels Association, website: http://www.ethanolrfa.org/industry/statistics/#E (visited January 2009)
[220] Statistics Canada website: http://www.statcan.gc.ca/pub/45-004-x/2008010/t007-eng.htm (visited January 2009)
[221] Canadian Renewable Fuels Association, website: http://www.bioxcorp.com/web_resource/news/20080610075133_ReleaseC33_052808_1.pdf (visited January 2009)
[222] Canadian Renewable Fuels Association, website: http://greenfuels.org/files/Release_IGPC_Dec17.pdf (visited January 2009).
[223] Canadian Renewable Fuels Association, website: http://greenfuels.org/lists.php#ethProd (visited January 2009)
[224] Canadian Renewable Fuels Association, website: http://www.bioxcorp.com/web_resource/news/20080610075133_ReleaseC33_052808_1.pdf (visited January 2009)
[225] Canadian Department of Foreign Affairs and International Trade, Canada-CARICOM initial assessment report, website: http://www.international.gc.ca/trade-agreements-accords-commerciaux/agr-acc/caricom-initial-initiale.aspx?lang=eng (visited January 2009)
[226] Ethanol Statistics, Issue Focus: Plant construction and process equipment, June 2008 Monthly Market review, Volume 1, Issue 2.

Climate Change – Kyoto Protocol

More countries in the future may create ethanol mandates to comply with the Kyoto Protocol. According to the last UNFCCC Belize country report (2007) [227], the results show a general increase of 11% in carbon dioxide emissions during the period 1994 to 2000 -- summing to 330.6 GHG per year (364,424 ton CO_2 per year).

According with Wang et. al. (2007), the use of ethanol may result in GHG emission reductions mainly because the carbon in fuel ethanol is taken up from the air during biological plant growth via photosynthesis. But the production of ethanol requires fossil fuel use and this generates GHG emissions. For this reason the use of ethanol does not result in a 100% reduction of GHG emissions. Nevertheless, based on the Well-to-wheels GHG emissions analysis for Cellulosic Ethanol and Gasoline (expressed in CO2 equivalent per million Btu of fuel produced and used),[228] CE generates about 13,000 CO2 gr/M.Btu and Gasoline 98,000 CO2gr/M.Btu. These estimations suggest that one gallon of gasoline can generate approx. 12 Kg of CO2 and one gallon of CE approx. 0.99 Kg of CO2, clear difference in emissions.

Given the aforementioned matrix, the 12 million of gallons of gasoline consumed in Belize generated 144,000 tones of CO2. It is possible to reduce this amount of CO2 emission by blending 10% of Ethanol to gasoline (1,200,000 gallons of Ethanol) leading to an output of 13,218 ton of CO2.[229]

Jatropha to Bio-diesel development

Bio-diesel research and development is ongoing in Belize. Studies indicate that there is a considerable potential for mid- to large-scale jatropha cultivation for bio-diesel production. Depending on the configuration of the bio-diesel supply and conversion chain, the waste generated from extracting the oily content of the jatropha curcas may become feedstock for cellulosic ethanol production; 100 kg fresh jatropha fruits translate into 76 kg of shells and 24 kg of fresh seeds. And 40,000 kg fruits are required for 2,000 liters of oil per hectare or 200 gallon per acres. A lot of the 'shell biomass' is water but still we have huge amounts of agricultural waste. At this point in time 200 acres are existing in Belize.[230]

8.4 Barriers to the Belizean Cellulosic Ethanol market growth

Market uncertainty

The uncertainty of the global market price development may be a factor for hesitation in developing this industry. Currently the ethanol market is closely tied to governmental taxes, subsidies and air quality policies. Major investments in new technologies as cellulosic ethanol production depend on putting in place a viable policy road map that investors can calculate a rate of return on investment. In general, one of the most significant barriers facing cellulosic ethanol is the difficulty in marketing the product through the established fuel distribution companies in fear for market loss in the transport sector, especially in developing countries. In addition, new enterprises usually face finance and business risk barriers during the start-up phase of the industry. In many countries ethanol projects have struggled with issues such as uncertainty in procedural requirements, and mistrust in the design/construction of facilities utilizing new technologies by government officials, the perceived risk of commodity price swings, and more recently difficulties with project financing due to the current global economic crisis.

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[227] May, J. (2007), greenhouse gas inventory, of the energy sector in Belize, Belize's second national communication, climate change project; http://www.hydromet.gov.bz/ENERGY%20GHG%20Inv%20Fin%20Rep.pdf
[228] M. Wang et. Al. 2007
[229] Calculated based on GHG emissions factors of gasoline minus emission factors of CE.
[230] Personal communications with Dipl. Ing. Sylvia Baumgart Laasner, Tropical Studies and Development Foundation Belize, Central America Belmopan, Belize.

National Renewable Energy Policy

The main barrier identified in this study to the development of a cellulosic ethanol industry in Belize is the lack of a comprehensive national (renewable) energy policy that clearly lays out a long-term strategy. The plan should promote cleaner and sustainable energy, higher level of diversification, a reduction in energy dependency on foreign fossil fuels, and guarantee the protection of the environment to allow for sustainable socio-economic development. A stable political and economic framework is imperative due to a number of reasons: First, ethanol is intended to partly replace gasoline, the price of which is extremely volatile and linked to very volatile petroleum prices. Certain decisions are therefore needed to ensure biofuels are competitive in the short- and medium-term. Second, the competitiveness question may conflict, at least in the beginning, with the objective of reducing energy dependency and hence promoting indigenous production. A clear political stance with long-term objectives must be defined to allow the industry the opportunity to stimulate or secure investments. The following issues mentioned below are additional barriers that could be mitigated by the establishment of such a National Renewable Energy Policy.

Competition for Cellulose Feedstock

Belcogen is a key market player when considering the availability of bagasse generated by the existing sugar mill. The Belize Sugar Industries Ltd (BSI) and BEL (Belize Electricity Limited) established Belcogen to operate and manage a 25 MW biomass co-generation power plant. The project is expected to reduce energy imports from Mexico by at least 50%, which is one of the main priorities to increase the energy supply security of the nation. The commissioning of the bagasse-fired cogeneration plant is planned for the beginning of 2009. The operation and financial viability of this co-gen plant is highly dependant on the continued supply of bagasse as the main feedstock product. So, the current or future generated bagasse may be completely allocated to co-generation. And therefore it is recommended to exclude bagasse as possible CE feedstock. An interesting aspect to take in account is that the cane residues on the lands can be harvested for CE production. The total potential of 109,141 metric tons of “green” cane residues (tops and leaves) is available for harvesting. Of the 1,121,353 metric ton of cellulosic biomass residues available from the agricultural sector in Belize (see Table 5.2), sugarcane bagasse represents 37.2% of this total.

As result of interviews, Mr. Henry Canton, Director of Citrus Product of Belize (CPB)[231], claimed that they have plans to launch a project in early 2009 that is focused on the drying of the waste stream (e.g. skill peel) by using heat recovered from an economizer to be installed at the current distillation unit at the process plant to dry the orange waste stream to 10% moisture content that can qualify as dry cattle feed (it contains the right balance of nutrients) and can be sold at a price of US$ 200 per metric ton. The remainder after the drying process is considered the black water and will pass through a waste water treatment unit. Current potential markets for the cattle feed are Dominican Republic and Costa Rica. This development indicates that 144,995 metric tons of CE feedstock originating from grapefruit, pomelos and citrus skins and pulps generated during the citrus processing may not be available in the future. This will lead to a decrease in cellulosic ethanol yield, but it is not anticipated to be as significant to disrupt domestic ethanol supply.

