Framework Contract EuropeAid: 127054/C/SER/multi - Lot 1
Rural Development

Biomass Feedstock and Cogeneration in the Sugar Industry of Jamaica

FWC1-138



FINAL REPORT

December 2011

Ministry of Energy and Mining, MEM

KEY DATA

Name of Project:	Biomass Feedstock and Cogeration in the Sugar Industry of Jamaica
Contractor:	Landell Mills Limited, Bryer-Ash Business Park, Bradford Road, Trowbridge, Wiltshire, BA14 8HE, UK Tel: +44 1225 763777 Fax: +44 1225 753678 www.landell-mills.com
Contracting Authority:	Framework Contract Europe Aid 127054/C/SER/multi - Lot 1
Start/End Date:	15 August to 31 December 2011
Beneficiary:	Ministry of Energy and Mining, MEM, Kingston, Jamaica
Primary Location:	Jamaica
Secondary Locations:	

DISTRIBUTION LIST

Recipient	Copies	Format
Ministry of Energy and Mining, MEM	1	Electronic
EEAS	1	Electronic

ACKNOWLEDGEMENTS

The consultant team was hosted by the Ministry of Energy and Mining during the mission. Many thanks go to the staff at the Ministry for supporting and enabling the different tasks during the mission. The coordination of all activities was done by Dr. Betsy Bandy in an excellent manner. During the data collection and the field trips/meetings the team came across numerous persons, who more than voluntarily provided insights into their business or responsibilities. Without this broad cooperation the mission could not have been accomplished.

Report submitted by
LANDELL MILLS LTD

This report has been prepared at the request and with the financial support of the European Commission. The content of this report is the sole responsibility of Landell Mills and can in no way be taken to reflect the views of the European Commission.

ABBREVIATIONS AND ACRONYMS

bar	Pressure Unit
bbl	Barrel
BTU	British Thermal Unit
CARDI	Caribbean Agricultural Research and Development Institute
CBI	Caribbean Basin Initiative
CDM	Clean Development Mechanism
CERE	Center of Excellence for Renewable Energy
CFL	Compact Fluorescent Lights
DSM	Demand Side Management
EU	European Union
E10	Gasoline with 10% bioethanol
EEAS	European External Action Service
ESCO	Energy Service Company
FIT	Feed-in Tariff
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GHG	Greenhouse Gases
GTZ/GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
h	Hour
ha	Hectar
IDF	Internatinal Development Foundation
IDB	Inter-American Development Bank
IMF	International Monetary Fund
IPP	Independent Power Producer
IRR	Internal Rate of Return
JAMALCO	Jamaica Aluminium Company
JD	Jamaica Dollar
JEP	Jamaica Energy Partners
JPPC	Jamaica Private Power Company
JRCS	Jamaican Recovery Cane Sugar
JPS	Jamaica Public Service Company
kWh	Kilowatthours
L	Litre
LCEP	Least Cost Expansion Planning
LCV	Lower Calorific Value
LRMC	Long Run Marginal Cost
MEM	Ministry of Energy and Mining
mill.	Million
MOA	Ministry of Agriculture
MSW	Municipal Solid Waste
MW	Megawatt
NEPA	National Environment and Planning Agency
NPV	Net Present Value
OAS	Organisation of American States
O&M	Operation and Maintenance
OUR	Office of Utilities Regulation
PCJ	Petroleum Corporation of Jamaica
PM	Particulate Matter
PPA	Power Purchase Agreement
PSI	Pounds per Square Inch
RE	Renewable Energy
SCJ	Sugar Corporation of Jamaica

SDE	Sugar Divestment Enterprise
SIRI	Sugar Industry Research Institute
SRC	Scientific Research Council
STU	Sugar Transformation Unit
SRF	Short Rotation Forestry
SWH	Solar Water Heaters
T	Tons
TC	Tons of Cane
TS	Tons of Sugar
USAID	United States Agency for International Development
USct	United States Cents
USD	United States Dollars
UTECH	University of Technology, Jamaica
UWI	University of the West Indies
WTE	Waste to Energy
Yr	Year
°C	Degree Celsius

CONTENTS

ABBREVIATIONS AND ACRONYMS I

TABLE OF TABLES VI

TABLE OF FIGURES VI

EXECUTIVE SUMMARY 1

1. INTRODUCTION 5

1.1. General Information on Jamaica 5
1.2. The energy situation of Jamaica 6
1.3. Background for this study 7

2. REVIEW OF POLICIES, PREVIOUS PROJECTS AND LITERATURE 10

2.1. Energy policy in Jamiaca 10
2.1.1. National general energy policy 10
2.1.2. National renewable energy policy 10
2.1.3. National biofuel policy 11
2.2. Summary of previous projects and reports 11
2.2.1. Proposals for sugar industry and cogeneration 11
2.2.2. Biomass production and availability 13
2.2.3. General energy related issues 14
2.3. literature overview on other relevant subjects 16
2.3.1. Increasing the sugar cane biomass availability and higher fibre yields 16
2.3.2. Biomass production and dedicated energy crops 17
2.3.3. Process improvements in the sugar production 20

3. PRESENT STATUS OF THE SUGAR SECTOR 21

3.1. Sugar and byproduct Production overview 21
3.2. the privatization strategy and link to agriculture and forestry 21
3.3. Situation in the individual sugar mills 23
3.3.1. Golden Grove 23
3.3.2. Everglades 24
3.3.3. Appleton 25
3.3.4. Worthy Park 26
3.3.5. Frome, Monymusk and Bernard Lodge 27
3.4. Rum production 29
3.5. BIOEthanol production 30

4. COGENERATION AND ELECTRICITY EXPORT 31

4.1. Regulatory conditions 31
4.2. Technical and economic requirements 33

5. BIOMASS ASSESSMENT 35

5.1. resources for biomass for energy 35
5.1.1. Byproducts in the sugar industry 35
i) Green Cane Harvesting 35
ii) High Fibre Cane Development 36
iii) Potential Increase in Fibre Availability 36
iv) Impact of Increased Cane Fibre Harvest 37
5.1.2. Waste or biomass materials 38
5.1.3. Dedicated energy crops 38
i) Woody Biomass Resources 39

ii) Leucaena Plantations as a Woody Biomass Source 40
iii) Non-Woody Dedicated Energy Crops 41
5.2. Supply chain analysis for additional biomass feedstock 42
5.2.1. Green Cane Harvesting 42
5.2.2. Development of new fibre species 42
5.3. Economic analysis of biomass feedstock supPly 43

6. DISCUSSION OF TECHNICAL AND ECONOMIC FEASIBILITY 45

6.1. Reduction of external energy supplies 45
6.2. Excess electricity production 46
6.3. Additional biomass feedstock for increased electricity production 49
6.4. Bioethanol production 50
6.5. Results of financial analysis 50
6.5.1. Base case results 50
6.5.2. Options in economic analysis 53
i) Feed-in tariff to 15 USct/kWh 53
ii) Sales to sugar mill based on electricity price of 11.56 USct/kWh 53
iii) Full cost payment for steam and electricity 54
iv) Use of coal as alternative to biomass 55
v) Sensitivity analysis 55
6.5.3. Next steps in refinement of economic assessment 57
6.5.4. Development of individual business cases for selected sugar mills 57
i) Golden Grove 57
ii) Everglades 63
iii) Appleton 68

7. ENVIRONMENTAL ASSESSMENT OF POSSIBLE ACTIVITIES 72

7.1. Sugar and electricity production 72
7.2. Bioethanol production 72
7.3. Sugar cane cultivation 73
7.4. dedicated Energy Crops 73
7.5. Climate change and carbon crediting 73

8. INSTITUTIONAL EVALUATION 76

8.1. policy and Finance 76
8.2. Research and Development 77
8.3. Private sector 78

9. PROJECT APPROACHES 79

9.1. Barriers and risks 79
9.2. Short term solution 79
9.3. long term solution 80
9.4. General requirements for a successful implementation 80
9.5. Customised project approaches for individual sugar mills 81
9.5.1. Appleton 81
9.5.2. Golden Grove 81
9.5.3. Everglades 82
9.5.4. Potentials at the remaining mills 82

10. RECOMMENDATIONS 83

11. ANNEXES 85

11.1. literature and Sources 85
11.2. Conversions and units 89
11.3. Workshop 90
11.3.1. Short term programme for biomass supply 93
11.3.2. Long term approach for dedicated energy crops 96

11.3.3. Tentative programme planning 99
11.4. Persons and Institutions 100
11.5. Additional information related to individual chapters 102
11.5.1. Chapter 1 102
11.5.2. Chapter 6 104

TABLE OF TABLES

Table 1.1: Composition of generating capacity……6
Table 3.1: Production figures for the sector, 2004 to 2011…… ...20
Table 3.2: Summary of technical details, Golden Grove……....23
Table 3.3: Summary of technical details, Everglades……..…24
Table 3.4: Summary of technical details, Appleton……..…25
Table 3.5: Summary of technical details, Worthy Park……..…...25
Table 3.6: Summary of technical details, Pan Caribbean Sugar……..26
Table 3.7: Energy efficiency indicators for all sugar mills……..27
Table 4.1: Electricity price development in the Caribbean……..……..…31
Table 5.1: Potential fibre increase using material in Jamaican testing programme ……...35
Table 5.2: Potential Increase in Fibre Yield with Green Harvesting and High Fiber Cane……..36
Table 5.3: Projected Land Required for Additional Biomass - Woody Biomass Only……..38
Table 5.4: Cost Estimates for Trash Recovery and Delivery to Factory……42
Table 6.1: Electricity production at sugar mills……47
Table 6.2: Additional biomass volume for year-round production……...49
Table 6.3: Financial analysis, base case……...…50
Table 6.4: Yearly profits per year for all mills, base case……..…..…51
Table 6.5: Financial analysis, FIT 15 USct/kWh……..……52
Table 6.6: Possible yearly profits with a FIT of 15 USct/kWh……..…..…52
Table 6.7: Internal sales with FIT 11.56 USct/kWh……..……..…53
Table 6.8: Full cost payment by the sugar mill……..……..…..53
Table 6.9: Coal as alternative to biomass……..……...…..54
Table 6.10: Increase in boiler efficiency by 5%.....55
Table 6.11: Reduction in capital costs, decrease of 2% interest rate…… ..……...55

TABLE OF FIGURES

Figure 1.1: Map of Jamaica……..……4
Figure 1.2: Primary Energy Supply Jamaica, 2009 (MEM 2009)……..……...5
Figure 1.3: Breakdown of renewable energy (final), 2009 (MEM 2009)……..5
Figure 6.1: Possible installed capacities at each mill under different pressure levels……..…46
Figure 6.2: Levels of export electricity……...…..48
Figure 6.3: Example of cost and benefit structure……..51
Figure 7.1: GHG emissions from biomass power plants and fossil sources……..71

EXECUTIVE SUMMARY

An EU-sponsored study was undertaken to assess the ability of the Jamaican sugar industry to contribute to electric power generation for the national grid through cogeneration and use of additional biomass as a fuel. The mission started in August 2011 and ended in December 2011 with the delivery of the draft final report.

Nearly 90% of all energy consumption in Jamaica consists of imported petroleum products. Renewable energy contributes the remaining 10% with a high share of traditional biomass fuels and some hydropower and wind energy. Electricity generation reaches 4,140 GWh per year mainly relying on fuel oil and diesel. The installed capacity for the public grid stands at roughly 850 MW.

Bagasse, the by-product of sugar cane processing, is used as the energy source in the sugar industry. The traditional operation of a sugar mill offers only a limited potential for exporting excess energy. Under the light of climate change issues, such as long term energy development and increased use of renewable energy, it appears that opportunities exist for the production of electricity from bagasse and other biomass fuels for the national grid on a larger scale.

The main objective of the energy policy is a move away from imported petroleum products and to increase energy security and sustainability. Renewable energy should have a share of 20% in the year 2030, the intermediate goal is a share of 11% for 2012. Different measures are mentioned and discussed, which are necessary on the regulatory (grid connection, wheeling, net metering) and financial aspects (tax credits, reduced duties) to enhance renewable energy. The agricultural sector and specially the sugar sector is the main producer of renewable energy, both for liquid fuels and for electricity. The target for sugar cane would be 3.3 million ton of cane per year. For cogeneration and electricity production a figure of 220 to 300 GWh yearly production with 94 MW installed capacities is estimated.

Several reports and feasibility studies have been written in the last 20 years on cogeneration in the sugar industry and on the potential for electricity exports to the national grid. The chapter 2.2.1 gives an overview of the most important studies and their main findings. More studies are revised, which address biomass assessments and general energy issues (renewable energy, energy efficiency etc.). A literature overview is given on international experience and findings on three different subjects: the increase of biomass production for energy purpose from sugar cane (cane trash and higher fibre content), the prospects for other and additional biomass crops (annual and perennial plants) and the impact of bagasse drying on the energy situation.

Jamaica has produced 3.5 million tons of cane (TC) during the seventies. Production has continuously declined in the last ten years down to a level of 1.3 million TC. For the actual crop some 1.8 million TC are expected. During that last period the sugar sector in Jamaica was not competitive compared with world market conditions and survived partly because of the preferred exports into the European Union. The situation has changed because the trade agreements have ceased, but simultaneously the world sugar prices increased. The developments on the world market enabled Jamaica to re-arrange the sugar sector. The sugar industry is fully privatised now.

Four out of the recent operating six sugar factories[1] were visited during the expert mission in Jamaica and their energy situation was analysed. Two of the newly privatised sugar mills had rather high specific energy requirements, two other mills - in private ownership for several decades - showed a better performance. Two key performance indicators are used for assessing the energy situation at a mill, i.e. the specific electricity consumption (in kWh/TC) and the specific steam demand (in tons of stem per TC).

When compared with international standards for traditional sugar factories (20 to 25 kWh/TC and steam below 5 t/TC), the average value for Jamaica for all sugar mills is rather high with 22

[1] *Two factories, Frome and Monymusk had just been handed over to the new ownership. Secondary information was used for their assessment.*

kWh/TC and 0.7 tons steam per TC. Fuel oil or diesel is consumed in addition to that reported demand, which increases the overall energy consumption. The conclusion of this exercise is, that the energy situation at the sugar mills must be improved before substantial amounts of energy can be produced in excess and exported to the national grid.

The regulatory framework for independent electricity production and the feed-in exists in Jamaica. However, there are certain discrepancies between the envisaged strategy for renewable energy development and the reality during the project negotiations with possible investors. The electricity sector is regulated from the Office of Utilities Regulations (OUR). The OUR has calculated avoided cost for the conventional electricity production (based on certain assumptions) at which rate independent producers can sell to the national grid resp. the grid operator, the Jamaica Public Service Company (JPS). Including a premium of 15% for renewable energy the FIT (feed-in tariff) stands at 10.73 USct/kWh for non-firm power and at 11.56 USct/kWh for firm power. The above quoted FIT is regarded as too low to encourage renewable energy development on a wider scale. The assessment of the avoided cost is questioned by different parties as well.

If the sugar sector should produce electricity for export, a paradigm shift is necessary. An average “fictive” sugar mill may install a 2 MW power plant, which can satisfy all of the energy needs of the factory. This plant is operated during the harvest season in the cogeneration mode because steam is the main energy carrier for sugar processing. Use of “modern” technologies could enable a power plant at the same mill to work at 10 MW or even 15 MW capacity, which is operated year-round. Technically, this is a movement from cogeneration towards independent power production.

One major objective is the continuous operation of such a proposed bigger power plant. The quantities of bagasse as the traditional fuel source are limited and not available out of the crop season. Therefore additional biomass fuels should be utilised. They can be sourced in the sugar sector through different innovations or a new supply chain for dedicated energy crops must be built up. In the short term the focus should be on increasing fibre availability from current sugar cane operations. Green cane harvesting and mechanical harvesting of cane could be implemented across the industry; these changes will greatly increase the amount of available biomass while returning a portion of the organic matter back to the soil. Methods for collection for cane trash (tops and leaves) could be implemented along with efficient storage methods of this resource along with other available bagasse. Ongoing programmes to develop high fibre cane varieties could be strengthened and the new varieties distributed to the farmers. For long term development of a biomass supply non-cane resources need to be evaluated and programmes to ensure their stability implemented. A detailed land use plan should be carried out for the lands surrounding the sugar factories and estates to identify non-cane land that is within a reasonable transport distance, environmentally sustainable and capable of growing selected dedicated energy crops. The target crops may include trees such as Leucaena, high fibre cane, grasses, biomass sorghum and others. Breeding and testing programmes should be established to ensure that best practices and high quality planting stock are used in the biomass operations.

The technical and economic feasibility for setting up biomass power plants is analysed in detail based on the findings and assessments reported above. Three scenarios can be presented differentiated by technological status. The base case is a rather inefficient operation of a power plant (near to present state-of-the-art, but newly erected) with an operating steam pressure of 20 bar[2]. An improvement of efficiency is possible by raising the pressure level to 40 bar. Then nearly the same amount of steam can produce more electricity through a turbine before using the steam in the lower pressure sections of the sugar mill. In a first instance a backpressure turbine might be installed. The highest efficiency and electricity output is possible by applying 80 bar steam and employing a condensing-extracting turbine. This plant is designed for pure continuous operation. Under the present production level of sugar cane the 20 bar option can

[2] *The pressure level (and the temperature level) in the boiler section can be used quite appropriate to describe the technological status.*

produce some 115 GWh per year with an installed capacity of 35 MW. The intermediate 40 bar option produces 220 GWh with 52 MW and finally, the 80 bar solution offers 410 GWh with 86 MW capacity. The demand for additional biomass sums up to 320,000 tons per year for all of the six power plants.

An economic model was developed for the different technological scenarios and for the individual sugar mills. Assumptions had been made to set the financial conditions and to make results comparable to other reports and findings. The base case is defined as a separate power plant receiving bagasse and supplying steam and electricity in return to the sugar factory. Excess electricity is sold to the grid. During off-the-crop season additional biomass is used at a certain price and quality and all electricity goes completely into export. At the present FIT-level the base case hardly ends up in financial viability. Only the very expensive 80 bar option is resulting for some locations in internal rates of return (IRR) of above 12.5%. Besides the value for IRR the production cost per kWh are calculated, which for the 40 bar option are between 12.5 and 15.2 USct/kWh and clearly higher than the FIT. If the FIT could be increased to 15 USct/kWh, most of the 40 bar options become more financially attractive (IRR above 12.5%). This positive result must be seen under the condition that additional biomass would be available and could be used instantly. However, all discussed solutions like high fibre cane, baling of cane trash or short rotation forestry need time until they are fully developed and in full operation. At least for the first years less profits and returns are expected. On the other side the model assumes energy supply for the mill without cost. Therefore, different calculations are presented showing the influence of a part or full cost-sharing.

For three sugar factories, namely Golden Grove, Everglades and Appleton customised business plans were discussed and are summarised in this report. More details are not presented here, but it appears that Appleton could be used as a good first demonstration project with reduced financial risks.

Two further chapters analyse the environmental impact of sugar production with the connected power production including greenhouse gas effects and the institutional situation with relevance to the project objectives.

The recommendations are very short and clear. With the present FIT no progress is possible by using the sugar sector for power production. The minimum requirement for a reasonable payback and financial return is a FIT of more than 15 USct/kWh. For the first project or for the first period (may be a couple of years) a premium of another 5 USct/kWh should be paid in order to attract hesitating investors and to compensate for the foreseeable losses in the start-up operation.

Without solving the above-mentioned issue any other recommendation would not have a solid justification. However, there is a need to increase efficiency in sugar production in any circumstance. Framework conditions beside FIT like power purchase agreements, grid connection, wheeling or net metering and exclusivity must be influenced positively not only for the sugar sector but for all renewable energies. Some tests and demonstration projects should be started for green cane harvesting, high fibre cane and field collection of cane trash to be prepared for further and future developments.

There is a good chance to produce green electricity in the sugar sector on a large scale, but the way to achieve possible objectives is not easy and not an automatic one.

1. INTRODUCTION

1.1. GENERAL INFORMATION ON JAMAICA

Jamaica is an island, one of the three biggest, in the Greater Antilles, which belongs to the Caribbean region. The total land area stretches over 10,991 km^2 with flat sections, coastal areas and also higher mountains in the interior (WIKI 2011). The general appearance of the island is seen in figure 1.1 for a first orientation.

Total population in Jamaica stand at some 2.8 million inhabitants. Roughly one third of the population is younger than 14 years. In the recent past population growth was no longer a problem, as the growth rate was reduced. In addition, there is a high rate of migration into neighbouring countries and industrialised states. Agriculture employs still the biggest share of the local workforce, but contributes only with 5% to the national income. Total Gross Domestic Product (GDP) was reported to be 4,172 USD in the year 2007 (WIKI 2011). Jamaica as a state shows one of the highest debt ratios in relation to GDP, debt service and financing projects are serious issues for the Government.

Traditionally Jamaica was an export country for agricultural products like sugar, rum and bananas. In recent history more income has been generated by the bauxite industry, where Jamaica is one of the leading producing countries, and the tourism sector. Export earnings are dominated by the bauxite industry, but since 2008 production in Jamaica has reduced and some operations have closed temporarily.

Import is dominated by petroleum products for all of the energy needs, machines and vehicles, other processed goods and food items.

Figure 1.1: Map of Jamaica



1.2. THE ENERGY SITUATION OF JAMAICA

The energy situation in Jamaica is determined by the import of liquid petroleum products for transport needs and for electricity generation. The level of consumption on average is some 60,000 barrels per day and accounts for nearly 90% of all energy demand. Jamaica´s total petroleum imports for the last 5 years are also shown in the annex under 11.6. The breakdown of the different primary energy supplies is shown in figure 1.2. Indigenous fossil resources are not contributing to the energy supply.

Figure 1.2: Primary Energy Supply Jamaica, 2009 (MEM 2009)

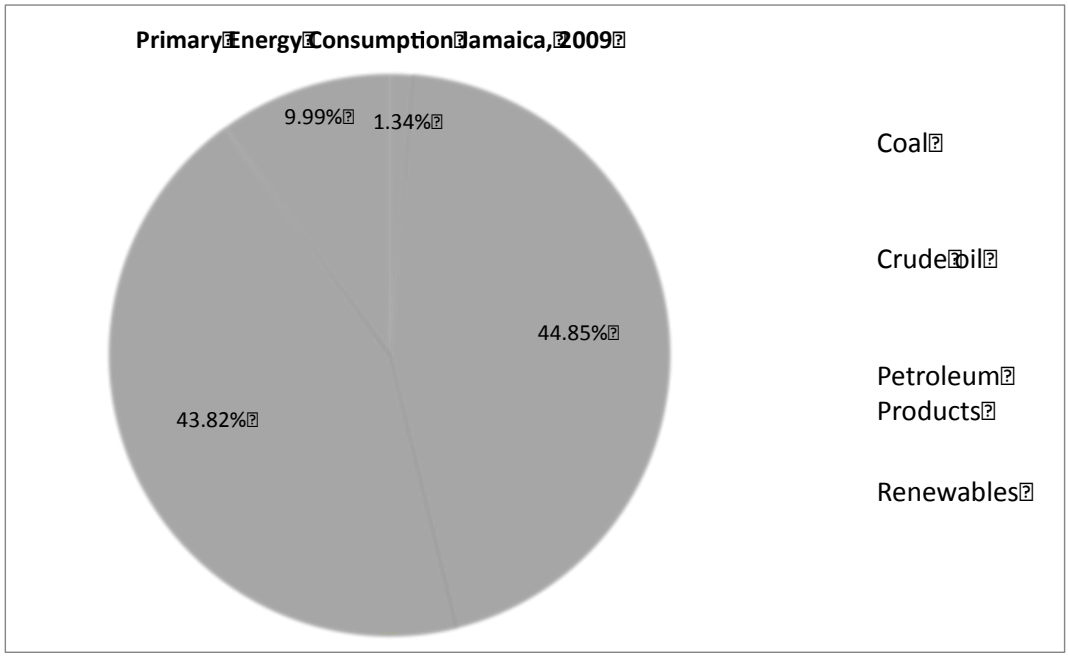
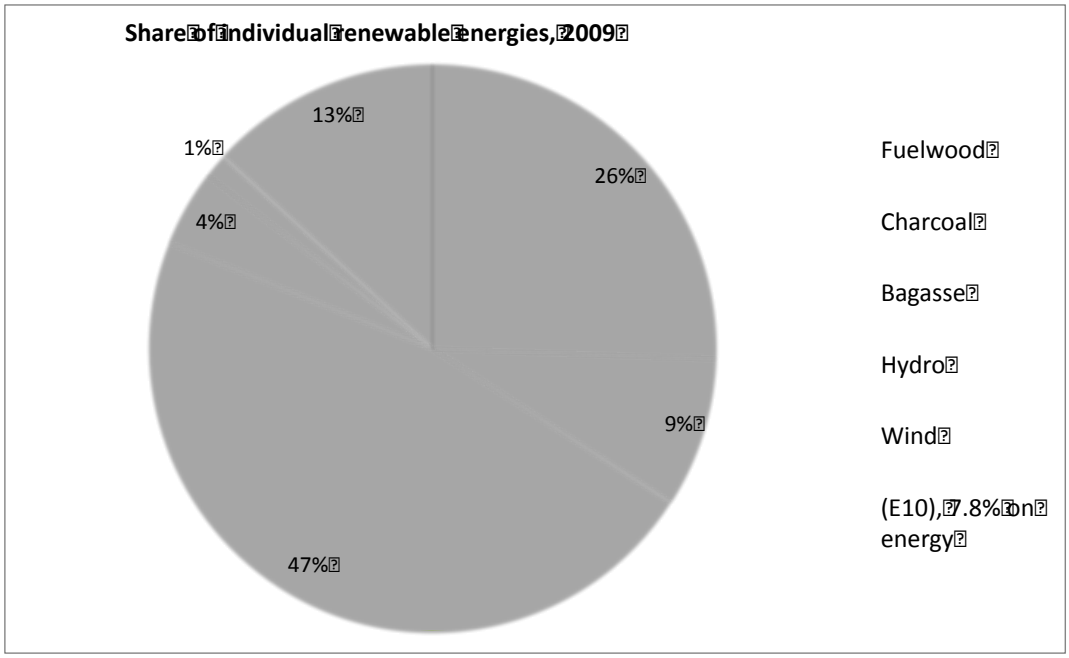


Figure 1.3: Breakdown of renewable energy (final), 2009 (MEM 2009)



Renewable energy is consumed in a traditional way as fuelwood and charcoal, mainly for cooking and small scale industrial applications. Together with the traditional use of bagasse in the sugar sector the share of renewable energy (traditional and modern) stands at some 9%

(MEM 2011). This also includes some hydropower and more recently wind power for electricity production. The distribution in between the renewable section (on final energy) is displayed as figure 1.3. Also transport fuels have a share of renewables, because (imported) bioethanol is used as a 10% blend to gasoline.

Electricity is produced from petroleum products mainly by thermal power plants and through gas turbines using heavy fuel oil and diesel respectively. The provisional figures for electricity generation reveal a total of 4,140 GWh net production. Out of this 152 GWh are contributed by hydropower and another 1,346 GWh are produced by Independent Power Producers (IPP) on the island. The grid operator and largest producer of electricity is the Jamaica Public Service Corporation (JPS). The overall electricity production figures for the last five years are given in the annex 11.6 (from MEM 2011-3). There had been no radical changes in consumption over the last 5 years.

Total installed capacity for public electricity generation on the island reaches 857 MW. The breakdown of generating capacity is shown in table 1.1. There are additional industrial generation capacities, namely in the bauxite and sugar industry.

Table1.1: Composition of generating capacity

Generating body/class	Capacity	Capacity	unit
Total	857		MW
JPS fossil	612		MW
Oil fired steam		292	MW
Fuel oil / Diesel		40	MW
Combined cycle		114	MW
Gas turbine (Diesel)		166	MW
IPP fossil	184		MW
JEP		124	MW
JPPC		60	MW
Renewables	61		MW
Hydropower, JPS		22.3	MW
Wind		38.7	MW
Off grid production, e.g. bauxite, industry, backups		(200)	MW
Sugar companies, installed		(23.5)	MW

Source: (OUR 2010-2), slightly changed and updated

1.3. BACKGROUND FOR THIS STUDY

Bagasse, a by-product of sugar cane processing, has traditionally been used as a fuel in sugar factories providing steam and electricity for the sugar production process. It has also been deemed a waste product, to be used up at the end of the harvesting / crushing season so as not to cause a waste management problem. Consequently, actual efficiency in utilising bagasse is an issue, the technology employed shows low conversion ratios and the energy utilisation in the factory is suboptimal, leading eventually to excess energy demand for fossil fuels.

