

# Preliminary Assessment of Bioenergy Production in the Caribbean



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# Preliminary Assessment of Bioenergy Production in the Caribbean

## Energy and Environment

UNDP is the UN's global development network, advocating for change and connecting countries to knowledge, experience and resources to help people build a better life. We are on the ground in 166 countries, working with them on their own solutions to global and national development challenges. As they develop local capacity, they draw on the people of UNDP and our wide range of partners.

Energy and environment are essential for sustainable development. The poor are disproportionately affected by environmental degradation and lack of access to clean affordable energy services. These are global issues as climate change, loss of biodiversity and ozone layer depletion cannot be addressed by countries acting alone. UNDP helps countries strengthen their capacity to address these challenges at global, national and community levels, seeking out and sharing best practices, providing innovative policy advice and linking partners through pilot projects that help poor people build sustainable livelihoods.

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# Foreword

The United Nations Development Programme (UNDP) is the UN's global development network, an organisation advocating for change and connecting countries to knowledge, experience and resources to help people build a better life. The sub-regional office located in Barbados serves the ten countries of Barbados and the Organisation of Eastern Caribbean states (OECS). These small island developing states (SIDS), which have to contend with the challenges of open and undiversified economies, continuing social inequities, a high incidence of poverty and HIV/AIDS and vulnerability to a variety of natural hazards, such as volcanic eruptions, earthquakes, hurricanes, floods and landslides, and climate change, also need to find ways to address their almost complete dependence on imported fuel, and to put in place a sustainable energy sector that can help drive the transformation of their economies. .

“Bioenergy in the Caribbean: Supporting Policy Dialogue on Sustainable Energy Services for Small Island Developing States through South-South Cooperation” was a project implemented through UNDP with funding assistance from the United Nations Foundation. It was designed to assist Caribbean SIDS identify avenues and practices to help improve their energy security and access to sustainable energy services. Specific objectives focused on enhancing knowledge management for the renewable energy sector, identifying capacity needs and subsequently addressing these needs, and intra-regional dialogue and sharing toward a sustainable energy path.

National focus group consultations were hosted in five islands to ascertain the state and needs of their energy sectors. Training workshops were held for science teachers and electrical and technicians engineers from various countries to enhance their knowledge and skills in renewable energy and its applications. An impact assessment was conducted across nine countries to study the degree of change caused by energy projects in the last decade in terms of improving energy security and sustainability through reduced dependence on fossil fuel imports and increasing use of indigenous renewable energy. It also identified remaining gaps and barriers in the industry, and offered recommendations for a way forward. Alongside CARICOM and the Caribbean Renewable Energy Development Programme (CREDP), the project supported development of an interactive online regional knowledge management hub – the Caribbean Information Platform on Renewable Energy (CIPORE: [www.cipore.org](http://www.cipore.org)). This site is a central hosting point for all data and information on renewable energy activities in the region, and allows communication between, and learning amongst, stakeholders. Also, this document, an output under the project, examines the



feasibility of bioenergy production in the Caribbean, to be used as an aid in developing follow on plans of action.

UNDP is committed to, and actively supports, initiatives that seek to reduce poverty and vulnerability. Renewable energy can provide access to clean, affordable energy services for the poor and rural communities. Bioenergy can help improve agricultural livelihoods and produce valuable energy from waste, thus improving waste treatment and reducing use of landfills. Sustainable bioenergy production is not a panacea for all energy challenges, and faces debates surrounding its impact on food markets and whether it can be truly sustainable and lessen greenhouse gas emissions. Nevertheless, it represents a potential solution for reviving agriculture, diversifying local energy markets and improving energy security.

Related climate change mitigation and adaptation measures assist in sustainable management of water resources, reduction of air pollution, conservation of biodiversity, and ecosystem protection. Ultimately, human settlements are dependent on such environmental goods and services. Climate change, disaster risk, and poverty are inextricably intertwined, and UNDP continues to strive to strengthen the capacity of developing countries to chart a low-emissions path because current patterns threaten to halt and even reverse the development gains of the last few decades, and reduce the likelihood of achieving the Millennium Development Goals by 2015. Climate change adaptation and attainment of a sustainable energy path demand that future development be done differently.



Michelle Gyles-McDonnough  
UNDP Resident Representative  
Barbados and the OECS

# Preface

This paper gives a brief overview of bioenergy technology and applications and represents a summary compilation of work done by various bodies, referenced at the end of the document, throughout Latin America and the Caribbean.

An extensive technical report on the economics and feasibility of biofuels in the Caribbean region entitled *Technical, Social and Economic Aspects of Agro-energy* can be requested from:

Inter-American Institute for Cooperation on Agriculture  
St. Lucia Country Office  
P.O Box 1223  
Castries  
St. Lucia  
Tel: +1 758 451 6760/1  
Fax: +1 758 451 6774  
Email: [iica.lc@iica.int](mailto:iica.lc@iica.int)

This document details experiences from around the globe, including the Philippines, Australia, Cuba, Brazil, and India. It also analyses challenges to and opportunities for developing an agro-energy industry in the Caribbean, including requirements for policy and legal frameworks, investment capital, hardware and infrastructure, national capacity and public ownership. The accompanying *Strategy for the Development of an Agro-energy Programme for the Caribbean Region* was presented at a regional high-level seminar on expansion of sustainable bioenergy opportunities in August 2007. It outlines strategies and programmes to enable the Caribbean to develop a sustainable bioenergy production sector, and the role of IICA in realizing this goal.

The World Bank has also assembled a policy research working paper *Review of Environmental, Economic and Policy Aspects of Biofuels* which deals with these issues from a global perspective. Further, the World Bank has developed a *RE Toolkit: a resource for renewable energy development* which analyses grid-connected and stand-alone systems, barriers to their implementation, and means to overcome them, as well as an overview of the various renewable technologies, including bioenergy.

The International Institute for Energy and Development (IIED) published a paper on *Biofuels production, trade and sustainable development: emerging issues* covering such topics as market development, trade barriers, WTO and GATT rules, and sustainability questions

relating to economic aspects such as energy diversification, environmental issues such as greenhouse gas mitigation, and social implications such as food security.

Further, in 2008 FAO in its annual publication *The State of Food and Agriculture* focused on the subject of biofuels prospects, risks and opportunities. With a global outlook, the document examines a number of issues, including economic and policy drivers, markets, and impacts on poverty, food security and the environment.

Finally, the International Union for Conservation of Nature (IUCN) produced a guide or toolkit entitled *Implementing Sustainable Bioenergy Production: A Compilation of Tools and Approaches* suggesting ways to reduce, manage and mitigate the risks associated with biofuels. It targets a variety of stakeholders, including communities, civil society, project developers, businesses, land owners and government ministries.

# Acronyms

AFD	Agence Française de Développement (French Development Agency)
B2	2% biodiesel mixture with conventional diesel
BAMC	Barbados Agricultural Management Company Ltd
BL&P	Barbados Light and Power Company Ltd
BNOCL	Barbados National Oil Company Ltd.
CARICOM	Caribbean Community
CARILEC	Caribbean Electric Utility Services Corporation
CBI	Caribbean Basin Initiative
CCGT	Combined cycle gas turbine
CDB	Caribbean Development Bank
CDM	Clean Development Mechanism
CER	Certified emission reductions
CIDA	Canadian International Development Agency
CREDP	Caribbean Renewable Energy Development Programme
E10	10% ethanol mixture with conventional gasoline
ECLAC	Economic Commission for Latin America and the Caribbean
EIA	Environmental impact assessment
EU	European Union
FFEM	Fonds Français pour l'Environnement Mondial (AFD)
FFV	Flex-fuel vehicle
GEF SGP	Global Environment Facility Small Grants Programme
GHG	Greenhouse gas
GMO	Genetically modified organism
GRENLEC	Grenada Electricity Services Ltd
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (German Agency for Technical Cooperation)

## ACRONYMS

IADB	Inter-American Development Bank
IICA	Inter-American Institute for Cooperation on Agriculture
IIED	International Institute for Energy and Development
IPCC	Inter-governmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
JPSCo	Jamaica Public Service Company
LCA	Life cycle analysis
LFG	Landfill gas
LPG	Liquefied petroleum gas
MTBE	Methyl tertiary-butyl ether
MDG	Millennium Development Goals
MOU	Memorandum of understanding
MSW	Municipal solid waste
NGO	Non-governmental organization
OAS	Organization of American States
OLADE	Organización Latinoamericana de Energía (Latin American Energy Organization)
OPEC	Organization of the Petroleum Exporting Countries
OUR	Office of Utilities Regulation, Jamaica
PIA	Power interchange agreement
PNPB	Programa Nacional de Produção e Uso de Biodiesel (National Biodiesel Production and Use Programme)
PPA	Power purchase agreement
SRC	Scientific Research Council, Jamaica
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
VINLEC	St. Vincent Electricity Services Ltd
VOC	Volatile organic compounds
VOME	Vegetable oil methyl ester nits and Nomenclature Introduction

# Units and Nomenclature

bbbl	barrels
cal	calories
CH <sub>4</sub>	methane
CO	carbon monoxide
CO <sub>2</sub>	carbon dioxide
ft	feet
G	giga (10 <sup>9</sup> )
gal	gallons
ha	hectares
H <sub>2</sub> O	water/water vapour
HFCs	hydrofluorocarbons
J	Joules
k	kilo (10 <sup>3</sup> )
km	kilometres
l	litres
lpd	litres per day
M	mega (10 <sup>6</sup> )
m <sup>3</sup>	cubic metres
N	Newtons
N <sub>2</sub> O	nitrous oxide
NO <sub>2</sub>	nitrogen dioxide
O <sub>3</sub>	ozone
PFCs	perfluorocarbons
SF <sub>6</sub>	sulphur hexafluoride
tCO <sub>2</sub>	tonnes of CO <sub>2</sub>
toe	tonnes of oil equivalent
W	Watts
Wh	Watt-hours
°C	degrees Celsius
€	Euros
\$	United States dollars (unless otherwise stated)

# 1

## Introduction



Biological energy (bioenergy) is derived from non-fossil organic (living or recently living) matter and its metabolic by products.

**F**urther distinction can be made, where biofuels are liquid or gaseous fuels from biomass which can be used to replace natural gas and some petroleum derivatives, e.g. diesel, gasoline/petrol, LPG<sup>1</sup>. However these terms are often used interchangeably.

Typically starchy and cereal crops are used to produce ethanol by fermentation. Biodiesel is extracted from oily plants and seeds, animal fats and waste vegetable oils. Biogas, which is mostly composed of methane, is generated during the anaerobic decomposition of organic matter, usually municipal solid waste (MSW) and sewage. Other organic by-products of industrial and manufacturing processes could also be considered biofuels when used for energy or electricity, e.g. 'black liquor' produced from paper and pulp production. These are considered first generation biofuels.

Selection of bioenergy crops, and thus the success of biofuel development, is influenced by a number of factors, including:

- agro-industrial productivity (litres of fuel per hectare);

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1 IUCN, 2008a

- power generation efficiency (kWh/tonne);
- technological availability (access and affordability);
- energy balance (energy contained/delivered : energy used in production);
- environmental impact of production;
- competition with food production; and
- incentives and barriers.

A wide array of crops is available for use as biofuel feedstock for petroleum substitution, and some are still being researched. Some of these are outlined in Table 1.

**TABLE 1: POTENTIAL BIOFUEL CROPS AS PETROLEUM SUBSTITUTES**

Plant	Fuel substitution	Primary biomass yield	Secondary biomass yield
jatropha castor	diesel – transport, power generation	seeds	-
cassava	gasoline	starch tubers	-
coconut	diesel – transport, power generation	oil	shells
oil palm	diesel – transport, power generation	oil	shells
fast growing trees	diesel or fuel oil – power generation	wood	-
fast growing legume trees	diesel or fuel oil – power generation LPG	leaves	wood
sugar cane	gasoline diesel – transport diesel or fuel oil – power generation	sucrose	fibres and cane trash
energy cane	gasoline diesel – transport diesel or fuel oil – power generation	fibres and cane trash	sugars

Source: Adapted from IICA, 2006b

Second generation biofuels use a broader range of cellulosic biomass, including grasses, woody perennials and agricultural wastes, and are converted using more advanced biochemical and thermochemical processes. Third generation biofuels consist of potential future fuels from “energy-designed” feedstocks for much improved production and conversion efficiencies.<sup>2</sup>

Bioenergy is not new. Statistics from the International Energy Agency (IEA) in 2007 indicated that bioenergy accounted for 10 percent of total primary energy and 78 percent of all renewable energy in 2005. In some developing countries it constitutes up to 80 percent of primary energy supplies. Due to recent rapid expansion of the sector, judicious planning and adaptation of existing knowledge to local contexts are necessary to maximize opportunities while minimizing environmental risks and social inequalities.<sup>3</sup>

<sup>2</sup> IUCN, 2008a

<sup>3</sup> IUCN, 2008a



## 1.1 Advantages of bioenergy

Many waste products can be converted into a useful resource by extracting fuels from them. This conversion will also lessen the burden on waste treatment and disposal processes or serve as a treatment system in itself and, consequently, also minimize pollution of land, groundwater and aquatic environments. Biomass residue from the processing of rice, soybean, sugarcane, used vegetable oils and organic MSW are all very valuable resources that can be converted to energy.

Indigenous and renewable energy sources, coupled with energy efficiency measures, significantly enhance a country's energy security and sustainability by reducing the importation of increasingly expensive and finite fossil fuels. Price volatility and resource and market monopolization all amplify the risk of supply deficits to non-oil-producing countries. Developing states in particular are heavily reliant on imports to sustain their small and fragile economies, and are spending greater proportions of their foreign exchange reserves on fuel imports. Thus, locally produced energy sources will translate into annual savings of millions in foreign exchange on fuel importation bills.

Using local energy sources offers opportunities for vast improvements in energy efficiency compared to standard practices due to the requisite new infrastructure that is required, which one expects to be the best reasonably available. Due to the higher capital costs and desire to shorten payback times, production capacity and efficiency would also be optimized. Additionally, because of pre-existing attributes such as a well-established and organised sugar industry and market, as well as the technological developments already available on the market, capital costs relating to areas such as research and land acquisition are averted.

Bioenergy production can increase agricultural productivity and rural development and assist in poverty alleviation. Sustainable industries mean sustainable jobs. Job creation would depend on the particular crop and its level of mechanization, and there is also employment potential in the construction sector and technical specializations.

The value added and associated potentials for diversification of agricultural products beyond the traditional outputs can help stabilize the cost of produce and prevent gluts in the market because the crop is utilized more efficiently. This added value increases when there is the capacity to convert the crop to fuel rather than simply growing feedstock for export. Further, bioenergy production could help stabilize or revive the agricultural sector, specifically the sugar industries in the region, shielding them from volatility in prices and export demand<sup>4</sup>.

Ethanol and biodiesel can be blended with conventional fuels in internal combustion engines with no need for modification. Biodiesel can be introduced directly into diesel engines. A blend of up to 10 percent of ethanol with gasoline (E10) is possible without engine alteration. These fuels have comparable mileage performances. Flex-fuel vehicles (FFVs)

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4 Loy and Coviello, 2005

### Definition: CLIMATE CHANGE

“Change in the state of the climate that can be identified by changes in the mean and/or variability of its properties that persists for an extended period, typically decades or longer, whether due to natural variability or human activity.” (IPCC, 2007)

“Change in climate attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.” (UN, 1992)

Climate change is anticipated to have many adverse impacts, including sea level rise, melting of the polar ice caps, altered precipitation patterns and seasons, increased frequency and intensity of extreme weather events (e.g. droughts, floods, storms), migration and extinction of species, expanded range of some vector-borne diseases (e.g. malaria). These have repercussions for social systems such as reduced freshwater availability due to saltwater intrusion into aquifers, decline in agricultural productivity, and displacement of settlements.