Forestry residues limited by forest protection and limited forests

Based on studies made on the sustainable forestry products extraction rates, it is concluded that for the preservation of the existing amount of forested lands, the level of biodiversity, and the government’s aim to further develop eco-tourism, it is recommended to exclude the future potential of continued wood waste extraction for cellulosic ethanol production. The following issues are some reasons for excluding

[231] Interview with Mr. Canton was held on Friday 22 of August, 2008 at the CPB office in Stan Creek, Belize.

future potential forest product waste extraction as part of the sustainable feedstock for cellulosic ethanol production:

- The Forest Act of 1920 was revised in 1995 and is currently being updated with the help of FAO where there is no clear overview of the to be established regime.
- Currently, the information about the status of the forest (biodiversity level, productivity level, etc.) is being updated. This is a three year project (2008-2010) supported by the FAO and results have to be awaited.
- Forest planning:
  - As per 2008, the forest resources equaled 17% of natural territory of Belize.
  - Forest planning is focused on the sustainable utilization and management of natural resources including all forest products (all floras), protected and unprotected, that may impact the commercial forest industry.
- Several licenses are provided to land owners: short, medium, and long term licenses (35-40 years) that lead to different types of forest activities and will impact the availability of cellulosic biomass feedstock. Short licenses: 1 year period, are applied nationally, but are very exploitative. The reason is that access roads are created or are over utilized, where in the raining season, it makes the roads unusable and limits access to lands. This impacts the farmers since they are restricted in transporting their goods from the farm to the markets. This is why it is only in the dry season that 1-year license holders are allowed to access their lands, this falls in line with the time limited for logging (8 months) generally from Oct 15 – Jun 15.
- In the case of commercial forest activities: royalties are charged for natural reserves per species basis and may cause a diversion in types of species exploited and therefore the CE feedstock type and availability. Royalties for mahogany is 1.21 B$ct/cubic foot. The annual revenue from forest extraction (timber) is on average between 1.2 – 1.5 MB$ which is comparable to <1 % of GDP (2008). The Ministry of Finance monitors the revenue streams within the lumber industry. The forest industry is characterized by two main product streams: one is the pine tree, this has a higher value in the industry, therefore there were increases in conversion efficiencies up to 60%; and other trees have a conversion efficiency for broad leave-trees is around 50%.
- Waste streams identified as sawdust, are used for landscaping or burned in on-site kilns and is a competitive utilization form of this potential CE feedstock.

Uncertainties in future feedstock prices

The availability and quality of the agricultural and forest residues are highly regional, and depend on what crops are grown locally and the quantities produced. Seasonality, including possible floods and droughts, is another issue that can affect quality. In order for a market to exist, there must be an efficient and established system of gathering, brokering and transporting the crop residues. Since there is currently no policy or regulations in place to manage agricultural and forest residues there is no guarantee that the biomass will be available for the cellulosic ethanol plant, neither is it known at what cost. As is the case for Belcogen, there is a need of a clear policy indicating that the cellulosic ethanol developer has priority access to the waste residues to guarantee a stable operation of the plant. Also since currently no value is attached to the residue, they have been assumed to be zero in this study. But in case of the emergence of competing biomass-to-energy systems or projects that require the same feedstock type, an increase in the waste residue value could occur. A clear long-term vision and strategy are critical to develop the CE market. Dedicated energy crops (crops grown specifically for the production of crop residue as a fuel) would to some extent be required.

Competing Transport Fuels

Several current and future potential competing alternative fuels have been identified in Belize. Among the main fuels are imported gasoline, natural gas, first generation ethanol production, and domestic refined gasoline.

Future Competing Ethanol

As was indicated in section 7.1, Belize Sugar Industry (BSI) has as part of its 10-year strategic plan the construction of a distillery for the production of dehydrated ethanol from molasses available at its mill. The molasses volume is estimated to be around 45 – 50 kilotons per year and it is anticipated that this amount of feedstock could yield an amount that satisfies about 10 - 15% of the current gasoline consumption in Belize. A national renewable energy policy could be a critical tool to determine priorities of the Government vis-à-vis the private sector and NGOs in Belize.

Liquefied Petroleum Gas (Butane)

In Belize, the usage of natural gas occurs (in the form of butane/propane) as an alternative transport fuel.[232] Since the early 2000, import taxes have been charged depending on the vehicle type and size. Trucks that are commonly used for work are taxed at 31% for 4 cylinder and 37% for 6 cylinders. Cars on the other hand (being considered luxury items) are higher taxed depending of the size of the engine i.e. 4 & 6 cylinders at 57% and 65%, respectively. This and the past shift of public transport companies towards using LPG fueled busses have led to increased LPG demand.[233] This means that, in particular the public transport sub-sector a clear competition for an E-10 ethanol to gasoline blend exists. Unfortunately there is no data on projections of LPG demand or the amount of vehicles currently running on LPG. Although the total amount of imported LPG (including propane and butane) can be determined for Belize, there is no data related to the fraction consumed in households for cooking, heating or in the transport sector as fuel for vehicles. Further analysis on this matter is recommended.

Domestic crude oil refining to gasoline

Since 2006 Belize started producing a small amount of oil[234], about 2,600 barrels per day (2007).[235] By 2006, there were about 15 petroleum exploration blocks, covering a total area of approximately 3.8 million acres of the Belizean territory (including on and off-shore sites), leased or under contract by several petrochemical companies.[236] More than 50 exploratory wells have been drilled with only commercial scale findings in 5 wells located in the Spanish Lookout area near the capital capitol Belmopan. The company exploring and exploiting this block and leading this venture is Belize Natural Energy Ltd. (BNE).[237] BNE has an early estimate of available reserves for the Spanish Lookout site set at 11 million barrels (2008).[238] BNE has managed to increase its production to 3,000 to 5,000 barrels a day in 2008. With the first commercial exploitation ongoing in the Spanish Lookout site in central Belize, several other interests have emerged for investing in other exploratory wells in the territory of Belize.[239] If sufficient volumes are found, there may be future potential for building a refinery in Belize whereby depending on the crude oil quality. Naphtha, kerosene, diesel, gasoline and other lighter distillates may be produced for local consumption, which are currently mainly imported from refineries in the U.S., Cuba

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[232] Launchpad Consulting Belize, CA & Azurdia I. (2003). Energy Sustainable Development Toward a National Energy Strategy for Belize Energy Sector Diagnostic, Public Utilities Commission of Belize

[233] Launchpad Consulting Belize, CA & Azurdia I. (2003). Energy Sustainable Development Toward a National Energy Strategy for Belize Energy Sector Diagnostic, Public Utilities Commission of Belize

[234] In the form of 38Þ-gravity API

[235] Energy Information Administration; http://tonto.eia.doe.gov/country/country_energy_data.cfm?fips=BH

[236] Belize Natural Energy Limited, BNEL Environmental Compliance Project, Iguana Creek Facility – Environmental Impact Assessment Report, January 2007

[237] New York Times, Touched by Oil and Hope in Belize http://www.nytimes.com/2006/02/21/business/worldbusiness/21belize.html?_r=1

[238] Belize newspaper Amandala, Taiwan to explore for oil offshore Belize, 16 January, 2009, website: http://www.amandala.com.bz/index.php?id=8024 (visited January 2009)

[239] https://www.chinapost.com.tw/taiwan/int'l%20%20community/2008/09/20/175581/Taiwan-Belize.htm

and Mexico. Most of the Belizean gasoline is imported from the PDVSA refinery located in the Dutch Antilles.[240]

Ongoing and planned activities cellulosic ethanol developments

According to Blue Diamond Ventures Company's website, they intend to develop and produce cellulosic-ethanol by establishing 3.5 million gallons per year production facility at the old Libertad Sugar Factory site in Belize.[241] There is further no other reference found upon other planned activities in this area.

[240] Statistical Institute of Belize, "06 Motor Vehicles Licenced by Dist. & Type AoS 2007" Stats Document.
[241] http://www.bluediamondventures.com/biofuels.php, web site visited: 12 June 2008

9 Conclusions and Recommendations

9.1 Discussion

Use and Limits of this Report

Before discussing the results of this assessment, it is important to reiterate the limits and scope of this study. The aim is to keep a high level of transparency on how this study has been conducted, the assumptions made, and the methodologies used to generate the results and conclusions. Here are some issues that need further explanation or were left out but are also key factors influencing the cellulosic ethanol market potential.

Cellulosic Ethanol production cost

The primary cost factor of ethanol production is the feedstock cost (See section 4). However, the assumption is made that in 2012 the industry will demonstrate the viability of commercial-scale ethanol production using cellulosic feedstock. The capital and operational costs were kept static in this study, where only the feedstock cost has been adapted to Belizean conditions. The technology development (learning curve via RD&D activities) will determine the medium- (2012) rates of increased efficiency, available unit capacity, and potential capital cost reductions. For this exercise, the provided data is deemed the best estimation of CE production costs in Belize. It is important to acknowledge that cellulosic ethanol is value-added product from waste residues generated by agricultural, forestry and waste management activities or services, which could lead to attractive alternatives to modify the existing agricultural, forestry and waste management sector configuration.

Cellulosic Ethanol production cost vs. Gasoline import price

In order to compare the cost of CE production in Belize with gasoline in an objective manner, the cost of CE was calculated based on the gasoline equivalent. This is because ethanol’s energy content is 30% lower to gasoline per tank volume. This is in itself disputable, because studies also indicate that due to the usage of ethanol the overall engine operation and fuel efficiency improves. Therefore one has to consider this conversion as a baseline data with improvement potential. Also the gathered gasoline price (at the port; without taxes; all grades average) originates from different unverified sources and there is lack of consistency in the data. Nevertheless it provides a qualitative perspective and due to the high volatility of petroleum, gasoline forecasts are always difficult to execute with a low uncertainty margin.