Using “modern” approaches the sugar sector can be seen as a net energy exporter if the principal surplus of bagasse can be converted to electricity and fed into the national grid. Once a modernised or refurbished power plant is in operation, more and other biomass fuels can be utilised in the off-season to produce electricity year-round. The conversion of molasses and possibly of the raw sugar juice into bio-ethanol offers more chances to increase renewable energy production and decrease the dependency from imported fossil fuels. However, ethanol production requires substantial process energy inputs (electricity and steam), which should be provided by the infrastructure of an existing sugar factory. This can be facilitated by sugar

factories with a certain degree of flexibility, which are both integrated energy and material producers (so called bio-refineries).

In the context of this assignment, the sugar industry is a vital component of Jamaica's economy providing USD 75 million annual foreign exchange earnings and employment of up to 38,000 persons. The potential of the sugar sector however remains untapped. Between 1998 and 2008, Jamaica depended on imported oil for more than 90% of its energy sources. The rapid increase in the price of oil in recent years has created an impetus to utilise the sugar sector in a way that can help Jamaica contribute to its own long term energy objectives. This would also increase employment opportunities, strengthen rural development and enhance the environmental and macro-economic situation.

This process, whilst beneficial, will be a paradigm shift in the traditional sugar industry of Jamaica. Therefore there is an apparent need to conduct a feasibility study to develop a framework for the development of biomass in Jamaica in line with the above.

The following specific objectives were set out for this mission:

- The state of the sugar industry is analysed, evaluated and reported (in terms of the energy situation);
- The potential for biomass resources from sugar activities is assessed (bagasse and field rest);
- The potential for additional biomass feedstock for continuous operation year-round is assessed;
- A programme is designed for the development of biomass energy in Jamaica. Technical and economic conditions are evaluated and the framework conditions are monitored;
- A strategy is recommended for a short-term implementation. Long term plans for additional feedstock options are developed.

The total mission was divided in two parts, one stay in August to September, the second stay from November to December 2011. In preparation for the mission, the following activities were planned and /or conducted throughout the mission:

a) Preparation of mission, travel and mobilisation;
b) Collection and review of existing literature on biofuel and biomass energy development in Jamaica;
c) Initial meetings with Ministries (MoA, MEM, NEPA) and other stakeholders to introduce the programme including the EU and other donors;
d) Review of existing policies and regulations for renewable energy development and production (IPP and/or feed-in);
e) Visit of all seven sugar factories and assessment of energy situation;
f) Preliminary assessment of available biomass resources, waste and by-products;
g) Identification of potential energy crops;
h) Collection of basic agronomic data for traditional crops and energy crops;
i) Collection and assessment of conditions for transport, handling, processing and upgrading of possible biomass feedstock;
j) Compilation of available information and database for all relevant biomass resources for this study;
k) Development of initial figures for technical and economic feasibility;
l) Drafting of inception report;
m) Discussion of initial findings and recommendations;
n) Complimentary data collection on production figures, resources, qualities of potential fuels and refining of already processed data;
o) End of first country mission;
p) Planning of workshop and coordination;
q) Start of second country mission;
r) Counter-check and completion of data from first country mission;

s) Identification and assessment of capacities for institutions involved in R&D in biomass energy and energy crops;
t) Draft and discussion of a short-term strategy embodied in a long-term development approach;
u) Discussions with institutions and the private sector to form a common platform for biomass energy;
v) Conduct of workshop for presenting findings of the study;
w) Further discussion and meetings to adjust initial findings, incl. field trips for verification;
x) Final collection of necessary figures for the completion of the study, the assessment and the evaluations;
y) Draft of final report;
z) Final report after comments and adjustments.

The following specific questions and assessments will be relevant:

- What is the present energy situation in the sugar factories, are they self-sufficient for energy?
- What technological implications are in existence (in terms of turbine and boiler technology, pressure levels, conversion efficiencies)?
- Can the sugar process be more effective?
- Can the consumption figures be compared to international benchmarks, for example the net electricity export potential of 120 kWh/TC (TC = ton of cane production)?
- What are the conditions for feed-in or for IPP-regulations (independent power producers)?
- Is there enough potential from bagasse in the first instance?
- Cane field tests, e.g. can cane tops and trash be utilised?
- Are there other biomass based waste materials or by-products available?
- Is there a chance to produce energy crops (specifically grown for electricity production)?
- How can improvements or pilots be implemented and how can stakeholders be convinced?
- How should the political and regulatory framework be for a successful implementation?
- What is the financial and economic implication?
- Can the environmental impact be measured, also in connection with sustainable production and international climate change issues (CDM)?

During the first mission from 15th August 2011 through 30th of September 2011 interviews and site visits were conducted to collect the necessary data and information. During the second mission the key element was to conduct a seminar and a stakeholder evaluation. Also during the second mission from 21st November to 20th December 2011, figures and findings were updated and discussed to form the base for the final report and recommendations. An overview of activities, list of persons met and interviewed are provided in the annex 11.5.

2. REVIEW OF POLICIES, PREVIOUS PROJECTS AND LITERATURE

2.1. ENERGY POLICY IN JAMIACA

In order to assess the national energy policy in Jamaica, three main documents should be analysed - the general energy policy, the renewable energy policy and the biofuel policy. All three policies are documented in publications and are in different states of official legislation. These documents are summarised below. The use of bagasse and the term cogeneration appears in few of the policies.

2.1.1. National ~~general~~ energy policy

The main objective of the general energy policy (MEM 2010-1) is to move Jamaica away from petroleum products, which now constitute 95 per cent of all energy demand. There should be a shift towards renewable energy, using natural gas and eventually coal in electricity generation and employ other forms of energy. Several areas are covered and analysed in the document with an emphasis on the security of supply, on the necessary infrastructure development, the chances for renewable energy, the need for conservation and efficiency and the necessity for a comprehensive policy and regulatory framework. The policy outlines the role of Government institutions as the leaders for energy management and eco-efficiency in industry. The general energy policy employs five sub-policies, which are Renewable Energy (RE), Energy-from-waste, Biofuels, Trading of Carbon Credits, Energy Conservation and Efficiency. Another policy sub-area is foreseen for Electricity (coming in 2011). The renewable energy policy as the main policy in the context of this study is deemed important and outlines targets for renewable energy contribution in different timeframes:

- a share of nine per cent in 2009;
- 11 per cent in 2012;
- 12.5 per cent in 2015 and
- 20 per cent in 2030.

As part of the efforts to reach these targets, more instruments as compared to existing ones are proposed such as net metering and wheeling (generation at one location, transport through the grid and consumption at another location). These measures should increase the willingness by individuals to invest in and utilise renewable energy.

2.1.2. National renewable energy policy

The national renewable energy policy formulates a strategy for the years 2009 to 2030 (MEM 2010-2). The main issue is diversity in renewable energy sources for increased energy security and sustainability. The target is set for 20 per cent contribution of renewables in 2030, an increase from the current level of nine per cent. The policy paper gives information and explanations of goals, objectives and planned activities.

In the short term the potential of energy from waste is assessed with a target of 1.3 million tons per year, which could be used for energy. Two proposals for a waste incineration and waste-to-energy plant are described with 45 MW and 20 MW installed electrical capacity, respectively. Biodiesel production is also proposed based on sources like jatropha and castor bean. Long term goals are not specified in this document nor are the specific RE resources to be used. However, a short term goal of 12 per cent RE is proposed for 2016.

Incentives such as reduced import tax and duties, higher depreciation allowance and tax credits for enabling the investment in RE are discussed. Further development of key components of the regulatory framework (net metering, grid connection etc.) are seen as a prerequisite for implementation of an effective policy. In addition to the more technical aspect of the renewable

energy policy other important components for a successful implementation such as consumer awareness, training programmes, research & development, implementation of best practises and benchmarking are included.

2.1.3. National biofuel policy

The last paper in the series is the national biofuel policy, covering the period from 2010 to 2030 (MEM 2010-3). It focuses on building a modern, efficient and diversified biofuel production for long-term energy security. The agricultural sector, especially the sugar industry, is the main instrument in achieving these goals through biomass-to-electricity generation, liquid biofuel production, cogeneration and biogas production.

The main prospects are seen for bioethanol produced locally from the sugar sector. A production target of 3.3 million tons of sugarcane (TC) per year is set which will increase also molasses production as one by-product. This is meant to reduce imports (mainly for rum production) as well as enable the production of 70 million litres of bioethanol. That target requires some 43,000 ha altogether of agricultural land. A SWOT[3] analysis reveals that land (idle land is available), water use and food security are not an obstacle to achieving these goals.

For cogeneration a potential of 220 to 300 GWh of electricity production per year based on up to 94 MW installed capacities is reported (from different studies). Given, that both cogeneration and bioethanol production will be relying on the same sugar cane resources, it is important to connect bioethanol production with cogeneration. Part of this policy will require a change in the price system for harvesting sugar cane and bagasse to facilitate the expanded function of cane in addition to sugar production alone. Recommendations are made for general improvement in the field operations including an end to cane burning, introduction of energy cane and a general improvement of irrigation systems, mechanisation and road systems. Another critical recommendation is to build capacity at the Sugar Industrial Research Institute (SIRI) to facilitate that proposed change.

Other topics covered in this document are general policy formulations, which include net metering, wheeling, tax credits and changes through the CDM mechanism. In terms of biofuel, no regulation for the local market and no incentive for local production of bioethanol is foreseen (E10 is imported at world market conditions).

2.2. SUMMARY OF PREVIOUS PROJECTS AND REPORTS

2.2.1. Proposals for sugar industry and cogeneration

In Jamaica there are currently seven sugar factories in operation: Frome, Monymusk, Bernard Lodge (out of operation in actual season), Appleton, Worthy Park, Golden Grove (previously known as St. Thomas) and Everglades (Trelawny/Long Pond). During the last 20 years a number of initiatives were started to produce excess electricity in the sugar sector as a whole or at individual sugar mills. Some studies were taken to the financial feasibility stage and recommendations were given on how to proceed and transform the ideas into activities. Unfortunately, up to now none of the studies have led to an investment project. Some of the major studies are summarised and analysed herewith.

One of the newest reports was financed by OAS and conducted by Winrock Consultants. The main focus of this report was on liquid biofuels and land availability for possible expansion (OAS 2011). The Winrock Report provides an overview on the biomass resources, economics, risk and technology assessment for biofuels development in Jamaica. Several potential biomass crops are evaluated for either combustion or oil production. The report outlines broadly that

[3] *SWOT = Strength, Weakness, Opportunities, Threads*

there are sufficient resources in Jamaica, both natural resources and technological, to provide sufficient electricity for the demand in Jamaica. Furthermore, the report compares the previous output of the sugar industry in contrast to the lower output in recent years. In particular regarding the sugar industry this report provides a number of recommendations for increasing the overall productivity of sugar cane and how this can relate to revitalising this industry. Some more findings in brief:

- Land is available to expand sugar cane production by putting former cane land back into production;
- Sugar cane yields are low compared to world standards, steps are outlined to increase cane productivity;
- Alternative crops for ethanol production are proposed. Sorghum which can produce two crops per year and Cassava which is possible but may not be the ideal crop in Jamaica;
- Biodiesel is based on castor beans or jatropha as a possibility;
- Institutional requirements and research needs are examined (especially the role of CERE, SIRI and SRC);
- Market analysis suggests that a higher feed-in tariff is needed, avoided fuel cost and dispatch should be updated to take the actual situation into account;
- Market in Jamaica exists for one large ethanol plant;
- Biodiesel production would require a large investment and is hindered by lack of an existing market or supporting infrastructure;
- Overview is given on processing for bioethanol and biodiesel including second generation technologies (enzymatic process, Fischer-Tropsch synthesis and use of algae as alternatives).

One of the more recent reports has analysed the situation under the aspect of falling world market sugar prices and the chances for indigenous bioethanol production coupled with an efficiency increase at the factories (MUKHERJI 2005). The recommendations are based on rising petrol costs and lowering sugar prices. There is a favourite option for importing refined sugar and molasses for rum and converting as much as possible to ethanol. Comparing this report from 2005 with today, the economic conditions outlined in this report are significantly different in the current market - sugar prices are higher and the market for bioethanol has cooled down. Some assumption for bioethanol production (highest cost is energy but this is free from cogeneration) might be challenged as the highest cost for bioethanol is raw material, followed by energy costs, which are much lower. One main question discussed was, whether Jamaica could produce at world-market conditions, either sugar or bioethanol. Some other key findings from the report are based on a technical evaluation and thus have more general character:

- Feedstock is available for off-season cogeneration from fuelwood plantations;
- An additional 20,000 ha should be developed for fuelwood plantations;
- Cogeneration should be considered in five factories – a total installed capacity of 91.5 MW, with export to the grid consisting of 56.3 MW and with a production of 445,328 MWh (equivalent to a full load of 7,919 hours);
- Vinasse is recommended only for compost or drying, not for biogas production;
- Quick calculation on the conversion process reveals reasonable figures;
- The report offers lots of financial figures for four different options consisting of ethanol and cogeneration;
- Cogeneration is considered in a new power plant, condensing-extraction turbine, 1.5 bar level to sugar and ethanol process plus eight bar for new sugar process, thermodynamics seem reasonable;
- The report is doing its own calculation of avoided costs for grid electricity;
- The report presents many tables and figures including energy and steam balances;
- The annex contains a proposal for a sugar refinery (remelting and crystallisation).

In 2003, a study was commissioned by the Sugar Corporation of Jamaica (SCJ) meant as a pre-feasibility study for the Frome sugar factory (GIBSON 2003). The Frome sugar factory was

analysed on its operational details and customised options for a new cogeneration unit attached to the mill were presented with the following details:

- Actual specific energy demand is given with 0.69 t steam per TC and 12.77 kWh/TC;
- Any cogeneration project needs energy efficiency improvement at the mill to reduce energy demand and increase the potential of power export to the national grid;
- New cogeneration is technically possible with steam parameters of 65 bar and 510 °C;
- An option is proposed to replace steam driven mills with electrical motors, this reduces steam demand but increases electricity consumption;
- For electricity generation during out of the cane crushing season, short rotation forestry and coal can be used. Scenarios with varying wood to coal proportions are given based on prices and harvested volumes;
- Investment cost for the complete power plant are estimated at 1,590 USD/kW (at 2003 prices);
- Economic analysis is provided for several scenarios with a payback time of five years;
- For economic analysis a feed-in tariff of 6.5 USct/kWh is used, an interest rate of 6.5 percent on 100 percent external capital is given and savings of roughly 1.5 million USD through avoided fuel cost and O&M for the old powerhouse are accounted for in the balance sheets.

An elder study was prepared by a consortium of engineers for the sugar mill Monymusk (RONCO/BECHTEL 1986) evaluating the cogeneration option as well. This included:

- Detailed analysis and planning for cogeneration and improved sugar production;
- Export of 35 MW off-season and 21 MW in-season;
- IPP concept for a new power plant (exchanging bagasse for steam and electricity);
- Field trash is estimated with 24 per cent of harvested cane (TC), material is dried and baled (10 per cent collected of total potential);
- Another 25 per cent on Calorific Value Base is supplied from fuel oil;
- Figures based on expansion of sugar operations;
- An extensive review of technical detail for equipment and a literature overview;
- Financial and economic calculations;
- The necessary feed-in tariff is slightly higher than avoided cost.

A further set of documents was reviewed. Some of these reports were quite outdated, but some also offered an insight into the Jamaican situation under a historical review. The production of energy cane and use of different biomass resources (grass type) was reviewed (BINGER 1982). Some useful technical information could be collected for a presentation on the sugar industry in Jamaica (REECE 2004). The recent development and the divestment process in Jamaica is explained (CALLAGHAN 2010). Another paper (TENPAGER 2011) focused mainly on discussing environmental concerns, including the impact on soil, water (1500 to 3000 L of irrigation water for one kg sugar), air (field burning and boilers) and biodiversity. A case study on Frome (estimated to be after 2008), stopped field burning and NEPA did an environmental assessment in 2008. There was a further focus on ethanol production, with three scenarios - one of which was formulated as a proposal (more land to sugar and bioethanol, but more biodiversity, socioeconomic development etc. necessary). There was a seminar on biofuel providing an overview on different biodiesel options (Biofuel Seminar in 2007).

2.2.2. Biomass production and availability

A trial of tree plantation species is described in the Font Hill report (PCJ 2000). This report provides the basis for initial investigation into developing a forestry industry in Jamaica for the purposes of providing a renewable fibre and fuel wood resource. Carried out by the Petroleum Corporation of Jamaica, five woody species were evaluated over a five year period and included growth, form, ecological and economic analyses. Based on this report, *Leucaena leucocephala* stood out as a promising species for cultivation of fuel wood based on a cross section of favourable results. Assuming that the performance at the Font Hill plantation can be replicated, *Leucaena* can be expected to produce over 23 tons of wood per hectare per year in a five year

rotation. The high degree of single stem trees and nearly 95 per cent survival rate is favourable for forestry operations. The *Leucaena* was used in a subsequent combustion test at the Frome factory.

A summary of the 2004 test of woodchips as a fuel source at the Frome sugar factory is given (OSBOURNE 2004). While the trial was subject to a number of technical problems that prevented carrying out all of the initial goals there was sufficient promise in the results obtained to suggest that woodchips could effectively be used as a fuel source at Frome. The *Leucaena* used in the test has a higher fuel value than bagasse, mainly because of the 35 to 40 per cent moisture content compared to the 50 per cent moisture content of bagasse. It was also found that wood chips could be fed into the boiler using the existing bagasse handling equipment. Given the favourable results obtained and the ability to use existing equipment, the use of wood biomass to supplement bagasse burning at Frome and other sugar factories may be a practical option to increase the availability of a domestic fuel source.

A biomass assessment was performed in the early 1990's (POPOTSINGH 1992). The methodology followed the classical approach and the report estimated the production of 36,000 t charcoal and 12.000 t fuelwood per year. Biogas at that time employed 38 plants on animal dung. At Bernard Lodge sugar factory charcoal briquettes from sugar cane rind (commercial production) were tried. One sawdust pellet plant (selling pellets to sugar industry) should have been in operation. Principal agricultural residues besides the above mentioned resources are citrus (used on-farm, for cattle feed, no additional potential), coconut (inner husks used for baking and other energy demand, green coconut husk have no use), banana (better for fertiliser and mulch instead for energy). A study in 1984 for Monymusk is mentioned for the production of energy cane and the storage of field residues for off-season. The then operating company ENERPLAN introduced a process using field residues (baling on the field) with up to 80 t/ha of biomass potential. The GTZ cane separation process was commercialised at Bernard Lodge. Further use of forestry residues was seen to be critical as only additional plantations and SRF (short rotation forestry) could deliver substantial amounts of biomass.

2.2.3. General energy related issues

An assessment of all renewable energy sources in Jamaica as part of a regional exercise was performed in 2005 (LOY 2005). The summary of the findings and some relevant figures are given below:

- An overview of renewable energy potential is given including: wind (several 20 MW of generators) and hydropower (additional potential limited);
- The largest potential is in the sugar industry (600,000 t bagasse could produce 220 GWh, this could be 300,000 GWh if the production area is increased);
- JPS generation costs are 7 USct/kWh (3 for O&M and 4 for fuel cost), IPPs are generating at a cost of 11.5 and 11.0 USct/kWh. Residential cost for the unit is on average 20 USct/kWh;
- Available waste resources are approximately 680,000 t per year with 65 per cent organic content;
- Biogas potential is limited;
- Solar radiation shows a value of 4.8 kWh/m^{2}day on yearly average;
- Biggest petroleum demand is in the bauxite industry (for self-generation of electricity), followed by public power production and transport;
- Grid expansion is targeted for 95 per cent of residents, 6000 houses have no grid access;
- Jamaica´s energy policy is based on a report from 1995;
- Previous experience with cogeneration was not ideal as a number of restrictive conditions were set and the potential capacity was very low;
- Below 15 MW installed capacity there is no tender necessary for IPP, below 2 MW it follows a standard procedure, no impact on LCEP (least cost expansion plan) is seen;

- Wind measurements on Manchester plateau indicate an average wind speed of 6.3 m/s at 40 m height;
- Hydropower is limited in size and year-round capacity (max 23.8 MW at present). Further technical potential of 80 MW is possible at one site but economics are not favourable;
- Available biomass is primarily sugar cane with woody biomass the next-most abundant resource;
- Wood production on plantations is possible with 90 t/ha fresh product at 8.9 USD/t and at a factory gate of 15 USD/t;
- Possible bioethanol production depends on local market and blending procedure and on the impact of the CBI (Caribbean Basin Initiative, which allows dehydration of imported hydrous ethanol in Jamaica for the US market at preferred conditions);
- Fuelwood is utilised for the local production of 37,000 t of charcoal plus some demand from industry;
- Forest cover is 30 per cent of the island or 325,000 ha under forest with demand matching supply;
- Estimated 50,000 ha are needed for sustainable charcoal and fuelwood production;
- Font hill plantation trial shows no economic return as a plantation business;
- Potential for waste is seen in landfilling and subsequent production of biogas as an energy carrier and for possible CDM-project;
- Total generation of 950,000 t waste, out of which 680,000 t is by MSW, transported to landfill, some 40 per cent of MSW is yard waste (biological) plus another food waste fraction;
- Biogas from liquid waste has potential from sewage treatment, individual septic tanks (SRC) and few agricultural plants (150 plants built or assessed by GTZ), rest of biogas potential is unknown;
- Solar and other Renewable Energy: good and high solar potential. Only 5,000 SWH (solar water heaters) installed, potential in the hotel sector. PV (photovoltaic) only in pilot installation of small off-grid systems. Better effect expected after introduction of net metering and in high income households;
- Carbon market figures are based on out-dated information;
- Proposals and recommendations in the study: for the sugar industry involvement of ESCOs or IPP for additional power production including the creation of a one-stop entity for reduced interest rates, soft loans, tax rebates and import tax reductions;
- Feed-in tariff should be based on prospective avoided costs, i.e. displaced power plants with their actual costs, not on the least cost principle. Rates should be fixed for 10 years and allowing for inflation, exchange rate changes (changing fossil fuel prices).

A similar study as described above was also performed on a regional level for energy efficiency (BINGER 2011). Three areas had been intensively analysed for energy efficiency improvements. These were the electricity generation by JPS, energy demand by bauxite and other industry and the high energy demand of the Water Commission. Generally, the main problems are high petrol usage in all sectors, a high energy demand per capita or per GDP, outdated power plants and only few incentives for efficient energy use. Some programmes in the past included assistance by USAID for energy audits in industry and commerce, a DSM programme for households and the commercial sector. There was also GEF financing and IDB funding for energy efficiency measures in the public sector. Actually customers can approach the Energy Fund which is administered by the Development Bank of Jamaica. The conditions are set at 10 per cent interest rate for seven years fixed.

The study further on gives an overview of different sectors (figures not consistent), laws and rules. A long list of recommendations and planned activities is provided. Net metering is favoured instead of net billing (as the procedure up to now). Combined Cycle power production and cogeneration should be used for electricity generation, also an increase of distributed generation incl. renewables should be envisaged. The different DSM measures could be

revitalised. On the account of JPS the technical and non-technical losses need to be addressed as soon as possible.

A World Bank paper analysed the conducted DSM-measures (WB 2006). The introduction of CFL (compact fluorescent lights) was mostly successful and there was some success for SWH (solar water heaters) in residential areas. No success in industry was reported for the DSM. Since JPS was privatised in the meanwhile, they are no longer a proponent of DSM.

A general description of renewable energies is given in a new book (WRIGHT 2010), but it is not very specific to Jamaica. Biomass is also analysed very generally, but it is stated that there is a need for a revised FIT and restructuring the avoided cost calculation.

2.3. LITERATURE OVERVIEW ON OTHER RELEVANT SUBJECTS

2.3.1. Increasing the sugar cane biomass availability and higher fibre yields

Sugar cane production has long used bagasse to fuel a portion of their power needs. At the time when this practice began oil prices were relatively low and bagasse was viewed as a waste product. Thus, bagasse burning was designed to be an inefficient process purposed to eliminate bagasse piles. With the advent of increasing worldwide prices for fossil fuels and the desire to reduce their use for environmental and security reasons there is growing desire to increase the use of bagasse for efficient power generation. Additionally, there is a desire to increase the production of fibre in order to allow generation of power in excess of sugar production needs and to provide that excess power to energy grids. Bagasse is usually obtained at 50 per cent moisture. Cane trash upon harvest is also obtained at 50 per cent moisture but can be field dried by the sun to 15 per cent over the course of two weeks (LARSON 2001).

Several studies have been conducted worldwide to increase the use of sugar cane fibre (FULMER 1991; HASSHUANI 2005; LARSON 2001; MACEDO 2001; PANKHURST 2005; Sugar Industry Research Institute, personal communication). These approaches include increasing the collection of available fibre as well as developing varieties of sugar cane that produce more fibre without reducing the yield of sugar. One of the obvious ways to increase collection of sugar cane fibre is to harvest the leaves and unused tops of the sugar cane plant. A long tradition in harvesting sugar cane calls for burning the stalks in the field pre-harvest to reduce the amount of leaves adhering to the cane stalk. In addition, the top third or so of the sugar cane stalk is removed and left in the field as it has a low sugar concentration.

The study done in 2005 mainly focuses on the effect of burning trash or alternatively its effect on soil and nutritional status if not burnt (HASSUANI 2005). The following summary can be given:

- In most sugar cane growing countries the practice of burning cane fields has been banned for environmental concerns;
- It evaluated the effects of leaving 100, 66, 33 and zero per cent of available cane trash on the field over a three-year period;
- Green cane is much more difficult to harvest manually and can also be problematic for mechanical harvesting in very high yielding stands;
- The results from this study suggested that the effect of local conditions such as cane variety, climate, pests, etc. were more important than the amount of trash left behind;
- The effect of cane yield from leaving trash on the field varied with location and environment with some stands experiencing an increased yield with cane trash remaining while others experienced no change or a decrease;
- The overall results suggest that cane trash harvest along with leaving a proportion of trash on the field can be an effective management tool that also supplies additional biomass for combustion but the situation for each location and environment needs to be evaluated individually.

Main points to be taken from another study (LARSON 2001) are:

- Harvesting the cane tops and leaves, collectively referred to as “cane trash” can present some technical challenges as well as increase field operational costs;
- The cane tops also represent a large potential biomass source.

For the situation in Australia the following results are of interest (PANKHURST 2005):

- A long term reduction in sugar cane productivity in Australia was linked to burning fields prior to cane harvest;
- Cane burning reduced soil fertility by removing organic matter that would otherwise be available for recycling in the soil;
- Study showed that retention of cane tops and leaves lead to improved soil fertility, increased sugar cane yield and an increase in soil organic matter.

2.3.2. Biomass production and dedicated energy crops

Biomass is typically obtained in a “wet” form. Drying improves the fuel value of biomass because it eliminates the need for the boiler to drive off the water in the material. Long term storage of biomass can present challenges. Firstly, biomass is bulky and has a much lower energy density than fossil fuels and thus takes up more room (OSBORNE 2004). Exposure to rain and wind can lower the quality of biomass as well as create a dust hazard. In addition, high moisture biomass (between 25 to 60 per cent moisture), such as bagasse, can spontaneously combust in storage due to the action of aerobic microorganisms which can generate large amounts of heat (HOBSON 2005; MACCASKILL 2011). Storage solutions for bagasse, which prevent degradation as well as reduce the likelihood of spontaneous combustion have been proposed and have been shown to be practical (HOBSON 2005; MACCASKILL 2011; WORMERSLEY 2010).

The use of dedicated energy crops is being pursued in many locations worldwide in an effort to replace fossil fuels, increase energy security and stimulate rural development. Energy crops can be used as plant oil sources for chemical and biodiesel production as well as a source of lignocellulose for direct combustion. As large-scale use of energy crops is still being developed there are many technical challenges that must be overcome (PERLACK 2011) including all phases of handling and logistics as well as production schemes in many cases.

One of the major concerns in implementing a biomass to energy program, aside from the cost, is the assurance of a steady supply chain. While woody biomass resources can often be harvested year-round, weather permitting, crops such as annual and perennial grasses often have discrete times during the year when they must be harvested (PERLACK 2011). This leads to harvesting, storage and delivery logistical issues that must be resolved (YU 2011).

In some cases a mixed crop approach has been proposed to insure that a continuous supply of biomass is available. In the southern USA, a rotation of sugar cane, energy cane, Miscanthus and sorghum is being researched (RICHARD 2011). In this scheme, a continuous supply is enabled by harvesting the various crops at different times of the year. This scheme is enabled, in part, by the use of common cultural practices and machinery. The mixed rotation allows for harvest of both sugar and cellulosic biomass and allows diversification of products.

More overview on the production of dedicated energy crops is given below.