Some of the effects are already being experienced in places around the world, most pointedly in low-lying, small islands and in poor communities.

The principal cause is accepted to be global warming of the earth’s surface and lower atmosphere resulting from rising greenhouse gas concentrations (e.g. CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, O<sub>3</sub>, SF<sub>6</sub>, HFCs, PFCs, H<sub>2</sub>O). These emissions are from anthropogenic activities such as industries, transport, agriculture, waste incineration and deforestation, with evidence indicating that significant changes began during the Industrial Revolution of the 1700s. CO<sub>2</sub> is responsible for about 60% of this enhanced greenhouse effect.

permit any blend of the fuels, even complete substitution, and are able to operate on conventional fossil fuels when biofuels are not available. Ethanol is an excellent oxygenate (reduces carbon monoxide (CO) emissions) and raises the octane number (acts as an anti-knocking agent) of fuel, and can substitute for the petrochemical fuel additive MTBE (methyl tertiary-butyl ether) which has been shown to pollute groundwater.

Biofuels can be substituted for traditional cooking fuels, such as kerosene, wood and charcoal, which are typically used in poor and/or rural households. This would reduce pressure on forest resources as well as improve indoor air quality by reducing particulates and pollutant gases within the home. By extension this improves the health of those more routinely exposed and more vulnerable to such conditions, such as women, children and the elderly, and lessens the risk of developing respiratory problems.

Some energy crops can help to restore marginal and degraded lands and thus increase agriculturally productive land area without encroaching on other uses. *Jatropha* is drought-resistant, needs minimal inputs and helps stabilize soil and retain moisture. It starts producing after less than a year and as a perennial it does not require uprooting the plant to reap the crop. The land could also be potentially used for intercropping.

Bioenergy supplies valuable commodities for the export market, particularly targeting Annex I countries<sup>5</sup> that have specific reduction GHG targets in accordance with the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC). This opens avenues for developing countries to pursue Clean Development Mechanism (CDM) funding offered under the UNFCCC. It will allow them to secure fiscal support for the development of the industry, mitigate climate change, make progress in achieving the Millennium Development Goals (MDGs) and earn revenue from carbon credits.

5 Annex I Parties to the UNFCCC are: Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, European Community, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom of Great Britain and Northern Ireland, United States of America

## 1.2 Disadvantages of bioenergy

Competing land uses must be addressed. Growing energy crops may reduce the amount of land available for growing food, thus raising food prices, which has been identified as a contributor to the current food crisis. It may also impact on housing needs, encroach on protected ecosystems, and encourage deforestation. Land ownership, land tenure and access to land play an important role and where these structures are weak or ill-defined the poor may become marginalized as large agri-businesses expand their production.

The forfeited revenue from imports must be taken into account. Fuel import duties also constitute substantial earnings for governments and lessening the quantity of oil imported automatically reduces this income source.

The financial competitiveness of bioenergy is highly variable. Influential factors include the biofuel under consideration, the type and place of origin of feedstock used, and the technology used. For instance, sugar cane yields more ethanol per ha than maize. Financial viability also depends heavily on world oil prices. OPEC (Organization of the Petroleum Exporting Countries) prices saw a 53 percent increase from January 2008 to the peak six months later at \$140/bbl in July 2008. This was followed by a rapid crash to 2005 levels with the daily price falling below \$40/bbl at least 15 times between December 2008 and February 2009<sup>6</sup>. Thus the viability and appeal of renewables have also fluctuated.

Initially bioenergy generation, particularly production and distribution infrastructure, is very capital intensive. Private sector investment is a critical component in mobilizing such ventures.

Trade barriers and subsidies distort the market and decrease the market access and competitiveness for developing countries where bioenergy can be produced more efficiently, as demonstrated by Brazil. Tariff systems tend to encourage developing countries to export unprocessed feedstock to the developed countries of Europe and the US where the majority of demand resides, thus circumventing possibilities to gain from value added products.

## 1.3 Other issues and uncertainties

There are a number of other factors accompanying development of bioenergy that may lead to positive and/or negative environmental and socioeconomic impacts, which need to be analysed comprehensively.

For instance, the need for new infrastructure such as processing plants, and possibly roads and mass transportation mechanisms, is beneficial in terms of providing employment and increasing skills of the work force. However consideration must be given to where this infrastructure is being placed, for instance whether it will displace settlements, cause deforestation, or be in a hazard-prone area. Introduction of genetically modified crop varieties (GMOs) can improve crop yields, reduce the use of agrochemicals and improve resistance to pests and disease. Alternatively, it is feared that GMOs could destroy local biodiversity

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6 <http://www.opec.org/home/basketDayArchives.aspx>

and be detrimental to small farmers because of the high costs of seeds and monopolized manufacture. The need for economies of scale to increase production efficiency can be a drawback for small farmers. In another light, farmers could form cooperatives and pool resources to maximize output and keep themselves competitive.

Another aspect is the introduction of incentives to promote the adoption of alternative fuels by industry and the public. These may include tax allowances for establishing production facilities, reduced fuel taxes on biodiesel and ethanol compared to traditional fuels, subsidies for purchasing FFVs, and rebates or tax waivers on production or conversion equipment. As the Brazilian ethanol and Barbados solar water heater experiences demonstrate, such measures can prove overwhelmingly successful to catalysing the widespread uptake of renewable energy in a country.

On the downside they can deplete scarce resources, take ecologically important lands, and increase pollution if not comprehensively planned. Developers must take due consideration of the types, nature and quantities of co-products and waste products that will be generated during the production process and how they will be treated. For instance, if chemicals are being used to scrub cooling towers the effluent cannot be mixed into a biological treatment system designed for the organic components of the waste. But there are treatment systems which effectively remove contaminants such that the wastewater can be reused in processing. Biological systems may also release methane that can be captured for electricity generation.

## 1.4 Biofuels, environment and climate change

### 1.4.1. Land use change and intensification

Competition for land will intensify as the market demand for and the production of bioenergy expand. Pressures on forests and human developments are increasing. In many countries, for example, the USA, more agricultural land is being segregated to grow maize and other crops for ethanol production as opposed to human consumption. This trend has led to the increase in prices of grain and staple foods in the region, as well as in feed prices for livestock, thus jeopardizing the food security of many in terms of quantity and affordability of food. There is also the potential to increase landlessness as rural communities and indigenous people dependent on forest resources and ecosystem services are displaced. Defensive arguments include the fact that marginal lands can be used to grow energy crops; biofuels are not envisioned as completely replacing fossil fuels; and food shortages are more related to inequitable distribution and high unemployment, therefore the betterment of livelihoods through bioenergy development will increase disposable income.

Land use conversion is a critical factor in assessing the greenhouse gas and energy balances of biofuels through life cycle analysis (LCA). This process compares the amount of energy used in the production of biofuels, the energy content of the biofuel, and the amounts and types of GHGs emitted at various stages of the process (cultivation, harvest, processing, transport, etc). Land use conversion to biofuel production can also trigger GHG release. For instance, the conversion of grassland to energy crops can release 300tCO<sub>2</sub> (tonnes of carbon dioxide) per ha per year; for forests it can be as much as 600-1,000tCO<sub>2</sub> per ha per year. This

compares to 1.8tCO<sub>2</sub> per ha per year saved by ethanol from maize, and a possible 8.6tCO<sub>2</sub> per ha per year saved using second generation crops. Some research even indicates that over a 30-year period more CO<sub>2</sub> would be sequestered (removed from the air) by employing forest conservation and restoration alongside fuel efficiency rather than by using biofuels.<sup>7</sup>

Growth in bioenergy demand far outstrips the historic rate of growth in crop yields. Whether this demand will be met by increased productivity, expansion in cultivated area, new crop varieties and technologies or improved practices determines the sustainability of the industry, the greenhouse gas balance, and environmental impacts. Previously non-viable plots may become profitable as commodity prices rise; this may lead to the conversion of unsuitable lands, or reintroduction of former agricultural lands to production. Adoption of integrated pest management, irrigation, new research and other means may be incorporated in order to increase yields on lands currently in production.<sup>8</sup> However, the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (4AR) surmises that even with relatively modest temperature increases (1-2°C) crop yields in tropical areas are expected to decrease<sup>9</sup>. By 2050 yields for various crops can decline in the region of 3-7 percent<sup>10</sup>. There are also issues of land rights and the seizing of traditional lands from local and indigenous communities to expand agriculture.

#### **1.4.2. Habitat destruction and biodiversity loss**

Furthermore, deforestation is again on the rise because lands are being cleared for agriculture, e.g. in Indonesia and Malaysia for the cultivation of palm trees for conversion of palm oil to biodiesel. Protesters argue that the entire life cycle of biodiesel manufacture would result in a net increase in greenhouse emissions from slash and burn clearance methods, burning of sugar cane before harvesting, removal of dense forest cover and other damaging practices.

Expansion into non-agricultural land may adversely impact provision of ecosystem services (e.g. water provision and filtration, food, medicine, carbon sequestration) and biodiversity loss. Displacement of food crops may also lead to relocation of those crops in natural habitats which may displace wild species, introduce chemicals and pests, among other detrimental effects. The desire to maximize crop yields may give rise to other problems relating to monocropping, habitat and soil degradation, high levels of water consumption, water pollution from agrochemicals, exploitation of labour and poor working conditions.

Biodiversity of natural ecosystems is threatened by habitat destruction from land use change. Research indicates that rising commodity prices due to increased bioenergy demand could induce land use change and intensification in Brazil, and agricultural expansion driven by these higher prices could endanger areas with high diversity of bird species. Monocropping also reduces the genetic diversity of crops, thus increasing susceptibility to disease and reducing possibilities for developing new varieties. Some second generation crops are considered invasive or potentially invasive species and thus a threat to biodiversity, water resources and agriculture.<sup>11</sup>

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7 FAO, 2008

8 FAO, 2008

9 IPCC, 2007

10 IFPRI, 2009

11 FAO, 2008

*"You have the power to chart a safer, more sustainable and prosperous course for this and future generations. The power to reduce the emissions that are causing climate change... to help the most vulnerable adapt to changes that are already under way... to catalyse a new era of global green growth. Now is your moment to act."*

UN Secretary-General Ban Ki-moon addressing global leaders at the Climate Change Summit Plenary in New York, 22 September 2009

### 1.4.3. Water and soils

Water for agriculture is becoming scarcer as competing uses increase. About 70 percent of freshwater resources worldwide are used for agriculture.<sup>12</sup> The IPCC 4AR indicates that under most climate change scenarios there is strong evidence that water resources in SIDS are likely to be seriously compromised. Annual river runoff and water availability are projected to decrease 10-30 percent by mid-century in some regions, some of which are already water stressed.<sup>13</sup>

Many of the crops presently used for bioenergy have high water requirements; processing can also use vast quantities of water, mainly for washing plants and seeds and for evaporative cooling. However expansion of irrigated systems pose the most concern given the impact on local water resource balances and limitations relating to unfavourable land tenure systems, costly land acquisition, and infrastructural requirements and costs for extraction, delivery and storage. Higher surface temperatures will also increase water demand, as well as induce changes in precipitation patterns and increase the likelihood of drought. Land use changes and cultivation and production processes may initiate or exacerbate problems of soil erosion and sedimentation of water courses, and of pollution of ground and surface waters from runoff of excess fertilisers and pesticides.<sup>14, 15</sup>

Soil quality, structure and stability are largely dependent on the techniques employed. Monocropping, waterlogging and salinisation of irrigated land, excessive application of agrochemicals, and clearance of crop residue are some contributors to poor soil quality and land degradation. Crop rotation, contour ploughing, intercropping, adequate drainage, and conservation or no tillage are some of the sustainable agricultural practices which can help maintain nutrients and organic content, minimize erosion, and prevent soil becoming infertile.

Feedstocks will impact the soil differently. Growing perennials such as sugar cane, palm and switchgrass instead of annual crops can increase soil cover and organic matter. Crops also differ based on their water and nutrient requirements. Some crops such as jatropha and grasses need fewer inputs and less intensive management, and can contribute to the improvement of marginal soils. Increasing demand for crop residues such as bagasse for energy production, if not managed sustainably, can have inimical effects on soil quality by reducing soil cover and organic content.<sup>16</sup>

### 1.4.4. Climate change

Debate continues to rage as to whether bioenergy is truly renewable or mitigative in terms of GHG emissions reduction. CO<sub>2</sub> is sequestered during the growth of energy crops as they store it in their biomass and the soil. Quantities of various greenhouse gases (GHG) emitted

12 FAO, 2008

13 IPCC, 2007

14 FAO, 2008

15 IFPRI, 2009

16 FAO, 2008

from combustion of bioethanol and biodiesel are significantly lower as compared to fossil fuels. Thus they serve a role in mitigating further climate change, and enabling Annex I countries to fulfil their emissions reduction commitments under the Kyoto Protocol.

There are also reductions in the amount of other pollutants such as sulphates, CO, VOCs, and particulate matter. However, the levels of reduction are dictated by the type of biofuel, feedstock, and conversion technology, inter alia. Capture and flaring of biogas, which is primarily methane (a GHG 25 times more potent than CO<sub>2</sub>), or conversion to electricity reduce its release into the atmosphere and its capacity for causing fires. Conversely, nitrous oxide (300 times more potent than CO<sub>2</sub>) is released from nitrogen fertilisers; other GHGs are released during different stages, such as during pesticide and fertiliser production, chemical processing, and transport and distribution<sup>17</sup>.

The energy balance (units of clean energy generated per unit of non-renewable energy used) of biofuels is, again, dependent on characteristics such as feedstock, climatic conditions, cultivation practices, and extraction and production technologies. For instance, the energy balance for cane-based ethanol from Brazil is on average 8.3, compared to 0.81-1.03 for wheat, and 0.56-0.65 for sugar beet.<sup>18</sup> The energy balance for sugar cane ethanol is so high relative to beet and maize mainly because biomass (bagasse from the cane) is used to produce electricity for the process. The use of fossil fuels in the production process will drastically reduce the potential for GHG reduction. Conversely there is the consideration that biofuels emit less CO, sulphates and particulate matter. This is also countered by greater emissions of NO<sub>2</sub>. Also, the value of co-products such as glycerine, fertiliser and electricity, must be factored into the LCAs emissions avoided from an additional or more polluting processes.

Most LCAs indicate emissions reductions in the range of 20-60 percent for first generation biofuels, assuming high-efficiency systems and ignoring emissions related to land use change. Efforts are underway to standardize the methodologies used for LCAs, e.g. how co-products and land use are accounted for, and identifying the broader social and environmental impacts.<sup>19</sup>

## 1.5 Why should bioenergy be considered for the Caribbean region?

Social inequalities, small and undiversified economies, high dependence on food and fuel imports, concentration of settlements and critical infrastructure in the coastal zone, and many other factors make Caribbean countries highly vulnerable to impacts of world trade markets, natural hazards and climate change. Every country will be affected by climate change. Forecasts indicate that climate change will result in greater vulnerability to hunger and poverty, less secure means of subsistence, exacerbation of social inequalities (including gender inequalities) and more environmental degradation. Hence the poorest and most vulnerable countries, which produce the lowest levels of emissions,<sup>20</sup> will be most affected.