Ethanol market price

The ethanol market is highly correlated to NYMEX gasoline prices, since in most cases the ethanol is blended at different rates with gasoline. The global ethanol market is rapidly expanding and changing and predicting future prices is difficult.

Study Methodology

The 5E approach used in this study is deemed an efficient tool for private and governmental organizations to evaluate the potential viability of all under-development and promising emerging renewable energy technologies. Also, this type of assessment methodology has the value of identifying potential problems with other candidate technologies, and it will help to point the way for solving those problems during e.g. multi-stakeholder meetings.

Blending/storage

The storage requirements and the blending process or technologies have not been taken in consideration in this study. This will become an important issue once a CE plant is commissioned, since there are several alternatives in how, when, and where to blend the ethanol with gasoline. There are many regulatory considerations that must be undertaken when offering ethanol blended fuels. Depending on techno-economic conditions blending can occur at the pump. This example may lead to the need to store ethanol and gasoline in separate tanks at the pump station, which will require additional space and investments costs for the distributor. Therefore when considering cellulosic ethanol production and consumption in Belize, a comprehensive study is needed on distribution, storage and consumption technicalities (also known as a plant-to-pump assessment).

Logistics/distribution/infrastructure

Cellulosic ethanol distribution has not been tackled in this report. One of the pressing factors for determining the final price of ethanol to the consumer is the logistical or distribution requirements and costs. It is worth mentioning that U.S. ethanol is produced and consumed in the Midwest.[242] This is interesting because here is a clear example of ethanol distributors trying to optimize the cost of ethanol by locating their businesses close to where the feedstock is produced.[243] Based, on this assessment, Belize being a relatively small country with an established gasoline distribution infrastructure mainly concentrated in urban areas, the future cellulosic ethanol distribution costs in Belize is deemed not significantly different to the current gasoline distribution costs. Factors as type and location of storage and blending will influence the distribution costs of ethanol.

Fuel Ethanol accreditation, standards and specifications[244,245,246]

One important technical factor to take in mind for the future Belizean CE ethanol distribution, blending and marketing are the developments in the international biofuels standards that may impact the value or even the marketability of Belizean fuel ethanol. Providing high quality fuels to consumers is the goal of every fuel manufacturer. Therefore it is recommended to engage in an early phase with international biofuels players, and collaborate with international and national organizations or institutions specialized in fuel standardization. Also it is important to asses other necessary steps for successful introduction of ethanol or ethanol blended fuels to a new or existing fuel distribution system. Ethanol is a flammable liquid similar to gasoline however it does have some chemical characteristics different from gasoline. Ethanol should be treated differently than gasoline when selecting certain storage and handling equipment. Before introducing ethanol into a new storage and transfer system or during the process of converting an existing system to handle ethanol or ethanol blended fuels, a thorough system evaluation should be conducted to ensure appropriate components and safety equipment have been selected and installed.

Fuel Economy

Determining the exact cause of reductions in fuel economy is not as easy as it seems. Fuel economy is the comparison of engine performance in distance terms with energy usage (miles per gallon), and it is influenced by many different factors, including excess cargo weight, vehicle condition and maintenance, proper tire inflation, use of air conditioning, consumer driving habits, climate related effects, and fuel composition. These factors produce similar and in most cases greater reductions in fuel economy than the

[242] http://www.ethanolrfa.org/industry/locations/
[243] http://www.afdc.energy.gov/afdc/pdfs/ethanol_refineries.pdf
[244] http://www.adm.com/en-US/products/Documents/Fuel%20Ethanol%20Specification.pdf
[245] American Petroleum Institute, website: http://www.api.org/Standards/faq/upload/BIOFUELS_STANDARDS_WEB_VERSION.swf (visited January 2009)
[246] Underwriters Laboratories, Information related to the Development of Safety Requirements for E85 Dispensers and Components, UL website: http://www.ul.com/gasandoil/development.html (visited January, 2009)

use of 10% ethanol in gasoline. Therefore a comprehensive action plan is needed to adequately tackling these issues for a sustainable cellulosic ethanol market development.

Public acceptance

Technical and financial support for small producers and consumers will be needed to achieve a successful public acceptance of ethanol use.[247] Although this aspect has not been discussed in detail in this study, it is of essence to realize that any future production of cellulosic ethanol in Belize will need to be concerned about public acceptance and should at the minimum be evaluated upon the following points:

1. Land Conversion
2. Biodiversity
3. Green House Gases life cycle assessment
4. Food Displacement
5. Protected Areas
6. Land Tenure

Especially rural regions are vulnerable to unsustainable projects; they suffer from lower incomes, higher unemployment, land ownership disputes and a relatively high dependency on the primary sector for job creation. Not-in-my-backyard opinions may surge if these projects are not transparent and inclusive to all the major stakeholders. It is recommended to create clear guidelines for biofuels project appraisal procedures, licensing and developing socio-environmental impact assessments. CE production is seen as a good contender to address some of these issues in a sustainable manner.

9.2 Conclusions

This study generated several results about factors influencing the cellulosic ethanol market potential in Belize and allows stakeholders and decision makers to make an informed choice or decision on whether to engage into the endeavor of developing a cellulosic ethanol market.

The results of this study are summarized below:

Current and potential future feedstock supply volume and costs

The total amount of cellulose feedstock currently available is about 717,469 metric tons per year. The biomass feedstock is composed of residues from cultivation, harvesting, and processing activities within the agricultural and forestry sectors. A large fraction of the feedstock also originates from the collection of organic or biodegradable waste from Municipal Solid Waste management activities. The average cost of collection and transport of the feedstock is estimated to be in the range of US$ 22.0 – 56.7 per ton. These values are calculated for transport distances ranging up to 52 miles radius (85km) from collection point to processing plant, where 90% of all available cellulosic biomass feedstock in Belize is available for collection or harvesting.

Identified suitable cellulosic ethanol sub-technology

Based on the accumulated data and analysis conducted the results indicate that the thermo-chemical conversion process is the best suitable sub-technology for the conversion of cellulose biomass feedstock into ethanol based on the prevailing and future potential conditions in Belize.

Among the reasons for this conclusion is that the thermo-chemical process requires much less biomass to achieve economic viability compared with the biochemical processes. The thermo-chemical process plant

[247] United Nations, Food and Agriculture Statistics Division, FAOSTAT. http//:faostat.foa.org/site/336/destoktopdefa<ault.aspx?pageID=336

has a higher potential to be dimensioned to the available annual feedstock in Belize compared to the bio-chemical process. The thermo-chemical process requires approximately 200 - 1,000 dry tons per day (58,400 – 292,000 dry tons per year[248]) of feedstock input for a small to medium size plant. While the bio-chemical process requires a critical feedstock volume of 2,205 dry tons per day (643,840 dry tons per year). Furthermore, thermo-chemical processes have on average higher conversion efficiencies and can convert a wider variety and heterogeneous composition of biomass feedstock, including organic wastes originating from MSW (see table 7.9). For instance, the thermo-chemical conversion process that utilize pyrolysis/steam reforming processes (no oxygen or air) are currently capable of economically producing bio-alcohols for as little as 250 dry tons per day of biomass and improvements in this thermo-chemical technology have the potential of reducing ethanol production costs to below $1.00/gallon by 2012.[249]

The average capital investment cost per unit is lower for the thermo chemical process compared to the bio-chemical process with higher potential reductions in CE production costs. Compared to the bio-chemical process technologies, the thermo-chemical technology components are more mature and considered off the shelf technologies, and are therefore more accessible on the global market and allow for transfer of the technology to Belize. These are some of the arguments to consider the thermo chemical process technology as a viable short- to medium-term (by 2012) applicable system to produce cellulosic ethanol in Belize.

The potential present and future Belizean cellulosic ethanol yield and production cost range

Belize has sufficient cellulose feedstock for the development of a mid-sized cellulosic ethanol plant (500,000-700,000 ton/year) with a CE yield of about 39.0 – 46.3 million gallons per year (based on 2008 Technology). In addition, with the expected technology improvements in 2012 a yield of approx. 50.2 – 68.9 million gallons per year could be possible. To achieve this, according to the 5E assessment, a thermo-chemical approach appears to be the best suitable technology to do this.

The estimated cost of production of cellulosic ethanol in Belize is between US$ 1.64 – US$ 2.89 per gallon under 2008 conditions. This is based on a feedstock cost ranging between US$ 22.0 – 56.7 per ton present within the distance of 52 mi radius (85 km) from a centralized located processing plant, where 90% of all available cellulosic biomass feedstock in Belize is available for harvesting. Based on a literature review, the cellulosic ethanol production cost may be reduced to about US$ 1.00 – 1.07 per gallon or less for the thermo-chemical process technologies and to US$ 0.74 – US$ 1.50 per gallon for bio-chemical process technologies.