A summary of the use of perennial energy grasses is found here (ATKINSON 2009):

- This UK study suggests that a sustainable, low-carbon technology for supplying energy demand can be met in part with perennial grasses such as Miscanthus;
- The success of such projects is dependent on developing an efficient supply chain;
- High density plantings are needed to maximise yield;

- The range of available germplasm and technology for propagating the rhizomes is a limiting factor;
- As Miscanthus must be established using rhizomes this results in high establishment costs;
- Miscanthus has the potential of high yields and low input requirements but establishment of the crop is slow and expensive. Three to four years is the typical time required from establishment to harvest. The crop will last for approximately 15 years;
- Harvesting equipment for hay and forage can be adapted to work with Miscanthus but is still in development in many areas.

This study gives an update of the major issues around perennial energy grasses (LANE 2010):

- Switchgrass is perennial and grows well on marginal and under-utilised lands, requires minimal input and can be harvested and handled using existing equipment;
- The crop's greatest potential is the amount of biomass it can produce, yield per acre is between 8 and 10 tons without improvements in the varieties under optimal conditions;
- Land-use patterns will need to change to accommodate the widespread growth of dedicated energy crops;
- Work also needs to be done to determine where each crop would grow best;
- Getting farmers engaged in the supply chain and growing those crops isn't easy because the demand for the crop is not clear, it represents a change from existing cultural practices and the prices for the material have not been established;
- In order to plant on a large scale, the correct seed varieties and plant materials need to be available making aggressive breeding programs essential.

Perennial forage grasses are being considered as bioenergy crops in this paper (SANDERSON 2008):

- An advantage of using forages as bioenergy crops is that farmers are familiar with their management and already have the capacity to grow, harvest, store, and transport them;
- Forage crops offer additional flexibility in management because they can be used for biomass or forage and the land can be returned to other uses or put into crop rotation;
- Perennial biomass crops require fewer inputs, produce more energy, and reduce Greenhouse Gas (GHG) emissions more than annual cropping systems;
- The attributes of switchgrass desirable for bioenergy cropping include its demonstrated high productivity across many environments, suitability for marginal and erosive land, relatively low water and nutrient requirements, and positive environmental benefits;
- As potential disadvantages, switchgrass can be slow to establish, and productive stands often take two years to develop;
- Compared with other crop species, switchgrass has received relatively little plant breeding attention and most cultivars of this species are not far removed from native germplasm;
- The primary use of Miscanthus biomass is envisioned principally as a feedstock in combustion steam generating electrical plants;
- A drawback to Miscanthus use is that it must be established and propagated vegetatively via rhizome cuttings, which delays full production until the second or third year and also requires irrigation and energy inputs during greenhouse propagation;
- A virtual comparison of Miscanthus production in Europe with switchgrass production in North America speculated that Miscanthus could produce twice as much biomass as switchgrass;
- Difficulties in stand establishment are often related to poor seed quality, improper planting depth, poor seedbed preparation, lack of weed control, and variable soil and weather conditions;
- Time of harvest also affects feedstock quality. In direct combustion systems, minerals in biomass can corrode and foul boilers;
- The ash concentration of switchgrass decreases as it matures leading to improved utility for conversion and potentially lower nitrogen requirements with a fall vs. summer harvest;

- Delaying biomass harvest from fall to spring reduces mineral and water concentration of perennial forage grasses, but may also reduce yields.

This gives a summary of short-rotation woody crops for bioenergy and biofuels applications (HINCHEE 2009):

- The economic feasibility of utilising tree biomass is improved by increasing productivity through alternative silvio-cultural systems, improved breeding and biotechnology;
- For systems in which thermochemical or gasification approaches are utilised, increased density will be an important trait, while increased lignin might be a desired trait for direct firing or co-firing of wood for energy;
- It is expected that short-rotation woody crops, such as fast growing species Populus, Salix, and Eucalyptus and their respective hybrids, will be planted as purpose-grown wood on sites that enable high productivity and proximity to the processing plant;
- Short-rotation, purpose-grown trees have a variety of inherent logistical benefits and economic advantages relative to other lignocellulosic energy crops;
- Trees can typically be harvested year-round and continue growing year after year providing a “living inventory” of available biomass;
- Trees have reduced storage and inventory holding costs and can minimsze shrinkage or degradation losses typically associated with storage of annually-harvested biomass;
- Short-rotation coppicing of hardwoods offers the promise to produce biomass for bioenergy;
- It is clear that to achieve the productivity gains required for tree biofuel and bioenergy applications, a significant research effort is needed for improving tree genetics and Silvio-cultural practices.

A new hybrid grass with very high yields for tropical environments is analysed and described (KUKKONEN 2009):

- Giant King Grass is a hybrid with napier grass that is suited to tropical and subtropical areas and has wide adaptability;
- Very high productivity, up to 350 tonnes per hectare, with low input requirements and good tolerance for stress;
- Giant King Grass is being tested in China and some tropical locations in commercial settings to determine its suitability as a bioenergy crop.

The use of sorghum and energy cane as dedicated energy crops is reviewed (MCCHUTCHEN 2008):

- Dedicated energy crops are highly suitable for areas with abundant sunlight and longer growing seasons;
- Economically viable bioenergy-production facilities will require the appropriate selection of crops to ensure year-round availability of feedstock tailored to local climatic, biotic, and soil stresses;
- Production and management systems must be developed and tailored to each crop and each climatic region to ensure optimal biomass yields. These actions will require a coordinated effort focused on the development of multiple crop-production systems;
- Sorghum offers considerable potential as a dedicated lignocellulosic biomass crop as it has high productivity, low input requirements and a great deal of diversity in the genus that can be used for future improvement;
- Photoperiod-sensitive sorghum will facilitate full-season production of biomass, and have yields in the range of 15 dry tons per ha and even greater yields are anticipated under optimum conditions;
- Sorghum is of particular interest because it is the only annual, high-tonnage dedicated energy crop with the potential for being produced on large acreages, and it already has an existing agronomic (e.g. seed) infrastructure;
- Sugarcane, particularly the high-tonnage varieties (i.e. energy cane), offers great potential as a bioenergy crop;

- Commercially grown varieties can produce up to 40 dry tons per acre under optimal conditions. Biomass productivity probably could be increased even more if sucrose accumulation were no longer a constraint on breeding programmes;
- Several other grass species have the potential to produce exceptional biomass yields, including Arundo, Miscanthus, and Miscanthus crossed with sugarcane hybrids, known as Miscane;
- The seasonal diversity of biomass production that these species afford may play an important role in ensuring year-round production of feedstock supplies.
- The development of sorghum, energy cane, and other biomass crops may require changes in land-use management but should include rotational cropping systems. Research is requisite for identifying which of these species will perform best in each climatic region;
- Target prices for energy crops should be in the range of 30 USD to 40 USD per dry (short) ton, to hold down the cost of biofuels. However, the production costs for dedicated energy crops range from 50 USD to 100 USD and more per dry (short) ton. The keys to reducing delivered cost will be high-tonnage crops and highly efficient production systems, but commercial quantities of biomass at rates lower than 50 USD per dry ton will be difficult.

2.3.3. Process improvements in the sugar production

Another way to increase the availability of biomass for energy is to improve the situation at the sugar mill either in producing more bagasse or by increasing the quality of bagasse. Quality as a fuel is basically dominated by ash and moisture content (besides particle size, density, ash melting point etc.). The biggest potential for increasing the energy situation is seen in the reduction of the moisture content of bagasse, which in a fresh state is more than 50%. Drying of bagasse would reduce its moisture content and ultimately increase fuel value. There are bagasse drying schemes and proposals for applications in the sugar industry. A short review is given here. A German supplier has a design ready for a flash drier for bagasse using the waste heat after the boiler. With 50% moisture of the bagasse as input it can be dried to 25% moisture at the end. A calculation for a medium sized sugar factory reduces bagasse input from 40 t/h down to 34 t/h after drying bagasse (TPET 2011). An adaptation of a roller type tube drier was designed to reduce moisture content from 59% to 40% (GOODRICH 2011). Above two types of driers had been indirect driers (no contact between flue gas and wet bagasse). The direct method (counter-flow of bagasse and hot flue gas) reduces investment cost. According to one supplier a reduction of moisture content by 5% is easily achieved. A final moisture content of 25% is also possible if flue gases are hotter at the entry and with some more sophisticated equipment. An overview is given for different bagasse drying methods in Brazil (SOSA 2004). The main conclusion is that with flue gas, realistically a reduction of moisture content from 50% down to 40% is achievable. There are different technological solutions possible with advantages and disadvantages (rotary driers, flash driers, drum type dryers).

The only way for bagasse drying is using the enthalpy of the flue gas. For high efficiency boilers the technological setup includes economisers and probably air-preheaters in the flue gas way. These measures cool down the flue gas after combustion and before entering the chimney. Thus, in a highly efficient boiler less energy is available for eventually bagasse drying. Direct methods have the main risk of ignition of the bagasse, if small spots are getting rapidly dried up. Indirect methods increase the investment costs and reduce the heat transfer. All of above lead to a situation where either the drying effect is only minimal (a few per cent) or the drier design is quite large and sophisticated. This might be the reason that pre-drying of bagasse is hardly a standard procedure in international sugar production.

3. PRESENT STATUS OF THE SUGAR SECTOR

3.1. SUGAR AND BYPRODUCT PRODUCTION OVERVIEW

In the past Jamaica has been the largest sugar producer in the world. However, in recent history the production of sugar in Jamaica has declined and other countries have expanded sugar production extensively. During the seventies Jamaica produced some 3.5 million TC (ton cane) per year on some 50,000 ha of sugar cane land. In the last ten years production slowed down to a minimum of 1.3 million TC on less than 30,000 ha. Since 2008, the year of food and energy price hikes, the production is increasing slowly to levels of 1.5 million TC. For 2011/12 it is expected, that some 1.8 Million TC could be harvested. The area under cultivation also increased again to some 35,000 ha. Up to now it is still not foreseeable, whether and when the level of production of the seventies would again be reached. The actual production figures for the last 7 resp. 8 seasons are given in table 3.1.

Table 3.1: Production figures for the sector, 2004 to 2011

Season	Cane, t/y	Area, ha	Sugar, t/y	Molasses, t/y	% Sugar	% Molasses
2011/12						
2010/11	1,512,084	n.a.	139,641	n.a.	9.24%	n.a.
2009/10	1,395,786	33,666	121,811	n.a.	8.73%	n.a.
2008/09	1,334,600	26,200	121,500	57,679	9.10%	4.32%
2007/08	1,752,000	29,900	140,900	62,900	8.04%	3.59%
2006/07	1,968,000	30,800	159,400	79,700	8.10%	4.05%
2005/06	1,745,300	30,000	142,300	74,500	8.15%	4.27%
2004/05	1,368,700	27,600	120,300	60,400	8.79%	4.41%

Sources: TRANSTEC 2011, SIA 2011-1, SIA 2011-2

In the last few years between 120,000 and 160,000 tonnes of commercial sugar (raw unrefined sugar) has been produced and mostly exported. Refined sugar in not produced on the island. The local demand for refined sugar is satisfied by imports. Another 60,000 to 80,000 t/a of molasses were available as a by-product. Actually all local molasses are absorbed by the rum industry. The local production satisfies the market only to 50%, the remainder is being imported from the neighbouring islands. This relative shortage of molasses is one reason for not considering a local bioethanol production (from molasses)[4].

3.2. THE PRIVATIZATION STRATEGY AND LINK TO AGRICULTURE AND FORESTRY

The sugar industry in Jamaica is faced with a major change. In essence the factories and the production of sugar will be fully privatised. The strategy is planned for the year 2022 and started in 2006. The whole plan is divided into certain steps (GOJ 2009, GOJ/EU 2008). The first step would be the transition period (planned for 2006 to 2009, which mainly includes the privatisation of the sugar mills) followed by the transformation period (2010 to 2015), which should increase competitiveness of the sector and solve some of the social issues related to sugar production and the rural economy. The last part of the process is called the consolidation phase (years 2016 to 2022), which should also diversify the sugar sector and build on long-term economic success. Included in this strategy papers are some technical issues like possible yield improvements, land use optimisation and a more efficient production (agricultural based in the

[4] *Also the raw sugar production is not large enough to consider a shift from raw sugar to bioethanol, as it is was proposed some years ago.*

first instance). The privatisation strategy, however, includes no specific energy targets or formulates future plans to include power production by the sector.

The main organisation dealing with all aspects of sugar in Jamaica is the Sugar Industrial Authority (SIA). Some information on its function and activities is taken from the relevant website (www.jamaicasugar.org). The SIA offers some historical background and updated information on the transformation process. The main drivers for relying on the sugar industry are the export earnings and the provision of local jobs throughout the value chain.

The annual report gives more background information (SIA 2011-12). The SIA sets the price for bagasse and sugar and announces the profit sharing on delivered tonnes of sugar. According to the latest information 62% of the profits are for the growers (either the estate or individual farmers) and 38% for manufacturer, i.e. the sugar mill. In the past, technical difficulties have hampered the factory operations. In Jamaica, the net crushing time represents only 57% of the theoretical crop season. A share of 23% is stoppage related to non-factory influences (field conditions and bad weather influence harvested volume etc.) whereby the factory stoppage reaches 20% of net time. Some 10% of the stops are related to technical problems. SIA announces and produces the statistics for all mills and the national picture (years 2008 and 2009 are available).

Attached to SIA is SIRI, the Sugar Industrial Research Institute. SIRI is more confined to produce the technical and agricultural data. Results from SIRI and their conducted research should benefit the whole industry. Both, SIA and SIRI are private organisations in principle and receive their funding through the sugar industry (and other third party finance).

Besides the self-organisation of the industry in the form of SIA and SIRI, the sugar sector also belongs to the portfolio of the Ministry of Agriculture, there are also some links to the Forestry Department (from www.moa.gov.jm and www.forestry.gov.jm). The rationale for the privatisation process is given through the report of an enquiry commission, which makes recommendations on the structure of the sugar industry (MOA 2010). For the further development of energy use from bagasse the idea developed is to incorporate a bagasse price component into the price formula for delivery of sugar cane to the factory. This should enhance producers to grow and deliver more fibres and not only try to maximise on sugar content. The method to calculate the feed-in tariff by OUR on the base of the avoided cost is generally accepted, but more transparency is demanded and the discussion should enable a higher premium for renewable energy. A clear biofuel policy on bioethanol especially touching the sugar industry is necessary. One of the problems in the Jamaican context is the distance to world market competiveness. The production costs are too high, the target should be around 12 USct/pound raw sugar, the average now in Jamaica is 37 USct/lb ranging from 20 USct/lb (private mill) to 75 USct/lb (small Government owned mill). An increase in yield would lessen the problem, both at the field and factory level, in addition a better use of byproducts would also improve the financial situation.

The immediate goal for agriculture is set for some 200,000 t sugar per year for local consumption and for the exports on the EU and US quota. The present production level must therefore be increased. This could be further enlarged to 300,000 t sugar per year including a sugar refinery and/or a local ethanol production from raw juice. For cogeneration it is clear that the price for produced electricity must be higher. It is also mentioned that a clear definition of cogeneration, the policy options and details of the power purchase agreements (PPA) and the avoided cost calculation must exist. Concerning the ethanol situation the evaluation is biased as the market for local ethanol is not secure or large. There are also some legal matters to clarify including the price sharing formula between farmer and factory. For example, to enhance export power production, bagasse can attract an extra payment, e.g. in Mauritius 3 to 4 USD/t is paid[5].

[5] *for 1995 already in Mauritius a price of 3.7 USD/t was paid for bagasse other than for sugar production (DEEPCHAND 2005). Inflated this would be some 5 USD/t nowadays.*

3.3. SITUATION IN THE INDIVIDUAL SUGAR MILLS

The starting point for the analysis is the actual situation at the sugar mills. Any opportunity for excess power production or by-product utilisation must fit into the production specifics of the sugar sector. As shown in chapter 2, there have been numerous attempts to improve the energy situation at the sugar mills and to export power to the grid. Some of these studies and proposals offer good indications for further development of the sector. In several cases, some figures are out-dated and some external factors have changed in looking into the previous reports. The major impetus now is due to the privatisation of the industry, which should enable a new insight and induce fresh capital into the sector. Two other factors are equally important: the prices for raw sugar are quite high driven by high demand (other people argue: and by some speculation or by the biofuel policy of certain countries) and the price for fossil energy is also still on a very high level after peaking in 2008. Based on this, the situation in the individual mills was once again analysed and summarised as a necessary input into the further assessments in the following chapters.

3.3.1. Golden Grove

The sugar factory Golden Grove was visited on 22th August 2011. Formerly and before privatisation this factory was known as St. Thomas.

The production level at the moment stays at 180,000 tons of cane (TC) per year. The crushing season stretches from January to June. The last season was 179 days, but in an ideal case only 150 days should be needed. The long-term target is to reach 300,000 TC per year through higher productivity mainly and to a lesser extent through expansion of the planting area. Actually the land area under cultivation is 2,700 ha (TRANSTEC 2011-2). Around 60% to 70% of the crop is harvested on own lands or under own management. The remaining cane is produced by 180 farmers in that area. Actual installed capacity should be at 65 TCPH (ton cane per hour). Envisaged is a capacity of 80 to 85 TCPH in the future.

The energy supply for the mill shows the following characteristic: A total of 4 boilers each 30,000 lb/h steam capacity at 180 psi (12.4 bar) are installed, generating on average 80,000 to 90,000 lb/h steam (36 to 40 t/h). Steam is used by two primary drives and one backpressure turbine with 1.5 MW electrical capacity. During the crushing season several problems occur with supply of cane and with technical difficulties at the mill, resulting in downtime of the mill and a mismatch between energy production and demand. This effects the theoretical self-sufficiency on energy of the mill based on bagasse alone und makes additional energy production or supply necessary. Diesel generator sets (total 1.9 MW) are installed to contribute to the total demand of the complex, which stands at 2.3 MW. Electricity is also purchased from JPS from time to time. During the last season 2010/11 the bill for external electricity totalled 74 mill. JD, in the crushing season 12 mill. JD per month and out of the season 1 mill. JD/month (at 29.09 JD/kWh average). Diesel is purchased for farm operations and for the generator sets. The estimation for diesel consumption at the generators gave 190,000 L for the last season. Bagasse is fired with 49.5% moisture content. Roughly 30% of the milled cane is bagasse, which is totally consumed during the season (some surplus of 200 to 2,000 t at the end of the season). Wood is bought as a start-up fuel in quantities of 400 to 500 t at a price of 1,000 JD/t (on-site) or for 1,200 JD/t delivered to the mill.

Harvesting practise is dominated by burning cane and manual harvest (some 8% of the crop by mechanical harvester). An incentive is paid (5% higher price) for delivery of green cane (not burnt on the field prior to harvest), but only 5% of total production is based on green cane harvest.

The sugar factory is owned by the Seprod group of companies. There is an investment programme for the next years mainly for optimising the production line (vacuum pans, centrifuges etc.) but also for possible boiler refurbishments. The operation of a modern biomass

power plant at the site is seen to be beneficial. Besides sales of surplus electricity to the grid operator, one option could be the wheeling of power (i.e. transporting electricity through the public grid and consuming it at locations belonging to the same group of companies). However, activities in producing additional biomass on estate lands or in the vicinity are not seen as an option at Golden Grove for the time being.

Based on the interview and with some additional internal calculation the following main figures are describing the energy situation at the Golden Grove sugar mill:

Table 3.2: Summary of technical details, Golden Grove

Description	Value	unit
Total production of cane	180,000	TC
Crushing rate, actual average	42	TCPH
Crushing rate, installed	65	TCPH
Steam production, actual average	38	t/h
Steam pressure	12.4	bar
Turbine electrical capacity	1.5	MW
Consumption of Diesel/fuel oil	190	kL
Specific electricity consumption	40.7	kWh/TC
Specific steam consumption/corrected	0.9 / 0.6	t/TC
Specific Diesel/Fuel oil consumption	4.5	kL/TCPH

3.3.2. Everglades

The Everglades sugar factory under new ownership combines the sugar factories at Long Pond and Hampden in the parish of Trelawny. The site was visited on 15th September 2011.

The planned production for a start in January 2012[6] is 84,000 TC mainly from estate farms. A total of 2,700 ha land is available for cane cultivation. After the takeover by the new management this land will continuously be taken under production. The target for the year 2015 is for the full 2,700 ha and a cane production of 175,000 TC based on an average yield of 65 TC/ha. Another 30% increase in cultivated area is possible with additional private farmers. The long term goals are for production levels of 250,000 TC per year.

Changes and refurbishments are being made at the power supply in advance of the new crushing season. The actual steam production reaches 131,000 lb/h or 59 t/h at a pressure level of 150 psi (10.3 bar). The electrical capacity of the turbine stands at 1.6 MW. Demand during the season is at 1.8 MW, the rest is supplied by JPS or produced with diesel generator sets. Heavy fuel oil has been used also for steam generation. This should no longer be practiced and only one boiler capable of burning fuel oil is still in use as stand-by. Total demand for diesel/fuel oil is 2.5 mill. L per season. The operation usually falls short of bagasse. The moisture content of the bagasse is high at 53% and it should be stable at 50% to improve the energy situation at the boiler section. If a continuous operation could be assured, estimations provide a 15% surplus of bagasse – a situation, which has never been realised.

The installed capacity for milling is 75 TCPH. Given the new start again, the used installed capacity would be 35 TCPH and the actual average is not higher than 20 TCPH. Based on the interview and with some additional internal calculation the following main figures are describing the present energy situation at the Everglades sugar mill:

[6] *In the last season the harvested cane was transported to other mills.*

Table 3.3: Summary of technical details, Everglades

Description	Value	unit
Total production of cane	84,000	TC
Crushing rate, actual average	20	TCPH
Crushing rate, installed	35 / 75	TCPH
Steam production, actual average	59	t/h
Steam pressure	10.3	bar
Turbine electrical capacity	1.6	MW
Consumption of Diesel/fuel oil	2,500	kL
Specific electricity consumption	24.03	kWh/TC
Specific steam consumption	0.79	t/TC
Specific Diesel/Fuel oil consumption	33.33	kL/TCPH

3.3.3. Appleton

The Appleton sugar mill has been privately owned for a long time. One distinction from the other mills is the off-grid operation of the system. Whereas in Jamaica the national grid operates on a frequency of 50 Hz, the sugar mill and the surrounding buildings and dwellings are serviced by an isolated grid network based on 60 Hz. Therefore no connection to the national grid exists and all of the power needs of the mill and estate must be produced on-site. The site was visited on 26th September 2011.

The production stands at 360,000[7] TC/yr, the ultimate aim would be 400,000 TC as the maximum production. External farmers deliver 50,000 TC, the bulk is produced on estate lands on roughly 4,000 ha. The total under production stands at 5,600 ha (TRANSTEC 2011-2). Some 85% of the harvest is mechanically done, but still on burnt cane. The amount of green cane reaching the mill is still small.

Appleton is the only factory with a modernised boiler setup in Jamaica. In 2002 a new boiler house was installed capable of 250,000 lb/h steam (113.4 t/h) at a higher pressure of 600 psi (41 bar). Because the downstream machinery is not designed for higher pressures, the boiler is operated at 450 psi (31 bar) and produces roughly 195,000 lb/h (88 t/h) steam only based on bagasse. One turbine with 2 MW capacity is installed. It consumes a portion of 32 t/h steam from the boiler at a rate of 35 lb/kWh (steam consumption of turbine 15.6 kg/kWh). Diesel generators are installed as well for the necessary off-season production and as back-up. The prime movers consume steam (30 t/h) on a similar level as the turbine. The rest of the steam is used directly in the sugar process. There is no real surplus of bagasse due to some operational difficulties (out of cane in rainy conditions for example). Small amounts are stored for the start-up of the next season. The average bagasse ratio is high in this location with 34%. Also a problem with high moisture content of the bagasse is reported being well above 50%, sometimes reaching 54% moisture.

The installed capacity is 150 TCPH. In theory the season should last only for 4 months. If continuously operating, 135 TCPH surplus of bagasse can be generated. Based on the interview and with some additional internal calculation the following main figures describe the present energy situation at the Appleton sugar mill:

[7] *Last season the production was 303,000 TC but some cane was processed from other estates*

Table 3.4: Summary of technical details, Appleton

Description	Value	unit
Total production of cane	360,000	TC
Crushing rate, actual average	110	TCPH
Crushing rate, installed	150	TCPH
Steam production, actual average	88 / 133.4	t/h
Steam pressure	31 / 40	bar
Turbine electrical capacity	2	MW
Consumption of Diesel/fuel oil	0	kL
Specific electricity consumption	16.50	kWh/TC
Specific steam consumption	0.6	t/TC
Specific Diesel/Fuel oil consumption	0	kL/TCPH

3.3.4. Worthy Park

The Worthy Park sugar mill is another mill with a long history of private ownership. This mill and the adjacent area are also being operated with 60 Hz and have no connection to the national grid. The mill was visited on 14th September 2011.

The Worthy Park sugar mill operates in a secluded valley, thus the immediate area available for cane cultivation is limited. Production capacity is 200,000 TC per year on a land area of approximately 3200 ha (TRANSTEC 2011-2). Agricultural operation on the estate constitutes 55% of the production, 45% of crops are delivered by farmers. Mechanical harvesters are used for 20% of the crop.

The installed capacity of this factory is 70 TCPH. Expansion is limited. Also the chance to improve the factory and to export power to the grid is not deemed favourable.

Based on the interview and with some additional internal calculation the following main figures describe the present energy situation at the Worthy Park sugar mill:

Table 3.5: Summary of technical details, Worthy Park

Description	Value	unit
Total production of cane	200,000	TC
Crushing rate, actual average	49	TCPH
Crushing rate, installed	70	TCPH
Steam production, actual average	34	t/h
Steam pressure	13.8	bar
Turbine electrical capacity	1.3 / 0.9	MW
Consumption of Diesel/fuel oil	0	kL
Specific electricity consumption	18.57	kWh/TC
Specific steam consumption	0.49	t/TC
Specific Diesel/Fuel oil consumption	0	kL/TCPH

The power supply consists of the boiler system with 4 boilers and a combined total capacity of 110,000 lb/h. Under normal conditions 70,000 to 80,000 lb/h steam are produced (31 to 36 t/h) and delivered to the mill section for the prime movers and the remaining 40% (13.6 t/h) of the

steam produces electricity at a turbine with a rating of 1.3 MW and a specific consumption of 15 kg steam/kWh. The basic requirement for power is 0.9 MW. The initial pressure stays at 200 psi (13.8 bar) with backpressure of 15.5 psi 1.07 bar). With a fibre content of 13% (on a dry basis) there is hardly an excess volume of bagasse. The factory is self-sufficient, some bagasse is saved for start-up in the new season and in addition some logwood is stored. Assuming fibre contents of 15.5% there might be a large surplus of bagasse available for export power.

3.3.5. Frome, Monymusk and Bernard Lodge

The previously Government owned sugar mills Frome, Monymusk and Bernard Lodge had been sold to a Chinese investor - the Complant group of companies which operates sugar mills throughout the world. Under the new name of the Pan Caribbean Sugar Company the two largest sugar mills in Jamaica (Frome and Monymusk) were grouped together and production at the Bernard Lodge site was terminated. The handover of the sugar mills happened during the first part of the expert mission. It was not possible to arrange an appointment with the new owners.

The agricultural area at Frome is 10,000 ha, at Monymusk some 4,600 ha and for Bernhard Lodge 4,200 ha. For the latter the crops were transported to the two other mills.

From information available through older reports and through experts in the field a descriptive picture can be given for these two mills. However, some of the data in the following table is assumed. Field operations and factory settings are in flux as the new owners are carrying out refurbishments and changes in every different aspect of the sugar production. Part of the arrangement between the Government of Jamaica and Complant was a commitment for investments into the whole infrastructure. A new biomass power plant is mentioned in that respect.

Table 3.6: Summary of technical details, Pan Caribbean Sugar

Description	**Frome**	**Monymusk**	unit
Total production of cane	550,000	320,000	TC
Crushing rate, actual average	130	75	TCPH
Crushing rate, installed	200	110	TCPH
Steam production, actual average	(190)	(145)	t/h
Steam pressure	13.8	13.8	bar
Turbine electrical capacity	8.5	8	MW
Consumption of Diesel/fuel oil	n.a.	n.a.	kL
Specific electricity consumption	28	40	kWh/TC
Specific steam consumption/corrected	0.7	0.8	t/TC
Specific Diesel/Fuel oil consumption	n.a.	n.a.	kL/TCPH

3.3.6. General situation of the sector in terms of energy efficiency

For a general view the present situation in the Jamaican sugar industry should be compared with international standards in terms of specific energy consumption. This “benchmark“ is very roughly set (for traditional sugar factories) with an electricity demand of 20 to 25 kWh/TC and a steam demand of below 0.5 tons of steam per ton of cane processed. These figures are based on a technology setup, where the prime movers in the mill are still steam operated. If these are exchanged with electrical motors, the steam consumption may be reduced to 0.4 t/TC and the electricity demand increases to 25 to 30 kWh/TC. In addition, no other fuels should be required. The a.m. set of figures basically describes an energy self-sufficient factory. There is less scope

for exporting power. Table 3.7 provides the figures for the Jamaican situation, which are based on one source originating from 2004 and the second set of figures based on the assessments during this mission.