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17 FAO, 2008

18 Dufey, 2006

19 FAO, 2008

20 UNDP, 2009

Projected costs to the Caribbean from inaction to climate change on average are \$10.7 billion by 2025, up to \$46.2 billion by 2100 as a result of hurricane damage, infrastructure damage due to sea level rise and losses in the tourism industry. These losses represent more than 75 percent of GDP in Haiti, St. Kitts, Dominica, Grenada and Turks and Caicos by the end of the century.<sup>21</sup> The 2009 Global Assessment Report on Disaster Risk Reduction indicates that countries with small and vulnerable economies such as SIDS have the highest economic vulnerability to natural hazards, and low resilience and high exposure to climate change impacts. Analyses from numerous countries around the world revealed that the Cayman Islands have the greatest relative population exposed to storm surges, as does Dominica for landslides. Dominica also has the highest relative mortality risk in the world.<sup>22</sup>

### BOX 1: WHY BIOENERGY FOR THE CARIBBEAN?

As small developing islands, the countries of the Caribbean have disproportionately high energy consumption patterns, in part because of their very large transient tourist populations. Tourism is a very resource intensive industry, using vast quantities of water, energy and food resources. Some islands also have very energy intensive industries such as cement manufacture and bauxite mining and refining. The construction industry is also very lucrative, with hotel and infrastructure development expanding as the islands progress economically.

Historically the vast majority of the islands were highly dependent on sugar cane cultivation, until tourism became predominant. Agriculture is still a very important sector in most countries. All of these sectors are energy and/or resource inefficient. Additionally, because of the high population densities, especially along the coasts, the immense amounts of waste landfilled or indiscriminately dumped are perilous to ground and surface water supplies, human health and marine environments, besides occupying an increasing proportion of the limited land area. With the exception of Trinidad and Tobago, all the islands are net importers of fossil fuels.

For these reasons, coupled with growing populations, economies and energy consumption, sustainable energy production is critical for the survival of these small states. Reliance on imported fuels threatens the security and development of the islands. Transport and electricity are the sectors with the greatest energy demand. Electricity generation in the region rose from 2,144.7MW in 1985 to 10,891.1MW in 2004. With a 5 percent growth rate, the fuel consumption for electricity production is projected to increase from 4,603MI per annum in 2004 to 12,822MI per year by 2025 (IICA, 2006b). Air pollution and the unmitigated impacts of climate change are also undesirable.

Besides needing an array of energy efficiency improvements across all sectors, biofuels present one solution in addressing this myriad of issues. The “waste” from agriculture and livestock, food and cooking, industry and human settlements can all be converted to energy. This would reduce the pressure on landfills, sewage disposal systems (where they exist), and pollution of water bodies. It would also revive the agricultural sectors, create jobs and save on foreign exchange expenditure. GHG emissions and pollution would be reduced from the transportation sector, smoke stacks and industrial processes. Methane from landfills and livestock rearing can be collected and flared or used for energy, which would also lessen the incidence of open fires.

21 Bueno et al, 2008

22 UNISDR, 2009



Growing populations, expanding industry and escalating energy demand and prices have forced gradual shifts in outlook regarding energy strategies and policies. The territories of the region in recent years have been turning their focus increasingly to renewable energy, and particularly to bioenergy. Various drivers surround these moves, including high dependence on fossil fuel imports, rising per capita energy consumption and waste production, crippled sugar industries, and creation of agreements such as the US-Brazil Biofuels Partnership, and the Caribbean Basin Initiative (CBI) which allows duty free export of ethanol to the United States.

The IICA Agro-energy Strategy<sup>23</sup> indicates that the organization will give priority attention to countries where the potential for bioenergy development is considered good or excellent, as illustrated in Table 2. Further, the IICA Regional Biofuels Industry Development Initiative outlines four main areas of focus in order for the prospective benefits of these industries to be realized:

- capacity development and public education;
- catalysing production of biofuels for transport;
- catalysing production of bioenergy for electricity generation; and
- development of small and medium-sized enterprises for biofuels.

**TABLE 2: COUNTRIES IN THE CARIBBEAN IDENTIFIED AS HAVING GOOD OR EXCELLENT POTENTIAL FOR BIOENERGY DEVELOPMENT**

Potential	Country	Lead crops	Biofuels market	Imported petroleum products 2004 (US\$'000)
Excellent	Belize	sugar cane oil seeds fast-growing trees	transport fuels power generation	73,185
	Guyana			164,004
	Cuba			1,449,014
	Dominican Republic			1,712,591
Good	Barbados	sugar cane	transport fuels power generation	209,451.3
	Jamaica	sugar cane	transport fuels	928,646.2
	Suriname	oil seeds fast-growing trees	power generation	162,381.4
	Trinidad and Tobago	sugar cane	transport fuels	1,258,352.8

Source: IICA, 2006a

In the medium term it is unlikely that there will be sufficient quantities of fossil fuels to meet global demands<sup>24</sup>. Coupled with the pollution and climate change from burning of these fuels, the expected shortfall presents the opportune time for the transition to renewable forms of energy. While production of bioenergy raises many concerns on several fronts, e.g. geopolitical implications, concerns over trade and food security, it provides an alternative by which countries can increase their self-sufficiency in energy production, reduce their carbon footprint, generate local employment, and chart a more sustainable development path.

Nevertheless, in climate change mitigation efforts and in driving to improve energy security, bioenergy cannot be the sole solution. There must be a combination of several measures, which must include energy/fuel efficiency and conservation, that can be adopted at various scales by the entire society and typically have a much lower cost per tonne of CO<sub>2</sub> abated. The strategy may also include use of other renewable forms of energy, reforestation and forest preservation, and more sustainable agricultural practices.

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24 IICA, 2007

# 2

## Bioethanol



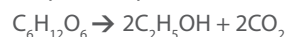
Bioethanol is a distilled liquid produced via the fermentation<sup>25</sup> of sugars from agricultural produce or by-products such as sorghum, sugar cane, maize, wheat, fruit, cane juice and molasses.

**H**ydrated ethanol is the output of distillation, but can be refined to obtain an anhydrous product.<sup>26</sup>

Ethanol can be used as a transport fuel either when blended with conventional petrol to power automobiles or used alone. It can be blended with petrol up to 10 percent (E10) without the need for engine modification. Its energy content and combustion efficiency are similar to those of conventional gasoline, and thus has approximately equivalent economic value.

Figure 1 below indicates the energy balance (units of clean energy generated per unit of non-renewable energy used) and environmental balance (GHG emissions per toe in equivalent tCO<sub>2</sub>) for various crops used to produce ethanol.

25 Fermentation is the biochemical process whereby sugars (e.g. glucose, sucrose) are broken down into ethanol and carbon dioxide under anaerobic conditions (i.e. in the absence of oxygen). The simplified equation below shows the conversion of glucose.



26 Dufey, 2006

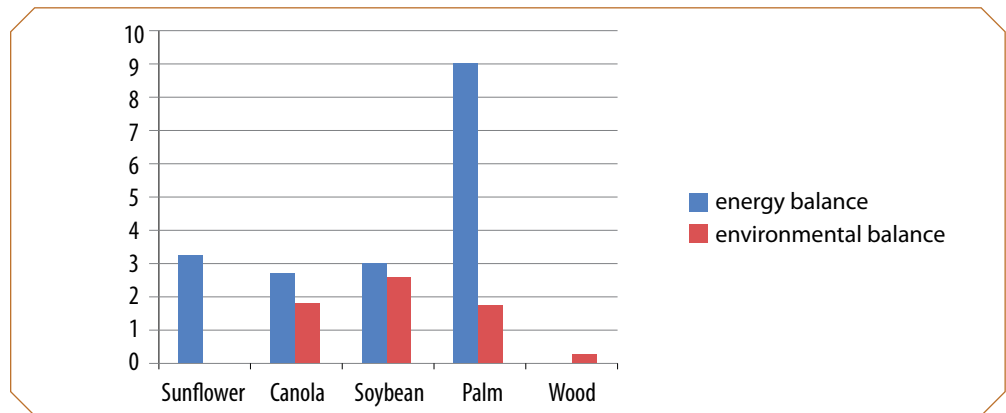


Figure 1: Energy and environmental balances for various crops used in ethanol production<sup>27</sup>

Agricultural research in this area focuses mainly on developing crop varieties that will give greater yields, on new cellulosic feedstocks, and testing the energy performance of ethanol-gasoline blends.

Sugar cane is the principal crop used in the region from which ethanol is derived. Captured below are the E10 production potential for various countries, along with present yield of sugar and amount of land available for cultivation.

TABLE 3: SUGAR CANE AREA UNDER CULTIVATION, PRODUCTION AND YIELD FOR COUNTRIES IN LATIN AMERICA AND THE CARIBBEAN

Country	Area under sugar cane	Recent sugar cane yield	Sugar production	
	'000 ha	kt/ha	t	t/ha
Argentina	296.8	66.05	2,030,653	6.84
Barbados	8.0	62.0	54,000	6.75
Belize	24.3	64.0	107,000	4.41
Bolivia	105.0	45.71	510,000	6.8
Brazil	5,800.0	77.0	29,500,000	5.1
Colombia	212.5	122.9	2,415,117	13.1
Costa Rica	52.0	75.3	382,824	8.0
Dominican Republic	350.0	40.0	464,000	1.3
Ecuador	78.0	78.0	510,000	6.8
Honduras	88.1	73.1	381,018	4.32
Jamaica	40.0	47.5	167,000	4.18
Mexico	680.0	77.5	5,800,000	8.5
Panama	37.0	56.8	165,000	4.5
Peru	66.2	102.4	694,599	12.0
Venezuela	130.0	67.7	706,000	5.4

Source: Adapted from IICA, 2007; data delivered between 2005 and 2007

27 Adapted from IICA, 2007

**TABLE 4: ETHANOL PRODUCTION POTENTIAL FOR VARIOUS COUNTRIES IN LATIN AMERICA AND THE CARIBBEAN TO FULFIL DEMAND FOR E10**

Country	Gasoline consumption	Area under sugar cane	Arable area	E10 ethanol demand	Current ethanol output	Area of sugar cane to meet E10 demand	
	'000 m <sup>3</sup>	'000 ha	'000 ha	'000 m <sup>3</sup>	'000 m <sup>3</sup>	'000 ha	%
Argentina	4,911.1	296.8	128,747.0	491.1	230.0	81.9	27.6
Barbados	124.4	8.0	19.0	12.4	0	2.1	26.3
Bolivia	763.4	105.0	37,087.0	76.3	33.8	12.7	12.1
Brazil	16,000.0	5,800.0	150,000.0	1,600.0	15,999.2	266.7	4.6
Colombia	4,937.0	212.5	45,911.0	493.7	270.0	63.0	29.7
Costa Rica	855.1	52.0	2,865.0	85.5	30.5	14.3	27.5
Dominican Republic	1,423.3	350.0	3,696.0	142.3	0	23.7	6.8
Ecuador	1,944.6	78.0	8,705.0	194.4	47.1	24.5	31.4
Guyana	130.0	49.0	1,740	13.0	23.6	2.2	4.5
Haiti	288.0	18.0	1,590.0	28.8	2.0	4.8	26.7
Honduras	457.2	88.1	2,936.0	45.7	26.3	7.6	8.6
Jamaica	699.8	40.0	513.0	70.0	12.0	11.7	29.3
Mexico	39,455.3	680.0	107,300.0	3,945.5	445.2	657.6	96.7
Panama	576.7	37.0	2,230.0	57.7	12.4	9.6	26.0
Peru	1,203.0	66.2	21,210.0	120.4	78.4	20.1	30.4
Suriname	106.5	3.0	89.0	10.6	0.4	1.8	60.0
Trinidad and Tobago	493.1	13.0	133.0	49.3	5.3	8.2	63.1
Venezuela	12,700.6	130.0	21,640.0	1,270.1	0	234.5	180.4

Source: Adapted from IICA, 2007

The last few years have seen many sugar-producing SIDS scaling back or closing their operations in response to unfavourable international markets. This is affecting the traditional landscape of many Caribbean countries and displacing many workers in the agricultural sector. However many SIDS are now seeking to transition into energy production. This has significant social benefits including employment generation, reduced foreign exchange outflows, and reduced greenhouse gas emissions<sup>28</sup>.

## 2.1 Initiatives in the Caribbean

### Barbados

Feasibility analyses<sup>29</sup> have been conducted to assess the viability of diversifying the sugar industry to produce refined and specialty sugars for local and international markets, molasses, bioethanol and electricity from bagasse cogeneration (Figure 2). The annual production capacity for ethanol was estimated at 14.4MI; and over 9,000Mt of molasses. Estimates of initial capital investment required are in the range of \$150 million; this is expected to translate to annual foreign exchange savings of \$39 million, which are comparable to or greater than revenue earned from sugar exports.

More recent figures suggest that at full capacity, to be attained by 2014, the system should have an annual production capacity of 23MI of anhydrous ethanol; 36,445t of molasses; and 15-20MW of electricity with input to the national grid<sup>30</sup>.

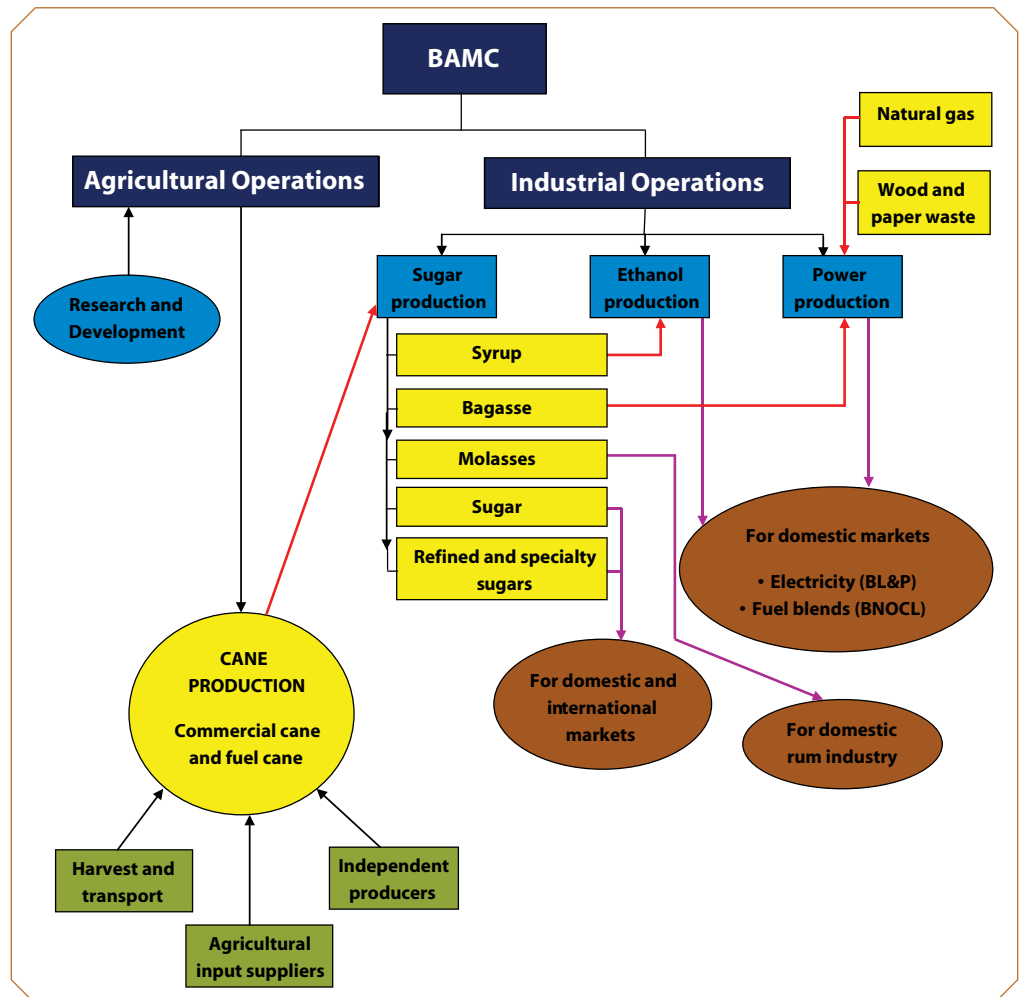


Figure 2: Restructuring and diversification of the Barbados cane industry<sup>31</sup>

29 Schaffer and Associates, 2006

30 Briggs, 2008

31 Adapted from Schaffer and Associates, 2006

**Cuba**<sup>32</sup>

The ethanol production industry in Cuba dates back to 1862, peaking in 1961. Investigations into the use of ethanol for the transport sector resumed in 1977. Hydrated ethanol is preferred due to such factors as its availability, physio-chemical properties, and cost. Results of studies looking at the use of a 25 percent hydrated ethanol blend with gasoline showed several benefits, including increasing the octane number by 10 units, eliminating 'knocking', and reducing incidences of spark plug failure. Unfortunately it could not be utilized commercially due to the possible separation of the mixture over time.