The market potential of cellulosic ethanol in Belize

Belize could be considered an attractive country with a high potential to move towards the development of a cellulosic ethanol market. The cellulosic ethanol market potential is very attractive since the prevailing conditions for sustainable feedstock supply and its costs are within acceptable margins with great improvement potential; the international research, development and deployment of both the thermo-chemical as the biochemical processes to convert cellulosic biomass into ethanol are plentiful, dynamic, and promising and may lead to considerable reductions in capital investment costs; increased efficiency and lower production costs; large global ethanol markets are emerging and opening for the potential export of Belizean ethanol; and last but most important, the Belizean government is in a great

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[248] The annual feedstock supply is calculated based on a 0.8 load factor multiplied by 365 days in a year. This load factor is common for bio-energy plant operation availability. The seasonal variation in feedstock availability is not included in these values. A dry ton has the same mass value as a metric ton, but the material (sludge, slurries, compost, and similar mixtures in which solid material is soaked with or suspended in water) has been dried to a relatively low, consistent moisture level (dry weight). If the material is in its natural, wet state, it is called a wet ton.

[249] Dennis Schuetzle, Gregory Tamblyn and Frederick Tornatore, TSS Consultants, 2007. Alcohol Fuels from Biomass – Assessment of Production Technologies. www.westgov.org/wga/initiatives/biomass/ASSESSMENT-BIOALCOHOL-tech.pdf

position to create a comprehensive National (Renewable) Energy Policy that outlines a clear long-term strategy that guarantees sustained investments and continuum of the Belizean renewable fuels industry.

To guarantee a steady market development it is necessary to implement a comprehensive national energy policy including for instance a renewable fuels standard, a policy related to greenhouse gas emission standards or reduction targets for all energy sources. Belize needs at the minimum a renewable fuels standard to determine a percentage of CE blend with gasoline and may even explore the potential to replace diesel for ethanol or blending it (known as E-diesel), as is the case in Sweden.[250] A renewable fuel standard basically means that a percentage of the transport fuel consumed in country is derived from renewable resources.

With a comprehensive national energy policy in place, there is a clear long-term guarantee to expand the ethanol or biofuels consumption market, reduce greenhouse gas emissions, improve rural economic development, expand and diversify fuel supplies, and advance new technologies. As a result, Belize could develop a new added value market for agriculture, forestry residues and MSW; help ensure a market for cellulosic ethanol that simultaneously provides benefits to ongoing climate change mitigation efforts.

A comprehensive energy policy could require that all fuel industries meet targeted greenhouse gas reduction goals through a minimum use of renewable fuels. To do that the Kyoto Protocol agreement can be used as background to justify, define and advance implementation activities by the government under this protocol. Working in partnership with organizations, universities, government and scientists, will make this pathway possible and warrants a public-private partnership to establish a renewable energy promotion entity in Belize.

The key result of this study is that a national energy policy is imperative for any renewable energy development in Belize and the primary recommendation is to use this perceived barrier (lack of a national energy policy) as an opportunity to address these issues that are needed for promoting and establishing a general renewable energy market, including cellulosic ethanol production. These new regulatory tools must be designed to address these barriers and opportunities that the renewable energy industry, including the biofuels industry, could generate alongside other national priorities as oil exploitation, forest conservation, climate change mitigation, and other socio-economic development requirements.

As a starting point, cellulosic ethanol development in Belize can build upon the past experiences of the now commercially viable 1st generation ethanol business. Since the final product is ethanol, there is less anticipated barriers envisioned in terms of price distortions and inefficient regulation as this has and is being addressed for the 1st generation ethanol systems. An international ethanol industry and markets (including Brazil, USA and EU) have already emerged and are becoming more and more mature. Experts, companies and governments from these regions could bring support and link their strategies to develop this market in Belize.

9.3 Recommendations

Commitment to CE development

As demonstrated in this report, Belize possesses considerable potential for the development of cellulosic ethanol, at such time as the technology for its production becomes commercially available. Given that the technology is not expected to be commercially available on a scale appropriate for Belize before the year 2012, we may ask, *what should be done today and in the near term to ensure that Belize is well positioned to attract early phase investments in this area?*

[250] Article; http://gas2.org/2008/04/15/scanias-ethanol-diesel-engine-runs-on-biodiesel-too/

- **Articulate National Energy Priorities via a National Energy Policy and/or Sustainable Energy Plan**
  - Set targets for the uses of renewable and non-renewable energy resources for both power and transportation
  - Outline goals for energy efficiency and conservation
  - Set goals for local and global environmental impacts from the energy sector
  - Establish goals for renewable transportation fuel production and use

- **Create Appropriate Energy Sector Governance Mechanisms**
  - Clearly specify single ministry responsible for energy including transportation fuels
  - Establish desk/directorate for renewable energy
  - Establish national energy committee which draws on the input of multiple sectors
  - Strengthen institutional capacity of said institutions

- **Develop First Generation Ethanol Production Industry**
  - Facilitate use of sugarcane/molasses for production of ethanol in the near-term
  - Establish ethanol sales chain/market (domestic and/or export of product)

- **Prepare Ethanol Production and Consumption Rules and Regulations**
  - International biofuels standards
  - Mandate ethanol blending requirements (E5, E10, other for domestic use)
  - Establish environmental and sustainability guidelines for biofuels
  - Organize public outreach and educational campaign

- **Explore Possible Institutional Support Mechanism to Achieve the Above Objectives**
  - Continue engagement with the OAS on sustainable energy matters
  - Build multi-stakeholder and agency partnerships for technical assistance
  - Investigate opportunities for bi-lateral and multi-lateral financial assistance to support activities