Table 3.7: Energy efficiency indicators for all sugar mills

Sugar mill		kWh/TC	t steam /TC	1000 L fuel oil/TCph
Frome	Reece 2004	28.33	0.63	6.66
	Own 2011	n.a.	n.a.	n.a.
Monymusk	Reece 2004	44.44	0.81	9.21
	Own 2011	n.a.	n.a.	n.a.
Bernard Lodge	Reece 2004	30.59	0.93	4.46
	Own 2011	n.a.	n.a.	n.a.
Appleton	Reece 2004	21.67	1.08	2.95
	Own 2011	16.50	0.60	0.00
Worthy Park	Reece 2004	27.33	0.63	0.00
	Own 2011	18.57	0.49	0.00
Golden Grove	Reece 2004	36.77	0.95	0.00
	Own 2011	40.70	0.90	4.50
Everglades	Reece 2004	17.81	0.36	8.08
	Own 2011	24.03	0.79	33.33
Average	Reece 2004	29.56	0.77	4.48
Average	Own 2011	22.24	0.69	9.46

Sources: based on data by REECE 2004, own figures

Although the figures during the mission in 2011 are not complete for all factories and there would be differences in methodology, a trend is clearly to be seen. The electricity demand is in a range, which is comparable to international standards and could be expected within this state of technologies. The additional diesel resp. fuel consumption is in most cases required for electricity production in generator sets, in cases where the bagasse driven power plant cannot deliver or does not deliver enough. The average figures given in 1000 L per milling capacity (in ton cane per hour) translate to some 4 L/TC in 2004 and some 2.5 L/TC in 2011. If electricity is produced by these liquid fuels, the respective energy content (at the actual efficiency) would add to the specific electricity consumption[8]. The figure for specific steam consumption with some 0.7 t/TC in 2011 for example is far beyond international standards for an average efficient sugar mill. In other words: too much steam is demanded by the process and obviously there is waste of steam along the production line. In Jamaica the prime movers are still steam driven engines and they consume a high portion of the steam produced. Also the downstream processes in the sugar section seem not to be operated using the most efficient procedures.

As one consequence there is additional energy demand by the sugar mills for either external electricity and/or for diesel/fuel oil for electricity generation and/or additional steam production. For this reason the chances for exporting power are naturally limited. To qualify the sugar sector to become an electricity exporting entity the energy demand for the process itself must be reduced.

[8] *On a rough calculation this diesel demand in gensets could be equivalent to another 5 to 10 kWh/TC, which might be added to above specific electricity demand.*

3.4. RUM PRODUCTION

All local produced molasses is used for the production of rum. Local supplies can only satisfy the demand by roughly 50%. Therefore molasses are imported by the rum distilleries. For the time being the process from molasses to rum is financially very attractive. If markets sustain, this would be the preferred use of the molasses by-product in the near future.

Sometimes the distillery is attached to a sugar mill, under the same ownership or under different owners. Rum production is also energy intensive. The main energy input is steam for the distillation/evaporation process. Electricity demand is in specific and absolute terms not that important. However, alcohol production is also seasonal and is not performed during the crushing season. Naturally there is only a limited chance to connect these two processes and to optimise energy use. The sugar mills, at least as the situation is at present in Jamaica, are already short of steam for the process. As a result there are also shortages of electricity. The additional demand of a distillery would put even more stress on the operation of the powerhouse. But if the energy supply is shifted to a “modern” biomass plant eventually operating year-round, this fact offers new opportunities for connecting energy demand and supply for these two production lines. They should be located near to each other, because the main energy exchange is for low pressure steam for distillation (which is produced by heavy fuel oil now).

An indication on the magnitude can be given as follows (for the Appleton distillery). A steam demand of 8 kg per L of pure alcohol is reported. The total yearly production of 7 million L would demand a yearly steam amount of 56,000 t. This is roughly 15% to 20% of all steam, which is produced during the crushing season at the sugar mill. The power demand is given with 350 kW during the high production cycle. As said above, the two production cycles are separated from each other in the season. But the concept of a bigger power plant operated on additional biomass in the off-season could easily supply steam and electricity to the distillery. Moreover, a steam demand (on relatively low pressure) would increase efficiency of the operation, because it reduces the amount of residual steam going to cooling towers.

Any detailed planning of new biomass power for an individual location therefore has to include the energy supply of a distillery, if there is a production site nearby.

Another EU-funded project (TRANSTEC 2011-1) is investigating the wastewater situation at the sugar and rum factories. The preliminary findings are giving background information on wastewater quantities and qualities. In cane processing the main wastewater source is only washing water with a low level of BOD/COD. More problematic is the wastewater from rum production (donder) with a high BOD/COD and severe environmental impacts if not treated properly.

Also this can be connected to the establishment of biomass power plants. The wastewater could be treated anaerobically and thus produce biogas as an additional energy either for boiler use or for electricity production. There could be exchanges of energy flows arranged to optimise the energy situation at the specific site. Another option for treating donder (wastewater of distillery) could be partially drying (reducing the water content) of the wastewater to improve further treatment steps with a high concentrated material.

The final report on that project is going to be released shortly. The main findings and recommendations are summarised for the sugar sector in general and for the rum industry in particular (TRANSTEC 2011-2) as:

Changes in the sugar sector

- Introduction of green cane harvesting;
- Cease the practise for burning cane;
- Introduce dry milling of cane to reduce the wastewater;

- Factory upgrades for processing and treatment facilities.

Changes in the rum industry

- The greatest potential for treatment of distillery waste by introduction of anaerobic digestion and use of biogas for energy demands;
- Treated vinasse should be used back in the fields with modern field distribution systems;
- There is great potential for utilising the nutrient value of the wastewater stream from rum production;
- One alternative method could be drying (steam evaporation) the vinasse to reduce volumes and increase the fertiliser value.

3.5. BIOETHANOL PRODUCTION

Jamaica has opted for a mandate for biofuels. The gasoline on the market should be E10, i.e. a mixture between 90% fossil gasoline and 10% bioethanol. The bioethanol is imported from Brazil and blended with fossil gasoline at the refinery resp. by the distributor.

The local market volume is 70 million L per year based on the E10-regulation. There are and had been plans to produce bioethanol in Jamaica as well.

For the present situation these ideas do have a limited rationale for some of these reasons:

- The local demand for E10 is comparably small;
- The economic size of a bioethanol refinery is bigger than the local market volume, i.e. a local production would be more expensive compared to world market;
- The sugar prices are high, there is no need to divert sugar to ethanol (as a biorefinery producing only bioethanol and no sugar), more so on a small scale;
- There is an undersupply of molasses for the rum industry, which drives the prices up. Molasses for bioethanol (the usual way) could most probably not compete.

It must be noted that the above reflects only the present state (since 2008). Bioethanol is an option for any sugar producing country. If some or any of the above situations are changing, the local production of bioethanol can have a clear rationale.

Therefore the bioethanol production should be included in the assessment for biomass power plants. In this respect the sustainability issue is quite important. Biofuels are monitored on their impact on net greenhouse gas emission reduction and certain minimum requirements are put in place at least by the EU and the US. Bioethanol can only meet these requirements if the energy demand for its processing is coming from renewable energy (compare the rum production assessment). Logically, bioethanol production must be attached to a sugar mill and be supplied with steam produced by bagasse and biomass fired boilers.[9]

[9] *There are few reports available proposing also bioethanol production. As this study concentrates on power production, bioethanol is only seen as a secondary effect on the possible power plant. The impact on sugar production and viability of the whole industry should not be neglected, however.*

4. COGENERATION AND ELECTRICITY EXPORT

4.1. REGULATORY CONDITIONS

Electricity generation in Jamaica is no longer monopolised. The Jamaica Public Service Company (JPS) is the only grid operator and responsible for distribution and transmission of electricity. JPS also owns and operates different power plants. Besides the traditional energy supplier JPS, the IPP (Independent Power Producers) are operating their own generating capacity and supply to the national grid. The IPP are reimbursed by JPS, which still sells all electricity to the customers. Nearly one third of the electricity is produced by three IPP running their power plants on fossil fuels (fuel oil and diesel). In addition, one larger wind farm is connected to the grid. Aside from IPPs (which are specifically defined as power producers for puiclic use), electricity for the grid could also be produced through cogeneration, i.e. the selling of surplus power from own generation in industry. Most of the heat and power is consumed for for the process needs in that particular industry.

The national grid is still operated as a monopoly. Given the small size of the island and the necessary infrastructural demands, the decision for leaving the grid under monopoly is understandable and has been justified through international consultants (CASTALIA 2011).

JPS is a privatised entity under foreign ownership. The regulatory issues are taken up by the OUR, (the Office of Utilities Regulations), which besides the electricity grid network also controls the water network and telecommunications. The OUR defines the requirements and conditions for independent power production and the supply resp. feed-in to the national grid.

A potential power producer has to seek permission from JPS for the production and the feed-in of electricity. He will negotiate a power purchase agreement (PPA), which sets the technical and economic conditions. There are no standard procedures available.

The electricity sold to JPS is remunerated by a fixed price per unit of production. The OUR publishes these rates based on the calculation of avoided costs. The calculation is based on the present energy mix and its individual costs and on projections for the future generation mix. Up to now the least cost expansion planning (LCEP) is the base for future projections. The latest edition (OUR 2010-1) states avoided cost of 9.33 USct/kWh for non-firm power (like fluctuating renewable sources or seasonal production from fossil sources) and 10.05 USct/kWh for firm power (reliable and year-round supply with a guaranteed availability). Renewable energy qualifies for a 15% premium on top of the a.m. prices. Also possible is a production under a short term contract (so called dump power), where existing generation capacity in industry could be used for (irregular) sales to JPS. In this case the avoided costs are the average monthly fuel cost as published by JPS (OUR 2010-1). No more background information, i.e. base assumptions for the calculation, is given in that report. A previous report had stated slightly different figures with 10.48 USct/kWh for firm and 8.88 USct/kWh for non-firm delivery (OUR 2008).

There is a controversial on-going discussion on the rationale for the calculation of avoided cost. In principle the long term avoided cost are based on a planned modernisation programme of generating capacity in Jamaica with the main element of use of LNG (liquid natural gas). LNG should be imported by a LNG offshore terminal and converted to power in high efficient combined cycle power plants. In contrast to that, present generation is based on low efficient and outdated equipment only operated on imported diesel and fuel oil. By that fact, present generation in Jamaica is very much dependent on the world oil market prices. As a result, electricity prices in Jamaica are comparably high. For different tariffs this could be an average of

30 to 35 USct/kWh[10]. The fuel cost alone (for example for the actual price period at nearly 20 USct/kWh) could constitute a significant portion of the whole electricity rate. The present feed-in tariffs (FIT) calculated as avoided costs according to a.m. definitions are too low to attract investors for setting up own generation capacity especially in the field of renewable energy. A number of reports and calculations for possible or reasonable FIT rates are available and being discussed with the different stakeholders (e.g. SMINK 2011). For biomass power plants the suggested tariff is set at around and above 15 USct/kWh.

The most recent report (CASTALIA 2011) shows a clearly different calculation. The theoretical generation cost for a power plant based on biomass resources is quoted as 12 USct/kWh (concept of LRMC, long run marginal cost). The calculation was made for a capacity of 60 MW and for specific investment cost of 3,000 USD per kW installed. The avoided cost for the marginal generation by JPS under present conditions should be at around 24 USct/kWh (non-firm 22 USct/kWh) and after the LNG introduction they could stand at up to 17 USct/kWh (and 15 or 16 USct/kWh for non-firm power). Different suggestions are also made for the minimum length of the contracting period for IPPs or renewable energy producers.

Consumers are protesting against the high electricity prices in Jamaica already. A further increase in end user prices because of higher FITs for renewable energies must be avoided (as this is the model in Europe for example). This is also the opinion on a regional level. The electricity prices in the Caribbean are regarded as very high (mainly due to small capacity and reliance on fossil liquid fuels) and could be seen as an obstacle for industrial and economic development (see table 4.1). In particular, the very small Caribbean islands experience high household tariffs. Larger islands like the Dominican Republic or countries on the mainland like Guyana can offer lower tariffs. In comparison to that, prices in Jamaica seem a bit too high because Jamaica is not a very small island.

Table 4.1: Electricity price development in the Caribbean

Country	1996	1997	2003	2004	2007	2008
Barbados	0.151	0.167	0.188	0.188		
Cuba	0.126	0.128	0.137	0.138		
Dominican Republic	0.084	0.082	0.107	0.150		
Grenada	0.193	0.193	0.221	0.221		
Guyana	0.079	0.078	0.059	0.059		
Haiti	0.102	0.096	0.060	0.060		
Jamaica	0.139	0.135	0.169	0.187	0.258	0.215
Suriname	0.171	0.171	0.171	0.129		
Trinidad and Tobago	0.029	0.028	0.036	0.036		

Source had been changed, only household tariff (BINGER 2011)

There is no objection to renewable energy, but if additional incentives are needed, they should be dealt with between the Government and producer and should not affect the end user. A tariff increase based on “subsidies” for renewable energy is not seen as appropriate (CARILEC 2011).

The main conflict to solve is a fair compromise between the reasonable FIT for renewable energy and the final price of electricity to end users and industry. In theory the regulatory framework is in existence and should allow the independent production of electricity.

[10] The rate schedule differentiates households, commercial and industry etc. The final price contains a demand and energy charge. In addition to that a fuel and IPP charge is added, which is adjusted monthly.

4.2. TECHNICAL AND ECONOMIC REQUIREMENTS

Besides the pure assessment of the regulatory framework, which is laid down in laws or procedures and is monitored by independent agencies and stakeholders, more conditions must be met in order to produce electricity for feed-in. These are technical issues and of course the financial situation under which a decision might be taken.

The first necessity is a power purchase agreement between the power producer and the grid operator. This PPA can be issued as an IPP or for cogeneration. An IPP is usually a bigger fossil plant only producing for the grid (some internal demand for the power plant and the operations there). Cogeneration in the technical definition is the parallel production of electricity and steam resp. heat for an industrial process or a factory. In most cases the operational setup is driven by the heat demand and electricity is the byproduct[11]. The share between electricity and heat is governed by the technical and thermodynamic conditions. If the process requirements use less electricity than what is produced (or demand at certain times), this amount can be supplied to the grid. The overall efficiency of cogeneration is (generally) larger in comparison to separated processing. Another aspect is self-generation. The industry may produce its own energy and consume it totally or may export part of it. Also some renewable energy sources can be utilised on-site by the owner of the appliance (e.g. a photovoltaic panel or a small wind mill). If the owner decides, to export some electricity and sell it to the public grid in times of surplus[12], a clear distinction and definition is necessary.

In technical terms the power plant at a sugar mill is clearly a cogeneration unit because steam is needed in the process and surplus electricity may be supplied to the grid. This, however, would not produce much excess energy. The design of the power plant would be made according to the energy demand (in this case the steam demand) of the sugar mill. To encourage more exports and to enable a year-round production, the design of the power plant needs a change, higher efficiency and larger capacities with substantially higher investments. Only during the crop season would steam be needed in the process, outside of the season the power plant would not be operated in the cogeneration mode. Still the plant must be sited near the sugar mill, as it would be necessary during the crop season and for the steam production. It is envisaged, that the logistics for additional biomass production and storage are also in favour of a location in the agricultural production area (the power plant is immobile and would exist for 20 years at the location). In this a.m. aspect (the technical condition) the proposed power plants would operate like an IPP.

The final decision on the definition depends also on the final set-up of the owner structure of the power plant. The owner and operator could be the sugar mill itself, a group of companies owning the sugar mill, a subsidiary of the group or the mill or a completely independent investor and operator (in the clear definition of an IPP). The power plant might sell the excess electricity to the pubic grid or may use it for its own demand but at different locations. As JPS has the monopoly on the public grid, the electricity may be transported through this grid paying a charge to JPS (wheeling). There could be technically and organisationally different definitions for a proposed power plant using bagasse and other biomass materials in the vicinity of a sugar mill.

The regulations set by OUR and JPS require that the power producer is responsible for the grid connection. For some of the sugar mills in Jamaica this means that landlines have to be reinforced or extended to take up the additional power. Also in most cases transformer stations would be needed. The compliance with grid quality and grid conditions (frequency, reactive power, harmonics etc.) is necessary as well.

---

[11] At least this applies for tropical countries. In cooler climates the heat production in winter can be utilised for heating purposes. Operation in summer produces mainly electricity.

[12] The other option is the off-grid operation. Here surplus must be stored in (expensive) batteries or the surplus is wasted.

There is no environmental regulation (in terms of emission control and licensing) for existing bagasse power plants. Existing bagasse cogeneration is allowed if a certain threshold efficiency is reached. New bagasse power plants must only apply particulate emission rules. These are restricted to 4,200 g PM (particulate matter) per t input fuel, which is a rather high threshold value in international comparison (NEPA 2011). Maximum values for German power plants operating on solid fuels is set at 20 mg/m^3 of total suspended solids. The above limit for Jamaica is some 50 times[13] higher than the value for Germany. The limit for coal power plants in Jamaica would be roughly by a factor of 10 lower compared to bagasse.

In most cases projects like these under consideration need external finance. The business cases must therefore take into account the requirements by banks for appraising projects. The experience in other countries (as Jamaica has not financed a biomass power plant yet) reveals that the supply of materials and the price for the materials is one crucial position in the business plan besides the actual FIT and the guaranteed length of the PPA.

In chapter 6 the economic background is discussed in detail for each of the locations and technical options. A model based on a spreadsheet calculation is introduced and allows adaptations and easy changes in the financial setup and assumptions. The reason for the modelling is to assess the financial viability of exporting power to the grid and using additional fuels during the off-season. Here the fictitious situation of a pure cogeneration project is presented and discussed. The final result should give an indication of the production cost of electricity if a new power house would be erected and only used for the purpose of sugar milling. The input data are based on a medium sized sugar factory and the technology status is the present 20 bar technology. The general assumptions of the model in chapter 6 remain the same (O&M cost, lifetime, interest rates etc.), only a few key data are chosen as follows:

- All bagasse would be used up (no value for bagasse);
- No export of electricity, no additional energy input;
- Sugar process demand, average in Jamaica, 23 kWh/TC and 0.7 t steam per TC (chapter 3);
- Production at 350,000 to 400,000 TC per year;
- Total crop season 4,000 hours gross;
- Boiler capacity 70 tons per hour;
- Turbine capacity 2.3 MW;
- Specific investment cost 3,000 USD per kW installed.

In cogeneration steam and electricity are produced. There are different ways to assess the individual production cost of each of these energy carriers. The total cost can be divided for example by the energy content, the volume or the alternative separate production. In this case the alternative production cost for steam is calculated in a second fictive model (only low pressure boiler, but newly constructed and all other general assumptions as above). The production cost for steam is then 3.9 USD per ton. Subtracting the “income” from steam production from the total yearly cost of the cogeneration plant divided by the electricity production, results in specific cost of 15.75 USct/kWh. These are important figures for the discussion in the following chapters.

In summary:

- If a sugar factory builds a completely new power house which supplies only steam and electricity to the sugar process during the harvest season by using its bagasse, then the full production cost are:

  For steam: 3.9 USD per ton;

  For electricity: 15.75 USct/kWh.

[13] *Figures cannot be directly compared as different units and measurements are used.*

5. BIOMASS ASSESSMENT

5.1. RESOURCES FOR BIOMASS FOR ENERGY

There is a wide range of potential biomass available in Jamaica, both from existing resources and development of new sources. As the purpose of this study is to enhance the ability of the sugar industry to use biomass for production of additional power, it is logical to focus first on enhancements that could be made to the existing industry followed by development of additional biomass resources to make up any potential shortfall.

Developing biomass resources available to Jamaica will focus on the availability of additional biomass from current sugar cane cultivation as well as additional sugar cane biomass that could be obtained through the introduction of new cane varieties. While growing more sugar cane is an option, another option is treating the existing supply through drying in order to increase its fuel value.

5.1.1. Byproducts in the sugar industry

The available byproducts in the sugar industry through cane harvesting consist of bagasse and cane trash. Sugar cane is grown as a perennial crop, harvested annually, transported to the factory where sugar juice is extracted by passing the stalks through a series of rollers to yield cane juice, bagasse and the remaining cane stalk material. The resulting cane juice is processed to yield both raw sugar and molasses. In the field prior to harvesting, the sugar cane is normally burned to remove the leaves from the stalk. This is done to facilitate manual harvesting or to speed up the rate of mechanical harvesting. Another benefit of burning the cane is the reduction of labour required to clean the cane prior to pressing. Once the fields are burned, roughly the top third of the cane stalk is removed, as it is low in sugar content and left in the field. The remaining stalks are transported to the factory as either long stalks from manual harvest or short “billets” of approximately 1/3 m length.

The sugar juice is the main raw material used for making high value products. All the other above-ground parts of the sugar cane plant are byproducts and can potentially be used to make power through combustion. Current general practice in the Jamaican sugar cane industry is to use only the bagasse as an energy source by burning it in the boilers. The other vegetative material, cane leaves and tops are either burned or left in the field.

i) Green Cane Harvesting

One issue with current practice is that cane field burning has been banned due to the resulting adverse environmental impact on air and soil quality. Though the practice is banned it is still widely practiced, most likely because it is easier to harvest burned cane. This is especially important because the majority of cane in Jamaica is harvested manually and there is a shortage of skilled cane cutters.

The cane tops and leaves, known collectively as cane trash, represent a significant amount of vegetative material. While estimates and measurements of the actual amount of cane trash vary with variety and environment, a generally accepted average figure for this material is 140 dry kg per ton of fresh (wet) cane, while the bagasse portion of sugar cane averages another 140 dry kg per ton of cane (HASSUANI 2005, LARSON 2001). These figures are given as averages of studies in several countries across many environments. The actual figures for cane tops and leaves in Jamaica will need to be determined through experimentation as this figure can vary with cane variety and environment as well as agronomic and harvesting practices.

If green cane harvesting rather than burning were instituted across Jamaica, the amount of available material for combustion would be increased by a large proportion. Studies of cane

trash recovery carried out in Brazil determined that the highest recovery rate of cane trash from field operations, including baling, was between 84 and 89 per cent (HASSUANI 2005, LARSON 2001). Using the higher figure for maximum theoretical yield, 89 per cent of the 140 dry kg of cane trash, or 125 dry kg per ton of cane, could be transported to the factory. It needs to be taken into account that while these trash recovery figures where determined by trying to mimic operational field conditions the actual yield of field trash will likely be lower because of challenges of scale as well as imperfections in filed layout that will affect the ability of baling machines to pick up trash. Nevertheless, it is likely that a significant amount of field trash would be available for combustion, perhaps a consistent yield in the range of 60 to 75 per cent of the total trash generated.

ii) High Fibre Cane Development

High fibre cane varieties are being developed in several cane breeding programmes around the world. These varieties can significantly increase the amount of fibre available throughout the plants without impacting the yield of sugar juice. SIRI in Jamaica has been evaluating high fibre cane varieties in their selection programme since 2004. Given that the cycle for introduction of new cane varieties is between 12 and 15 years, it is possible that high fibre cane varieties will be available to Jamaican growers by 2016.

Table 5.1 shows how high fibre cane can increase fibre yields without negatively impacting sugar extraction. The data from SIRI field trials shows cane fibre yield, theoretical Jamaican recovered sugar (JRCS) percentage and the ratio of tons cane (TC) over tons sugar (TS). The top portion of the table shows results for two current Jamaican commercial cane varieties while the bottom portion shows data for five selected varieties in the actual selection programme. Note that the fibre yield from the test varieties increased by 32 per cent while having little impact on sugar yield.

Table 5.1: Potential Fibre Increase Using Material in Jamaican Testing Programme

Variety		Cane Fiber, %	Theoretical JRCS, %	Ratio TC/TS
Standard Commercial	BJ4752	13.57	9.11	10.97
	BJ7505	16.55	7.69	13.00
	Average	15.06	8.40	11.99
High Fibre	A	19.72	8.87	11.27
	B	20.32	8.46	11.82
	C	19.76	8.38	11.94
	D	19.77	8.22	12.16
	E	20.40	8.47	12.47
	Average	19.89	8.48	11.80
Fibre Level Increase	Test Average / Standard Average	1.32	1.01	0.98
	Percent Change	32%	1%	-2%

Source: Sugar Industry Research Institute

iii) Potential Increase in Fibre Availability

In order to illustrate the potential increase in fibre available from sugar cane operations the contribution from the efficient harvesting of cane trash and the use of high fibre cane was calculated and the results shown in Table 5.2. Note that Table 5.2 is meant only to show the theoretical potential of fibre yield. Actual yield figures will depend on methods used for harvest and transport and will also be influenced by the variety of cane grown as well as the local environmental conditions. Nevertheless, the calculations are useful to show the amount of fibre potentially available.

In the current Jamaican situation, no cane trash is harvested. The leaves are burned prior to harvest and the cane tops are left in the field. These figures are represented by the "Burned Cane" column in Table 5.2. On a dry weight basis, bagasse represents approximately 140 kg per ton of cane harvested. Since no trash is recovered, the baseline figure for biomass available for combustion is 140 dry kg per ton of cane harvested. In reality the bagasse is obtained at 50 per cent moisture following crushing but for the purposes of this calculation the moisture content and the impact of the combustion process will not be considered in this section.

Table 5.2: Potential Increase in Fibre Yield with Green Harvesting and High Fibre Cane

Description	Burned Cane	Green Harvest	High Fibre + Green Harvest
Cane (kg)	1,000	1,000	1,000
Bagasse (dry kg/ton cane)	140	140	185
Trash (dry kg/ton cane)	0	125	165
Bagasse + Trash (dry kg/ton cane)	140	265	350
Increase compared to Green Harvest			32%
Increase compared to Burned Cane		89%	150%

With the elimination of cane burning the amount of biomass available increases, the impact is show in the "Green Harvest" column of Table 5.2. The amount of bagasse harvested is assumed to be unchanged in this scenario. Along with green cane harvesting the calculation assumes that the cane tops and leaf trash will now be made available for combustion. Using a theoretical yield of cane trash of 89 per cent based on the discussion above, an additional 125 dry tons of biomass is obtained for each ton of cane harvested. This is an 89 per cent increase in available biomass. Furthermore, if field drying is used, this additional biomass is delivered to the factory at 15 per cent moisture making it a more efficient fuel than bagasse at 50 per cent moisture.

Table 5.2 also shows how adoption of high fibre cane can further increase the amount of biomass fibre available for combustion. The data presented above showing the results of the Jamaican high fibre cane trials suggests that cane fibre content can be increased from 15 per cent to almost 20 per cent (dry basis, average yields) without impacting the sugar extraction yield. The use of high fibre cane can potentially increase available fibre for combustion a further 32 per cent over green harvesting and 150 per cent over burned cane. In this calculation the assumption is that the high fibre cane characteristic causes a uniform increase in fibre content throughout the entire plant, stalk and leaves included. Even if the increased fibre availability is applied to the bagasse only, use of high fibre cane varieties will result in an extra 45 dry kg of fibre per ton of cane harvested.

iv) Impact of Increased Cane Fibre Harvest

This simple example of implementing green cane harvesting and adoption of high fibre cane varieties can have a significant effect on the available fuel supply for power generation. Assuming that no other process improvements are made in the factory to increase capacity or fuel use efficiency, switching to green cane harvesting and collection of cane trash will increase the fibre supply by 89 per cent. Addition of high fibre cane increases the fibre supply compared to burned cane by 150 per cent. Of course these increases of 89 and 150 per cent are the theoretical maximum yields for the near term situation using the best available technology. It is likely that the actual yields will be lower but will still represent a significant increase in fibre yields from sugar cane operations using the existing land base.

In practical terms, the additional fibre will greatly increase the amount of fibre available for cogeneration of electricity. If a factory does not currently generate enough bagasse to cover all its power requirements during crushing season, a switch to green cane methods will most likely make up the shortfall and even provide an excess of fibre.