Experiments blending 25 percent hydrated ethanol in diesel engines demonstrated that 21 to 23 percent less diesel was used with the mixture, and separation did not occur. However, 1.5-2 units of ethanol were required for every unit of diesel replaced, and a special device was needed for the fuels to be injected separately.

**Dominican Republic**<sup>33</sup>

Data show that the Dominican Republic has the potential to produce 50-60Mt of biomass annually from 300,000ha of sugar cane. Since the gradual closure of sugar mills starting in the 1980s, sugar production has progressively declined and by 2007 the cultivated area was 125,000ha. Therefore their first objective is to reclaim an additional 130,000ha of abandoned lands to initiate the bioethanol programme. The aim is to diversify the industry so as to yield 300-1,500 million gallons of ethanol per year along with biogas, with annual expansion of the cultivated area eventually to 700,000ha dedicated to bioethanol production.

**Guyana**<sup>34</sup>

Assessments show that more than sufficient quantities of ethanol can be produced from molasses (with a more favourable price comparison than using cane juice) to achieve a 10 percent substitution of gasoline without altering the area of land presently under cultivation. The daily production capacity required would be 65,000lpd utilizing 38 percent of the available current supply of molasses.

A plant of this size would cost about \$6.5 million; this compares to importation costs of \$5.4 million in 2005. Depending on the raw material used (molasses or cane juice), 30,000-280,000m<sup>3</sup> of ethanol can be produced annually. In light of the removal of preferential trade agreements across the Caribbean, Guyana is also looking to expand sugar production by 50 percent, diversifying products, generating electricity from bagasse and producing ethanol.

**Jamaica**

At present Jamaica has a production capacity of 606Ml for dehydrating ethanol from Europe and Brazil which is then exported to the United States under the CBI<sup>35</sup>.

Bioethanol is being considered for its application in transport. Jamaica Broilers Ltd, with cooperation from Brazilian investors, constructed an ethanol plant, opened in August 2007,

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32 Villareal, 2005

33 Tabar, 2007

34 Horta, 2007

35 Tulloch and Barrett-Edwards, 2007

with an annual production capacity of 230MI. Generation of E10 commenced in 2008, using feedstock imported from Brazil, and the blend is available at petrol stations throughout the country. Local feedstocks under consideration are sugar cane and cassava.

Vast improvement in the efficiency of the operation of the industry is crucial for the viability of this venture. Privatization is presently underway, and is expected to yield marked changes in productivity and energy consumption.

To achieve an E10 mix in transport fuel by 2010, it is projected that an additional 19,000ha of land are need for growing sugar cane. This assumes an annual rate of growth in demand of 4 percent, which would see consumption rise from 68MI for an E10 blend in 2004 to 91MI.<sup>36</sup>

### St. Kitts-Nevis

Brazil and the US have pledged technical assistance to the twin island state in the development of biofuels from sugar cane. A memorandum of understanding (MOU) to Advance Cooperation on Biofuels was signed by the three governments in March 2007, in which it was agreed that St. Kitts and Nevis would receive assistance for the completion of a national energy policy, assessment of agricultural land available for sugar, building investor support, and capacity building for decision makers<sup>37</sup>.

The US-Brazil Biofuels Partnership also encompasses Haiti and the Dominican Republic. In association with the OAS and IADB, these governments will fund feasibility studies to investigate soil quality, the types of sugar cane most appropriate for local conditions, environmental impact, and potential for rural development.<sup>38</sup>

Recent research has indicated that, based on sugar cane production in 2004, the estimated annual ethanol production potential is 21MI from cane juice and bagasse. This has an economic value of \$10-15 million depending on the price of crude oil (\$70-100/bbl). The electricity output is projected in the range of 15-50GWh, depending on crop yield and energy conversion efficiency.<sup>39</sup>

*"We have only one planet to live on. We must ensure that the way we live and develop is consistent with keeping its ecosystems in balance. We must all find a different, more sustainable way to grow our economies, and ensure that poor people and nations have the opportunity to create a better life for themselves."*

Op-Ed "A green deal for rich and poor nations" by Helen Clark, UNDP Administrator, 8 September 2009

### Suriname

Suriname has neither national policy nor government incentives for development of bioenergy. There are very limited technical, financial, infrastructural and human capacities; as well as a number of political and bureaucratic barriers. The country possesses petroleum resources and has developed hydropower, which form the main bases for energy.

Nevertheless, bioenergy presents potential for increase in technical skills, employment and government revenue. Suriname has a vast land area (over 160,000km<sup>2</sup>), with 85

36 Loy and Coviello, 2005

37 [http://www.caribbeantoday.com/index.php?option=com\\_content&task=view&id=2186&Itemid=162](http://www.caribbeantoday.com/index.php?option=com_content&task=view&id=2186&Itemid=162)

38 <http://www.cuopm.com/newsitem.asp?articlenumber=1324>

39 Binger, 2008



percent forest cover<sup>40</sup>. This affords opportunity for agricultural expansion, but also engenders the likelihood of high deforestation, monoculture and subsequent soil infertility and effects of pests and disease.

### Trinidad and Tobago

This twin island state currently has no policy stance on biofuels, but is anticipating the development of a national energy policy in the near future in which this matter will be addressed. There is a lack of incentives for renewable energy development due to the inexpensive petroleum products derived from local resources. However these reserves are diminishing. Further, the sugar cane industry has been closed for a number of years. There is an ethanol purification plant which operates in Point Fortin, and exports the finished product is exported to the United States.<sup>41</sup>

## 2.2 Initiatives in Latin America

### Brazil

Brazil's National Alcohol Programme (Proálcool), pioneered in the 1970s, is the largest fossil fuel substitution initiative within the transport fuel market. It is the most efficient example of extraction of ethanol from sugar cane in the world, with the fuel being competitive at oil prices of \$30-40 per barrel. Government controls, subsidies and incentives that were used to foster the growth of the programme were gradually removed from the mid-1990s to 2002. The tremendous progress and increases in productivity over the last 30 years have been as a result of progressive introduction of new technologies, sugar cane species and management practices, which has resulted in efficiency improvements in areas such as transport, extraction and fermentation.<sup>42</sup> Bioethanol is now a highly competitive commodity in Brazil's transport fuel market, as illustrated in Figure 3.



Figure 3: Fuel station in Brazil displaying prices for ethanol (at top) and conventional gasoline<sup>43</sup>

40 Universiteit van Suriname, 2007

41 ECLAC, 2007

42 Moreira, 2003

43 Moreira, 2003

Furthermore, the demand created by Brazil's policies has revolutionised the automobile market. By 2005 seven global manufacturers (Fiat, Volkswagen, General Motors, Ford, Citroën, Renault and Peugeot) were offering 24 FFV models with all the necessary engine and vehicle modifications. By this time there were 2.5 million pure hydrated ethanol vehicles in Brazil's national fleet, and 608 billion FFVs using blends from E25 to E100.<sup>44</sup>

The IADB has earmarked more than \$2.5 million for Brazil to support the country's objective of tripling ethanol production by 2020. There have also been discussions surrounding technical assistance and facilitating technology transfer to enable other countries in the region to benefit from Brazil's experience.<sup>45</sup>

### Colombia<sup>46,47</sup>

In 2001 a Fuel Ethanol Law was approved which demanded use of sugarcane-derived ethanol in transport from 2006. This is part of an initiative to use renewable energy to improve air quality in cities, create jobs and promote sustainable development. Domestic gasoline would be blended to E10, with a production capacity of 2.5Ml per day. No gasoline taxes are levied on the ethanol substitute. There are to be nine distilleries, creating an expected 170,000 jobs for farmers, and requiring an additional 150,000ha of sugar cane. It will increase the average earnings of farmers and the contribution to GDP from agriculture. Production costs are estimated at \$0.90-1.15/gal. Sales are expected to generate \$400 million annually. Required investment will total \$680 million, and expected fuel importation savings are at least \$150 million per annum.

Proposals were also included for substituting \$20 million of imported beverage ethanol, which would allow reopening of 12 liquor plants mothballed because of vinasse contamination, and generate associated employment.

Further, the IADB is contemplating financing a \$20 million biodiesel enterprise using palm oil as the raw material. This is anticipated to eventually have an annual production of 100,000t.<sup>48</sup>

### El Salvador

Here, as well as in Costa Rica, the IADB has financed feasibility studies and technical assistance in areas such as market development, regulation and public outreach to help the countries achieve their target of E10 blended gasoline<sup>49</sup>.

44 Lucon, et al, 2005

45 IADB, 2007

<http://www.iadb.org/NEWS/detail.cfm?language=English&ARTID=3779&id=3779&CFID=5303067&CFTOKEN=56941889>

46 Cala Hederich, 2002

47 2002 <http://www.iea.org/Textbase/work/2002/ccv/ccv1%20echeverri.pdf>

48 IADB, 2007

49 <http://news.mongabay.com/bioenergy/2007/04/inter-american-development-bank-to.html>

# 3 Biodiesel



Catalysed<sup>50</sup> transesterification<sup>51</sup> of ethanol and vegetable oil produces biodiesel or vegetable oil methyl ester (VOME) with glycerine as a by-product.

Inputs include soya, palm, jatropha, coconut and sunflower oil, waste cooking oil, tallow and animal fats.<sup>52</sup> Rapeseed, soya and palm oil currently tend to dominate the biodiesel markets in developed and developing countries. While its use is not yet widespread, jatropha seems to hold much promise as a feedstock. It is a perennial crop which can grow on marginal lands in dry conditions, and has a very high energy balance. This is encouraging in light of the food-fuel debate, where biofuel crops are occupying vast tracts of agricultural land usually used to grow food for human or livestock consumption. There are also issues of deforestation in Malaysia and Indonesia over cultivating plantations to grow oil palms.

Figure 4 below indicates the energy balance (units of clean energy generated per unit of non-renewable energy used) and environmental balance (GHG emissions per toe in equivalent tCO<sub>2</sub>) for various crops used to produce ethanol.

50 Catalysts alter the rate of a chemical reaction, typically increasing it, by creating an alternative reaction pathway, but are not reagents and are thus not consumed by the reaction.

51 Transesterification refers to the switching of an organic group of an ester with that of an alcohol.

52 Dufey, 2006

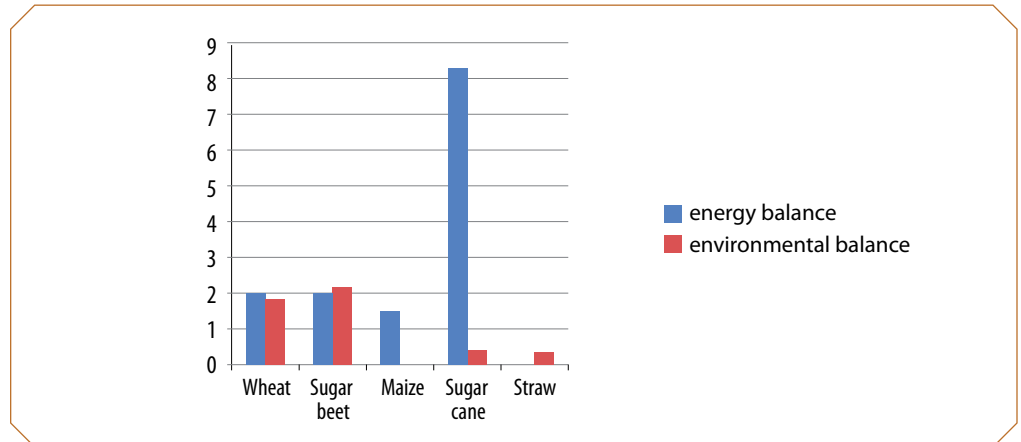


Figure 4: Energy and environmental balances for various crops used in biodiesel production<sup>53</sup>

### 3.1 Initiatives in the Caribbean

#### Barbados

Located at Counterpart Caribbean/Future Centre Trust a private entity, NativeSun NRG, produces biodiesel from waste cooking oil, shown in Figure 5. With support enlisted from the nearby Lester Vaughan Secondary School, NativeSun NRG sells the biodiesel for use in agricultural machinery and private transportation<sup>54</sup>. Collaboration with the school has opened an avenue for broader community involvement, with the students engaging their households, neighbours and others in collection of the waste oil. It has also fostered broader environmental education within the school, and provides an income stream for the Environmental Club. This venture was started with the support of the GEF Small Grants Programme (SGP) for Barbados and the OECS, and has developed to the level where it has received a commitment of investment capital from international interests for further expansion of the initiative to other islands.



Figure 5: Biodiesel manufacture from waste cooking oil in Barbados<sup>55</sup>

53 Adapted from IICA, 2007

54 [http://sgp.undp.org/web/projects/9741/community\\_based\\_recycling\\_programme\\_produciton\\_of\\_biodiesel\\_from\\_used\\_vegetable\\_oil\\_with\\_the\\_lester\\_.html](http://sgp.undp.org/web/projects/9741/community_based_recycling_programme_produciton_of_biodiesel_from_used_vegetable_oil_with_the_lester_.html)

55 GEF SGP Barbados and the OECS photo stock, 2008

### Jamaica

Locally-grown feedstock options for biodiesel include oils from rapeseed, castor, palm, jatropha and sunflower. The production target for 2010 is 73Ml. Land requirements to achieve substitution with B10 are in the range of 65,000-96,500ha.<sup>56</sup>

### Guyana

In August 2007, a MOU was signed between the OAS, IICA, IADB and the Government of Guyana during the regional high-level seminar "Expanding bioenergy opportunities in the Caribbean"<sup>57</sup>. The parties have committed to explore promotion and financing of initiatives in energy efficiency, renewable energy and bioenergy in the region; develop a CARICOM agro-energy strategy; and help member states access world biofuel markets.