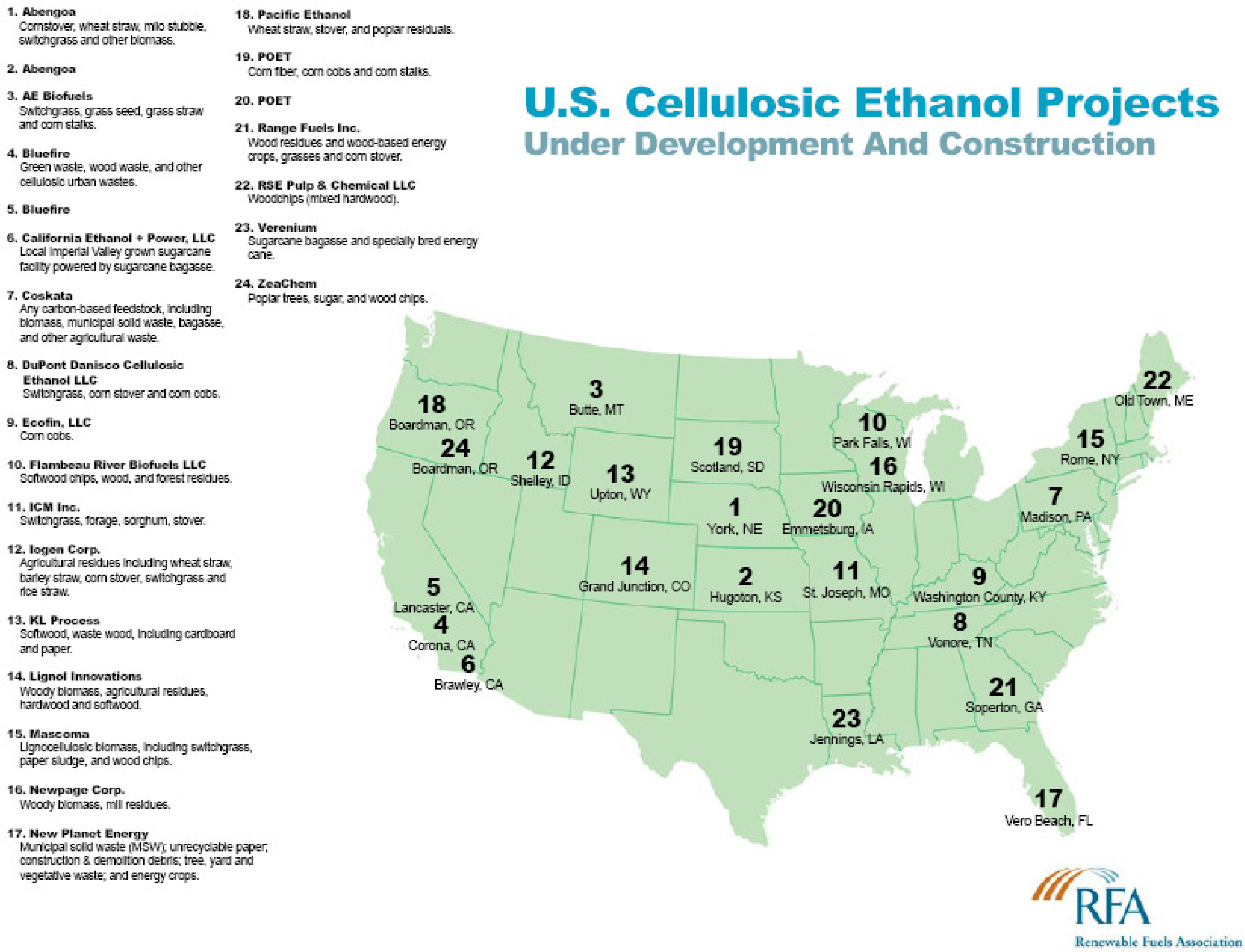
10 Annexes

Annex 11.1 General Statistics of Belize

Dimensions	**170 mls (274 Km) N-S, 68 mls. (109 Km) E-W**
Area	8,867 sq. mls. (22, 700 Km)
Rainfall (annual average)	51 ins (1,295 mm) N, 175 ins (4, 445 mm) S
Temperature range	10°- 35° C (50° - 95°F)
Population	273,700 (mid-year 2003)
Population density	31 / sq. ml (12 /sq. km) (mid-year 2003)
Life expectancy	Females: 73.5 yrs., Males: 66.7 yrs
Population growth rate	3.0 %
Currency	Dollar (BZE$), fixed exchange rate, BZE $2.00 = US $1.00

Source: CSO 2001

Annex 11.2 U.S. Cellulosic Ethanol Projects under Development and Construction[251]



o Abengoa Bioenergy	www.abengoabioenergy.com
o Archer Daniels Midland	www.admworld.com
o Aventine Renewable Energy Holdings, Inc.	www.aventinerei.com
o Green Plains Renewable Energy.	www.gpreethanol.com
o Lignol Energy Corporation	www.lignol.ca
o Pacific Ethanol, Inc.	www.pacificethanol.net
o Renova Energy (Wyoming Ethanol)	www.renovaenergy.com
o The Andersons Inc.	www.andersonsinc.com
o U.S. BioEnergy Corp.	www.usbioenergy.net
o VeraSun Energy Corporation	www.verasun.com
o Xethanol BioFuels, LLC	www.xethanol.com
o Genencor International	http://www.genencor.com
o POET Energy	www.poetenergy.com
o Novozymes	www.novozymes.com
o Range Fuels	http://www.rangefuels.com/
o Alico	http://www.alicoinc.com/

[251] U.S. Renewable Fuels Association, document: http://www.ethanolrfa.org/resource/cellulosic/documents/CellulosicPlantMap.pdf

Annex 11.3 Ethanol Production Capacity installed in the EU (as per Dec 2008)[252]

MS	Company	PC	Feedstock
Austria	Agrana (Pischelsdorf)	240	Wheat, maize
Belgium	BioWanz (Wanze)	300	Wheat, sugar juice
	AlcoBioFuel (Gent)	150	Wheat
	Amylum (Aalst)	32	Wheat
Bulgaria	Euro Ethyl GmbH (Silistra)	10	Maize
Czech Republic	Agroetanol TTD (Dobrovice)	65	Sugar juice
Finland	St1 (Lappeenranta)	1.5	Organic
	St1(Närpiö)	1.5	Organic
	St1 (Hamina)	44	Hydrous alcohol
France	Tereos (Artenay)	40	Sugar juice
	Tereos (Provins)	30	Sugar juice
	Tereos (Morains)	40	Sugar juice
	Tereos (Lillers)	80	Sugar juice
	Tereos (Lillebonne)	250	Wheat
	Tereos (Origny)	300	Sugar juice
	Cristanol (Arcis sur Aube)	100	Sugar juice
	Cristanol I (Bazancourt)	150	Sugar beet, sugar juice
	Cristanol/Deulep (St. Gilles)	40	Wine alcohol
	Saint Louis Sucre	90	Sugar juice
	CropEnergies AG (Dunkerque)	100	Hydrous alcohol
	AB Bioenergy France (Lacq)	250	Wine alcohol, maize
	Roquette (Beinheim)	75	Wheat
Germany	Verbio AG (Zörbig)	100	Cereals
	Verbio AG (Schwedt)	230	Cereals, sugar juice
	CropEnergies AG (Zeitz)	360	Cereals, sugar juice
	Fuel 21 (Klein Wanzleben)	130	Sugar juice
	Prokon (Stade)	120	Wheat
	Danisco (Anklam)	53	Sugar juice
	KWST (Hannover)	40	Wine alcohol
	SASOL (Herne)	76	Hydrous alcohol
Hungary	Hungrana Kft. (Szabadegyháza)	170	Maize
	Györ Distillery	40	Maize
Italy	Silcompa (Correggio)	60	Hydrous alcohol
	Alcoplus (Ferrara)	42	Cereals
	IMA (Bertolino Group)	200	Wine alcohol
Latvia	Jaunpagastas (Riga)	12	
Lithuania	Biofuture	31	Rye, Wheat
Netherlands	Royal Nedalco (Bergen op Zoom)	35	C-Starch
Poland	Akwawit (Lezno)	100	Cereals)

[252] European Bioethanol Fuel Association, website: http://www.ebio.org/statistics.php?id=5 (visited January 2009)

	Cargill (Wroclaw)	36	C-Starch
Romania	Amochim	18	
Spain	Ecocarburantes (Cartagena)	150	Barley, wheat
	Bioetanol Galicia (Teixeiro)	176	Cereals
	Biocarburantes C&L (Babilafuente)	195	Cereals
	Acciona (Alcázar de San Juan)	32	Wine alcohol
Sweden	Agroetanol	210	Cereals
	SEKAB	90	Wine alcohol
	SEKAB	10	Pulp
UK	British Sugar plc (Downham)	70	Sugar juice
Total		5175	

Annex 11.4 Ethanol Projects under development in the EU (as per Dec 2008)[253]

MS	Company	PC	Feedstock
Bulgaria	Euro Ethyl GmbH (Silistra)	30	Maize
	Crystal Chemicals	13	
Czech Republic	PLP (Trmice)	100	Cereals (possibly sugar as well)
	Korfil a.s. (Vrdy)	100	Cereals
	Ethanol Energy (Vrdy)	70	Cereals, maize
Denmark	Dong Energy (Kalundborg)	17.6	Straw, wheat
France	Cristanol II (Bazancourt)	200	Wheat, glucose
	Roquette (Beinheim)	35	Wheat
Germany	Wabio Bioenergie (Bad Köstritz)	8.4	Waste
	Bioethanol Emsland (Papenburg)	90	
Greece	Helenic Sugar EBZ	150	Sugar beet, molasses, cereals
Hungary	First Hungarian Bioethanol Kft (Elsö Magyar Bioethanol Termelökst)	90	Maize
Italy	Grandi Molini (Porto Marghera)	130	Cereals
Lithuania	Bioetan	100	Cereals
Netherlands	Abengoa (Rotterdam)	480	Wheat
	Nivoba BV (Wijster)	100	Cereals
Slovakia	Enviral	138	Corn
Slovenia	Slovnafta (Bratislava)	75	Wheat
Spain	Biocarburantes Castilla & Leon (Salamanca)	5	Ligno-cellulose
	SNIACE II (Zamora)	150	Wheat
	Alcoholes Biocarburantes de Extremadura (Albiex)	110	
UK	Ensus plc (Teesside)	400	Wheat
	Vivergo (Hull)	420	Wheat
Total		3012	

[253] European Bioethanol Fuel Association, website: http://www.ebio.org/statistics.php?id=6 (visited January 2009)

Annex 11.5 Different Residue to Product Ration (RPR) per crops[254]

Banana[255]					
Reference	**RPR**	**Moisture %**	**C %**	**N %**	**LHV MJ/Kg.**
Pattison '99			1.60	1.54	
Oranges (In this research was assuming a similar rate for grapefruit and pomelos)[256]					
Reference	**RPR**	**Moisture %**	**C %**	**N %**	**LHV MJ/Kg.**
El Tamzini et al. '04 (in the field)					
Canton '08 (during the process)	0.5				
Sugar Cane Bagasse					
Reference	**RPR**	**Moisture %**	**C %**	**N %**	**LHV MJ/Kg.**
Webb '79		52			9.22
Vimal '79	0.33	48			9.29
AIT-EEC '83	0.14	50			
Strehler '87	1.16	40-60	47	0.3	7.75
Ryan et al. '91	0.1-0.3		43		18.1
Bhattacharya et al. '93	0.29	49			
Sugar Cane Tops/Leaves					
Reference	**RPR**	**Moisture %**	**C %**	**N %**	**LHV MJ/Kg.**
Vimal '79					
AIT-EEC '83	0.125				
USAID '89	0.3				
Rice Straw					
Reference	**RPR**	**Moisture %**	**C %**	**N %**	**LHV MJ/Kg.**
Webb '79		10-12			
Vimal '79	1.88				
AIT-EEC '83	0.42	27			15.10
BEPP '85	2.86				
Barnard et al. '85	1.40 - 2.90				
Strehler '87	1.40	12-22	41.44	0.67	10.9
Bhattacharya '90	0.452	12-71	24.79		16.02
Massaquoi '90	1.10 - 3.00				
Ishaque '91	1.40				
Ryan et al. '91	1.10 - 2.90				
Kristoferson et al. '91	1.10 - 2.90				
Bhattacharya et al. '93	1.757	12-71			16.02