5.1.2. Waste or biomass materials

Agricultural, communal and industrial wastes can also be used as a source of combustible fuel. In Jamaica such sources could be coffee pulp, coconut husks or similar materials. Over the course of this study no clear large volume supply became obvious that was co-located with the sugar factories visited. Furthermore, the form of agricultural and other waste often requires special handling and transport. The different studies, which had been performed in Jamaica (see chapter 2), have not identified large volumes of available biomass materials coming from agriculture or forestry. The only source of magnitude would be municipal solid waste (MSW) with a relatively high organic content. Generation of MSW is high in dense populated areas whereas the sugar mills are located in the countryside. Utilisation of MSW poses logistical challenges besides the issue of appropriate processing and combustion technology. Therefore MSW is not considered a viable source for additional biomass in the sugar sector.

This study focuses on agricultural wastes within the sugar cane industry alone and development of dedicated energy crops within close proximity of the sugar factories. While additional waste products may be a suitable source of fuel for cogeneration, their consideration is being included for study in the long term approaches

5.1.3. Dedicated energy crops

Dedicated energy crops are being considered in many parts of the world as a biomass source to reduce use of fossil fuels and to develop local energy resources. The most commonly used dedicated energy crops over history have been woody crops, usually trees. More recently grasses (switchgrass, Miscanthus, king grass and others), bamboo, fibre sorghum, energy cane and oil crops (jatropha, castor, oil palm) have been under development.

While there has been some use of maize and soybean as energy crops, these crops are also sources of food and their diversion to non-food uses is being questioned in many parts of the world. Other objections to using maize and soybean for energy purposes are their relatively high requirement for fertiliser and water. Low nutrient and water requirements are preferred for dedicated energy crops in order to take advantage of marginal lands, which have lower fertility and/or soil moisture. It is important to realise, however, that though many dedicated energy crops can be grown on marginal lands they would still require management in order to realise acceptable yields.

Like any agricultural system, dedicated energy crop growth on marginal lands requires careful matching of the species being considered with the local environment and the needs for fibre. Each dedicated energy crop has unique fibre characteristics, environmental requirements, harvesting systems, storage needs and systems for processing prior to use.

Adoption of dedicated energy crops in Jamaica has great potential to supply fibre to the sugar industry as well as additional biomass to power facilities. As this study focuses on meeting the needs of the sugar industry, this discussion will only consider additional biomass in that sense, but the principles outlined here can be applied to any industry with biomass needs. Sugar factories in Jamaica are distributed across a wide variety of environments on the island. For this reason, the additional fibre requirements at each sugar factory will need to be considered separately, but the general process is the same for each location.

As Jamaica does not have extensive plantations of dedicated energy crops, their use will require establishment of a new industry for the country. The species being considered for Jamaica include trees (*Leucaena*), energy cane, sorghum and a variety of grasses (king grass, guinea grass, etc). In each case these candidates are not listed as invasive species for Jamaica and are already being grown or have been grown to some extent on the island. Additional dedicated energy crops may be considered for Jamaica as long as they are not considered invasive and can thrive in the selected environment.

i) Woody Biomass Resources

This study makes an estimate of how much additional biomass would be needed to provide firm power generation at Jamaican sugar factories. The assessment here details the number of hectares that would be required in tree plantations to provide the required tonnage of woody biomass. This particular assessment does not take into consideration the additional biomass possibly obtained from cane trash harvest. The tons of biomass required for selected sugar factories were determined in another part of this study (chapter 6) and are shown in table 5.3 below. For each of the selected sugar factories the demand for additional biomass can be met through a number of sources. Table 5.3 shows how the biomass demand can be met through woody biomass alone.

A previous study in Jamaica by the PCJ suggested that *Leucaena* would be a candidate species for developing a plantation forestry industry in Jamaica (PCJ 2000). *Leucaena* has the advantage of growth on marginal land, relatively high productivity and a predominance of single-stem trees which makes it compatible with forestry operations. The Font Hill study demonstrated an annual production of 23 tons of biomass per hectare based on a five-year rotation. It is reasonable to assume that if a plantation forestry programme were developed using *Leucaena* that the productivity would increase over time as improved planting stock and silvacultural practices were introduced. Nevertheless, the scenario outlined in table 5.3 provides assumptions for *Leucaena* which are relatively conservative with regards to productivity, 20 and 15 tons per hectare per year.

Table 5.3: Projected Land Required for Additional Biomass - Woody Biomass Only

Description	*Frome*	*Appleton*	*Monymusk*	*Worthy Park*	*Golden Grove*	*Everglades*
Tons Biomass Needed, t	93,300	94,200	50,700	34,400	29,700	16,500
ha, Plantation area[1]	10,000	5,600	4,600	3,200	2,700	2,700 (target)
Leucaena Lower Estimate						
Hectares needed @ 15 t/ha	6,220	6,280	3,380	2,293	1,980	1,100
Land Use 35 km radius	1.62%	1.63%	0.88%	0.60%	0.51%	0.29%
Land Use 10 km radius	8.80%	8.88%	4.78%	3.24%	2.80%	1.56%
Leucaena Higher Estimate						
Hectares needed @ 20 t/ha	4,665	4,710	2,535	1,720	1,485	825
Land Use 35 km radius	1.21%	1.22%	0.66%	0.45%	0.39%	0.21%
Land Use 10 km radius	6.60%	6.66%	3.59%	2.43%	2.10%	1.17%

1 figures taken from (TRANSTEC 2011-2)

For example, the biomass demand of the Frome sugar factory, 93,300 tons per year, could be satisfied with 6,220 hectares of *Leucaena* plantation at 15 t/ha productivity or 4,665 hectares at 20 t/ha productivity. Assuming a transport radius of 35 km around the factory the plantations would use 1.40 or 1.05 percent of the total land within that circle. Apparently a better comparison can be made with the total land under sugar cane cultivation for that particular mill. For Frome some 10,000 ha of sugar field are reported (see chapter 2). The additional area for biomass is slightly lower than that figure. For all other mills[14], there is the trend that a bit less hectares of plantation for woody biomass are needed as they operate for sugar cane. Or in

[14] The exception is Appleton. The crop season is reported shorter, so the additional biomass operation is longer to reach a full year operation.

other words, the additional biomass would double the sugar factory in terms of field operation and land demand.

Minimum recommended size for profitability of *Leucaena* plantations is 191 hectares. Thus, in order to support the Frome factory, a maximum of 28 plantations would be required with 15 t/ha productivity or 21 plantations with 20 t/ha productivity. If cane trash or high fibre cane were to be incorporated as a biomass source the area needed for *Leucaena* plantations would be reduced.

ii) Leucaena Plantations as a Woody Biomass Source

Woody biomass is a reasonable choice for meeting the additional biomass demands that are not met by cane trash and high fibre cane and *Leucaena* plantations are a good candidate for woody biomass supply in Jamaica. PCJ has already conducted a study comparing several woody species in a trial plantation in their Font Hill study (PCJ 2000). *Leucaena* proved to be a desirable species in this study because of its relatively high level of productivity as well as having a desirable trait of a high proportion of single stemmed trunks.

Leucaena is a species already familiar to Jamaica and wood harvest for the charcoal industry is already established. Thus, the familiarity of *Leucaena* is a positive driver for its adoption in Jamaica. *Leucaena* is already grown as a plantation forest species in tropical regions thus the knowledge base for establishing plantations in Jamaica is readily available in addition to the promising results of previous studies on the island. When *Leucaena* is grown on short rotations of four to six years the harvest operations can easily accommodate manual harvesting as the trunk weights at that age can be handled by two workers. Mechanised harvesting techniques are also available for *Leucaena* allowing a wide variety of harvesting methods depending on the existing conditions.

Genetic resources for the ongoing improvement of *Leucaena* are available. Complaints about weediness and its invasive nature can be addressed through the use of improved selections and hybrids (VAN DEN BELT 1985, STEPPLER 1987). The *Leucaena* used in the Font Hill study is of the genus *leucocephala* and is likely a high seed producing variety. The Leuceana species choices for most plantations are either low seed producing varieties, hybrids and others that are either self-infertile or of low self-fertility. Thus a wide range of planting stock is available to suit the needs of individual growers.

The Font Hill study established that 191 hectares is the lowest recommended size for *Leucaena* plantations. A feasibility assessment for a 200 ha plot found that an initial investment of 6 million JD with subsequent investments of 26 million JD over five years would generate income of 12 million JD per year from the fifth year. After seven years the initial capital of 6 million JD would be recovered. The 200 ha business enterprise showed a positive NPV of 565,502 JD. In addition, there is potential for additional sources of income by growing row crops or pasture between the *Leucaena* for at least the first three years of tree growth. This model of "agroforestry" has been practiced in developing countries for decades and has been gaining popularity in developed countries over the past several years. Studies have shown that agroforestry practices can be highly beneficial, not only in terms of income, but also for sustainability and protection of environmental resources. Economically, the agroforestry model gives growers a diversified income base as well as providing annual income from the row crops until the trees are ready for harvest.

A study specific to identifying suitable land for *Leucaena* plantations in Jamaica is required. This study can take advantage of earlier land use studies as well as a PCJ land use study that is currently underway. Leuceana grows best in the lowlands of the tropics, at an altitude below 500 m and with an annual rainfall of 600-1700 mm (FAO 2010). It is likely that varieties of *Leucaena* can be identified that can do well outside of these parameters as well since it is a genus with a great deal of variability (VAN DEN BELT 1985, STEPPLER 1987). Some *Leucaena* has flourished in Hawaii with less than 250 mm rainfall per year. The species can tolerate a wide range of temperatures, but is killed by frost. Its root system allows it to survive in

a variety of soil conditions, but it grows best in neutral or alkaline soils, and does poorly in acidic soils. In addition to a study to identify suitable plantation land in Jamaica, a comprehensive evaluation of *Leucaena* varieties and agronomic practices should also be carried out prior to establishing the first *Leucaena* plantations.

Woody species have several advantages over other dedicated energy crops especially in harvesting and storage logistics. While grassy dedicated energy crops (king grass, switchgrass, sorghum, etc.) have high productivity they generally require harvesting within a relatively narrow time frame of several weeks followed by a baling operation and long term storage in order to provide year-round biomass supply.

Woody species do not have time-critical harvest times and can be cut at any time of the year providing that the weather conditions permit. Logs can easily be stored long term without further processing nor do they require covers to protect them from rain. These features are highly desirable given the Jamaican weather patterns as well as eliminating the need to build covered storage for wood. Logs can be harvested and stockpiled outdoors to ensure a steady fuel supply during the rainy seasons in Jamaica when it is difficult or impossible to gain access to plantations for harvest.

iii) Non-Woody Dedicated Energy Crops

Sorghum (sweet varieties and forage varieties) has the advantage of using many of the same cultivation methods as sugar cane and other common crops. Both types of sorghum can be grown on marginal land and, in some cases, saline land. Sorghum is similar in form to sugar cane and thus the likely advantage of similar harvest and post-harvest handling. Forage sorghum is a high fibre, high growth rate crop that can be used in combustion applications. Forage sorghum in the USA (Texas) can commonly yield 33 dry metric tons per hectare, and possibly more under optimum conditions (MCCUTCHEN 2008). Sweet sorghum, also an annual crop, is commonly used as a sugar source and can be grown on marginal lands. Sweet sorghum has been tested in Jamaica and has the advantage of maturing after the normal sugar cane harvest period (FOREST 1988, FRANCIS 1987). Sweet sorghum sugar is not suitable for crystalline sugar production but is an excellent feedstock for molasses and ethanol applications. Thus, sorghum in Jamaica could be used as either a dedicated fibre feedstock (forage varieties) or for ethanol and molasses production (sweet varieties).

Another option for marginal lands in Jamaica are varieties of sugarcane that have low sugar content and high fibre yields. Some of these varieties may do well on marginal lands and be dedicated to combustion. Advantages are familiarity of cultivation, harvesting and handling methods. Such varieties would need to be evaluated for suitability.

Grasses are an option for a Jamaican fibre crop. Miscanthus is a perennial grass that does well in tropical areas with yields up to 33 tons per hectare, depending on the environment (ISUE 2010). Giant king grass, a hybrid of king grass with another species, is another possibility for the Jamaican environment with very high yields of 350 tons per hectare (wet weight, KUKKONEN 2009). The invasiveness of giant king grass is not clear at this time.

Grasses native to Jamaica that could be considered for development as dedicated energy crops include king grass and guinea grass. These grasses are often found growing along roadsides and in large wild areas. Some testing is being carried out as part of the bauxite mine land reclamation project. These tests will provide more information as to the suitability of these species as plantation crops.

Bamboo is another species widely found in Jamaica. However, it is considered an invasive species. For this reason, bamboo is not being considered for development as an energy crop. Bamboo may, however, find a place as an energy source in an eradication programme where, rather than allowing the bamboo to degrade on the forest floor, it would be delivered to an end user for combustion.

5.2. SUPPLY CHAIN ANALYSIS FOR ADDITIONAL BIOMASS FEEDSTOCK

5.2.1. Green Cane Harvesting

In the case of green cane harvesting and collection of cane trash there are some unique challenges with the supply chain because of the required changes to existing protocol. There is the benefit that these changes to the protocol have been researched in other sugar cane producing countries and the improvements can most likely be directly transferred to the Jamaican industry.

Challenges in Jamaica with green cane harvesting include more difficultly in manual harvesting due to the increased amount of leaf material impeding the use of machetes and of leafy mass that must be manipulated. Mechanical harvesting methods will most likely be required to efficiently harvest green cane. This will be a major challenge for Jamaica as the bulk of harvesting currently is manual. In addition, a good deal of the mechanical harvesting is done on burned cane in order either to allow faster harvesting or to overcome design inefficiencies of current equipment for harvesting green cane.

Since green cane also has more leaf material attached to the stem, cleaning the cane prior to crushing will also be necessary. Dry harvest methods have been developed in Brazil and Cuba that can serve as models for Jamaica. The dry harvest methods have the added advantage of greatly reduced contaminated water runoff at the sugar mill along with the reduced need to treat that waste stream.

Handling of cane trash (leaves and tops) will present a new challenge in Jamaica. A detailed study was carried out in Brazil that addresses this issue (HASSUANI 2005). Methods for collecting, processing and transporting cane trash were evaluated using both materials handling and economic metrics.

5.2.2. Development of new fibre species

All biomass supply chains have similar basic requirements regarding growing, maintaining, harvesting, transporting and processing the material. The methods for developing and supporting new energy crop species are well known and generally available in scientific literature and will not be discussed in detail here.

Briefly, to test new species for their utility and to develop a logistics supply chain, the following are required:

- acquisition of promising varieties for the intended environmental region and establishment of initial performance trials;
- characterisation of the biomass combustion properties, including the ash generated;
- establishment of the proper fertilisation and irrigation protocols for the specific area;
- determination of methods and equipment needed for planting, maintaining and harvesting the crop; and
- determination of the type of equipment needed for loading, transport and unloading of the crop.

Also, determination of suitable storage facilities may be necessary.

Biomass for fuel has relatively low density and low energy content compared to coal and fuel oil. For this reason, biomass must be grown within a relatively short distance from the point where it will be used. In the USA, a 50 mile radius surrounding an end user is generally thought of as an acceptable haul distance. For Jamaica, this distance will need to be determined by considering a number of factors like production price of the biomass, transportation costs and cost of the fuel that biomass will be replacing on an energy density basis.

5.3. ECONOMIC ANALYSIS OF BIOMASS FEEDSTOCK SUPPLY

A detailed economic study of biomass feedstock supply is beyond the scope of the current mission because there is little to no data available for the Jamaican situation regarding the specific recommendations. The Winrock study (OAS 2011) of biofuels development for Jamaica includes some economic analysis, but it focuses on liquid biofuels rather than biomass for cogeneration. There are however some economic analyses available that may serve as a starting point for a detailed Jamaican study.

Reports on green cane harvesting combined with collection of cane trash for power generation have included detailed economic analyses for many aspects of this process (LARSON 2001, HASSUANI 2005). These studies break down the cost of gathering trash, baling, loading, unloading and transport, as well as indirect costs of agronomy due to altered cultural practices. Table 5.4 shows some of these costs in US dollars per dry ton. Note the general agreement of the two studies in terms of cost suggesting a good estimate for the Jamaican situation. The Brazilian study (HASSUANI 2005) goes into a great deal of detail regarding impact of operational costs at the mill, but includes ethanol production in addition to sugar.

Table 5.4: Cost Estimates for Trash Recovery and Delivery to Factory (USD per dry ton)

Operation for Trash Recovery	Brazil Study	Cuba Study	Average
Windrowing	0.60	0.68	0.64
Baling	3.94	4.43	4.19
Bale Loading	1.43	1.64	1.54
Field Trailering	1.18	1.35	1.27
Bale Transport	1.95	2.20	2.08
Bale Unloading	0.51	0.59	0.55
Totals:	9.61	10.89	10.27

Sources: Brazil study (HASSUANI 2005) Cuba study (LARSON 2001)

Transport of biomass fuel represents a major proportion of cost. Biomass fuel is in general a low density, low value material, especially compared to higher value materials such a sugar cane. Compared to coal, oil and gasoline, biomass fuels have lower fuel densities and thus the volume to transport an equivalent amount of energy is quite a bit higher. For this reason, it is advantageous to grow biomass fuel as close as possible to the end user to reduce transportation costs.

An assessment for wood production and delivery costs in Jamaica estimates that fast growing trees species could be produced for 8.90 USD per ton and sold to end users for 15.00 USD per ton (LOY 2005). When adjusted for inflation between 2005 and 2010 the production cost would be approximately 15.81 USD per ton with a sale price of 24.86 USD per ton[15]. Based on the calculated price of woody biomass in the south-eastern USA and Brazil, these figures are reasonable (AZAR 2000). In the a.m. study the calculated delivery price per GJ for woody biomass was 3 USD in the south-east USA and 1.5 USD in Brazil. Inflation from 2000 to 2011 would add approximately 33 per cent to those prices or roughly end up at 4 USD per GJ and 2 USD/GJ in Brazil. The inflation adjusted sale price for the LOY 2005 study in Jamaica is 2.44 USD per GJ for delivered wood in Jamaica.

A recent survey of pulpwood prices in the south-eastern USA, including delivery, by several commercial services revealed that pine pulpwood prices ranged between 26 and 34 USD per metric tonne of wet wood while hardwood pulpwood ranged between 21 and 29 USD (GALIK

[15] *Wood prices at a sugar mill were quoted between 1,000 and 1,200 JD per ton (or 12 to 15 USD/ton). Obviously this was illegally felt or wood from private plots (in small quantities).*

2009, STUBER 2011, FOREST2MILL 2010). These are very reliable prices as they are gathered from direct surveys of wood buyers. These figures are comparable to the LOY 2005 inflation adjusted price. Pulpwood production figures are probably the best model for a fuel wood plantation programme in Jamaica as pulpwood represents a fast-growing, relatively low cost woody biomass with a predictable supply chain.

There are many factors that make prediction of the delivered price of woody biomass difficult in Jamaica. While there is an existing wood harvesting business it is not of the organisation and scale required for a sustainable fuel supply. The majority of wood in Jamaica is harvested from natural stands and relies on natural regeneration. While this practice can be sustained at a low harvest level, if the demand for woody biomass as a fuel increases it will be necessary to implement an organised effect to develop a plantation forestry industry in the country. Development of a plantation forestry industry would have the benefit of a continuous and predictable supply of woody biomass especially when coupled with an organised logistics system for biomass harvest and transport. The increased costs of capital equipment, land and operation would be more than offset by the increased yields of biomass from plantations. The increased yields come from a combination of continually improved genetics and agronomic practices as well as streamlined logistics of harvest, which increase worker productivity.

An estimation of a final delivery price for field trash or woody biomass is extremely difficult especially for Jamaica as a small island nation. The market is limited, there is no real competition or an alternative, so supply and demand situations can change rapidly and influence prices in both directions. For the sake of this analysis the base case scenario uses a price for additional biomass of **20 USD per ton** on air dry base (not wet, not dry weight), which would represent the form and quality of delivery and end-use.

6. DISCUSSION OF TECHNICAL AND ECONOMIC FEASIBILITY

6.1. REDUCTION OF EXTERNAL ENERGY SUPPLIES

As outlined in chapter 3.3, some of the Jamaican sugar factories depend on external energy supplies for steam production and/or electricity. Theoretically the energy content in the bagasse should be sufficient to satisfy all energy needs of a sugar mill for the complete processing.

The reality is governed by the technical setup. The traditional mills in Jamaica and elsewhere are designed and based on a low-pressure boiler system and an electricity production by backpressure turbines. The steam conditions are set at or below 20 bar pressure. The 20 bar (approximately 290 psi) steam is supplied to the prime movers which are steam driven engines for cane crushing and transport of the crushed cane at the intake section. The depressurised steam is used in the downstream process in the cooking and evaporation section. Part of the produced steam is sent to a backpressure turbine where at relatively low efficiencies (usually 5% based on input biomass) electricity is generated and consumed for the mill operation. Also here the leaving steam after the turbine is used in downstream energy consumption.

Two effects are determining the overall energy performance of the mill: the efficiency of generation and the efficient use of energy in the process. The international accepted values for a traditional sugar mill are given with 20 to 25 kWh per TC and with a steam demand below 0.5 t per TC. Due to lack of maintenance or repair and suboptimal performance in the different sections of the mill the steam and power demand could be higher. Same applies to the generating section (both steam and electricity), where through leakages, uncontrolled production and malfunctions less energy is delivered as theoretically possible. Another aspect is the interruption of cane supplies during the crop season or uncontrolled downtime at the mill, which leads to an unbalance between supply (which is bagasse for the energy production) and demand for steam and electricity at a specific time. The consequence is in most cases a situation short of steam. Since the prime movers have priority for the process continuation, electricity production by steam turbine is cut off or reduced (and power bought from the grid or produced by diesel) or in severe cases fuel oil is burnt in the boilers to produce more steam (e.g. for restart).

The first priority is to bring the sugar mill to a situation where it is self-sufficient in energy. Only after this step one can think of exporting excess energy. If a new power plant is built or major investments being done on the powerhouse at a mill, these investments are wrongly perceived if the (relatively expensively) produced energy is wasted afterwards. In this study the downstream process is not in focus, but it must be noted that improvements are necessary on that part.

The major improvement is a change from the steam driven crushing section to electricity driven and inverter controlled motors in that part. With that much less steam is needed, which alternatively can be used to produce more electricity, even if the power demand increases due to the additional installations.

The reduction of external energy demand is also vital for cost effective production. The high price for diesel/fuel oil and electricity cuts back on possible profits from the sugar production. In some cases it is estimated that one third of all sugar revenues are needed for external energy supplies.

The state of most of the powerhouses in the sugar mills in Jamaica[16] is such, that hardly any infrastructure can be utilised for upgrading or refurbishment. The technology in most cases is “World War 2”-standard. Improving the energy situation at a mill would mean the destruction of

[16] *This applies specially for the new privatized mills.*

the old powerhouse and a built up of a complete new power section for the mill. If that is considered, then the chances should be assessed, how with some more investment much more energy can be produced and excess energy sold to the national grid. The size of the possible project defines whether it is still a cogeneration project for the sugar mill with some (minor) exports or a completely new power plant, which produces some energy for the mill and another relevant portion for export. Depending on the actual sugar price, which is quite high at the moment, energy production could bring similar revenues per year as total sugar sales.

6.2. EXCESS ELECTRICITY PRODUCTION

Only if the energy demand of the sugar mill is in line with benchmark figures it is sensible to export excess energy. In order to produce enough volume for export, there is a technological change necessary. The traditional sugar mill with 15 bar boiler technology and backpressure turbines is not designed for an export-oriented operation. There is a need to switch to high steam pressure levels which will produce more electricity out of the same unit amount of steam. To maximise further on the power production the condensing type of turbines[17] must be employed instead of the backpressure system. During the crushing season steam is needed at the factory. In a very modern approach this can be organised with a condensing-extracting turbine, which supplies steam at a certain pressure level (on the cost of electricity output) on demand. If no steam is required the power output is higher. This turbine technology is more sophisticated and more expensive. A thorough consideration and evaluation is therefore necessary. A condensing extracting turbine is only viable on a high pressure level and in capacities beyond 5 MW or so.

As mentioned, the energy demand of a traditional mill could be set to 20 to 25 kWh/TC. This amount of electricity is produced in well managed 15 bar mills. Using present technologies a production level of more than 140 kWh/TC is possible at higher pressures and with higher efficient equipment. Deducting the demand, this makes an export level of 120 kWh/TC easily possible.

For the assessment of excess electricity production one can define three different scenarios, which might reflect appropriate technology situations. A decision for which scenario a sugar mill may opt for depends on its ultimate objective (only self generation or exports), the initial investments and the political framework conditions. In order to initiate a discussion the following three models are presented:

- **The 20 bar case:** this is in essence not more than the status quo in the industry and should be used as the reference. We use a slight increase in pressure level and a turbine with higher efficiency. This results in small amounts of export power, if the mill is rather efficient. The case reflects the situation where the mill needs a new powerhouse anyway and has to build it to continue operation. Some existing equipment and infrastructure might still be used and reduce initial investments.

- **The 40 bar case:** In this option a new powerhouse must be built using a state-of-the-art boiler with 40 bar production of steam. All steam is passed through a backpressure turbine with high efficiency. During the crushing season (and if still steam engines are installed) the backpressure will stay at 15 bar. If no steam is demanded at 15 bar, the backpressure can be reduced to 1 or 1.5 bar. This setup is an intermediate stage since no condensing option is used and the production of power in the off-season is less efficient. The 40 bar option is mainly a crop season option. If the conditions are favourable for year-round production, this could be started with the backpressure turbine. If then after a couple of years the off-season biomass production might be established, the power plant can be upgraded through an additional turbine or a change

[17] *The full condensing turbine does not supply steam for prime movers, only low pressure and low temperature steam is available for possible cogeneration.*

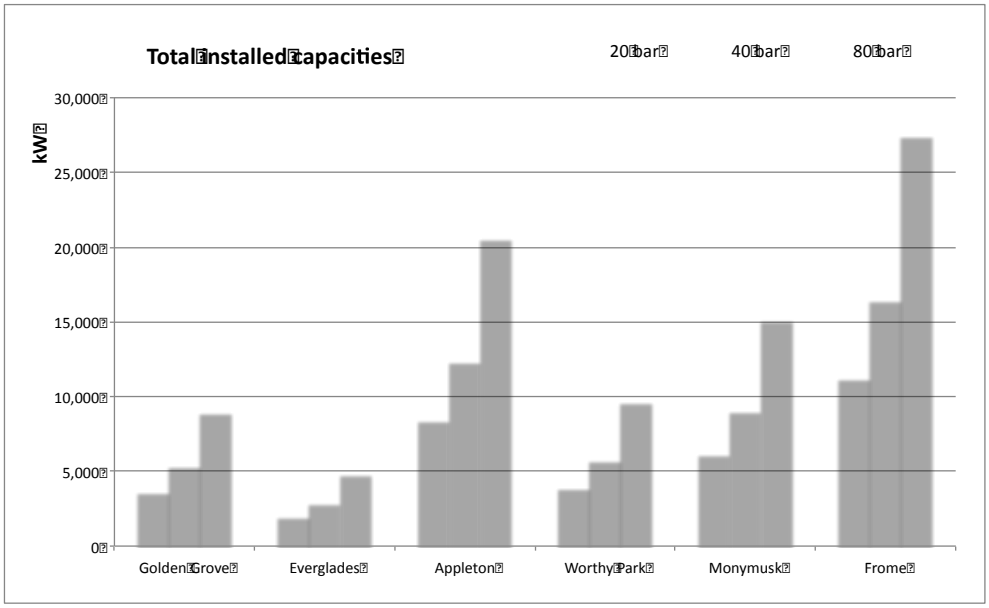
of the turbine to a condensing-extracting mode. This case is not the most efficient one but could be an option to improve the situation step by step and to avoid high initial investments. Another variant is the split of turbines between backpressure and condensing type and using them in parallel or alternating.

- **The 80 bar case:** In order to maximise exports, high pressure is needed for high electricity production. The size and the cost of such a power plant ultimately calls for a continuous operation, not only during the 6 month crushing period. Otherwise pay back periods are too long. The highest flexibility is reached with a condensing-extracting turbine connected to a high pressure boiler system. During the crop season steam is extracted in volume and pressure demanded by the process. In the off-season the turbine runs in full condensing mode and maximises power output. Also this option is flexible for additional steam demand (distillery or eventually bioethanol production in off-season).

A similar approach can be found in different sugar producing countries. Taking Mauritius for example where in 1988 the power production was 13 kWh/TC, in 2000 already 60 kWh/TC and one factory recently went up to 125 kWh/TC. According to the source the pressure regime for non-firm power was in the range of 24 to 31 bar, whereas for exporting firm power between 44 and 83 bar were applied (DEEPCHAND 2005). These figures are in line with above assumptions. There are higher pressure levels built for power plants with better efficiencies. In most cases these are large with several 100 MW coal power plants, which cannot be compared with the biomass power plants usually in the 10 MW range.