In April 2008, \$925,000 in grants was approved from the IADB's Japan Special Fund and its Sustainable Energy and Climate Change Initiative Fund. This would go towards institutional strengthening, finalization of the national agroenergy policy, training, supporting field visits by potential foreign investors, and conducting feasibility and pre-investment studies.<sup>58</sup>

## WHAT CAN YOU DO?

If in Barbados, you can collect the oil used in cooking, filter out the food remains and store it in plastic bottles (let it cool first!). Take it to Counterpart Caribbean at the Future Centre Trust at No 2, Edgehill, St. Thomas. Your oil will be transformed into a clean fuel instead of dumped into the drains to pollute the groundwater system. You may also purchase biodiesel at this location for all diesel-powered vehicles and machinery.

If you are interested in starting such an initiative in your territory you may contact the GEF SGP in Barbados, Belize, Cuba, Dominican Republic, Jamaica, Trinidad or other countries for advice and support. It can be a community-level project, or can be as expansive as including fast food and restaurant operations. Think globally, act locally.

<sup>56</sup> Tulloch and Barrett-Edwards, 2007

<sup>57</sup> IADB news release 6.08.2007

<http://www.iadb.org/NEWS/detail.cfm?Language=En&parid=2&artType=PR&artid=3977&id=3977&CFID=5303067&CFTOKEN=56941889>

<sup>58</sup> <http://www.stabroeknews.com/2008/news/local/08/21/idb-government-to-sign-agro-energy-agreement/>

## 3.2 Initiatives in Latin America

### Brazil<sup>59</sup>

The country noted as a forerunner for its advances in bioethanol production has embarked on a programme for biodiesel, with government authorization of commercial production, initially for B2 (2 percent blend of biodiesel with regular diesel). The National Biodiesel Production and Use Programme (PNPB) is a collaboration of 14 ministries under an Inter-ministerial Executive Committee (CEI).

There is a great degree of flexibility in the type of oilseeds grown as feedstock, as well as in the techniques used for refining. This facilitates participation by farmers and farmers' groups on all scales and at all levels, and ensures lands are used optimally. However, all output must conform to the international quality standards dictated by the regulatory authority.

Jobs will be created in construction of plants, transport and distribution, farming, technical assistance, and refining. Crops can be grown in isolated rural communities to replace the diesel used for electricity from generators.

### Nicaragua

In 1994, a collaborative venture of the Austrian government, Petronic, the Union of Agricultural Cooperatives and the National Autonomous University of Nicaragua commenced with the planting of an initial 1000ha of *Jatropha curcas*. The five-year project would have annual outputs of 1,700t of biodiesel, 1,600t of animal fodder with 56 to 58 percent protein content, 144t of glycerol, and 1,800t of oilseed shells for heat generation.<sup>60</sup> An economic feasibility study was previously completed by Petrotrin, with Nicaragua fulfilling World Bank defined cost effectiveness criteria for such a project, namely extensive wastelands, high transportation costs, availability of labour, and the need to offset expenditure on diesel imports.<sup>61</sup>

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59 Ministry of Mines and Energy, n.d.

60 Mayorga, 2005

61 Grimm, n.d.

# 4

## Biogas and solid fuels



Over 2.5 billion people rely on traditional uses of biomass for heating and cooking.<sup>62</sup>

**H**owever, there is a diverse array of modern applications for conversion of biomass to energy, here specifically referring to energy extracted directly from the biomass rather than any of its metabolic products such as sugars and oils. Sewage, MSW, wood, garden waste and agricultural waste such as rice husks and bagasse are among the possible raw materials. Energy is extracted by combustion of the material itself for heat, producing process steam or electricity. Alternatively, products of decomposition, e.g. methane, are used for heat or electricity. Notably, there must be due consideration given to cultural perceptions relating to use of treated sewage or even greywater as these may not be very amenable to some societies. Adequate regulations and monitoring systems must also be in place to ensure proper procedures to avoid contamination, as well as quality standards for the end products.

Energy-from-waste technologies result in a number of additional benefits beside creating a renewable energy source. These include reduced toxic and GHG emissions; better waste treatment and disposal; less pressure on landfills, extending their longevity; fertilizer production; and reduced pathogens and pollution of air, soil, groundwater and aquatic environments.

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62 IUCN, 2008b

## 4.1 Initiatives in the Caribbean

### 4.1.1. Biogas

Biogas is produced by the biodegradation of organic matter under anoxic conditions. This organic matter includes animal waste, sewage and wastewater, abattoir effluent<sup>63</sup>, and the organic portion of MSW. The cycle involves numerous types of microorganisms, including methanogens which generate methane (CH<sub>4</sub>).

*“But our planet needs more than just action by governments and corporations; it needs each of us. Although individual decisions may seem small in the face of global threats and trends, when billions of people join forces in common purpose we can make a tremendous difference.”*

Statement by UN Secretary-General Ban Ki-moon on World Environment Day 2009

#### Barbados

An environmental impact assessment (EIA) was conducted in relation to a planned waste-to-energy project for collecting landfill gas (LFG) to convert it to electricity. Models estimated LFG generation rates in the order of 14Mm<sup>3</sup> per year. Observations from surface sampling indicated actual rates of 3.7Mm<sup>3</sup>. There is also an associated wind farm which is expected to have an annual output of 16.5GWh of electricity.<sup>64</sup>

The project is to be operated as a public-private partnership between Barbados and a Canadian firm. Phase I involves design, construction and operation of a LFG collection and flaring system. Phase II entails the construction and operation of a 2-5MW electricity generation plant or a leachate treatment system, depending on the consistency of LFG production. The justification for this project lies in stabilization of the landfill, increased rate of regeneration of the site, improved air quality, reduced hazards from risk of fire, explosion and groundwater contamination, and reduction of GHGs (CH<sub>4</sub> and CO<sub>2</sub>). There are surrounding issues relating to ownership of the land, which the Sanitation Service Authority has been renting towards purchase. A draft Landfill Agreement has been prepared since ownership needs to be finalized for the project to be eligible under the CDM.<sup>65</sup>

#### Jamaica

Although, due to the poor management of disposal sites, the potential for LFG capture is lower than might be expected for MSW with an organic content of 65 percent, including 40 percent yard waste, proposals for CDM projects have nonetheless been submitted to the Government.<sup>66</sup> A suggested alternative is the controlled decomposition of separated organic waste, which would generate biogas to cooking, heating or electricity, as well as fertilizer.

Biogas can also be derived from treatment of liquid wastes (sewage, effluents, sludge, etc) with high organic content. The existing central sewage system manages 30 percent of the island's domestic wastewater at a primary treatment level. The approximately 150 treatment facilities are almost 50 years old and in deplorable condition.<sup>67</sup> In 1978 OLADE, the Ministry

63 IUCN, 2008b

64 R.J. Burnside International and Biothermica International Inc, 2003b

65 Marshall, 2008

66 Loy and Coviello, 2005

67 Loy and Coviello, 2005



of Mining and Energy, the Ministry of Agriculture, and SRC initiated a pilot project aimed at appropriately adapting the design of and constructing biodigesters for use by livestock small farmers, and to transfer the technology and expertise. The rationale was to reduce the impact of the energy crisis on the poor, particularly those in rural communities. Nine demonstration plants were constructed, using designs from Mexico, Brazil, China, Costa Rica and Guatemala and evaluation of the digesters was based on costs, performance, and operation and maintenance requirements. An indigenous adaptation was created, but cost was prohibitive to wide dissemination. Thus in 1983 the programme expanded to create a revolving loan fund to subsidize the costs.<sup>68</sup>

The public education component of the programme proved very effective, promoting energy diversification through waste diversion. It was enhanced by a United Nations University (UNU) which included training of agricultural extension workers and introduction of biodigesters to selected farming communities. Further a design improvement put forward by the CDB and GTZ enabled a local NGO to get involved in the project. Also, SRC was able to broaden its technology dissemination through a farmers' information centre, an agricultural training school, and a penal institution.

Jamaica's Energy Minister announced in October 2009 that the country has contracted a firm to construct two waste-to-energy plants. It is anticipated that this investment will see generation of 18 percent of the island's electricity and reduce fuel imports by 700,000 bbl, thus saving \$60 million annually.<sup>69</sup>

#### **St. Lucia**

With support from the government, IICA, the Bank of St. Lucia and UNDP a cadre of small farmers travelled to Costa Rica in 2008 for an intensive training course in the construction and use of biodigesters. These will enable waste products to be transformed into useful energy and by-products and reduce associated pollution. With this new capacity, the farmers are expected to share their knowledge and spread the application of the technology for more sustainable management of the agricultural sector in their country.

#### **4.1.2. Biomass cogeneration**

Cogeneration is the simultaneous generation of mechanical and/or electrical energy plus thermal energy or process heat using the same energy source within a single facility. It improves the efficiency of the heat and electricity system from by 33 percent to possibly as much as 80 percent. "Topping" cycles are typical in most industries, where fuel input is used first to produce electricity after which the thermal energy is recovered. "Bottoming" cycles are less common, usually associated with high-temperature processes.<sup>70</sup>

#### **Barbados**

The combined cycle gas turbine (CCGT) in the sugar industry diversification programme is projected to produce up to 30MW of electricity from bagasse, with cultivation of high-fibre cane varieties.<sup>71</sup>

68 UNDP SUSSC, 1999

69 Jamaica Gleaner, 2009

70 Barrett, 2002

71 Schaffer and Associates, 2006

### Guyana<sup>72</sup>

Improvement in the efficiency of boilers, i.e. increased pressure, could realize generation of 1,400GW of energy from bagasse from 3.4Mt of cane, compared to current outputs of 30MW. This output duration is of course limited by the length of the harvest season which provides the fuel source, unless a supplemental source is found.

Rice is also considered a potential source for electricity production on small cogeneration plants. With approximately 110,000t of rice husk residue produced from the annual crop of over 500,000t (in 2004), the energy potential of this waste product is equivalent to about 11 percent of diesel consumption.

Timber production is another major industry in Guyana, thus wood is under consideration for electricity production in small cogeneration plants. Conservative estimates suggest that about 33 percent of the resource ends up as waste from sawmills. Calculated outputs reached 1.55Mtoe, almost treble the country's diesel consumption.

### Jamaica

In conjunction with the production of ethanol, the bagasse derived from the sugar cane can be used to generate an additional 300GWh of electricity annually. Conventional cogeneration resulted in process efficiencies of less than 10 percent when it was considered primarily a disposal process. The total amount of energy that can be extracted from sugar cane depends on its fibre content, the moisture of the bagasse which determines its net calorific value, and the technology used for energy conversion<sup>73</sup>. High temperature and pressure boilers need to be used, which would improve the quantity of energy produced from cane and bagasse, allowing export to the grid, as indicated in the following table. The old boilers served principally as incinerators to dispose of the bagasse, and not for maximising energy production; hence they were of low efficiency<sup>74</sup>.

**TABLE 5: COMPARATIVE EFFICIENCY OF BOILERS IN ENERGY PRODUCTION FROM CANE**

Boiler type	Low temperature and pressure	High temperature and pressure
Power generation (kWh/t cane)	20-30	90-160
Net power (kWh/t bagasse)	60	370-510
Heat rate (kcal/kWh)	21,000	6,000-8,000

Source: Loy and Coviello, 2005

Further improvements could be realized with the use of other cane residues such as leaves and with application of gasification techniques.

<sup>72</sup> Horta, 2007

<sup>73</sup> Loy and Coviello, 2005

<sup>74</sup> Barrett, 2002

### 4.1.3. Fuelwood

#### Jamaica<sup>75</sup>

Forty-one percent of households depend on fuelwood, harvested from 9,000ha of forest plantation. Energy crop plantations, using rapidly-growing species such as acacia and cassia, can yield 108-118t/ha according to research. Plantation design would include staged planting, partial harvesting, coppicing for regeneration, low maintenance and five-year harvest cycles. *Leucaena leucocephala* and *Cassia siamea* performed best in the demonstration fuelwood project conducted by the Petroleum Corporation of Jamaica ending in 2000.<sup>76</sup>

This is also being considered as an alternative fuel to be utilized during the off season (May-November), supplied by energy plantations. Studies indicate that to supplement a harvest of 2.7Mt of sugar, 226,000t of supplemental fuelwood feedstock from 12,600ha would be needed. Research indicates that the sustainability of forests would not be threatened by this additional activity.

## WHAT CAN YOU DO?

Composting is a simple, age-old process that can be done in your backyard. Uncooked fruit and vegetable waste is collected so that it naturally decomposes into a product which can be used as soil fertilizer. A small anaerobic digester can be purchased to contain the waste, or just a patch of soil (make sure to enclose it to keep out animals, and to rotate the mixture every few days).

Farmers can use biodigesters to transform manure from their livestock into fertilizer, and can also use the methane gas as fuel for cooking. The equipment can be constructed for various capacities.

Local abbatoirs can invest in a biogas plant. After the gas is cleaned and compressed it can be used as a substitute for natural gas for cooking or electricity. The sludge can also be utilised as fertilizer. (IUCN, 2008b)

## 4.2 Initiatives in Latin America

### 4.2.1. Biogas

In Ecuador, a project was started in late 2000 by a local NGO with the assistance of GEF SGP where biogas digesters were installed at an educational institution and orphanage which accommodates about 1,200 people. Sewage and animal waste derived from surrounding farms are the inputs which produce methane and fertilizer. About 12m<sup>3</sup> are processed daily. This has resulted in a 60 percent reduction in the use of butane for cooking, and production of a saleable commodity in the fertilizer which is also used in the school's orchards. There is also a wastewater reclamation system with a fat trap and biological filter, which allows reuse

75 Loy and Coviello, 2005

76 Barrett, 2002

of the water for laundry, gardening and toilets. This has eliminated the dumping of waste directly into the land and marine environments, and has reduced water consumption in this drought-prone area.<sup>77</sup>

Brazil registered the first greenhouse emissions reduction project under the CDM in 2004.<sup>78</sup> The NovaGerar LFG to Energy Project has gas collection and leachate drainage systems and modular electricity generating plants at two sites.<sup>79</sup>

These are but two small examples of the work being done throughout Latin America. Under the UNFCCC CDM Mexico has had a series of 30 methane recovery and power generation projects approved between October 2006 and November 2007. In Honduras, Costa Rica and Guatemala there are biogas recovery and electricity production projects using palm oil mill effluent as the resource base. The ordinarily uncontrolled methane emissions from these wastewater treatment lagoons are instead being utilized as a renewable power source and for greenhouse gas reduction.<sup>80</sup> The project in Guatemala is expected by 2014 to be treating 245,000m<sup>3</sup> of effluent yearly, and to capture 12.2Mm<sup>3</sup> of CH<sub>4</sub> over its seven years. This is expected to result in an emissions reduction of over 212,000 tCO<sub>2</sub> and produce 36.6GWh of electricity.<sup>81</sup>

#### **4.2.2. Biomass cogeneration**

Sugar cane plants all across Latin America are being upgraded with high pressure boilers in order to maximise the efficiency of their resource use through bagasse cogeneration. They are also using other “waste” matter to supply electricity needs.