[254] International Plant Genetic Resources Institute, Rome, Italy.
FAO, http://www.fao.org/wairdocs/ILRI/x5495E/x5495e03.htm
FAO, http://www.fao.org/wairdocs/ILRI/x5495E/x5495e00.htm#Contents

[255] Pattison T. (1999), Effects of residual banana organic matter on burrowing nematode (Radopholus similis) in established plantations; http://nematologists.org.au/Jan99/banana_jan1999.htm

[256] Orange RPR retrieved from:
http://www.fao.org/world/Regional/RNE/morelinks/Publications/English/EXPERT%20CONSULTATION%20AGR%20.pdf

Rice Husk					
Reference	**RPR**	**Moisture %**	**C %**	**N %**	**LHV MJ/Kg.**
Bhushan '77					18-19
Webb '79	0.20-0.25	10.5			16
FAO '82	0.35	7.26			24.75
AIT-EEC '83	0.30	14			21.14
BEPP '85	0.321				
Ryan et al. '91	0.30				15-20
Mahajan et al. '92	0.30	8.92			17.34
Bhattacharya et al. '93	0.267	12.37		1.50	0.7

Maize Stalk					
Reference	**RPR**	**Moisture %**	**C %**	**N %**	**LHV MJ/Kg.**
Webb '79					
Vimal '79	2.0				
AIT-EEC '83	2.3				
Barnard et al. '85	2.0-2.3				
Strehler '87	1.0	22	47	0.8	5.25
Massaquoi '90	1.0-2.5				
Desai '90	2.08				
Ryan et al. '91	1.0-2.5	Air Dry			

Maize Cob					
Reference	**RPR**	**Moisture %**	**C %**	**N %**	**LHV MJ/Kg.**
Bhushan '77					
Webb '79	0.86	7			
Vimal '79	0.3				
AIT-EEC '83	0.2				
Barnard et al. '85	0.2-0.5				
Massaquoi '90	0.2-0.5				
Ryan et al. '91	0.7-1.8	7.53	43.14		16.28
Bhattacharya et al. '93	0.273				

Maize Husks					
Reference	**RPR**	**Moisture %**	**C %**	**N %**	**LHV MJ/Kg.**
Bhushan '77					
Webb '79	0.9				
Massaquoi '90	0.2				
Ryan et al. '91	0.2				

Roots and Tubers[257]					
Reference	**RPR**	**Moisture %**	**C %**	**N %**	**LHV MJ/Kg.**
Hermann and Heller '97					
FAO '91	0.66				

Sorghum Straw					
Reference	**RPR**	**Moisture %**	**C %**	**N %**	**LHV MJ/Kg.**
Smill '83					
Bernard et al. '85	0.1617				
Massaquoi '90	0.9-4.6				
Desai '90	2.26				
Ishaque '91	1				
Kristoferson '91	0.9-4.9				
Ryan et al. '91	0.9-4.6				
Bhattacharya et al. '93	1.25	15	42.55		12.38

Papaya					
Reference	**RPR**	**Moisture %**	**C %**	**N %**	**LHV MJ/Kg.**
Realistic level of residue production from Papaya currently does not exist. Further, Papaya represent less than 2% of the total agriculture production. For this reason, until better data is available, we will continue use deliberately a coefficient similar to orange, pomelo, etc with a RPR value of ***0.3***					

Vegetables					
Reference	**RPR**	**Moisture %**	**C %**	**N %**	**LHV MJ/Kg.**
Realistic levels of residue production from Vegetables, used have a range 0.2-1 In this case we used ***0.5*** as a conservative value.					

Sources:

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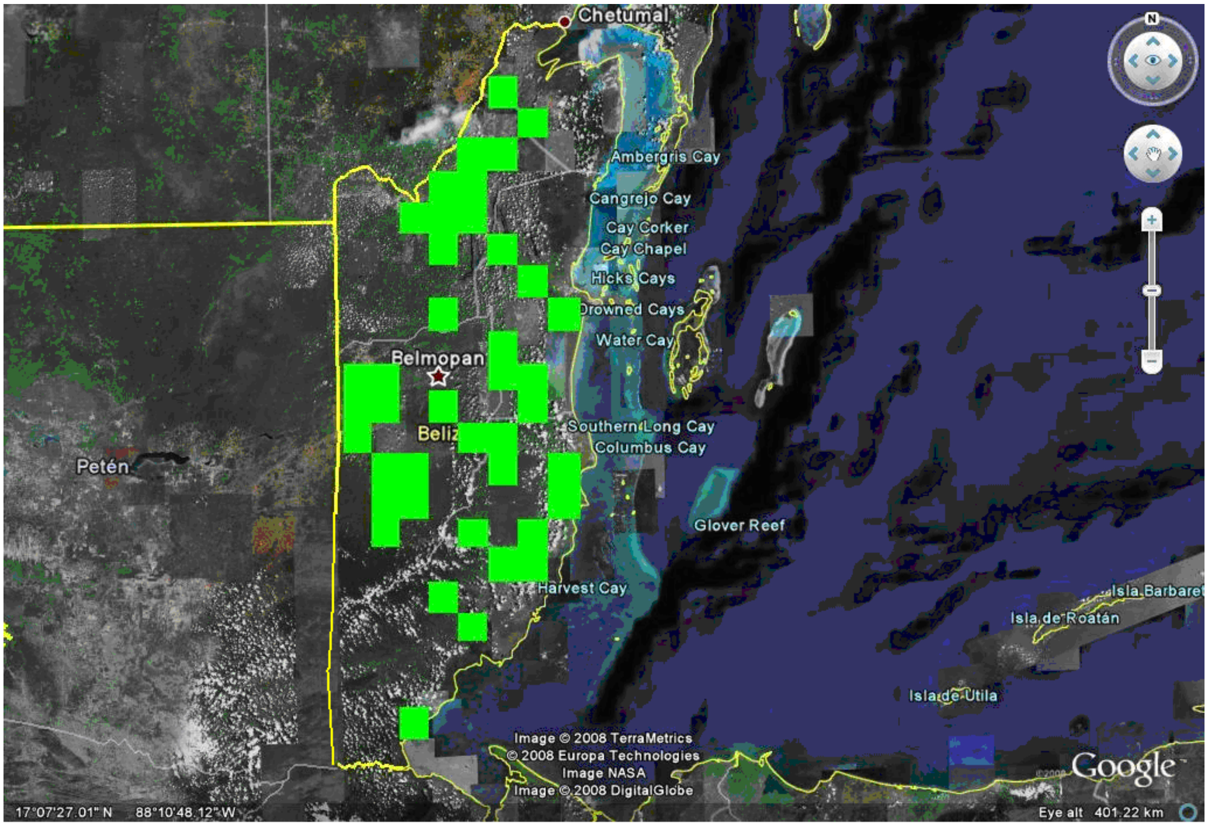
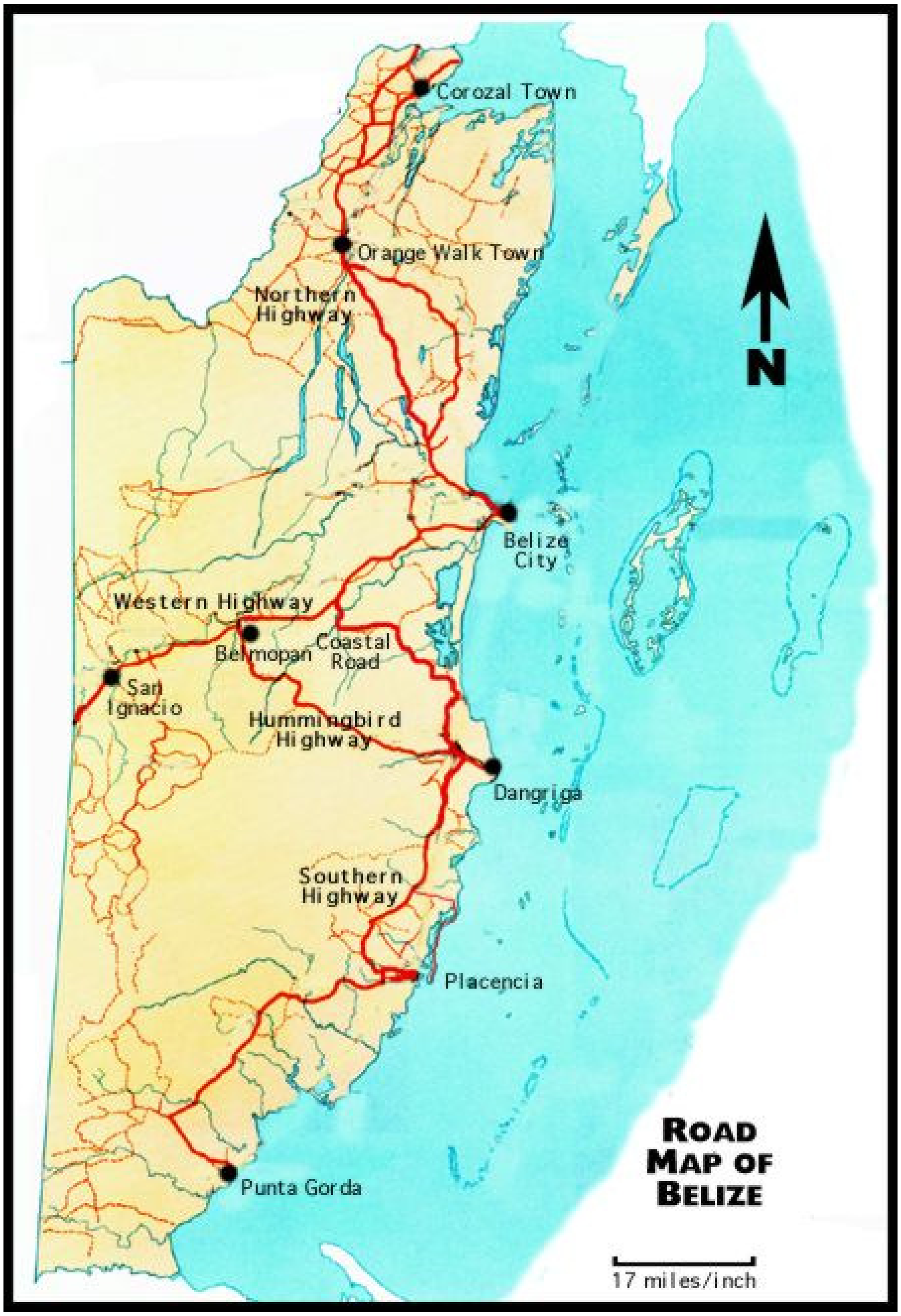
Annex 11.6 Areas available with residues in Belize