The different cases also have different overall potentials. A basic feature is that all bagasse is consumed during the crushing season. Less efficient low pressure systems can produce less energy. Higher pressure and higher efficiency produces more energy from the same amount of resources. Applying the above considerations to Jamaican, the individual potential at each mill could be calculated based on the following conditions. The present cane production is used and a 30% bagasse ratio assumed. This bagasse in converted to steam in the 20 bar, 40 bar and 80 bar options, the steam demand of the mill (as surveyed above) is satisfied as well as the electricity demand. Applying the efficiency of a modern boiler (this gives the total steam production possible with the amount of bagasse available) and the different efficiencies of the three pressure levels for the turbine setup, the result is the maximum capacity of the turbine for power generation during the crop season. Figure 6.1 shows the results for the 6 actual running mills in Jamaica.

Figure 6.1: Possible installed capacities at each mill under different pressure levels



Sources: own figures

On the 20 bar option the capacities range from 2 to 11 MW. A slight increase is seen for the 40 bar option. Now the capacities from the smallest to the biggest plant are 2.9 and 16.5 MW respectively. In the 80 bar option 4.8 to 27.4 MW are calculated. Based on this conservative assessment the 20 bar option could add theoretically 35 MW of generating capacity in Jamaica for all six operating sugar mills. This would be roughly 4% of total generating capacity in Jamaica (JPS plus IPP). The 40 bar option can reach up to 52 MW generating capacity or 6% of national value. With the 80 bar option 86 MW installed capacity might be possible. In this case the biomass power plants could add 10% of existing capacity. These capacities are based on the present sugar cane production. Increases in production would also increase power capacities. On the other hand it must be stated that if once a decision is taken for a certain technology, the potential is bound for the next 20 years to that technology[18].

Table 6.1 shows the export production of electricity in the six operating mills based on the technological setup. Three different figures are presented, use of bagasse alone, additional biomass alone and the combined effect. The use of bagasse only as fuel, i.e. the seasonal operation delivers limited amounts of electricity in the 20 bar case. Increases are possible for the 40 bar option towards a total of 64,000 MWh. This can be more than doubled if the 80 bar case is realised. The biomass only option has the advantage that the sugar mill does not need energy for production and the total of produced power can be exported. Therefore some 100,000 MWh are already possible with the 20 bar option (if biomass material is stored and the power plant is running year-round). The next case with 40 bar produces 155,000 MWh per year and finally 260,000 MWh is possible from additional biomass use at the power plants employing the 80 bar technology. With the combined operation the 20 bar option could deliver 2.8% of national electricity demand. The increase in pressure to 40 bar expands that figure to 5.3% of all demand. The maximum potential for the 80 bar case can produce 9.9% of national electricity demand per year.

Table 6.1: Electricity production at sugar mills

	Bagasse only			Biomass only			Combined operation		
Location	**20 bar**	**40 bar**	**80 bar**	**20 bar**	**40 bar**	**80 bar**	**20 bar**	**40 bar**	**80 bar**
Golden Grove	0	4,336	13,483	9,867	14,526	24,202	9,867	18,862	37,684
Everglades	0	4,045	8,577	5,481	8,068	13,443	5,481	12,113	22,021
Appleton	5,995	15,682	33,408	31,267	46,030	76,693	37,261	61,712	110,102
Worthy Park	2,782	7,851	17,636	11,425	16,819	28,023	14,207	24,670	45,659
Monymusk	0	10,288	27,556	16,815	24,754	41,244	16,815	35,042	68,800
Frome	0	22,066	50,880	30,974	45,599	75,974	30,974	67,665	126,854
Total, MWh	**8,777**	**64,267**	**151,540**	**105,827**	**155,796**	**259,579**	**114,604**	**220,063**	**411,119**
National, %	**0.2%**	**1.6%**	**3.7%**	**2.6%**	**3.8%**	**6.3%**	**2.8%**	**5.3%**	**9.9%**

The above figures imply a certain efficiency at the different conversion steps. In this case after the boiler with a specific efficiency (assumed 80% here from bagasse or fuel to steam) the different turbine systems are employed based on their specific steam consumption. Figures used in the baseline scenario are 11 kg steam per kWh at the 20 bar backpressure turbine. This may be compared to the consumption at the existing mills with some 15 kg/kWh (Appleton for example). The increase to 40 bar should reduce the specific steam consumption at the turbine down to 7 kg/kWh. The condensing type turbine for 80 bar may consume as slow as 4 kg/kWh. Using the above quoted figures from available steam one can calculate the electricity output

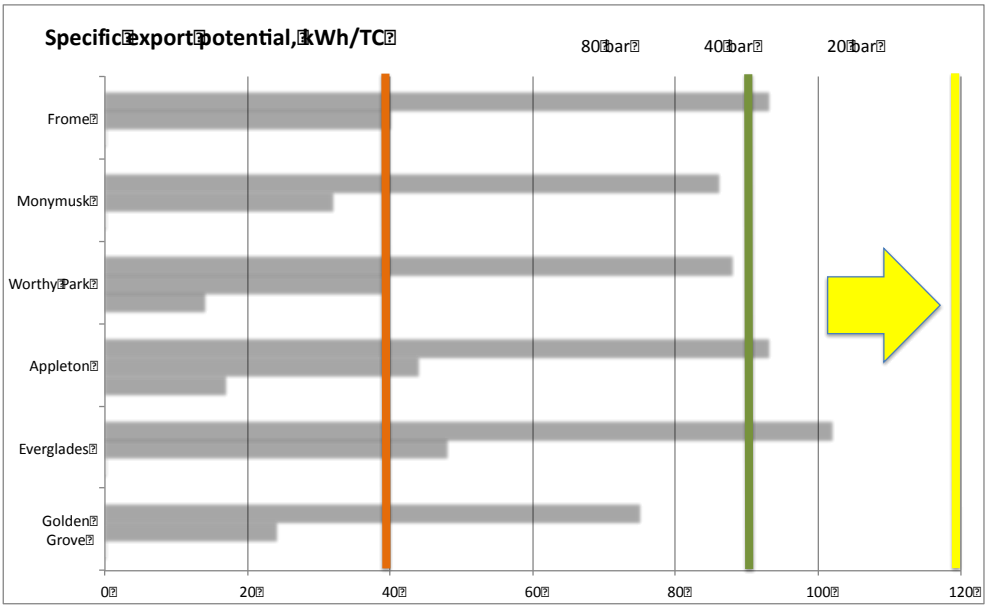
[18] *If for example a smaller capacity is chosen, bagasse might be saved throughout the season for use in the off-season.*

resp. production for that set of parameters. Taking all factors together, the overall efficiency (from fuel to electricity) for the different options is:

20 bar	**9.19%**
40 bar	**13.53%**
80 bar	**22.55%**

How this compares to international levels is shown in figure 6.2. The specific export electricity is taken as the comparator. In the 20 bar option only small excess energy is produced. Only two mills are able to export, the other mills have a too high self-consumption. The switch to 40 bar technology should result in some 40 kWh/TC of exports. Some factories reach that figure exactly, some are below and some are above that. The 80 bar option applied to Jamaica gives average figures of 90 kWh/TC. This is already an improvement but there is still scope for higher efficiencies and productivities if compared to the 120 kWh/TC target figure (see figure 6.2).

Figure 6.2: Levels of export electricity



6.3. ADDITIONAL BIOMASS FEEDSTOCK FOR INCREASED ELECTRICITY PRODUCTION

In chapter 5 it has been shown, at what costs and qualities additional biomass fuels could be made available at the proposed biomass power plant.

The assumption for the technical model are that the biomass power plant could be operated for some 7,000 full-load hours per year, which is a reasonable figure for biomass power plants. Deducting the gross operating time for the sugar crop season (at full load, but also planned and unexpected stoppage) one can assess the available time left per mill and consequently the amount of fuel, which is needed to continue operation in the off-season. The actual demand for additional biomass is not a function of the pressure level and of the installed capacity. In all cases biomass is a fixed quantity but in the higher pressure cases more electricity can be produced from the same quantity. In all three technological cases the same amount of biomass is needed. The different efficiencies compensate the effect, meaning the same amount of biomass produces more net electricity at a higher pressure level. The table 6.2 gives the summary of this calculation. Biomass demand for the off-season is between less than 20,000 t/yr and some 30,000 t/yr at the smaller mills and up to nearly 100,000 t/yr at the larger mills.

The case for Appleton seems slightly outstanding. The reason is that Appleton has a shorter crushing season and thus more time available for biomass utilisation and as a consequence a higher yearly demand for biomass.

For further economic analysis it has not been specified what type of additional biomass is being used. This could be cane trash, short rotation forestry or any other energy crop. An average price of 20 USD/t and a LCV (lower calorific value) of 13 GJ/t is taken for biomass in the economic analysis.

Table 6.2: Additional biomass volume for year-round production

Sugar mill	Biomass t/year
Golden Grove	29,700
Appleton	94,200
Everglades	16,500
Worthy Park	34,400
Frome	93,300
Monymusk	50,700

Sources: own figures

6.4. BIOETHANOL PRODUCTION

The actual situation in the sugar sector in Jamaica does not favour the production of bioethanol. There is already a shortage of molasses for rum production and the sugar prices are relatively high. This prevents the shift from raw sugar to ethanol production. However, if bioethanol was produced by the sugar industry, it would have important implications on the energy situation of the mills. Ethanol production consumes large amount of steam for all of the distillation processes (and comparable less electricity), which could reduce the net export figures as presented above. In order to keep the model calculations transparent this opportunity is not included in the evaluation.

6.5. RESULTS OF FINANCIAL ANALYSIS

6.5.1. Base case results

An economic model was developed for the evaluation of the financial viability of the project ideas. A whole set of assumptions need to be made to define and calculate the final results. The major detail is the operation of the power plant as an independent entity. This at least is true for the technical setup. Organisationally or financially different procedures could be applied, whatever the best opportunity would be. If one assumed, that the power plant is buying bagasse and additional biomass at certain prices (a fictive price for bagasse), produces steam and electricity and sells to different customers, i.e. the sugar factory and the grid operator. The sales of steam to the mill are based on the avoided costs (total cost minus capital cost) of a boiler operating on low pressure and producing steam only, not in cogeneration. The electricity price then is calculated out of the difference between bagasse purchase by the power plant from the sugar mill and steam sales from the power plant to the sugar mill. In summary, the sugar mill supplies bagasse for a certain amount of money and has to buy back steam and electricity for the same amount of money. The overall balance is zero. All results are seen from the perspective of the proposed power plant. The base case means in effect, that bagasse is for free and in exchange the power plant has to deliver certain amounts of steam and electricity to the sugar mill. Excess electricity can be sold to the grid. In the off-season additional biomass has to be purchased and all electricity is sold to the grid. Investments and operating costs must get a return based on the exported amount of energy.

Using this model the sugar mill profits from not having to invest in and to operate its own power supply. The sugar mill gets its energy for free. It has no cost shares to bear at all. Whether this is justified and fair, would be discussed. Other variations of cost-sharing are presented later. But possible savings due to decreased dependency on external power or diesel/fuel oil should be credited to the power plant. As already discussed earlier, the shift from a pure cogeneration project (for the energy needs of the mill) towards an export oriented independent power producer is necessary to induce larger capacities and electricity figures. The "average" mill in Jamaica would need a cogeneration power plant with some 2 MW for a maximum of 4,000 hours per year. If export power is desired, the capacity can be increased to 10 or 15 MW and in extreme cases to 25 MW for 7,000 to 8,000 operating hours per year. Thus, the installed capacities (and the costs) for the proposed export power plants are in magnitudes larger compared to what the sugar mill would invest for its own generation. In a fair cost-sharing arrangement the sugar mill would therefore have to contribute only the minor part, whereas the bigger part should be assigned to the export power activity. Because the model offers costs for bagasse and steam and power exchanges, different alternatives can be calculated and shown.

The table in Annex 11.6.6 gives a summary of all other assumptions being made for the economic model. The important base figures are as follows:

- 20 year lifetime, 10 year credit period;
- equity 30%, loan 70%;
- interest rate nominal 12.5%, commercial 14%;
- Price for bagasse 7 USD/ton;
- Price for additional biomass 20 USD/ton;
- Steam sales internal 3 USD/ton (equals roughly fictive production cost);
- Internal electricity sales differ (export according to OUR, firm power and renewable);
- Specific investment costs in a range of 2,000 to 2,300 USD per kWe;
- Operation and maintenance with 4% of investment cost per year;
- Insurance cost as 1.5%;
- Personnel cost, water cost etc. are added.

The base case for the six sugar mill locations and the three technology levels are displayed in table 6.3. As key indicators the internal rate of return in % and the full production cost per exported kWh of electricity are chosen.

Table 6.3: Financial analysis, base case

Description	20 bar	40 bar	80 bar
Golden Grove, IRR%	-4.75%	3.94%	10.65%
Golden Grove, USct/kWh	19.42	15.21	12.38
Everglades, IRR%	5.14%	7.29%	11.67%
Everglades, USct/kWh	15.75	13.49	11.90
Appleton, IRR%	(5.68%)	26.83%	26.77%
Appleton, USct/kWh	(13.89)	8.12	7.55
Worthy Park, IRR%	-0.69%	9.98%	14.62%
Worthy Park, USct/kWh	16.58	12.54	10.71
Frome, IRR%	n.a.	10.03%	13.68%
Frome, USct/kWh	22.11	12.55	11.06
Monymusk, IRR%	n.a.	7.28%	12.87%
Monymusk, USct/kWh	32.23	13.69	11.40

It can be seen that in most cases the IRR is below 12.5%, which is used as the threshold level resp. the minimal bank lending rate. Accordingly in only a few rare cases a profit is being made. Profits are only possible for the larger factories and if choosing the 80 bar option. The analysis

of the production costs per unit electricity reveals that in most cases production cost are higher than in comparison to the FIT, which is given at the moment (firm contract with 15% premium for renewable) with 11.56 USct/kWh. Production cost in the 20 bar option are in the range of 20 USct/kWh and far out of reach for the present FIT regime. The 40 bar option shows production costs in most cases below 15 USct/kWh. Only the Appleton case is a singular exception because there is already a 40 bar boiler installed, which reduces investment cost substantially.

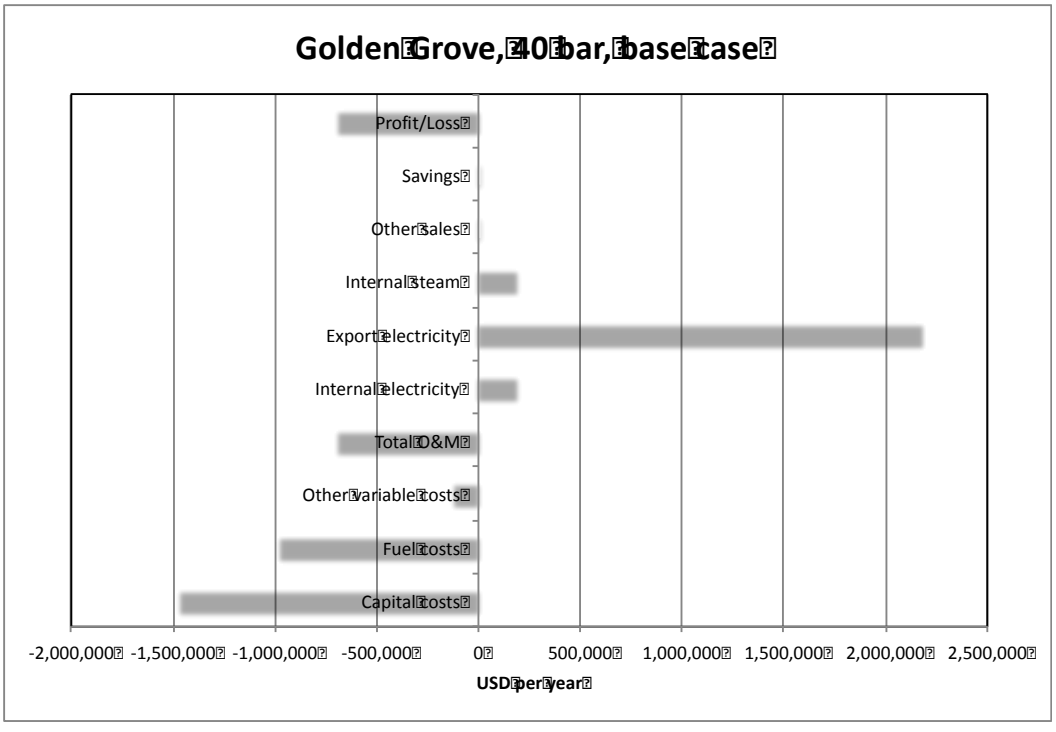
The profits in the base case are in most cases negative (see table 6.4). Even the 80 bar option would result in very marginal net profits per year, which would not encourage investors. Again only the case Appleton shows, that profits in 2 to 4 mill. USD per year might be achieved.

Table 6.4: Yearly profits per year for all mills, base case

Description	20 bar	40 bar	80 bar
Golden Grove, USD/year	-775,424	-688,684	-308,524
Everglades, USD/year	-229,750	-233,629	-74,634
Appleton, USD/year	n.a.	2,124,564	4,412,509
Worthy Park, USct/kWh	-713,412	-241,890	388,697
Frome, USD/year	-3,266,630	-667,997	629,703
Monymusk, USD/year	-4,475,461	-745,948	107,740

Only one example[19] is shown as a figure for the cost and benefit structure and for the base case (figure 6.3), here for the Golden Grove factory and the 40 bar option.

Figure 6.3: Example of cost and benefit structure



The two major cost items are capital costs and fuel costs. Only part of the internal fuel costs are recovered by the sales of steam and electricity back to the sugar mill (internal). The bigger share is the cost for additional biomass. The interest rate is quite high. Thus, capital costs

[19] *The electronic version of the economic model has a figure for each mill and case.*

based on 70% lending quota are also substantial. Specific investments costs were taken as the average of Asian prices (can go below 1,500 USD/kWe) and European/North-American prices (up to 4,000 USD/kWe including all environmental protection technology). In comparison to other projects the capital costs here are higher. Usually the fuel costs are the biggest cost portion in biomass power plants (on international comparison). The only substantial income is generated by electricity sales, but this is not enough to recover all expenses. On the yearly balance a loss is accrued. The total O&M seem to be quite high as well. Here it should be noted that the technology is new to Jamaica and spare parts etc. have to be imported and a slightly higher rate was used in the economic model to be on the safe side. In general, the breakdown of costs and benefits looks similar to all factories and in principle for the three cases.

6.5.2. Options in economic analysis

i) Feed-in tariff to 15 USct/kWh

Table 6.5 shows the IRR in a case where the FIT is increased to 15 USct/kWh, which is a level being recommended by several studies. The production costs remain the same, therefore they are not displayed here. Now it can be seen that more options are available with an acceptable IRR (marked in yellow). Most importantly, also the 40 bar case seems to get more financial viability. This would be of advantage for the smaller mills (minimising risk and reducing initial investments) as they would not go to the high pressure and high efficient system in the first step. The 20 bar option does not provide sufficient return (as expected because all cost are to be borne by a relatively small amount of export energy).

Table 6.5: Financial analysis, FIT 15 USct/kWh

Description	20 bar	40 bar	80 bar
Golden Grove, IRR%	4.47%	12.06%	18.05%
Everglades, IRR%	11.28%	16.22%	19.56%
Appleton, IRR%	15.40%	40.28%	38.28%
Worthy Park, IRR%	8.96%	18.35%	22.69%
Frome, IRR%	n.a.	18.19%	21.40%
Monymusk, IRR%	n.a.	15.45%	20.59%

The situation on the yearly profits is improved, as table 6.6 displays. In some cases reasonable profits are possible with the 40 bar option. In the 80 bar option the bigger mills can expect profits of between 2 and 8 mill. USD per year.

Table 6.6: Possible yearly profits with a FIT of 15 USct/kWh

Description	20 bar	40 bar	80 bar
Golden Grove, USD/year	-436,011	-39,840	987,822
Everglades, USD/year	-41,218	183,059	682,875
Appleton, USD/year	n.a.	4,247,460	8,200,003
Worthy Park, USD/year	-224,701	606,753	1,959,362
Frome, USD/year	-2,201,141	1,659,666	4,993,468
Monymusk USD/year	-2,879,038	459,501	2,474,461

ii) Sales to sugar mill based on electricity price of 11.56 USct/kWh

One point of discussion is the justification for the very cheap delivery of electricity to the sugar mill (which is the result of the balance between steam sales and bagasse purchase) and by this somehow subsidising the operation of the sugar factory (as the mill has no power plant to operate and needs no investments). To show the effect of this “subsidy” on the overall

economics, one option is calculated where the sugar mill has to pay the same tariff, which is paid by the grid operator. This should improve the financial situation of the power plant as the sugar mills now share a higher part of the total costs. The final results are shown in table 6.7.

Table 6.7: Internal sales with FIT 11.56 USct/kWh

Description	20 bar	40 bar	80 bar
Golden Grove, IRR%	10.25%	11.99%	14.43%
Golden Grove, USct/kWh	12.90	11.80	10.67
Everglades, IRR%	10.72%	11.15%	13.53%
Everglades, USct/kWh	12.65	12.08	11.13
Appleton, IRR%	7.83%	28.47%	27.56%
Appleton, USct/kWh	13.21	7.70	7.32
Worthy Park, IRR%	4.11%	12.24%	15.78%
Worthy Park, USct/kWh	15.06	11.66	10.23
Frome, IRR%	-0.23%	14.67%	16.03%
Frome, USct/kWh	17.96	10.65	10.05
Monymusk, IRR%	#ZAHL!	15.66%	17.00%
Monymusk, USct/kWh	24.86	10.15	9.60

This possible revenue increase for the biomass power plant shows a slightly similar effect on the overall financial performance as the increase of the FIT to 15 USct/kWh. The 40 bar option is still on just financially viable in most of the calculated sugar mills. As a compromise the sugar mills could get a certain amount of electricity at a very low price and have to pay the FIT for any amount of electricity going over this minimum demand (it would also encourage energy efficiency efforts). This measure and an increase of the FIT to 15 USct/kWh would then also make all 40 bar options financially viable.

iii) Full cost payment for steam and electricity

This is the most extreme position for the cost-sharing in favour of the new power plant. In chapter 4 the fictive full cost for a cogeneration unit only for the purpose of the sugar mill had been discussed. The bagasse would be free of cost and the power plant supplies back steam for 3.9 USD/t and electricity for 15.75 USct/kWh (Table 6.8).

Table 6.8: Full cost payment by the sugar mill

Description	40 bar	80 bar
Golden Grove, IRR%	15.88%	16.44%
Golden Grove, USct/kWh	9.90	9.72
Everglades, IRR%	13.64%	14.79%
Everglades, USct/kWh	11.11	10.59
Appleton, IRR%	30.68%	28.62%
Appleton, USct/kWh	7.14	7.01
Worthy Park, IRR%	14.43%	16.94%
Worthy Park, USct/kWh	10.77	9.75
Frome, IRR%	17.53%	17.53%
Frome, USct/kWh	9.40	9.39
Monymusk, IRR%	19.72%	19.14%
Monymusk, USct/kWh	8.25	8.63

This extreme option gives all 40 and 80 bar options a financial viability. The production costs of the exported unit of electricity are in ranges from 9 to 11 USct/kWh and therefore below the present FIT of 11.56 USct/kWh. But it would be rather unfair to charge the sugar mill with more than 15.75 USct and sell to the grid for only 11.56 USct/kWh.

It is therefore very important in this case for the power plant to operate year-round in order to make it financially vialable. If electricity sales from additional biomass are excluded (and the costs for biomass set to zero), all options end up in a negative cash flow. For an operation of a bigger power plant only during the crop season, the initial investments are too high. Even the application of short-term power (taken the FIT as avoided fuel cost of 19 USct/kWh) does not result in positive financial data.

The options i) to iii) should show what effect a fair cost-sharing agreement between the sugar mill and the power producer would have on the overall economic performance. It is important in the sense of this report, what is regarded as a reasonable FIT paid by JPS to the proposed power plant. At what costs and conditions the power plant finally buys their material and sells steam and power internally, would be their internal business model. But obviously, the present regulations for the FIT are not sufficient for a positive investment decision.

iv) Use of coal as alternative to biomass

Theoretically, imported coal might be used as additional fuel for the out-of-crop-season. The results for this are presented in table 6.9. The price for coal is somehow 6 times higher than for the biomass (assumed to 120 USD/t). But the heating value is only twice as high. Consequently the fuel costs increase substantially.

Table 6.9: Coal as alternative to biomass

Description	20 bar	40 bar	80 bar
Golden Grove, IRR%	negative	negative	2.93%
Golden Grove, USct/kWh	30.80	21.16	15.36
Everglades, IRR%	negative	negative	3.99%
Everglades, USct/kWh	27.13	18.64	14.73
Appleton, IRR%	negative	-0.27%	15.44%
Appleton, USct/kWh	23.44	13.88	10.78
Worthy Park, IRR%	negative	-14.98%	7.08%
Worthy Park, USct/kWh	25.73	17.81	13.56
Frome, IRR%	negative	-11.70%	6.60%
Frome, USct/kWh	33.49	17.76	13.84
Monymusk, IRR%	negative	negative	5.69%
Monymusk, USct/kWh	43.61	19.15	14.18

No real financial viability can be seen for this strategy, also considering that no logistics are available for shipping, unloading and transporting coal to the individual sugar mills. The uncertainties for coal are far too high to be considered a real alternative.

v) Sensitivity analysis

Once an economic model is built up, a series of changes can be made to different assumptions and the effects be shown. At this stage too many options would confuse and complicate the necessary decision-making. Therefore only two sensitivities are presented, one technical and one financial.

Efficiency along the complete production chain is important. High initial investment must be justified by effectively utilised materials and resources. The base case already assumes state-of-the-art technology and efficiencies. To demonstrate the possible effect, an increase of boiler efficiency of 5% is assumed (through better operation, reduction of losses etc.). The results in table 6.10 (in comparison to the base case) show, that a production cost reduction by 0.5 USct/kWh and an IRR increase by 2% is possible. This again is a good argument for sound technology and good operational procedures.

Table 6.10: Increase in boiler efficiency by 5%

Description	20 bar	40 bar	80 bar
Golden Grove, IRR%	-2.27%	6.04%	12.29%
Golden Grove, USct/kWh	18.28	14.22	11.65
Everglades, IRR%	6.54%	9.16%	13.24%
Everglades, Usct/kWh	14.83	12.76	11.27
Appleton, IRR%	8.76%	29.56%	29.08%
Appleton, Usct/kWh	12.79	7.66	7.13
Worthy Park, IRR%	3.04%	11.80%	16.29%
Worthy Park, Usct/kWh	15.08	11.82	10.11
Frome, IRR%	negative	11.79%	15.24%
Frome, Usct/kWh	20.81	11.83	10.46
Monymusk, IRR%	negative	9.20%	14.48%
Monymusk, Usct/kWh	30.33	12.86	10.76

Financial implications could be cheaper investments etc., here a 2 % decrease of interest rate is assumed to show the effect of reduced capital costs (Table 6.11). By definition the IRR (as only the net revenues against the total capital are seen) does not change but the specific production costs are lower. With 2% less interest around 1 USct/kWh lower production cost are possible. At whatever feed-in tariff the operation works, it increases the overall profits. Also fine-tuning of the capital outlay and crediting could influence the overall result substantially.

Table 6.11: Reduction in capital costs, decrease of 2% interest rate

Description	20 bar	40 bar	80 bar
Golden Grove, USct/kWh	18.22	14.28	11.49
Everglades, USct/kWh	14.53	12.72	11.08
Appleton, USct/kWh	13.16	7.69	7.05
Worthy Park, USct/kWh	15.67	11.75	9.94
Frome, USct/kWh	20.92	11.74	10.25
Monymusk, USct/kWh	31.02	12.84	10.58

6.5.3. Next steps in refinement of economic assessment

The next step is to refine and adjust the individual cases and design them to be more site specific and in cooperation with the owners and/or possible investors. The following strategy should be pursued in developing possible projects:

- Setting the base case: this would be a separated power plant at the mill location, only seasonal operation, only bagasse as fuel, some small exports to the grid;
- Effect of high fibre cane: leads to more bagasse and higher specific electricity output, more exports in the crop season and possible extension of power production for several weeks into the off-season, more earnings from exports, possible incentives for farmers for high fibre delivery;
- Use of cane tops and trash: in parallel with the increase of green cane harvesting and after the successful introduction of logistical concept (field collection, baling, transport), storage for off-season, extended operational time of power plant, more exports;
- Additional biomass fuels: if there is still a fuel gap to fill, buying or processing of biomass fuels, alternative could be coal (impacts to monitor);
- Re-assessment of agreement between power plant and sugar mill: reduced price only for benchmark demand for steam and power, above that demand delivery at market prices (improves profitability of power plant and is an incentive for the sugar mill to increase efficiency).