An Argentinean CDM initiative has 10.95MW of installed capacity, using a biomass direct combustion boiler with 81 percent conversion efficiency, fuelled by peanut hulls and sunflower husks. This replaces open burning of the agricultural waste, consisting of 119,000-128,000t of hulls and 55,000-64,000t of husks annually. It is calculated to reduce annual emissions by almost 31,000tCO<sub>2</sub> over the project’s 21-year lifetime.<sup>82</sup>

The Monte Rosa Bagasse Cogeneration Project in Nicaragua was registered as a CDM project in June 2006. When the project was conceptualized the sugar mill had an installed capacity of 7MW. By the end of Phase I the plant was using 18MW of its now 26MW installed capacity. Through phased increases in energy efficiency, generating capacity and production of bagasse it would create 35 jobs and produce 98,200MWh in 2004 to displace 119,800bbl of imported oil and save \$3.5 million annually. By 2008 it was projected that this would increase to 120,000MWh to give estimated emissions reductions of 89,305tCO<sub>2</sub>.<sup>83</sup> In the most recent monitoring report submitted in March 2009 figures indicate that the amount of electricity sold to the grid from December 2008 to February 2009 was 56.6MWh. This equated to over 41,000tCO<sub>2</sub> in emissions reductions.<sup>84</sup>

77 GEF SGP, 2003

78 UNFCCC, 2009

79 NovaGerar, 2008

80 <http://cdm.unfccc.int/Projects/projsearch.html>

81 Extractora del Atlantico S.A., 2008

82 Aceitera General Deheza S.A., 2007

83 Monte Rosa S.A. and Eenergy Brasil Ltda, 2005

84 Eenergy Brasil Ltda, 2009

# 5

## Economic comparison



Comparative estimates are presented for the production of biofuels in countries across the region.

The values in Tables 7-10 have been accumulated or calculated from various studies, papers and reports. Figures that are not included are the tonnes of CO<sub>2</sub> that are avoided by biofuel substitution, and potential earnings through the CDM through certified emission reductions (CERs). All figures have been calculated to reflect operations for one year.

**TABLE 6: SELECT DEMOGRAPHIC AND ENERGY STATISTICS FOR SELECTED COUNTRIES IN LATIN AMERICA AND THE CARIBBEAN**

	Brazil	Colombia	Jamaica	Guyana	Barbados	St. Kitts-Nevis
Population size (2007) <sup>1</sup>	190,010,647	44,379,598	2,780,132	769,095	280,946	39,349
GDP PPP (US\$) (2007)	1.838tril	320.4bil	13.47bil	4.057bil	5.53bil	726mil
Total land area (km <sup>2</sup> )	8,511,965	1,138,910	10,991	214,970	431	261
Arable area (%)	6.93	2.01	15.83	2.23	37.21	19.44

	Brazil	Colombia	Jamaica	Guyana	Barbados	St. Kitts-Nevis
Electricity production (kWh) (2005)	396.4bil	50.47bil	6.985bil	807.3mil	953mil	125mil
Electricity consumption (kWh) (2005)	368.5bil	38.91bil	6.131bil	750.7mil	886.3mil	116.3mil
Oil consumption (bbl/day) (2005)	(2006) 2.1mil	264,000	72,000	10,500	9,000	900
Oil importation (bbl/day) (2004)	674,500	6 453	71,420	10,070	7,071	871.6
Natural gas consumption (m <sup>3</sup> ) (2005)	17.85bil	6.397bil	0	0	27.97mil	0
Natural gas importation (m <sup>3</sup> ) (2005)	8.478bil	0	0	0	0	0
Existing RE policy			10% RE in electricity by 2010, 15% by 2020 <sup>2</sup>	65% fuel from agro-energy by 2020 <sup>3</sup>	20% RE by 2026 <sup>4</sup>	20% RE by 2015 <sup>5</sup>

<sup>1</sup> All data from The World Factbook 2008

<sup>2</sup> Green Paper: Jamaica Energy Policy 2006-2020

<sup>3</sup> Guyana Draft Agro-energy Policy

<sup>4</sup> Barbados Draft National Energy Policy 2006-2025

<sup>5</sup> St. Kitts and Nevis Draft Sustainable Energy Plan 2007

**TABLE 7: PROJECTED OR EXISTING CAPACITY FOR BIOETHANOL PRODUCTION FOR SELECTED COUNTRIES IN LATIN AMERICA AND THE CARIBBEAN**

	Colombia <sup>1</sup>	Jamaica <sup>2</sup>	Guyana <sup>3</sup>	Barbados <sup>4</sup>	St. Kitts-Nevis <sup>5</sup>
Feedstock	cane juice	cane juice	molasses	cane juice	cane juice
Production capacity (MI/yr)	162-1,458	68	11.6	14.4	15
Infrastructure costs (US\$millions)	680	~30	6.5	156	8
Labour/human resource costs (US\$/yr)	510-765mil		112,520		
Land area required (ha)	150,000	~57,000	~12,000	~1,600-2,000	2,000
Area already acquired (ha)		~38,000	~12,000		
Estimated/actual unit cost (US\$/l)	0.198-0.304	0.41-0.44	0.246-0.392		0.17-0.50
Forex savings (US\$millions/yr)	150		5.4	8.425	15

	Colombia <sup>1</sup>	Jamaica <sup>2</sup>	Guyana <sup>3</sup>	Barbados <sup>4</sup>	St. Kitts-Nevis <sup>5</sup>
Existing RE policy	E10 in domestic gasoline	phase out of MTBE from 2006 with E10 E15 in 5 yrs		E85 by 2026	10% RE by 2010

<sup>1</sup> Cala-Hederich, 2003 (LAMNET), IEA <http://www.iea.org/Textbase/work/2002/ccv/ccv1%20echeverri.pdf>

<sup>2</sup>Loy and Coviello, 2005

<sup>3</sup>Horta, 2007

<sup>4</sup>Schaffer and Associates, 2006

<sup>5</sup>Binger, 2008; Williams, 2008

**TABLE 8: PROJECTED CAPACITY FOR BIODIESEL PRODUCTION IN BRAZIL AND BARBADOS**

	Brazil <sup>1</sup>	Barbados
Feedstock	various	vegetable oil
Production capacity (MI/yr)	800	
Blend	B2 mandatory	B100
Land area required	1.5Mha	n/a
Area already under agriculture	150Mha	n/a
Estimated/actual unit cost (US\$/l)		0.725 <sup>2</sup>
Forex savings (US\$millions/yr)	160	
Existing RE policy	B5 mandatory by 2013	2% by 2010 10% by 2025

<sup>1</sup> Ministry of Mines and Energy, n.d.

<sup>2</sup> Personal communication. Boyce-Drakes, 2008.

**TABLE 9: PROJECTED OR EXISTING CAPACITY FOR PRODUCTION OF ENERGY FROM SOLID BIOMASS FOR SELECTED COUNTRIES IN THE CARIBBEAN**

	Jamaica <sup>1</sup>		Guyana <sup>2</sup>		Barbados <sup>3</sup>
Feedstock	bagasse	fuelwood	rice husks	wood waste	bagasse
Production capacity	68MW	63MW	36400toe	1.55mil toe	30MW
Infrastructure costs (US\$millions)	22.264 (25MW)				156
Land area required	n/a	12,600ha	130,000ha	n/a	1618-2023
Yield	2.7Mt	226kt	110.3kt	449,000m <sup>3</sup>	>178,016.4t
Area already acquired	n/a		130,000ha	n/a	

	Jamaica <sup>1</sup>		Guyana <sup>2</sup>		Barbados <sup>3</sup>
Estimated/actual unit cost		8.90/t \$0.04/kWh			
Sale price (US\$/kWh)	0.065	0.06			
Forex savings (US\$millions/yr)	(22.3Mgal oil)				12.21
Income generated (US\$millions/yr)	44.7	11.37			
Existing RE policy					30MW by 2010

<sup>1</sup> Loy and Coviello, 2005; Barrett, 2002

<sup>2</sup> Horta, 2007

<sup>3</sup> Briggs, 2008; Schaffer and Associates, 2006

**TABLE 10: PROJECTED OR EXISTING CAPACITY FOR PRODUCTION OF ENERGY FROM LANDFILL GAS IN JAMAICA AND BARBADOS**

	Jamaica <sup>1</sup>	Barbados <sup>2</sup>
Feedstock	Landfill gas	Landfill gas
Raw material/'000 t	247 (organic MSW)	365
Production capacity	180m <sup>3</sup> /t	3-5MW
Land area required	n/a	n/a
Yield/Mm <sup>3</sup>	29.250-46.8	3.7
Existing RE policy	encourage development of domestic biogas industry and technologies incorporate biogas production systems into energy efficiency building codes	5-10MW by 2026

<sup>1</sup> Loy and Coviello, 2005

<sup>2</sup> R.J. Burnside International and Biothermica International Inc. 2003.



# 6

## Lessons learned



Highlighted below are some of the major lessons arising during this review. Other prevalent issues of concern not addressed here include trade barriers, energy balances and life cycle analysis, and food security.

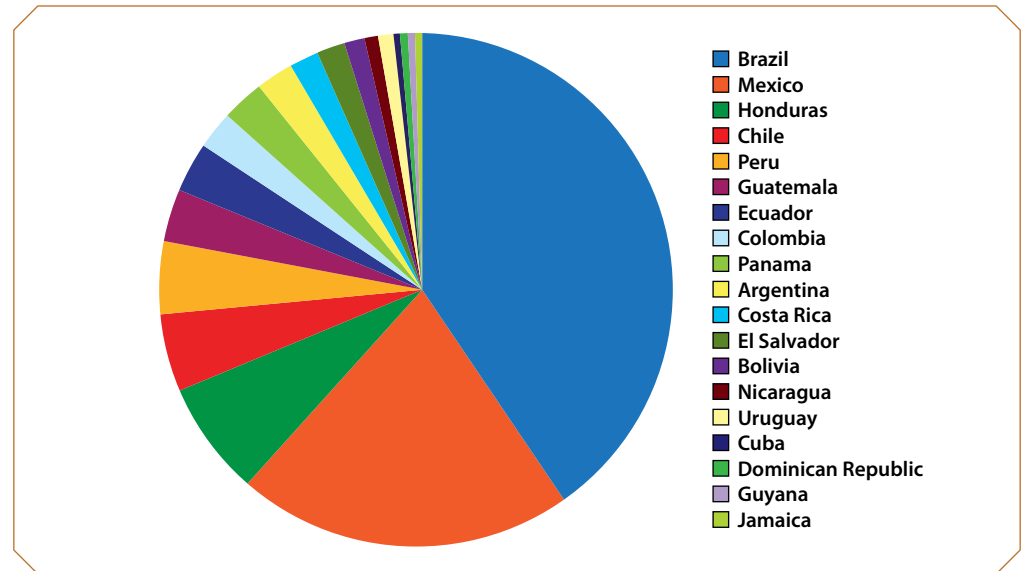
### 6.1 Utilization of available funding mechanisms and other resources

**B**etween January 2005 and April 2008, 908 proposals were submitted by developing countries for project funding through the UNFCCC CDM under the sectoral scope of “Energy industries (renewable/non-renewable)”. Of these 337 were submitted by India, 236 by China, and 232 by Latin America and the Caribbean (LAC). Over 300 were biomass-related, approximately 150 related to hydropower, 161 to wind, and around 10 to geothermal, solar and tidal projects combined. The remainder mainly focussed on energy efficiency, waste heat recovery, converting to combined cycle generation and switching to natural gas from other fossil fuels.<sup>85</sup>

From the LAC region, 96 proposals were submitted by Brazil, 45 by Mexico, and 1 each from four Caribbean countries (see Figure 2). Of the projects from this region 43 percent were biogas, biomass or biofuel related. Only seven projects were rejected, three received

85 <http://cdm.unfccc.int/Projects/projsearch.html>

corrections after review, and three were seeking registration. Guyana's Skeldon Bagasse Cogeneration Project, registered in May 2008, is the first biomass project under CDM from the Caribbean. It is only the second project from the English-speaking Caribbean submitted to CDM, the first being Jamaica's Wigton Wind Farm. Brazil has had only two proposals rejected; Mexico, Peru, Ecuador, and El Salvador none. These statistics illustrate the importance of innovative thought and perseverance.



**Figure 6: Distribution of CDM applications among countries of Latin America and the Caribbean submitted between January 2005 and April 2008**

Several other mechanisms are currently becoming, or will soon become, available for the funding of renewable energy projects, including GEF funds and carbon financing schemes. However, it is often the case that small Caribbean countries do not have the resources available to dedicate to pursuing these funds, which are then allocated to the larger developing nations with greater human capacity and experience. It should also be noted that the larger developing nations are able to attempt projects on a larger scale, and thus develop greater economies of scale and derive greater benefits from carbon trading mechanisms.

Nevertheless there are a myriad of development assistance agencies and other entities willing to support the countries, individually and regionally, in these efforts, and some have already done so and continue to do so. Examples include the OAS-supported Geo-Caribbes project which seeks to develop geothermal energy in a number of islands including Dominica and St. Lucia; and the UNDP/GEF/GTZ Caribbean Renewable Energy Development Programme (CREDP) which focuses on assisting the region in the areas of capacity, financing, and information, and creating favourable policy and market environments for renewables. Conversely, there are instances where such agencies help to develop projects and are granted funding but governments are slow in implementing the projects for a variety of reasons, including limited human and technical capacity, and shifting government priorities. Such situations make it difficult to secure funding resources in the future.

## 6.2 Appropriate nature of activities

The previously mentioned SRC/MME/OLADE biodigester project in Jamaica was successful in uniting several national institutions, forming a multi-sectoral project team from the SRC, MME and Ministry of Agriculture. However, the models proved too expensive and livestock requirements too great for adoption by small farmers and the main benefits of the National Biogas Programme accrued to medium and large scale farms.<sup>86</sup> Other influences included the protracted bureaucratic process for accessing the revolving loan fund, and the impact of natural disasters in 1988. It was also noted that insufficient consideration was given to the process of “innovation-diffusion” in technology transfer, including its sociological and technical factors.

Conversely, the small-scale Ecuadorian initiative related previously illustrates the potential benefits and success that can be reaped by developing an appropriate and environmentally sustainable activity that is simultaneously tailored to specifically tackle a local issue. By using the biodigesters the school was able to eliminate problems relating to marine pollution, waste disposal, water consumption and human health, as well as alleviate energy and water costs, and generate income through agriculture.

## 6.3 Interagency coordination and resource sharing

The Jamaican biodigester project demonstrated effective coordination and cooperation between national institutions as they merged resources. This was possible within the established context of clearly defined and realistic objectives.

Effective allocation of responsibilities also enabled various agencies to take advantage of appropriate opportunities and furthered the results that could be achieved in a given aspect. For instance, the success of the SRC public awareness programme led to more requests for technical assessment of suitability as individual interest in the household benefits grew. Additionally, research by the SRC identified previously overlooked factors influencing rates of technology transfer and adoption such as perception of comparative advantage, and compatibility with existing systems.<sup>87</sup>

## 6.4 Government intervention and incentives

Nicaragua’s jatropha experience emphasised the political prerequisites for successful biofuels production, these being:

- establishment of a national energy policy supporting development of renewable energy;
- a regulatory framework to control the biofuels market;
- legislation to stimulate domestic and foreign investment in all relevant sectors;
- incentives to fossil fuel stakeholders to participate in the development of this market;
- well-defined and established land rights; and
- a trustworthy judiciary system.<sup>88</sup>

86 UNDP SUSSC, 1999

87 UNDP SUSSC, 1999

88 Mayorga, 2005

In 1931 a law was passed in Brazil making the mixing of 5 percent anhydrous ethanol with imported gasoline mandatory, then extended in 1938 to mixing with locally produced gasoline. The Institute of Sugar and Alcohol (IAA) was formed in 1933 with the mandate of securing market equilibrium with stocks, sugar production quotas, and control on commercialization. Proálcool was created in 1975, in response to the international oil crisis, and is the world's first and most successful large scale biodiesel programme. Incentive measures included guaranteed ethanol prices, compulsory sale at fuel stations, tax reduction for ethanol fuelled vehicles, and subsidised loans for ethanol producers.<sup>89</sup> Brazil is the only country in the world where FFVs capable of using E100 are commonplace. Innovative leadership by the government and proper planning and execution of Proálcool have resulted in a flourishing world-leading industry where government subsidization is not needed.