* Green box represent the areas of potential feedstock for CE production

Annex 11.7 Road maps of Belize[258]



***Red lines are the principal roads of Belize**

[258] http://www.belize.net/html/maps/roadmap.shtml

Annex 11.8 Description of the 5E method

The "5E" assessment approach used to assess the principal candidate technologies includes the following components: technology evaluation (E1); energy efficiency (E2); environmental impacts (E3); economic viability (E4); and socio-political and human resource effectiveness (E5). Each of these components is described further below. This 5E assessment is designed to assist in:

- Determining the commercial viability of promising technologies for the conversion of various biomass feedstocks to renewable fuels, other forms of bioenergy, and renewable chemical products
- Comparing the range of available and prospective technology options for obtaining transportation fuels, electricity and other forms of bioenergy and bioproducts from biomass resources
- Estimating the likelihood, extent and timetable for new bioenergy technologies to enter the marketplace, gain acceptance by stakeholders and the general public, and contribute to energy supplies

Processes, products and co-products included in this assessment include the conversion of cellulosic feedstocks to bioalcohols, biopower and bioheat. The growing, collecting, and transportation of feedstock, and its associated impacts, are beyond the scope of this study.

Technology Evaluation (E1)
E1 evaluates the progress of the Research, Development, Demonstration, and Deployment (R3D) stages for each technology type. The validation of each stage is necessary to ensure the long-term success of the commercially deployed production facility. The R3D validation stages are:

Research – Laboratory studies have been successfully carried out using bench-scale experiments to validate key chemical and physical concepts, principles and processes. Computer models have been used to analyze and validate the technology. The research has been documented in patents and/or publications in peer-reviewed journals.

Development – All unit and chemical/physical processes have been validated on a 0.5-10 ton/day pilot plant. Processes for the preparation and introduction of the biomass have been perfected. Accurate mass and energy balance measurements for each unit process have been made. The unit processes have been run for a sufficient time period to ensure that mass and energy conversion efficiencies have not degraded with time.

Demonstration – The objective of the demonstration plant is to fully establish and develop specifications as necessary for the construction of a commercial full-scale plant. This demonstration plant should be able to process more than 20-25 tons/day of biomass on an annual basis. Its design includes the incorporation of on-line chemical and physical sensors and control systems to run the plant continuously for several days as a totally integrated system. The hardware for recycle loops is included so that recycling process can be fully evaluated. The demonstration plant is used to help determine the potential robustness of each unit process and component for the full-scale production plant.

Deployment – This final stage includes the engineering and design of a commercial scale plant within the expected capital costs. The operating and maintenance costs are within due diligence estimates, as determined after the plant has been running for 329 days/year, 24 hrs/day for at least 1 calendar year (preferably two calendar years). The energy and/or fuel production yields are within anticipated design specifications.

Energy Efficiency (E2)
E2 compares the energy efficiencies for the production of bioalcohol fuels, and any merchantable co-products such as electricity. Energy efficiency of the fuel production process is also one of the key determinants of the relative greenhouse gas contribution of the full fuel cycle. The criteria for the production of alcohol fuels are as follows:

- Excellent: >45% thermal energy efficiency
- Good: 40-45% thermal energy efficiency
- Fair: 30-35% thermal energy efficiency
- Poor: 25-30% thermal energy efficiency
- Not Acceptable: <25% thermal energy efficiency

Environmental Impacts (E3)
E3 is based upon the potential impact of each system with respect to air, water and solid waste emissions and the consumption of natural resources in the production process. An acceptable technology is one that results in environmental benefits on a total life cycle assessment (LCA) or systems analysis compared to current production technologies. A summary of environmental assessment ratings is as follows:

<u>Excellent</u>
Minimal or no environmental impact is anticipated.
<u>Good</u>
There will be a modest increase in emissions, which will be within the limits of the current EPA and other required environmental permits.
<u>Fair</u>
There will be a moderate increase in emissions. However, this increase will be acceptable to applicable regulatory agencies (such as EPA or state/local air quality districts) after approval of the required environmental permits.
<u>Not Acceptable</u>
There will be a significant increase in emissions at levels that are not acceptable to the EPA and local community. Securing required environmental permits will be difficult to impossible.

Economic Viability (E4)
E4 determines the cost of fuel production ($/gallon or $/MMBTU), electricity production ($/kWh or $/MMBTU) and amortized costs ($/Yr) for the candidate technologies. This fuel and energy production cost can be compared to the current, average wholesale rate of fuel and electricity production from conventional processes. Subsidies are not considered in these economic assessments. These cost estimates can also be used to predict the Return on Investment (ROI) for a production plant. Such ROI estimates can be compared with past, current and projected market data for ethanol produced from current production processes. The criteria for ROI ratings are summarized as follows:

- Excellent: >30%
- Good: 18% to 30%
- Fair: 10% to 18%
- Not Acceptable: <10%

Socio-Political Effectiveness (E5)
E5 evaluates selected socio-political factors such as compliance with government regulations, societal benefits, environmental stewardship, and stakeholder needs and concerns. This evaluation determines if the deployment of the technology will be acceptable to all interested parties such as government regulatory groups, NGO's, environmental groups, local and regional communities and other relevant organizations.

Annex 11.9 Administrative body in Belize

Principal Administration Bodies

The principal governmental agencies responsible for environmental protection and natural resources management are the Ministry of Natural Resources, and the Environment (MNREI), the Ministry of Agriculture and Fisheries (MAF), the Ministry of Health, and the Ministry of Tourism. These Ministries are empowered by legislation, which govern the use of the natural resources and environment.
The MNREI, is one of the largest Ministries of the Government of Belize. It includes the DoE, Geology and Petroleum Department (GPD), Forest Department (FD), Lands and Surveys Department (Lands), Land Utilization Authority (LUA) and the Land Valuation Department. Among these departments are also various important sections such as the Conservation Division of the Forest Department.