The main reason for a step-by-step approach is that all different measures for extending the power production would need time before being established. The effects of high fibre cane can be seen only after at least one more generation of cane varieties, which may take 5 years and more. The logistics for collecting cane trash with all necessary machinery and experience for optimal use may also take several years before this is available across the island. Also additional biomass in the quantities which are required for a full scale year-round operation need several years before regular harvesting can take place. Consequently, the strategy would be to start with bagasse and easily accessible biomass fuels, upgrade the biomass delivery system and extend the production period.

One major difficulty arises through the time lag between the start of the project and full capacity utilisation. The above financial assessments have already shown the difficulties of operating the proposed power plant with bagasse and additional biomass on a year-round basis (under existing conditions). Using bagasse solely in the crop season would not lead to any financial viability, even under extremely high feed-in tariffs. The production cost would reach 25 to 30 USct/kWh. Thus, even under favourable conditions the first few years a loss situation has to be expected, before gradually the financial conditions improve. The incentives in the starting period need to be higher to cover the additional financial risk. But if no power plant is erected, no demand for additional biomass is created and then all the measures to produce more biomass would not be started and executed. A pull situation must be initiated through the proposed power plant and the framework conditions must compensate for the initial risks and financial difficulties.

6.5.4. Development of individual business cases for selected sugar mills

After the first mission was completed and a seminar was conducted during the second mission, additional meetings were held with interested sugar mills. In these meetings individual proposals were presented and discussed. Three sugar mills participated in this exercise.

i) Golden Grove

The proposed biomass power plant should be an entirely new build on the grounds of the sugar mill. Apparently, there is not much scope for using existing equipment, more so as a higher pressure level is anticipated to increase efficiencies and possible electricity output. That is: technically it would be an independent power producer (IPP) concept. Legally or

organisationally other forms are possible and depend also on negotiations and definitions with the OUR resp. JPS on the terms and definitions of self-generation, cogeneration, ownership, wheeling etc[20].

To reduce risks in initial investments and project sizing, a two-step approach might be followed for the setting up of export power production:

- First stage

Instalment of a new power plant with 40 bar steam conditions and based on backpressure turbines. Operation is factory and season orientated. Gradually more power can be produced with additional biomass and the economic situation can be improved from year to year. Capacity could be 5 MW electrical gross output. The expansion of the 2nd stage should be planned already and preparations built in, if possible;

- Second stage

Shift to 80 bar steam conditions and condensing-extracting turbine, either by adding a second line (and take the first one as backup and additional producer) or by refurbishing the boiler and replacing the turbine. Capacity should be 8 MW, or perhaps 10 MW on an optimistic approach. This plant must be operated year-round to show a reasonable payback.

The following data have been used in the financial model presented afterwards:

- Production level: 250,000 TC (present is 180,000 TC, plan is 300,000 TC);
- Usable capacity: 85 TC per hour;
- Energy demand in sugar production should be more efficient
  - 25 kWh electricity per TC;
  - 0.6 t steam per TC, 50% for prime movers at 15 bar and 50% for operations at 1.5 bar;
- Grid connection for smaller capacities (below 20 MW) only 2 km power line and transformer, price indication by JPS.

Results of the financial analysis for the **5 MW proposal**
Base case (investments into new power plant, year-round production with additional biomass, but tops and trash is sufficient, bagasse costs are levelled with steam and power demand by the sugar factory, feed-in tariff is only 11.56 USct/kWh):

- no financial viability, production cost for exported unit are 13.6 USct/kWh

Changes to above base case (included are the possible savings from avoided cost for electricity and fuel oil/diesel as of now):

- Internal Rate of Return, IRR = 14.74%, simple payback 7 years;
- Production cost of export power = 10.49 USct/kWh;
- First year balance sheet: +288.000 USD/year.

The other extreme position (power plant receives bagasse free and sell steam and electricity for full cost with 3.9 USD/t and 15.75 USct/kWh) shows nearly similar results on the key figures (IRR of 14.38% and 7 years). A profit is made, but interestingly the production cost for export power is high with 16.48 USct/kWh, meaning that export power is “subsidized” by the sugar mill. The new bill for the sugar mill is 1.423 mill. USD, but only savings of 842,000 USD are realised. If bagasse is prized with 525,000 USD the situation for the sugar mill improves but the power plant now lose money (base case as above, no financial viability).

[20] *For the factory alone there is only demand for a 2 MW maximum electrical capacity plant and all the steam production. This is the cogeneration approach for self-production of energy. A plant with 5 MW or even 10 MW should be recognised as an IPP, because the main function is to produce energy for export.*

In addition, increase feed-in tariff increased to 15 USct/kWh (which is recommended by a few studies) and still include possible savings:

- Internal Rate of Return, IRR = 21.5%, simple payback 5 years;
- Production cost of export power = 10.49 USct/kWh (did not change);
- First year balance sheet: +1,200,000 USD/year.

The above development of financial viability shows the necessary compromise between cost-sharing by the sugar mill and a reasonable feed-in tariff. For full operation the 15 USct/kWh might be enough, the present possible tariff is too low.

Without the additional biomass supply and year round production there is no financial viability, even if during the crop season a feed-in for short term supplies (dump power) of 19 USct/kWh is used. The production costs in this case are calculated as 22.55 USct/kWh. The investments into a 5 MW power plant cannot be returned only during the crop season and thereafter the plant is put idle for half of the remaining year without any income generation. To make this case viable a feed-in tariff of at least 25 USct/kWh is needed (for the transition period).

Based on the given information of electricity costs for all SEPROD activities a yearly power consumption of 6 mill. kWh is estimated. The above designed power plant can produce 9.5 mill. kWh as export from bagasse during the crop season and another 17.4 mill. kWh in the off-season (from additional biomass). Thus, prospective production is higher than all demand of SEPROD and a sale (or additional sale) to JPS is necessary, even if wheeling can be applied.

Results for the financial analysis for a high pressure **8 MW power plant**
The higher pressure results in more export potential from bagasse, because it is better utilised. Then a bigger plant during the off-season produces more power from the additional biomass fuels. The overall economics is improving. The base case as defined above including year-round production is just at the edge of getting attractive with:

- Internal Rate of Return, IRR = 13.27%, simple payback 7 years;
- Production cost of export power = 11.23 USct/kWh;
- First year balance sheet: +142,000 USD/year.

If a feed-in tariff of 15 USct/kWh can be achieved:

- Internal Rate of Return, IRR = 20.88%, simple payback 5 years;
- Production cost of export power = 11.23 USct/kWh (did not change!!);
- First year balance sheet: +1,630,000 USD/year.

Or as alternative, if the present external energy costs can be saved:

- Internal Rate of Return, IRR = 17.66%, simple payback 6 years;
- Production cost of export power = 9.28 USct/kWh;
- First year balance sheet: +984,000 USD/year.

But, as shown above already, a seasonal production only based on bagasse does not lead to financial viability.

One **alternative** could be a smaller high pressure system from the beginning, for example a 5 MW plant with 80 bar and a condensing-extracting turbine. Bagasse would be saved throughout the season, 3 MW exported and afterwards the electricity production continued on 5 MW export until the bagasse is used up. Then gradually more fuels can be sourced and utilised.

Some major discussion points have been the impact of green cane harvesting and the collection of cane trash on the financial arrangements with farmers. It is more or less accepted, that farmers should receive more money if they deliver more fibres. Another concern is the time needed to implement the whole project, which may take 3 years or so. Their own plans were for a 3.5 MW upgrade of the power house. The proposed 5 MW plant is in reach of their plans. For

a 10 MW the initial capital outlay is too high. More technical details have to be cleared before cane trash can be utilised (baling, transport, storage, disintegration before boiler etc.). The bioethanol option is still considered as one activity in the off-season either from molasses or from other sugar sources.

The technical background and one example of the financial model calculations (yearly cost model) follow on the next two pages.

Technical details

Name of sugar factory	**Golden Grove**			
TC production	250,000.00	TC/year		
Bagase production	0.30	%		
Total Bagasse	75,000.00	t/year		
Energy demand				
Electricity	25.00	kWh/TC		
	6,250.00	MWh/year		
	2.13	MW max	1.50	MW average
Steam demand	0.60	t/TC		
total and for sugar process	150,000.00	t/year		
	51.00	tph max steam	36	tph average
Steam for milling at 15 bar	75,000.00	t/year	0.3	t steam / TC
Steam for turbine	75,000.00	t/year	0.3	t steam / TC
Crushing rate, nominal	85.00	tph		
Crushing rate, actual	60.00	tph		
Full crushing time	2,941.18	hours		
off - time	1,225.49	hours		
Total operational time	4,166.67	hours		
	173.61	days		
Maximum power plant	7,400.00	hours		
Additional operational time	3,233.33	hours		
Possible power plant				thermal capacity
Bagasse input	152,083.33	MWh/year	51.71	MW max
Boiler efficiency	0.85	%	36.50	MW average
Steam production	(demand for prime movers need to be subtracted)			
40 bar	153,083.88	t/year		
	52.05	tph max steam		
	36.74	tph average steam		
			effiencies	
Steam demand for mill at 15 bar	75,000.00	t/year		
Available for backpress 40 to 15	75,000.00	t/year		
specific demand backpress 40 bar	7	t steam per MWH		
	4,669.40	MWh	3.07%	
	1.59	MW capacity		
Available for export on backpressure	78,083.88	t/year		
	7	t steam per MWH		
	11,154.84	MWh	7.33%	
	3.79	MW capacity		
Total production from bagasse	**15,824.24**	**MWh**	10.40%	
Combined capacity	**5.38**	**MW**		
Off-season operation				
possible electricity production	17,396.12	MWh		
biomass demand	120,976.91	MWh		
Biomass general	13.00	GJ/t		
Biomass amount	33,501.30	t/year		
Theoretical trash generation	0.30	t/TC		
Theoretical available trash	75,000.00	tons/year		
Trash recovery	44.67%			
Alternative IPP high pressure				
Steam production	(demand for prime movers need to be subtracted)			
80 bar	145,748.51	t/year		
	49.55	tph max steam		
	34.98	tph average steam		
			effiencies	
Steam demand for mill at 15 bar	75,000.00	t/year		
Available for backpress 80 to 15	75,000.00	t/year		
specific demand backpress 80 bar	7	t steam per MWH		
	5,910.83	MWh	3.89%	
	2.01	MW capacity		
Available for export on backpressure	70,748.51	t/year		
	4	t steam per MWH		
	17,687.13	MWh	11.63%	
	6.01	MW capacity		
Total production from bagasse	**23,597.96**	**MWh**	15.52%	
Combined capacity	**8.02**	**MW**		
Off-season operation				
possible electricity production	25,942.03	MWh		
biomass demand	108,278.29	MWh		
Biomass general	13.00	GJ/t		
Biomass amount	29,984.76	t/year		
Theoretical trash generation	0.30	t/TC		
Theoretical available trash	75,000.00	tons/year		
Trash recovery	39.98%			

Input data cell by user		
Assumed data cell		
Final results and comment cell		
Open and white cell: results of calculation		

Description of the project case

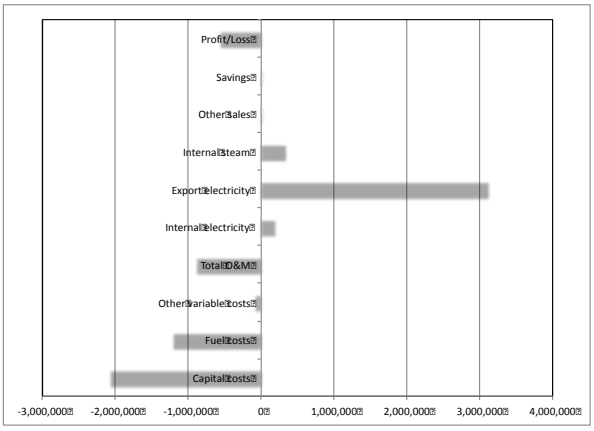
Golden Grove, 40 bar backpressure new power plant

Annuity method for specific production cost

		Data	Units	
Installed Electrical capacity		5,400	kW	
Capital -linked payments				
Boiler		7,000,000	USD	
Cost of turbine		5,000,000	USD	
Other equipment cost		0	USD	
Total equipment cost		12,000,000	USD	
Cost of Engineering and Civil work		1,200,000	USD	
EPC (engineering, procurement, construction) cost		13,200,000	USD	
Land cost		0	USD	
Grid connection cost		840,000	USD	
Import duty, % of foreign EPC cost	3.0%	360,000	USD	
Construction time insurance, % of Equipment cost	1.5%	180,000	USD	
Other capital linked costs, **here 50Hz/60 Hz converter**		0	USD	
Sub-Total		14,580,000	USD	
Contingencies (?% of sub-total)	2.0%	291,600	USD	
Capital investment		**14,871,600**	**USD**	on EPC
- specific investment cost		**2,754**	USD/kW	2,444
Life time		20	Year	
Real loan rate		12.50%	%	
Annuity Factor		0.138	-	
Annuity of capital investment		**2,053,705**	**USD/year**	
Economical Conditions:				
Loan Financing		70%		
Equity Capital		30%		
Principal, Bank Loan		10,410,120	USD	
Equity Capital		4,461,480	USD	
Pay-back Period, Loan		10	Year	
Commercial loan		14.00%	%	
Bank Loan (interest + capital) repayment		**1,995,761**	**USD/year**	
consumption-linked payments				
Bagasse demand		75,000	Ton/year	
Bagasse price		7.00	USD/ton	
Total bagasse costs		525,000	USD/year	
Other fuel demand		33,501	Ton/year	
Other fuel cost		20	USD/ton	
Total other fuel cost		670,026	USD/year	
Fuel demand cost in first year		**1,195,026**	**USD/year**	
In case of electricity demand/deficit	9,574	0	MWh/year	
Unit price for electricity JPS		29	Usct/kWh	
Electricity cost in season		**0**	**USD/a**	
Raw Water consumption per year		300,000	m/year	
Unit price of water		0.24	USD/m3	
Raw water cost in first year		**71,429**	USD/year	
Other consumption-linked costs		**0**	USD/year	
Total Consumption-linked cost in first year		**1,266,455**	**USD/year**	
Operation-linked payments				
O&M costs	4.00%	528,000	USD/year	
Number of Staff Employed		15	Persons	
Average Salary		10,000	USD/year	
Total Salary and Adm.		150,000	USD/year	
Insurance cost	1.50%	198,000	USD/year	
Other operational costs		0	USD/year	
Total Operation and maintenance cost in first year		**876,000**	USD/year	
Total Payments		**4,196,159**	USD/year	
without capital cost (annuity)		2,142,455	USD/year	
Revenues				
Power production in season		15,824	MWh/year	
Own Consumption in season		6,250	MWh/year	25.00 kWh/TC
Surplus (or deficit) in season		9,574	MWh/year	
Difference between bagasse costs and steam sales		187,500	USD/a	
Calculated unit price after steam sale		3.00	USct/kWh	
Revenue for own consumption		**187,500**	USD/a	
Avaliable for export in season		9,574	MWh/year	38.30 kWh/TC
Power production off-season		17,396	MWh/year	
Unit price of electricity sold		11.56	USct/kWh	
Non firm power		10.73	USct/kWh	
Revenue from electricity sale		**3,117,773**	USD/a	
Total revenue from electricity sold		**3,305,273**	**USD/a**	
Steam Production, gross		153,084	ton/year	
Steam for prime movers		75,000	ton/year	
Unit price of steam (internal use)		3.00	USD/t	
Revenue from steam (internal use)		225,000	USD/a	
Additional low pressure steam		75,000	ton/year	
Unit price of low pressure steam sold		1.50	USD/MWh	
Revenue from steam sale (external sell)		112,500	USD/a	
Total revenue from Steam sold		**337,500**	**USD/a**	
Typical content of byproduct		0%	%	
Amount of by product		0	ton/year	
Unit price of by product		50.00	USD/ton	
Revenue from by product		**0**	**USD/a**	
Price of CERs traded		10	EURO/t CO2	
Emission factor as per PDD	0.63	0.0000	t CO2/MWh	
Amount of CER		0	t CO2	
Revenue from CDM business		**0**	**USD/year**	
Savings				
Avoided electricity	2400	0	MWh/year	
Unit price		29	USct/kWh	
Avoided electricity cost		0	USD/year	
Avoided fuel oil	190000	0	L/year	
Unit price		0.77	USD/L	
Avoided fuel oil cost		0	USD/year	
Total savings		**0**	**USD/year**	
Total revenue and savings		3,642,773	USD/year	
Total Balance		**-553,386**	**USD/year**	
Total Balance all revenues minus operational costs		1,500,319	USD/year	
Production cost for the export electricity unit		**13.612**	USct/kWh	

Results of costs and revenues for graph

	USD/year
Capital costs	-2,053,705
Fuel costs	-1,195,026
Other variable co	-71,429
Total O&M	-876,000
Internal electricit	187,500
Export electricity	3,117,773
Internal steam	337,500
Other sales	0
Savings	0
Profit/Loss	-553,386



Calculation of production cost for export unit		
26,970	MWh/year	
4,196,159	Costs	
525,000	Revenues before export to grid	
3,671,159	Open cost	
13.61182907	Usct/kWh to be zero	

ii) Everglades

This is a brief description for a proposed power plant project at Everglades. Some general conclusions are drawn from the presentations on 7th December 2011. The main points discussed have been:

- The pressure level at the mill/power plant must be higher in order to get more power produced and exported;
- There is a need to use steam and electricity most efficiently in the mill;
- Bagasse is still the main fuel during the crop. Additional biomass should come through sugar cane related sources (high fibre cane, energy cane, tops and trash, green harvesting). This potential is already sufficient;
- The present tariff paid by JPS and controlled by OUR is not sufficient to put investors in a financially viable situation.

The build of the proposed biomass power plant should be entirely new on the grounds of the sugar mill. Apparently, there is not much scope for using existing equipment, more so as a higher pressure level is anticipated to increase efficiencies and possible electricity output. That is: technically it would be an independent power producer (IPP) concept. Legally or organisationally other forms are possible and depend also on negotiations and definitions with the OUR on the terms self-generation, cogeneration, ownership etc[21].

To reduce risks in initial investments and project sizing, a two-step approach might be followed:

- First stage

Instalment of a new power plant with 40 bar steam conditions and based on backpressure turbines. Operation is factory and season orientated in the first instance. Gradually more power can be produced with additional biomass during the non-crop season and the economic situation can be improved from year to year. Capacity could be 4.5 MW electrical gross output. The expansion towards the 2nd stage should be planned already and preparations built into, if possible[22].

- Second stage

Shift to 80 bar steam conditions and condensing-extracting turbine, either by adding a second line (and take the first one as backup and additional producer) or by refurbishing the boiler and replacing the turbine. Capacity should be 7 MW, may be 8 to 10 MW on an optimistic approach. This plant must be operated year-round to show a reasonable payback.

The following data have been used in the financial model presented lateron:

- Production level: 175,000 TC (present is 84,000 TC, plan is 175,000 TC);
- Usable capacity: 75 TC per hour;
- Energy demand in sugar production should be more efficient
  - 25 kWh electricity per TC;
  - 0.6 t steam per TC, 50% for prime movers at 15 bar and 50% for operations at 1.5 bar;
- Grid connection for smaller capacities, only 2 km power line and transformer with resp. capacity, prices from JPS[23].

Results of the financial analysis for the **4.5 MW proposal**

[21] *For the factory alone there is only demand for a 1.6 MW maximum electrical capacity plant and all the steam production. This is the cogeneration approach for self-production of energy. A plant with 4.5 MW or even 10 MW should be recognised as an IPP, because the main function is to produce energy for export.*
[22] *This could be a second parallel line or a possible upgrade of the boiler to higher pressures and a new turbine.*
[23] *The grid connection costs are calculated extra*

Base case (investments into new power plant, year-round production with additional biomass, but tops and trash is sufficient, bagasse cost are levelled with steam and power supply to sugar factory, feed-in tariff is only 11.56 USct/kWh):

- no financial viability, production cost for exported unit are 13.24 USct/kWh

Changes to base case (include possible savings from avoided cost for electricity and fuel oil/diesel as of now):

- Internal Rate of Return, IRR = 13.8%, simple payback 7 years;
- Production cost of export power = 10.976 USct/kWh;
- First year balance sheet: +137.000 USD/year.

In addition, increase feed-in tariff to 15 USct/kWh (which is recommended by a few studies) and still include possible savings:

- Internal Rate of Return, IRR = 21.01%, simple payback 5 years;
- Production cost of export power = 10.976 USct/kWh (did not change);
- First year balance sheet: +945,000 USD/year.

Without the additional biomass supply and year round production there is no financial viability, even if during the crop season a feed-in for short-term supplies (dump power) of 19 USct/kWh is used. The investments into a 4.5 MW power plant cannot be returned only during the crop season without using it for half of the remaining year.

Results for the financial analysis for a high pressure **6.8 MW power plant**

The higher pressure results in more export potential from bagasse, because it is better utilised. Then a bigger plant during the off-season produces more power from the additional biomass fuels. The overall economics are getting better. The base case as defined above including year-round production is just at the edge of getting attractive with:

- Internal Rate of Return, IRR = 13.43%, simple payback 7 years;
- Production cost of export power = 11.17 USct/kWh;
- First year balance sheet: +146,000 USD/year.

If a feed-in tariff of 15 USct/kWh can be achieved:

- Internal Rate of Return, IRR = 21.13%, simple payback 5 years;
- Production cost of export power = 11.17 USct/kWh (did not change);
- First year balance sheet: +1,440,000 USD/year.

But, as shown above already, a seasonal production only based on bagasse does not lead to financial viability. The time of utilisation of investment is too low.

One **alternative** could be a smaller high-pressure system from the beginning, for example a 4.5 MW plant with 80 bar and a condensing-extracting turbine. Bagasse would be saved throughout the season, some 3 MW exported and afterwards the electricity production continued on 4.5 MW export until the bagasse is used up.

Discussion included the anticipated production level. If the total crop would reach 280,000 TC/yr, which is the long term objective, the proposed power plants could be larger with 6.5 MW for 40 bar and 9.9 MW for 80 bar instead. The larger size improves the financial position slightly for all of the different options.

Further discussion concentrated on the “fictive” pricing for bagasse. This is a sensitive issue not only for the relationship between sugar mill and power plant but also for the payment details between sugar mills and farmer. The sugar factory must concentrate on the viable production of sugar under world market conditions and be competitive also if sugar prices are going down

again. In the sugar divestment programme cogeneration was included. It was mentioned that cogeneration should be profitable in 3 years. Thus, the Government has the obligation to set the framework conditions in the right order.

The technical background and one example of the financial model calculations (yearly cost model) follows on the next two pages.

Technical details

Name of sugar factory	**Everglades**			
TC production	175,000.00	TC/year		
Bagase production	0.32	%		
Total Bagasse	56,000.00	t/year		
Energy demand				
Electricity	25.00	kWh/TC		
	4,375.00	MWh/year		
	1.63	MW max	1.13	MW average
Steam demand	0.60	t/TC		
total and for sugar process	105,000.00	t/year		
	39.00	tph max steam	27	tph average
Steam for milling at 15 bar	52,500.00	t/year	0.3	t steam / TC
Steam for turbine	52,500.00	t/year	0.3	t steam / TC
Crushing rate, nominal	65.00	tph		
Crushing rate, actual	45.00	tph		
Full crushing time	2,692.31	hours		
off - time	1,196.58	hours		
Total operational time	3,888.89	hours		
	162.04	days		
Maximum power plant	7,400.00	hours		
Additional operational time	3,511.11	hours		
Possible power plant				thermal capacity
Bagasse input	113,555.56	MWh/year	42.18	MW max
Boiler efficiency	0.85	%	29.20	MW average
Steam production	(demand for prime movers need to be subtracted)			
40 bar	114,302.63	t/year		
	42.46	tph max steam		
	29.39	tph average steam		
			effiencies	
Steam demand for mill at 15 bar	52,500.00	t/year		
Available for backpress 40 to 15	52,500.00	t/year		
specific demand backpress 40 bar	7	t steam per MWH		
	3,268.58	MWh	2.88%	
	1.21	MW capacity		
Available for export on backpressure	61,802.63	t/year		
	7	t steam per MWH		
	8,828.95	MWh	7.78%	
	3.28	MW capacity		
Total production from bagasse	**12,097.53**	**MWh**	10.65%	
Combined capacity	**4.49**	**MW**		
Off-season operation				
possible electricity production	15,776.71	MWh		
biomass demand	109,715.18	MWh		
Biomass general	13.00	GJ/t		
Biomass amount	30,382.67	t/year		
Theoretical trash generation	0.30	t/TC		
Theoretical available trash	52,500.00	tons/year		
Trash recovery	57.87%			

Alternative IPP high pressure				
Steam production	(demand for prime movers need to be subtracted)			
80 bar	108,825.56	t/year		
	40.42	tph max steam		
	27.98	tph average steam		
			effiencies	
Steam demand for mill at 15 bar	52,500.00	t/year		
Available for backpress 80 to 15	52,500.00	t/year		
specific demand backpress 80 bar	7	t steam per MWH		
	4,137.58	MWh	3.64%	
	1.54	MW capacity		
Available for export on backpressure	56,325.56	t/year		
	4	t steam per MWH		
	14,081.39	MWh	12.40%	
	5.23	MW capacity		
Total production from bagasse	**18,218.97**	**MWh**	16.04%	
Combined capacity	**6.77**	**MW**		
Off-season operation				
possible electricity production	23,759.85	MWh		
biomass demand	99,170.21	MWh		
Biomass general	13.00	GJ/t		
Biomass amount	27,462.52	t/year		
Theoretical trash generation	0.30	t/TC		
Theoretical available trash	52,500.00	tons/year		
Trash recovery	52.31%			

Input data cell by user		
Assumed data cell		
Final results and comment cell		
Open and white cell: results of calculation		

Description of the project case

Everglades, 40 bar backpressure new power plant

Annuity method for specific production cost

		Data	Units	
Installed Electrical capacity		4,500	kW	
Capital -linked payments				
Boiler		5,700,000	USD	
Cost of turbine		4,200,000	USD	
Other equipment cost		0	USD	
Total equipment cost		9,900,000	USD	
Cost of Engineering and Civil work		950,000	USD	
EPC (engineering, procurement, construction) cost		10,850,000	USD	
Land cost		0	USD	
Grid connection cost		780,000	USD	
Import duty, % of foreign EPC cost	3.0%	297,000	USD	
Construction time insurance, % of Equipment cost	1.5%	148,500	USD	
Other capital linked costs, **here 50Hz/60 Hz converter**		0	USD	
Sub-Total		12,075,500	USD	
Contingencies (?% of sub-total)	2.0%	241,510	USD	
Capital investment		**12,317,010**	**USD**	on EPC
- specific investment cost		**2,737**	USD/kW	2,411
Life time		20	Year	
Real loan rate		12.50%	%	
Annuity Factor		0.138	-	
Annuity of capital investment		**1,700,927**	**USD/year**	

Economical Conditions:			
Loan Financing		70%	
Equity Capital		30%	
Principal, Bank Loan		8,621,907	USD
Equity Capital		3,695,103	USD
Pay-back Period, Loan		10	Year
Commercial loan		14.00%	%
Bank Loan (interest + capital) repayment		**1,652,936**	**USD/year**

consumption-linked payments			
Bagasse demand		56,000	Ton/year
Bagasse price		7.00	USD/ton
Total bagasse costs		392,000	USD/year
Other fuel demand		30,383	Ton/year
Other fuel cost		20	USD/ton
Total other fuel cost		607,653	USD/year
Fuel demand cost in first year		**999,653**	**USD/year**
In case of electricity demand/deficit	7,723	0	MWh/year
Unit price for electricity JPS		29	Usct/kWh
Electricity cost in season		**0**	**USD/a**
Raw Water consumption per year		200,000	m/year
Unit price of water		0.24	USD/m3
Raw water cost in first year		**47,619**	USD/year
Other consumption-linked costs		**0**	USD/year
Total Consumption-linked cost in first year		**1,047,272**	**USD/year**