Once the Brazilian government endorsed commercial use of biodiesel, within one year it had issued a regulatory framework, organized the production chain and lines of credit, and structured the technological base. Renewables now account for over 40 percent of the country's energy consumption, compared to a global average of 13.6 percent.<sup>90</sup>

Federal Law No. 11.097 of 2005 designed the road map for commercial biodiesel use in the country. B2 mixed with diesel became mandatory from January 2006<sup>91</sup>. The PNPB gives priority to incorporating family agriculture, and promoting creation of consortia and cooperatives by small farmers. In terms of locations for implementation, it considers every viable option, relative to the types of oilseed being grown. Because of the widely scattered regional coverage the government also united research institutions and universities in 23 states to form the Brazilian Biodiesel Technology Network (RBTB).

The regulatory framework ensures the competitiveness of biodiesel through a system of laws and decrees which govern blending, forms of use and differential taxation. They include measures for guaranteeing supplies and fuel quality standards, and take into account the diversity of oilseeds available, and the government's social inclusion policy. The "Social Fuel" seal denotes that a biodiesel producer has purchased feedstock from farmers and has contracts with them guaranteeing income levels, training and technical assistance.<sup>92</sup>

Direct positive actions such as these have helped to facilitate the growth of the biodiesel industry in Brazil and have made the ethanol industry the flourishing powerhouse that it is today. They demonstrate tangible government support and commitment, and provide security for the producers along the supply chain for their commodity, particularly the small farmers. They have also incorporated the academic sector to provide essential research and technical assistance services, and linked various production areas across the country's vast landscape. Coupled with social policies and the regulatory framework, the government has created an effective network to ensure the active pursuit of bioenergy development in the country. Further, it was all coordinated within the short span of one year.

Similarly, the Dominican Republic has instituted a set of mechanisms which favour the

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89 GTZ, 2005

90 Ministry of Mines and Energy, n.d.

91 GTZ, 2005

92 Ministry of Mines and Energy, n.d.

development of renewable technologies over the use of fossil fuels. These include<sup>93</sup>:

- General Electricity Act – preferential treatment of companies generating electricity from renewables if prices and conditions are identical, and a 10-year tax exemption;
- Hydrocarbon Act – fund created for promotion of renewables and energy saving programmes which was supported by 5 percent of the hydrocarbon tax in 2006; and
- Renewable Energy Act – tax exemptions for renewable technology components; lower transmission fees for electricity from renewable energy; income tax exemptions and fiscal incentives for IPPs.

## 6.5 Progressive development

Brazil's first experiments with alcohol-fuelled vehicles began in 1912, and the first vehicles were on the road by 1925. E5 blends were introduced in 1931. 1966 saw the ratio increased to 10 percent on a voluntary basis. For E10, no engine modifications are necessary. After the introduction of Proálcool in 1975, the first purely alcohol fuelled cars were introduced in 1979, when the blend ratio was raised from 15 to 20 percent. In 2003, it was again raised to E25, and FFVs were introduced into the market.

This brought a greater range of options to the market, giving the consumers the choice of their fuel composition, based mainly on price. Prior to this the options were hydrated ethanol vehicles which run on E95 but do not support gasoline or gasohol (anhydrous E20-E26 plus gasoline); and gasohol engines which cannot use hydrated ethanol.<sup>94</sup>

Gradual changes coupled closely with restructuring the sugar industry have led to this highly successful transition. Efficiency and technology improvements have accompanied the shift, which has touched a variety of sectors within the economy, generating employment as well as mitigating GHG emissions. Supporting legislation can also help ensure the overall environmental sustainability of the industry, such as the regulations requiring incremental introduction of green harvesting for recovering cane trash to increase the biomass available for energy production.<sup>95</sup>

## 6.6 Private sector support

The National Association of Motor Vehicle Manufacturers in Brazil has assured clients that their diesel engine warranties are covered for use of B2<sup>96</sup>. In conjunction with the government support previously illustrated, actions such as these express the private sector's buy-in and the reliability and safety of the renewable product, and will encourage consumers to adopt its usage.

93 Tabar, 2007

94 IICA, 2006b

95 IICA, 2006b

96 Ministry of Mines and Energy, n.d.

## 6.7 Market liberalization

Chile has one of the most open access electricity systems in the world. In the 1980s the government liberalized its markets, privatized all electricity companies, and allowed the private sector the key investment role. The companies were split into separate generation, transmission and distribution utilities. The National Energy Commission (CNE) was formed as the chief regulatory and policy making body. New laws permit free entry and competition in generation, sale by the owner of any electricity generating facility, a non-exclusive concession system for distribution, and pricing based on marginal costs with standard periodic review, and guarantee the right to sell surplus electricity on the spot market.<sup>97</sup>

Caribbean territories typically have a system of monopolization on electricity generation and distribution via the national grid. Many countries however are exploring options for permitting grid connection of independent power producers (IPPs). Barbados Light and Power Company (BL&P) submitted a proposal to the Fair Trading Commission (the Regulator) in May 2009 for the introduction of “time-of-use” rates, which assign a higher value to electricity used during peak times; “interruptable” service rates for commercial customers with generators; and feed-in tariffs for grid-connected renewable energy.<sup>98</sup>

CREDP has been liaising with the Caribbean Electric Utility Services Corporation (CARILEC), which is the association of electric utilities from across the region, for harmonized reform of the electricity sector to permit establishment of IPPs and inter-connection to the grid. Points of contention that remain include pricing and metering mechanisms, the utility needing to maintain stand-by production capacity if the IPP returns to the grid, and the comparative regulations for the utility and IPP.<sup>99</sup>

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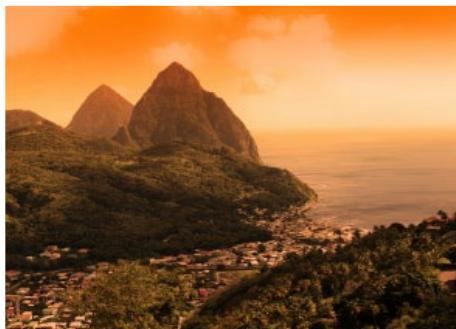
97 Jadresic, 2000

98 Blackman, 2009

99 Discussions from the CREDP Second Meeting of Experts and Stakeholders Concerning the Development of Harmonised Legislation for the Reform of the Electric Sector, 9-11 April 2008, Barbados

# 7

## Other renewable energy technologies in the Caribbean



For a number of reasons the amount of investment in renewable technology in the Caribbean has not grown despite the abundance of natural resources available.

Some of these reasons are:

- the relative viability of renewable technologies is linked to the fluctuating price of crude oil;
- institutional arrangements with the electric utilities in most of the islands guarantee them a monopoly on transmission and distribution;
- capital investment required is very high;
- resistance/inertia; and
- full privatization of utilities is difficult in a small economy.

### 7.1 Wind energy

Wind power is an ancient form of renewable energy, utilised in the region since the days of slavery in processing sugar cane in windmills, a few of which still exist today. They are still in use in Cuba for supplying water to livestock<sup>100</sup>. Modern wind turbines are a proven

100 <http://embacu.cubaminrex.cu/Default.aspx?tabid=3770>

technology, with many large scale global manufacturers and distributors. Turbines can be produced in sizes ranging from capacities of a few kW to 5MW or more. This allows applications to range from a single turbine to power a household to large scale wind farms spanning vast swathes of land. Wind power at present is commercially competitive with conventional fuels.

Jamaica has the only commercial wind power in the region. The Wigton Wind Farm was commissioned in April 2004 as a subsidiary of the Petroleum Corporation of Jamaica (PCJ). The government-owned PCJ is mandated to develop indigenous renewable energy and support the achievement of the goals stipulated in the Energy Sector Policy.

Located 240m above sea level, the farm has twenty-three 900kWh turbines, giving a total capacity of about 20.7MW and generating 53GWh annually with a capacity factor of 30 percent. The total project cost was approximately \$26.2 million. A 20-year power interchange agreement (PIA) exists with the Jamaica Public Service Company (JPSCo) and the power produced is fed directly into the national grid with the power generating licence having been issued by the Office of Utilities Regulation (OUR). An Emission Reduction Purchase Agreement (ERPA) was signed with the CAF Netherlands Facility for sale of CERs in December 2005, in operation from April 2004 to December 2012. Over \$4 million are saved annually in fossil fuel imports, with revenue being generated from the CERs and the grid.<sup>101</sup>

BL&P in Barbados has a proposal for the development of a wind farm in Lamberts, St. Lucy. A feasibility study was conducted in 2004 to evaluate four possible sites based on environmental, financial, technical and wind data. The Lamberts Plantation site displayed the most favourable wind regime, expected to generate electricity for 90 percent of the time. The total installed capacity of 10MW from 11 turbines and annual production of 28GWh is expected to reduce fuel costs by approximately \$2.8 million each year. Projected capital costs total \$15.2 million, and average production costs \$0.067/kWh (estimated in 2007). Many issues were addressed during public consultations with residents of the surrounding areas, including concerns about setback distances, noise, shadow flicker, and aesthetic impacts. Plans are for the farm to be commissioned by 2010.<sup>102</sup>

Other pertinent issues surrounding wind development in the region are those relating to the economies of scale and comparative cost of the turbines if a single country purchases turbines for a “small” project versus several islands placing an order; as well as the waiting time to receive the order which can range from 18-24 months<sup>103</sup> as global demand increases. Suggestion of offshore wind farms must be viewed within the context of the dependency of the islands on tourism, and the topography of the coastal shelves. For instance, wind turbines need to be within a maximum depth of 60ft of water, but the Barbados shelf drops to 100ft within a mile offshore, therefore they could not be placed at a sufficiently acceptable distance<sup>104</sup>.

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101 Jackman, 2008

102 Blackman, 2008

103 Blackman, 2008

104 Blackman, 2009



## 7.2 Solar power

There is a long history of utilizing solar power in the region for water heating. 1974 saw the initial introduction of a range of government incentives for solar water heaters (SWHs) in Barbados, including rebates and tax deductions, coupled with a series of disincentives for electric heaters such as a 30 percent consumption tax, which resulted in widespread installation of SWHs across the island. It has caused the evolution of a thriving manufacturing industry, which has expanded to other islands in the region as well as Africa. Barbados now has approximately 50,000 systems installed, has the highest surface area of SWHs in the world, and is among the top three in density of installations per household.<sup>105</sup>

Photovoltaic (PV) systems are being investigated by a number of utilities in the region, with GRENLEC in Grenada already possessing operating systems. Connecting IPPs to the grid are a primary concern for utility companies in the region; and options for net-metering, feed-in tariffs and other mechanisms are being explored, most recently by VINLEC and BL&P. A major hindrance is the monopoly which most companies have on generation and/or transmission and distribution. Under CREDP there were several consultations and development of harmonized legislation for reform of the electric sector. The objectives of these reforms included<sup>106</sup>:

- creating an investment climate to foster uptake of renewables by utilities, their customers and large scale IPPs;
- reduction in the fuel surcharge in electric tariffs;
- providing a shield against volatile fossil fuel prices;
- reducing fossil fuel imports;
- enhanced security of energy supply; and
- reduction in greenhouse gas emissions.

The cost of stand alone PV systems is significantly higher due to the price of the battery system; however they are still a plausible alternative for remote areas into which it would be comparatively more expensive for the utility to extend its transmission lines. Nevertheless, the cost of PV technology is constantly decreasing, and the variety of applications is expanding with the use of thin film technologies, tandem and triple junction cells, and alloy semiconductors which continue to improve their conversion efficiency.<sup>107</sup>

In Suriname solar power is being used in drinking water treatment. Holding tanks, pumps, filters and other equipment are used in various communities to remove mercury contamination caused by illegal mining operations. This initiative was spearheaded by the local Rotary Club and executed with a high level of community inclusion to ensure compatibility with their needs, lifestyles, and future continuity.<sup>108</sup>

At the University of the West Indies there are various solar technologies at the three campuses,

105 Husbands, J. Solar Dynamics. Presentation during the UNDP Focus Group Consultation on Renewable Energy, 27 April 2009, Barbados.

106 Clarke, R. CREDP. Speech at the CREDP Second Meeting of Experts and Stakeholders Concerning the Development of Harmonised Legislation for the Reform of the Electric Sector, 9-11 April 2008, Barbados.

107 Haraksingh, I UWI St. Augustine Campus. CARILEC Training Session on Photovoltaic Technologies, 30-31 March 2009, St. Vincent and the Grenadines

108 <http://cipore.org/suriname-project-delivers-clean-water-through-the-use-of-renewable-energy/>

including solar cookers, solar distillation and PV modules. However, solar concentrators have not been explored in the region to any extent. Resale and distribution of domestic solar ovens through the Eastern Caribbean is being led by a family in the Grenadines<sup>109</sup>.

### 7.3 Geothermal energy

Geothermal potential is restricted to those islands with volcanic origins. Nonetheless, because of the large quantity of energy that can be harnessed and the close proximity of the islands, development considerations for the resource have included proposals to export the energy to neighbouring islands.

Development of a geothermal resource is very expensive and involves a very protracted process. Surface and deep exploration can take 1-2 years, costing in the region of \$10 million. Power plant design and contract negotiations can consume another 2 years. The cost of actual construction can be on the scale of \$100 million, and take an additional 2 years. On the other hand, a plant can be operated for 30 years and even indefinitely as long as the heat source remains.<sup>110</sup>

#### WHAT CAN YOU DO?

The solar water heating industry is continually expanding in the region. These devices are a no-input method of generating and storing hot water for everyday use. Systems are available in a variety of sizes, making them applicable for homes and big business, and some countries offer rebates and other incentives to make the cost more favourable.

Solar ovens are small, portable, and fuel-free. They use reflectors and a tempered glass lid to concentrate and trap the heat from the sun in order to bake, boil or steam your food. They may be used even on a cloudy day, just taking a longer time to cook. They may also be used as solar dryers to dry or dehydrate foods. Solar ovens are ideal for use in remote locations, and in post-disaster conditions.

PV systems are another option for householders, though more expensive. There is much flexibility in the size of the system required depending on the percentage of your electricity needs that you want the system to provide. An important consideration is whether it will be a stand-alone system with battery storage, or if it will be grid-connected. Batteries and associated components tend to increase the cost of PV systems markedly; however it does mean that you are independent of fossil fuels and are not affected by outages on the grid. For grid-connected systems the utility company needs to have policies which allow IPPs to connect to the grid and a structured payment/compensation mechanism in relation to the amount of electricity that you supply or take from the grid.

The flexibility of PV systems also makes them ideal for use in the commercial sector. They can be incorporated into building façades, atria, roofs, etc. New technologies such as thin film are increasing the number of applications for PV and gradually reducing the costs.

Wind power can also be adopted at the small scale, with the vast range of sizes in which turbines are manufactured. But before erecting a turbine in your backyard, you must consider applicable planning regulations, neighbours, the wind regime in your area and consequent variability in quantity and rate of electricity produced, and whether grid-connection is permitted by the utility.

109 Personal communication. Belmar, August 2009.

110 Rodríguez, 2008

The OAS/UNEP/AfD Geo-Caribbean project has been operating in Dominica, St. Kitts and Nevis, and St. Lucia with activities including resource exploration, policy preparation, and designing drilling risk/feasibility financing tools. The project aims to facilitate commercialization of geothermal electricity production, and also considers inter-island connectivity for transmission<sup>111</sup>.