The Environmental Protection Act legally established the DoE which is charged with a wide range of responsibilities including the guidance of development by industry, the encouragement of the adoption of environmentally friendly technology, the control of pollution, the request and administration of the EIA process, and the sustainable use of the natural resources and the environment.

The Forest Department is responsible for the approval of mangrove alteration permits and for implementation of the Wildlife Protection Act, 1981. The Forest Department is also the enforcing agency for the Wildlife Protection Act 2000.

The Public Health Department of the Ministry of Health is responsible for overseeing a wide range of public health matters including the on site sanitary working conditions of projects and developments.
The National Institute of Culture and History (NICH) houses the Institute of Archaeology, which is responsible for the administration of the archaeology countrywide. The Institute of Archaeology monitors all ongoing archaeological projects in Belize and issues permits for site work. The Institute is also responsible for all aspects involving any ancient Maya remains, artefacts and structures.

The Environmental Impact Assessment Process

The Environmental Impact Assessment process in Belize is comprehensive and follows internationally accepted stages:
1. Screening – determination as to whether an EIA is required;
2. Scoping – definition of the issues to be covered in the EIA;
3. Environmental impact assessment and reporting;
4. Public consultation;
5. Review process; and
6. Preparation of an environmental management system (management, mitigation, monitoring and enforcement).

Anyone embarking on a development project has to apply to the DoE for a determination as to whether the development requires an EIA (paragraph 3(2) and 11 of the EIA Regulations). Schedule I to the EIA Regulations identifies those types of projects for which an EIA is mandatory, while Schedule II to the Regulations identifies projects which may require an EIA subject to the nature of the project and its location. The DoE has to make their determination within 30 days of receipt of the request (paragraph 14). The developer has to submit draft terms of reference (ToR) to the DoE for the EIA (paragraph 15). The DoE has to examine the ToR, advise the developer as to whether the ToR are satisfactory, and in the case that they are unsatisfactory, direct the developer to make changes (paragraph 16). The developer can start on the EIA once the ToR have been agreed and submit the EIA report to the DoE by the agreed date (paragraph 17).

During the course of the EIA, the developer has to provide an opportunity for meetings with interested members of the public, in order to provide information concerning the proposed undertaking to those potentially affected by the scheme and to record the concerns of the local community. The DoE may also invite written comments from interested persons concerning the environmental impacts and may also put forward written comments to the developer, which have to be answered. The procedures for public consultation are to be determined by the DoE (paragraph 18).

The requirements for the EIA report are set out in paragraph 19 to the Regulations. The EIA report must include:

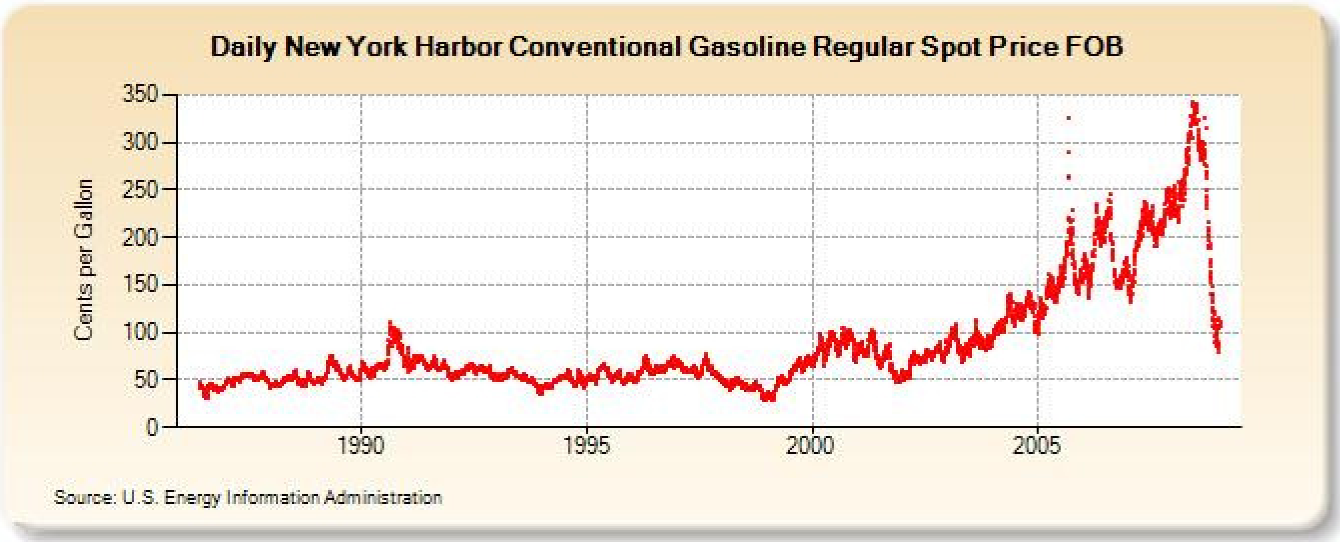
- A cover page with contact details and an abstract of the EIA report;
- A summary using non technical language;
- A table of contents;
- A description of the policy, legal and administrative framework;
- A description of the proposed development;
- A description of the environment;
- An assessment of the significant environmental effects;
- An assessment of all reasonable alternatives;
- mitigation and residual effects;
- A mitigation and monitoring plan; and
- A description of consultations with government agencies, NGOs and the public.

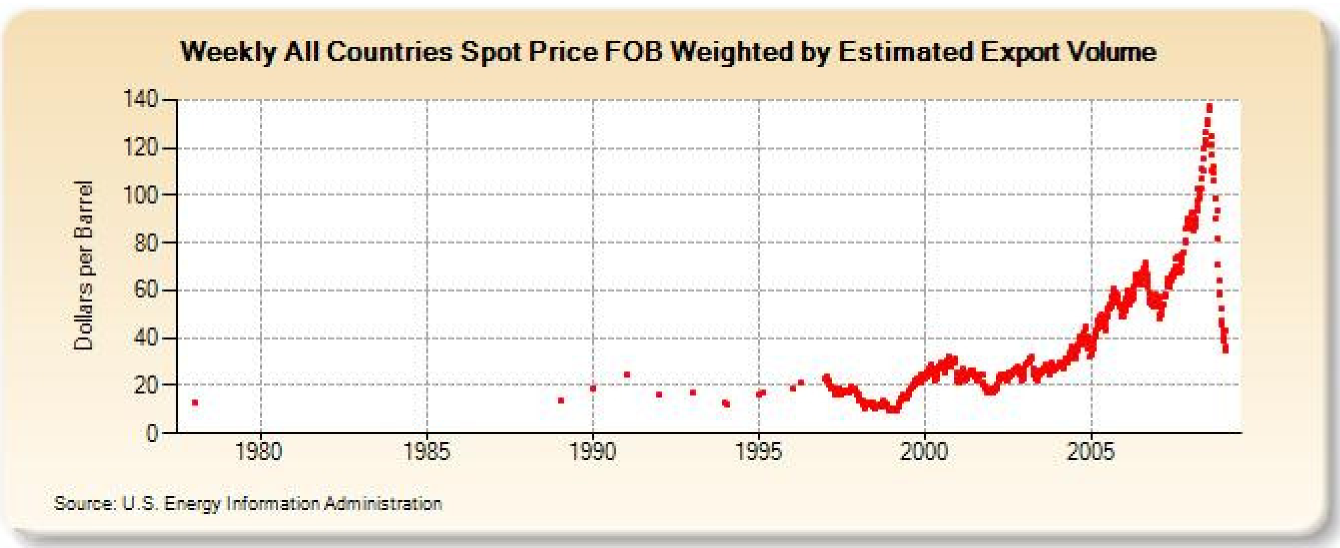
The developer has to publish details of where the EIA may be obtained in the local media including procedures for making comments on the EIA report (paragraph 20).

The National Environmental Appraisal Committee (NEAC) is the legal agency responsible for the reviewing ElA reports, advising the DoE of the adequacy or otherwise of the EIA, and advising the DoE on the need for a public hearing (paragraphs 23, 24 and 25). NEAC is chaired by the Chief Environmental Officer, who is also the head of the Department of Environment (DOE) of the Ministry of Natural Resources, Local Government and the Environment. The committee is made up of representatives from the main environmental government agencies (paragraph 25).

At the final stage of approval, the DoE requires the developer to sign an Environmental Compliance Plan, a legal document to which the developer has to adhere. This document is legally binding and contains the mitiga tion measures, stages of development, and technology to be utilized during the various phases of the project. It also makes provisions for monitoring and enforcement of the conditions agreed to and provisions for failure to implement the agreement. In the event that NEAC decides that the project should not go ahead on environmental grounds, there is an appeals procedure, whereby the development may appeal to the Minister.

Annex 11.10 Cost of the international gasoline price and the gasoline spot prices





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