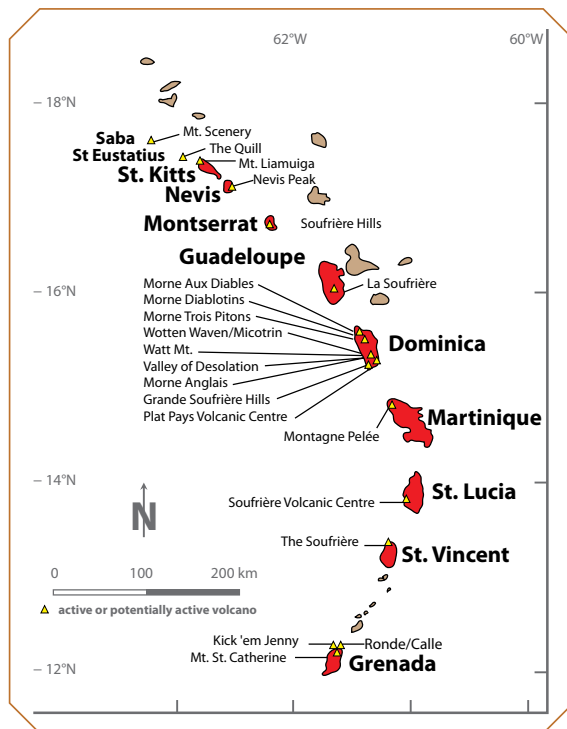


Figure 7: Active volcanic centres of the Lesser Antilles<sup>115</sup>

With several islands possessing geothermal potential (see Figure 5), a number of them have begun to exploit this resource, including Dominica, Nevis and Saba. There are 19 potentially active volcanoes in the Lesser Antilles, with six erupting in the last 400 years. Dominica has nine volcanic centres compared to one for most other islands<sup>112</sup>. In April 2009, the Nevis Electricity Company signed a power purchase agreement (PPA) with West Indies Power Nevis Ltd as the contractors for development of the island's geothermal resources<sup>113</sup>. Following geophysical, geological and geochemical analyses and feasibility studies, drilling was due to commence in June 2009 in Dominica. Full commercialization of the resource is anticipated to cost \$350 million.<sup>114</sup> Dominica is also considering the exportation of electricity to neighbouring Guadeloupe and Martinique. This interconnection project is funded to the tune of €4 million, with €1.5 million from the EU.<sup>115</sup>

## 7.4 Hydroelectricity

Hydropower, like geothermal, is very country-specific according to the geology and hydrology. The technology is well-established in a number of Caribbean countries, including St. Vincent, Cuba, Dominica, and Jamaica, each with multiple plants in operation. However, hydroelectricity has its disadvantages and limitations. Consideration must be given to the reduced water flow downstream of the dam and its impact on the ecosystem and human uses. The increased temperature of the water exiting the power plant also has negative effects on the ecosystem.

111 Lambrides, 2008

112 Joseph, 2008

113 <http://cipore.org/nevis-marks-another-milestone-in-geothermal-development/>

114 <http://cipore.org/dominica-forging-ahead-with-geothermal-resource-development%e2%80%a6-drilling-expected-to-begin-june-2009/>

115 <http://cipore.org/%e2%80%9cpreparation-of-a-geothermal-based-cross-border-electrical-interconnection-in-the-caribbean%e2%80%9d/>

116 Joseph, 2008

# 8

## Second generation biofuels



Second generation biofuels utilize different feedstocks and usually more complex conversion technologies compared to first generation biofuels to improve the conversion efficiency and favourability of biofuels relative to fossil fuels.

**T**hese methods use lignocellulosic biomass that, whilst more difficult to break down, generally costs less than first generation feedstocks. While the technology is still under development and commercialization still a number of years away, analyses indicate that they offer emissions reductions in the region of 70-90 percent compared to conventional fossil fuels.<sup>117</sup> Two of the main conversion processes are expanded on below.

### 8.1 The Fischer-Tropsch process

The Fischer-Tropsch (F-T) process generates biodiesel from biomass and organic resources such as wood and straw via gasification. These low-lipid<sup>118</sup> feedstocks are heated in a low-O<sub>2</sub>

117 FAO, 2008

118 Lipids are a group of naturally occurring molecules which include fatty acids, sterols (e.g. cholesterol) and fat-soluble vitamins (e.g. vitamins A, D, E and K).

environment to produce a synthesis gas (syngas) containing H<sub>2</sub> and CO. This then undergoes a catalytic F-T hydrogenation<sup>119</sup> to produce a hydrocarbon product that is more similar to conventional petroleum than the typical alkyl-ester biodiesel. Secondary F-T products include lighter and heavier hydrocarbons which can be employed in other purposes.<sup>120</sup>

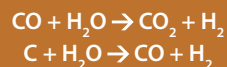
Gasification can make use of a variety of input organic materials including plastics and waste, as well as coal and petroleum. Syngas can also be used directly in internal combustion engines, or used to produce methane or hydrogen for electricity or fuel cells. The inorganic ash remains may be used as fertiliser. Waste gasification, from which electricity may be generated, is also a treatment alternative to incineration.

There are very few industrial scale gasification plants in the world. One is the Güssing combined heat and power (CHP) plant in Austria which has been operating since 2002. It processes wood chips in a fast internal circulating fluidized bed (FICFB) gasification process and has an output of 2MW of electricity and 4.5MW of heat. A description of the process is given in Box 2.

Unlike conventional gasifiers which are operated with air, the advantage of the FICFB system is its production of nitrogen-free gas, which can be exploited as a syngas for energy or in the chemical industry after appropriate cleaning and treatment.<sup>121</sup>

#### BOX 2: OPERATION OF THE FICFB GASIFICATION SYSTEM

Biomass entering the stationary fluidized bed gasification reactor is heated, dried, de-volatilized and converted to carbon dioxide, carbon monoxide, methane, hydrogen, steam and char. Simultaneously the strongly endothermic gasification reactions (reactions with water vapour) take place:



A chute connects the gasification with the combustion section, operating as a circulating fluidized bed. Bed material, together with any non-gasified carbon, is transported through this chute into the combustion section, where the remaining carbon is fully combusted. The heated bed material is separated by, for example, a cyclone and re-fed into the gasification section.

The necessary heat required for the gasification reactions is produced by burning carbon brought along with the bed material into the combustion section. Additionally, the temperature in the combustion section is controlled by supplementary fuel, such as re-circulated product gas or wood.

The gasification section is fluidized with steam, and the combustion section with air, resulting in two separate gas streams: a nearly nitrogen-free product gas with a calorific value of 12MJ/Nm<sup>3</sup> (dry) and a flue gas from the combustion section.

*Source: Bolhàr-Nordenkampf, M. et al, 2002*

119 Hydrogenation is the chemical addition of hydrogen to another molecule. Catalysts are typically used to lower the physical conditions (temperature and pressure) needed for the reaction to occur.

120 Holbein, et al, 2004

121 Bolhàr-Nordenkampf, M. et al, 2002

## 8.2 Lignocellulosic bioethanol

Cellulosic biomass is the most abundant biological material in the world. This significantly broadens the quantity and diversity of potential biofuel feedstocks. Possible energy crops include grasses such as switchgrass and miscanthus; and short-rotation, woody species such as eucalyptus. Waste products from agriculture, forestry, municipal waste, and food processing may also be employed, e.g. straw, leaves, sawdust, and nut shells. These feedstocks are more robust than those of first generation biofuels therefore being easier to store and handle. It is also more difficult and expensive to convert their cellulose and hemicelluloses into sugars, but the material is less costly than that for first generation fuels. Conversely, their bulk necessitates good transportation infrastructure to transfer the materials after harvest or recovery.<sup>122</sup>

Lignocellulosic bioethanol is synthesized using enzymes in the breakdown of the cellulose and lignin compounds; this is currently one of the prohibitive factors in the commercialization of this technology, being inefficient and expensive. Its promise lies in:

- the feedstock being fast-growing, perennial short rotation coppices and grasses that can be cultivated on marginal land, thus avoiding deforestation and usage of valuable arable lands;
- having greater energy content and biomass yield per ha as the entire plant is available for conversion; and
- cultivation requiring few inputs, e.g. fertilizer.

Thus it would have a more favourable energy balance than crops typically used, further increased by use of renewable energy for processing. However the process is currently very inefficient, producing a very dilute mixture, and refining is highly energy intensive.<sup>123</sup>

In the continuing development of this technology, consideration must also be given to the role of decomposing organic matter in soil fertility and the potential impacts of removing these residues, such as greater use of nitrate fertilizers, water pollution, and topsoil erosion. The function of dead plant matter as microhabitats also raises issues relating to the associated biodiversity. Other factors to take into account include propagation of plants which may be invasive species, and the risks of using of genetic engineering to overcome the commercialization barriers being faced, and the impact of these organisms on natural ecosystems.

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122 FAO, 2008

123 Dufey, 2006

# 9 Conclusions



**T**he goals of the *Strategy for the Development of an Agro-energy Programme for the Caribbean Region* are to improve energy security and economic resilience, and support rural development by reducing vulnerabilities relating to dependence on imported fossil fuels and diversifying and increasing the sustainability and profitability of the agricultural sectors. To facilitate the development of sustainable bioenergy industries within the Caribbean, a number of critical issues need to be addressed:

## Governance

A portfolio of policies and regulations is necessary to encourage generation of renewable energy by the utility and IPPs. Monopolies dominate the region's energy sector, and legislative provisions often place the remit for electricity generation and/or transmission solely with the utility. Appropriate frameworks allowing IPPs entry into the market should be designed, such as PPAs. They should be accompanied by strategic plans and targets for increasing the proportion of the market which is occupied by renewable energy. Systems should be structured such that the utility is not adversely affected by a sudden loss of its customer base but is also able to shed some of its fossil fuel-based baseload and increase its use of renewables.

Land use regulations are paramount in the bioenergy arena. Sustainable land management practices, incentives based on environmental benefits, and securing access to lands are vital to sustainable bioenergy industries. Environmental legislation is also necessary to prevent

destruction of natural systems and habitats, and exploitation of resources on which the industry ultimately depends.<sup>124</sup> Enforcement of such measures, which in some countries is notably ineffectual, needs to be prioritized.

### Sustainability

Production of bioenergy crops relies on the integrity of the supporting ecosystem supplying the necessary goods and services (e.g. biomass, climate and water regulation, soil structure and stability). Therefore, like any sustainable agricultural practice certain methods must be adopted and avoided to reduce soil erosion, water logging, nutrient depletion, excessive fertilization, etc.

Moreover, a number of tools may be applied to improve the sustainability of the system, starting from the planning stages. LCA and resource management tools are used to help quantify and manage adverse impacts from bioenergy. Payment for ecosystem services (PES) and other economic tools provide incentives for producers to adhere to best practices. Certification and product standards help to create and support markets for sustainably manufactured biofuels. Social equity and gender tools aid the mainstreaming of the needs of marginalized groups.<sup>125</sup>

### Equitable distribution of costs and benefits

Costs are not limited to monetary exchanges. Social and environmental consequences are borne not only by the project developers and immediate beneficiaries, but also by other players who may or may not be directly involved with the initiative. Monocultures, habitat alteration, job creation and loss, land acquisition and compensation, cultural disruption, and resource consumption are some of the elements which must be addressed in terms of their negative and positive impacts on various parties.

### Appropriate technology

As demonstrated in Jamaica, the scale of the activity and the specific conversion technology used must be compatible with the nature and size of the market, accessibility of raw materials and availability of other process inputs, e.g. water resources, cost and reliability of the technology, and the available technical capacity for construction, operation and maintenance. Environmental impacts of the technology must be assessed, particularly its life cycle emissions to determine whether it is truly avoiding emissions or if it is a net greenhouse emitter.

With countries of such small size the amount of land occupied by the operations is a significant determinant in its feasibility since land use is highly competitive, particularly where there is insufficient housing and also areas protected for their environmental and cultural significance.

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124 IICA, 2006a

125 IUCN, 2008a



Community involvement and buy-in are critical for the acceptance and flourishing of a technology, particularly at the household scale. A family must be able to afford to buy the equipment and it should have a long lifetime, require little maintenance, and have relatively short payback times and tangible benefits (e.g. money saved, useable by-products) to be adopted by broad segments of the population.

### Competitiveness

For bioenergy in particular, the high cost per unit of output is a major inhibiting factor, which is typically a function of small scale, high capital costs, and expensive raw materials.<sup>126</sup> With time renewable energy technologies on a whole are becoming more efficient, using cheaper and fewer materials, and becoming less expensive overall. In a climate where oil prices are highly unstable, at any given time their direct competitiveness fluctuates. However, given the finite nature of fossil fuels and the continuing advancement of renewable technologies, in the long term renewables are generally more competitive across the lifetime of the system.

*"...developing countries need the support of partners to move along a low-carbon development pathway. They need better access to carbon financing to pay for that, and the skills to put that money to work where it is needed. That includes driving private and public finance towards cleaner investments in energy, transport and other infrastructure, and in industry."*

Op-Ed "A green deal for rich and poor nations" by Helen Clark, UNDP Administrator, 8 September 2009

### Research, development and demonstration

Whilst small developing islands may not be at the forefront of conceptualizing and commercializing new and emerging technologies due to economic and technical capacity constraints, there is an urgent need to find means to sustainably use indigenous resources to produce energy, and to adapt known technologies to unique Caribbean needs. For instance, university research has been engaged in investigating the use of breadfruit and castor as feedstock for producing biodiesel<sup>127</sup>. Regionally based research and application should be increasingly fostered, with capacity being enhanced through regional cooperation in accessing grants and other funds and through use of regional and international academic networks to share information.

### Financing

CDM, the MDG Carbon Facility, the Adaptation Fund, and other mechanisms that will evolve out of the post-Kyoto regime, are but some of the financing solutions geared toward GHG reduction and climate change adaptation. Multilateral and bilateral donors, e.g. EU, CIDA, IADB and Norway are increasingly turning their focus to climate change mitigation and adaptation, particularly integrating such activities as crosscutting themes across all programmes. This is particularly favourable for developing states, small islands more so, as they are predicted to suffer the most devastating impacts from climate change.

<sup>126</sup> Moreira, 2003

<sup>127</sup> Discussions from the OLADE/UNEP/CIDA Clean Development Mechanism Workshop, 13-15 May 2008, Barbados

The private sector must also be engaged. As part of their corporate social responsibility, commercial banks and credit unions should be encouraged to invest in initiatives that are environmentally sustainable. Other financing mechanisms such as BLT (build, lease, transfer) and BOOT (build, own, operate, transfer) should be explored.

### Capacity development

At the national and regional levels improvement in technical skills, knowledge, technology, organization and coordination are requisite for the effective implementation of bioenergy programmes. Technical assistance components are often incorporated into the support offered by donors; and mechanisms such as the CDM have stipulations regarding the transfer of knowledge and technology from developed to developing countries. In accepting such assistance, countries must ensure that the necessary skills are developed among the local work force and remain within the country. Often when international consultants execute activities on behalf of a government training is minimal or absent, resulting in no local capacity being built to ensure the sustainability of the initiative.

Planning, execution and monitoring are aspects which need to be performed in consultation with a host of stakeholders. Inter-agency and inter-sectoral integration are areas which traditionally are deficient. Coordination at this level needs to be ably supported by accurate and timely data, and technical knowledge for informed and sound decision making. An overall national strategy should contain guiding principles to which all operations should conform.

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