Operation-linked payments			
O&M costs	4.00%	434,000	USD/year
Number of Staff Employed		15	Persons
Average Salary		10,000	USD/year
Total Salary and Adm.		150,000	USD/year
Insurance cost	1.50%	162,750	USD/year
Other operational costs		0	USD/year
Total Operation and maintenance cost in first year		**746,750**	USD/year

Total Payments		**3,494,949**	USD/year
without capital cost (annuity)		1,794,022	USD/year

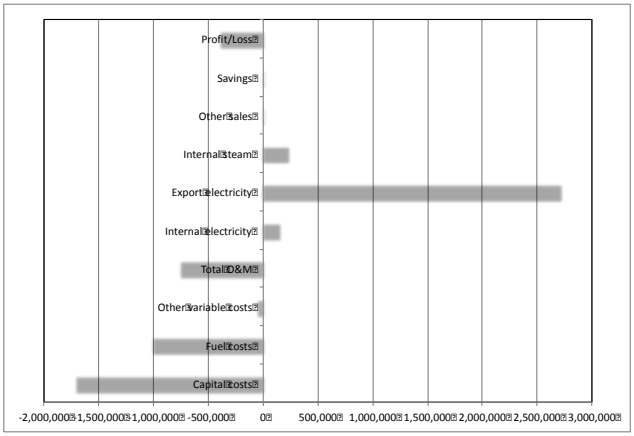
Revenues				
Power production in season		12,098	MWh/year	
Own Consumption in season		4,375	MWh/year	25.00 kWh/TC
Surplus (or deficit) in season		7,723	MWh/year	
Difference between bagasse costs and steam sales		155,750	USD/a	
Calculated unit price after steam sale		3.56	USct/kWh	
Revenue for own consumption		**155,750**	USD/a	
Avaliable for export in season		7,723	MWh/year	44.13 kWh/TC
Power production off-season		15,777	MWh/year	
Unit price of electricity sold		11.56	USct/kWh	
Non firm power		10.73	USct/kWh	
Revenue from electricity sale		**2,716,512**	USD/a	
Total revenue from electricity sold		**2,872,262**	**USD/a**	
Steam Production, gross		114,303	ton/year	
Steam for prime movers		52,500	ton/year	
Unit price of steam (internal use)		3.00	USD/t	
Revenue from steam (internal use)		157,500	USD/a	
Alddditional low pressure steam		52,500	ton/year	
Unit price of low pressure steam sold		1.50	USD/MWh	
Revenue from steam sale (external sell)		78,750	USD/a	
Total revenue from Steam sold		**236,250**	**USD/a**	
Typical content of byproduct		0%	%	
Amount of by product		0	ton/year	
Unit price of by product		50.00	USD/ton	
Revenue from by product		**0**	**USD/a**	
Price of CERs traded		10	EURO/t CO2	
Emission factor as per PDD	0.63	0.0000	t CO2/MWh	
Amount of CER		0	t CO2	
Revenue from CDM business		**0**	**USD/year**	

Savings			
Avoided electricity	480	0	MWh/year
Unit price		29	USct/kWh
Avoided electricity cost		0	USD/year
Avoided fuel oil	500000	0	L/year
Unit price		0.77	USD/L
Avoided fuel oil cost		0	USD/year
Total savings		**0**	**USD/year**

Total revenue and savings		3,108,512	USD/year
Total Balance		**-386,437**	**USD/year**
Total Balance all revenues minus operational costs		1,314,490	USD/year
Production cost for the export electricity unit		**13.204**	USct/kWh

Results of costs and revenues for graph

	USD/year
Capital costs	-1,700,927
Fuel costs	-999,653
Other variable c	-47,619
Total O&M	-746,750
Internal electricit	155,750
Export electricity	2,716,512
Internal steam	236,250
Other sales	0
Savings	0
Profit/Loss	-386,437



Calculation of production cost for export unit		
23,499	MWh/year	
3,494,949	Costs	
392,000	Revenues before export to grid	
3,102,949	Open cost	
13.20446389	Usct/kWh to be zero	

iii) Appleton

This is a brief description for a proposed power plant project at Appleton. Some general conclusions are drawn from the presentations on 7th December 2011. The main points discussed have been:

- The pressure level at the mill/power plant must be higher in order to get more power produced and exported;
- There is need to use steam and electricity most efficiently in the mill;
- Bagasse is still the main fuel during the crop. Additional biomass should come through sugar cane related sources (high fibre cane, energy cane, tops and trash, green harvesting). This potential is already sufficient;
- The present tariff paid by JPS and controlled by OUR is not sufficient to put investors in a financially viable situation. More incentives are required.

The situation at Appleton is an exception for two reasons. The sugar mill decided to install a new boiler system a couple of years ago. This boiler is designed for 40 bar and 113 tph (tons per hour) steam (being 600 psi and 250,000 lb/hr). The factory and the surrounding estate and houses are operated on an isolated grid system with a 60 Hz frequency. No connection exists to the national grid (which uses the 50 Hz system). If excess electricity is supplied to the grid, a frequency conversion must be installed on the cost of the project. On the other hand, a boiler is already installed which reduces the initial investment substantially. Overall, there should be a beneficial situation.

The **proposed project** would rely on the installed boiler and aims to utilise its capacity fully (both at pressure and production level). The installed capacity of the boiler is sufficient to produce much more excess power as it is done now. The technical overview and the energy and steam balance indicate that there is a generation capacity of 15 MW based on 40 bar pressure and on condensing turbine technology. The following setup could be installed: one 1.78 MW backpressure turbine for 40 bar down to 15 bar mainly in operation during the crop season and delivering the electricity demand plus most of the steam demand for prime movers (15 bar) and the sugar processing on a lower pressure level. This turbine could be operated on 60 Hz. There is already a 2 MW turbine on site but with lower efficiencies than are anticipated in this proposal (and operating on lower pressure). An upgrade or refurbishment could be considered, otherwise the new turbine as specified above should be added. For year-round production and exports to the grid a nearly 15 MW condensing turbine (14.77 MW) can be utilised connected to a 50 Hz system and resp. generator. To produce electricity for the factory and community from outside of the crop season a frequency conversion for roughly 1 MW from 50 Hz to 60 Hz is added. This technology can also be used as a backup during the crop[24]. It is assumed that a grid connection can be made to the 69 kV line, which passes near the estate at a distance of some 5 to 6 km. Some more key data have been used in the financial model presented:

- Production level: 400,000 TC (present is 360,000 TC, 34% bagasse);
- Usable capacity:150 TC per hour;
- Energy demand in sugar production as it is
    - 16.5 kWh electricity per TC;
    - 0.6 t steam per TC, 50% for prime movers at 15 bar and 50% for operations at 1.5 bar.

Results of the financial analysis

More assumptions and details are given in the attached spreadsheets. Costs and benefits are assumed, calculated and analysed. Basic decision-making data should be the internal rate of return and the production cost of the exported energy unit. Total investments are in the vicinity

[24] There are quotations for a 2 MW converter in the range of 0.8 to 1.3 mill. USD. For the a.m. 1 MW a budget is given with 1.1 mill. USD.

of 25 million USD for turbine, changes in the structure and grid connection including frequency converter.
The base case for a year-round production (3,700 hours in off-season) in a 15 MW power plant ends with the following performance (base case feed-in tariff of 11.56 USct/kWh):

- Internal rate of return, IRR = 32%;
- Simple payback: 5 years;
- Production cost: 6.5 USct/kWh;
- Profit/loss in the first year: +4.7 mill. USD.

Above figures assume a continuous operation with additional biomass supplies throughout the year. This needs some time to be established. It could well be that in the first years the system for biomass delivery is not established and the power plant has to stop operation. The case with only exporting power from bagasse during the crop season results with:

- Internal rate of return, IRR = 10%;
- Simple payback: 9 years;
- Production cost: 12.9 USct/kWh;
- Profit/loss in the first year: - 500,000 USD (but with O%M of 800,000 USD).

But in this situation one could argue, that the power plant is only for short term supply and thus applies the so-called dump power concept. Here the avoided fuel cost is paid as feed-in, which at present stays at 19 USct/kWh. Based on this, the situation improves to:

- Internal rate of return, IRR = 22.5%;
- Simple payback: 5years;
- Production cost: 12.9 USct/kWh;
- Profit/loss in the first year: +2.28 mill. USD:

In summary, the reality for this proposed power plant could be between seasonal bagasse only and full year operation and for a feed-in tariff of 11.56 or 15 (as proposed for other projects) or even 19 USct/kWh. It appears that under all options and assumptions this could be a financially viable project.

Considering an installation of 80 bar technology, installed capacities could reach 20 or 25 MW and increase the export power volume. As shown in the general case description, the financial viability increases automatically for the larger projects on a higher pressure level. This option may be considered in the mid term planning. But it would require the installation of a totally new boiler-turbine setup with high investments.

Discussions and important issues surround the different technical issues which must be solved before a decision for a new power plant can be taken. These include problems at the factory (high bagasse moisture, cane handling) and at field level (green cane harvesting, possible baling of cane trash). The operation of a power plant is seen as a business case outside of the sugar part, a partnership or even an IPP-agreement are seen as alternatives.

The technical background and one example of the financial model calculations (yearly cost model) follow on the next two pages.

Technical details

Name of sugar factory	**Appleton**			
TC production	400,000.00	TC/year		
Bagase production	0.34	%		
Total Bagasse	136,000.00	t/year		
Energy demand				
Electricity	16.50	kWh/TC		
	6,600.00	MWh/year		
	2.48	MW max	1.82	MW average
Steam demand	0.60	t/TC		
total and for sugar process	240,000.00	t/year		
	90.00	tph max steam	66	tph average
Steam for milling at 15 bar	120,000.00	t/year	0.3	t steam / TC
Steam for turbine	120,000.00	t/year	0.3	t steam / TC
Crushing rate, nominal	150.00	tph		
Crushing rate, actual	110.00	tph		
Full crushing time	2,666.67	hours		
off - time	969.70	hours		
Total operational time	3,636.36	hours		
	151.52	days		
Maximum power plant	7,400.00	hours		
Additional operational time	3,763.64	hours		
Possible power plant				thermal capacity
Bagasse input	275,777.78	MWh/year	103.42	MW max
Boiler efficiency	0.85	%	75.84	MW average
Steam production	(demand for prime movers need to be subtracted)			
40 bar	277,592.11	t/year		
	104.10	tph max steam		
	76.34	tph average steam		
			effiencies	
Steam demand for mill at 15 bar	120,000.00	t/year		
Available for backpress 40 to 15	120,000.00	t/year		
specific demand backpress 40 bar	11	t steam per MWH		
	4,754.30	MWh	1.72%	
	1.78	MW capacity		
Available for condensing	157,592.11	t/year		
	4	t steam per MWH		
	39,398.03	MWh	14.29%	
	14.77	MW capacity		
Total production from bagasse	**44,152.33**	**MWh**	16.01%	
Off-season operation				
possible electricity production	55,604.94	MWh		
biomass demand	220,966.04	MWh		
Biomass general	13.00	GJ/t		
Biomass amount	61,190.60	t/year		
Theoretical trash generation	0.30	t/TC		
Theoretical available trash	120,000.00	tons/year		
Trash recovery	50.99%			

Input data cell by user		
Assumed data cell		
Final results and comment cell		
Open and white cell: results of calculation		

Description of the project case

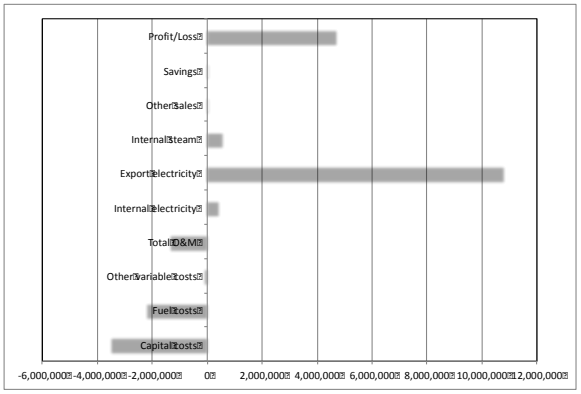
Appleton, full use of 40 bar boiler capacity, instalment of condensing turbine 15 MW and upgrade backpressure turbine for crop season, additional biomass only trash

Annuity method for specific production cost

		Data	Units	
Installed Electrical capacity		15,000	kW	
Capital -linked payments				
Boiler refurbishment		2,500,000	USD	
Cost of turbine		14,000,000	USD	
Other equipment cost		2,000,000	USD	
Total equipment cost		18,500,000	USD	
Cost of Engineering and Civil work		1,600,000	USD	
EPC (engineering, procurement, construction) cost		20,100,000	USD	
Land cost		0	USD	
Grid connection cost		2,500,000	USD	
Import duty, % of foreign EPC cost	3.0%	555,000	USD	
Construction time insurance, % of Equipment cost	1.5%	277,500	USD	
Other capital linked costs, **here 50Hz/60 Hz converter**		1,100,000	USD	
Sub-Total		24,532,500	USD	
Contingencies (?% of sub-total)	2.0%	490,650	USD	
Capital investment		**25,023,150**	**USD**	on EPC
- specific investment cost		**1,668**	USD/kW	1,340
Life time		20	Year	
Real loan rate		12.50%	%	
Annuity Factor		0.138	-	
Annuity of capital investment		**3,455,590**	**USD/year**	
Economical Conditions:				
Loan Financing		70%		
Equity Capital		30%		
Principal, Bank Loan		17,516,205	USD	
Equity Capital		7,506,945	USD	
Pay-back Period, Loan		10	Year	
Commercial loan		14.00%	%	
Bank Loan (interest + capital) repayment		**3,358,094**	**USD/year**	
consumption-linked payments				
Bagasse demand		136,000	Ton/year	
Bagasse price		7.00	USD/ton	
Total bagasse costs		952,000	USD/year	
Other fuel demand		61,191	Ton/year	
Other fuel cost		20	USD/ton	
Total other fuel cost		1,223,812	USD/year	
Fuel demand cost in first year		**2,175,812**	**USD/year**	
In case of electricity demand/deficit	37,552	0	MWh/year	
Unit price for electricity JPS		29	Usct/kWh	
Electricity cost in season		**0**	**USD/a**	
Raw Water consumption per year		400,000	m/year	
Unit price of water		0.24	USD/m3	
Raw water cost in first year		**95,238**	USD/year	
Other consumption-linked costs		**0**	USD/year	
Total Consumption-linked cost in first year		**2,271,050**	**USD/year**	
Operation-linked payments				
O&M costs	4.00%	804,000	USD/year	
Number of Staff Employed		20	Persons	
Average Salary		10,000	USD/year	
Total Salary and Adm.		200,000	USD/year	
Insurance cost	1.50%	301,500	USD/year	
Other operational costs		0	USD/year	
Total Operation and maintenance cost in first year		**1,305,500**	USD/year	
Total Payments		**7,032,140**	USD/year	
without capital cost (annuity)		3,576,550	USD/year	
Revenues				
Power production in season		44,152	MWh/year	
Own Consumption in season		6,600	MWh/year	16.50 kWh/TC
Surplus (or deficit) in season		37,552	MWh/year	
Difference between bagasse costs and steam sales		412,000	USD/a	
Calculated unit price after steam sale		6.24	USct/kWh	
Revenue for own consumption		**412,000**	USD/a	
Avaliable for export in season		37,552	MWh/year	93.88 kWh/TC
Power production off-season		55,605	MWh/year	
Unit price of electricity sold		11.56	USct/kWh	
Non firm power		10.73	USct/kWh	
Revenue from electricity sale		**10,768,980**	USD/a	
Total revenue from electricity sold		**11,180,980**	**USD/a**	
Steam Production, gross		277,592	ton/year	
Steam for prime movers		120,000	ton/year	
Unit price of steam (internal use)		3.00	USD/t	
Revenue from steam (internal use)		360,000	USD/a	
Aldditional low pressure steam		120,000	ton/year	
Unit price of low pressure steam sold		1.50	USD/MWh	
Revenue from steam sale (external sell)		180,000	USD/a	
Total revenue from Steam sold		**540,000**	**USD/a**	
Typical content of byproduct		0%	%	
Amount of by product		0	ton/year	
Unit price of by product		50.00	USD/ton	
Revenue from by product		**0**	**USD/a**	
Price of CERs traded		10	EURO/t CO2	
Emission factor as per PDD	0.63	0.0000	t CO2/MWh	
Amount of CER		0	t CO2	
Revenue from CDM business		**0**	**USD/year**	
Savings				
Avoided electricity	2400	0	MWh/year	
Unit price		29	USct/kWh	
Avoided electricity cost		0	USD/year	
Avoided fuel oil	190000	0	L/year	
Unit price		0.77	USD/L	
Avoided fuel oil cost		0	USD/year	
Total savings		**0**	**USD/year**	
Total revenue and savings		11,720,980	USD/year	
Total Balance		**4,688,840**	**USD/year**	
Total Balance all revenues minus operational costs		8,144,430	USD/year	
Production cost for the export electricity unit		**6.527**	USct/kWh	

Results of costs and revenues for graph

	USD/year
Capital costs	-3,455,590
Fuel costs	-2,175,812
Other variable c	-95,238
Total O&M	-1,305,500
Internal electricit	412,000
Export electricity	10,768,980
Internal steam	540,000
Other sales	0
Savings	0
Profit/Loss	4,688,840



Calculation of production cost for export unit

93,157	MWh/year	
7,032,140	Costs	
952,000	Revenues before export to grid	
6,080,140	Open cost	
6.526748166	Usct/kWh to be zero	

7. ENVIRONMENTAL ASSESSMENT OF POSSIBLE ACTIVITIES

7.1. SUGAR AND ELECTRICITY PRODUCTION

The environmental impact of sugar production as such is minimal. Sugar is not a hazardous waste, in the process of cooking and crystallization only a few chemicals are used with small volumes in comparison to the total mass of sugar. Emissions from the processing are steam through leakages in the steam system and the odour of sugar cooking.

The wastewater problem in the sugar sector is treated by another recent study (TRANSTEC 2011-2). The wash water at the mill is only contaminated to a medium level. Problematic is the wastewater situation during rum production.

A major impact on the environment through sugar production is caused by the powerhouse and here through the combustion of biomass resp. bagasse. Due to the age and status of existing boilers, the efficiency in the system is low and there are hardly any automatic control systems in place. In addition, there is no regulation enforced for emission control of existing boilers. The emission level seems to be high at least in periods where the supply of bagasse is stopped or delayed. The start and stop of boilers causes un-burnt carbon to be released through the chimney. Also the “light” fuel bagasse tends to create higher dust emissions. Incomplete combustion of biomass can also lead to hazardous substances being emitted, mainly Carbon Monoxide CO. The combustion temperature in the boiler is relatively low due to the high moisture content of bagasse, which automatically reduces the possible formation of NOx. The fuel bagasse shows only small contents of Sulphur and heavy metals, which prevents possible emissions.

Besides emissions into air, the ash is left after the combustion process. It may contain un-burnt carbon to a certain extent. The other substances are plant matter, which had been incorporated in the fuel bagasse before. Therefore the ash can be brought back to the fields as a mineral fertilizer.

A new boiler system automatically will reduce local emissions for two reasons. The boiler is built as state-of-the-art with technical features for an efficient and clean combustion. In addition, the operation as a power plant and for excess electricity forces the operator to run the boiler according to specification and to obtain the maximum efficiency. In most aspects high efficiency operation would also mean cleaner combustion. The introduction of new boilers thus will reduce local emissions substantially. The efficient boiler operation will also lead to a better quality of the ashes (less carbon content).

7.2. BIOETHANOL PRODUCTION

The problems with rum production had been mentioned already in different sections of this report. If bioethanol would be produced on a larger scale, the same principal problems occur mainly with the wastewater treatment of vinasse (the remains after fermentation). A new bioethanol production might be designed already with a wastewater treatment system or includes a biogas system, which treats wastewater and produces energy for the process. At least a portion of the energy demand of the process for bioethanol can be supplied through biogas. Some additional energy is necessary, which could be supplied through the sugar mill, if in the vicinity. Otherwise fossil fuels are used in the process which have a higher environmental impact (mainly Sulphur Dioxide SO_2 emissions and un-burnt carbons with sometime hazardous substances especially from low quality petrol based fuels).

7.3. SUGAR CANE CULTIVATION

This study supports the end of cane field burning and a move to green cane harvesting. The switch to green cane harvesting will have a positive impact on air and soil quality.

During the harvest time the burning of the cane fields causes severe local emissions, which are quite hazardous as the combustion process is not controlled. Cane fields are near to villages and emissions are easily driven by wind towards populated areas.

A shift to green cane use and collection of cane trash presents an opportunity to assess the potential environmental impact on soil fertility in cane fields. Leaving organic matter from cane trash on the fields can have beneficial effects on soil fertility and moisture retention. A blanket of cane trash also has the potential to shade developing weeds and eliminate the need for herbicide applications. Alternately, a large blanket of organic matter can serve as an environment for development of pathogens and possibly impede subsequent field operations.

Environmental effects of green cane harvesting and trash collection will need to be determined in local Jamaican environmental conditions and cultural practices. Previous studies have shown that collection of a portion of cane trash from the fields can be carried out in a manner that protects field fertility and provides a balance between operational and economic factors (HUSSUANI 2005, PANKHURST 2005). The recommendations for cane removal need to be determined based on a number of local factors including the cane variety used, soil fertility, available rainfall and/or irrigation, pathogens present, and equipment available to carry out the trash collection operation. There is no general guideline except that cane trash recovery can be applied in selected circumstances. It will be necessary to determine the amount of trash that can be recovered for each Jamaican environment.

7.4. DEDICATED ENERGY CROPS

The environmental impact of dedicated energy crops will have the same environmental issues as any agricultural operation, including sugar cane cultivation. Issues such as fertilizer runoff into water sources, water use, soil nutrient depletion, soil compaction, fuel use during operation and damage to roadways all need to be considered.

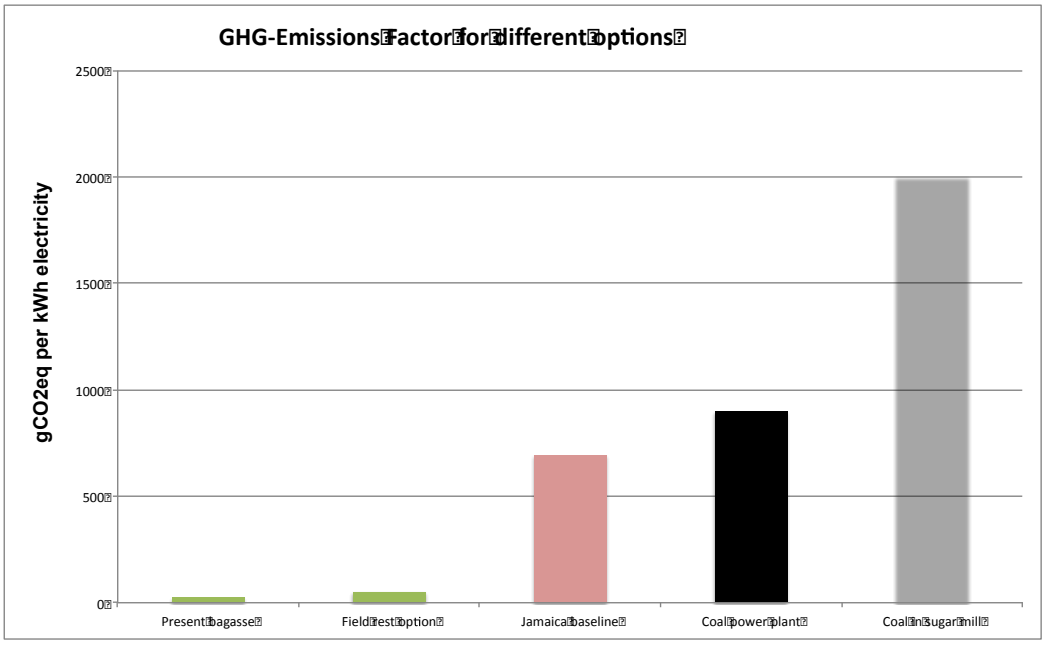
The selection of the crop species for energy production is as important as the cultural practices used in its cultivation. Long-term environmental effects need to be weighed as to the need for fibre and maintenance of soil fertility as well as air and water quality. Production of dedicated energy crops, in reality, is no different than cultivation of other crops. As there are many available sources on environmental impact of dedicated energy crops, this study will not provide a detailed review here. Rather, an environmental review of potential energy crops is being proposed in the long-term project to develop such resources for Jamaica.

7.5. CLIMATE CHANGE AND CARBON CREDITING

Renewable energies are employed and meant to reduce greenhouse gas emissions. If electricity is produced, this amount could substitute a similar amount of electricity normally produced by fossil fuels. In Jamaica these fuels are diesel and fuel oil. The emission factor of grid electricity in Jamaica is given by the MEM (MEM 2011-1) with 0.6927 t CO_{2eq} per MWh. Per definition the combustion of biomass is CO_2 free. However, emissions are accounted for from methane CH_4 and Nitrous Oxide N_2O during the combustion. As these substances are not measured in a combustion process, default values are given by the relevant IPCC-methodologies. Although bagasse as a biomass fuel produces no CO_2 directly, through the combustion process small amounts of CO_{2eq} are produced by CH_4 and N_2O formation and emission (after equivalent transformation).
Bagasse at source is emission free seen from the production cycle perspective. It is a by-product. All emissions from agriculture, harvest and transport etc. of sugar cane are assigned to

the sugar production and the final product sugar, no allocation is made[25] between sugar and bagasse. Further on in the cycle, however, an allocation may be applied to sugar and molasses, because molasses is treated as a secondary product of commercial relevance. In this case for bagasse only the emissions from combustion (no share from agriculture) need to be accounted for as CO_{2eq}. For bagasse (slightly differing for different efficiencies) one has to calculate with 25 to 30 g CO_{2eq} per kWh or 0.025 to 0.03 t CO_{2eq} /MWh (e.g. compare SIEMERS 2010). In comparison to the Jamaica grid emission huge savings in the region of more than 660 g CO_{2eq} /kWh are possible (compare figure 7). If, for example field rest trash and tops is used in that biomass power plant, at the origin of trash and tops the resource is emission free as well (in the field). But from there it needs to be compacted (baled) and transported mainly consuming diesel for tractor and lorry. This adds a small amount of direct CO_2 and CO_{2eq} to the balance. Roughly one can estimate a range of 25 to 80 g CO_{2eq}/kWh for field-based residues (e.g. compare SIEMERS 2010).. Also this value leaves enough scope for GHG savings, as shown in figure 7.1. with the second bar from left.

Figure 7.1: GHG emissions from biomass power plants and fossil sources



The figure 7.1 gives an indication for GHG-mission from a modern coal power plant, which emits between 800 to 1,000 g CO_{2eq}/kWh (international average). As discussed earlier, the efficiencies in the biomass power plant under consideration are not very high in comparison to large modern fossil plants. If coal is being burnt as alternative in the small biomass power plant, the resulting GHG emissions could be as high as 2,500 g CO_{2eq}/kWh based on the effect of the relatively low overall efficiency. In terms of GHG balance the use of coal in biomass power plants is a clear disadvantage and could reduce the previous big savings made possible by bagasse and field rest substantially.

If GHG savings are realised, a possible new project could find an interest as a CDM project and generate additional income. The economic model has an option for additional revenues from the sales of carbon credits. A possible application for a CDM project, however, needs to be carefully planned and built up according to the relevant methodologies.

[25] There is a discussion ongoing to allocate some LCA emissions to bagasse and see both sugar and bagasse as products.

For the time being a project could be registered as a biomass power plant (and not as cogeneration) producing electricity for the national grid. The additionality[26] issue could at least be solved for the first projects with the definition as new and highly efficient power plants, which are not in place and not usual in the sector in Jamaica. But this is subject to a more thorough analysis.

If the project is designed as a cogenerating option the base case could be the additional use of fossil fuels which is replaced by this new cogeneration unit and could in addition export some electricity which is replacing fossil fuel produced electricity in the national grid. This option might create more possible carbon credits.

[26] *The project must show additional benefits, which are enabled through the CDM mechanism and would not be in place without it.*

8. INSTITUTIONAL EVALUATION

8.1. POLICY AND FINANCE

The main responsibility for energy matters lies at the Ministry of Energy and Mining (MEM). This ministry defines the energy policy and is the executing agency for all energy issues. The different objectives for energy policy, for example: the share of renewable energy in future decades, are formulated by the Ministry. The documents on the different energy policies also give clear directions of measures and activities to reach that formulated targets. Some problems are seen as to how the Ministry executes the strategies and keeps track on the planned activities. One reason is the internal operation of the Ministry, where sometimes other priorities are set and necessary activities or decisions have to be postponed. Although it is not easy to evaluate performance from outside, it is felt, that a larger problem is the coordination between the different Ministries on what the political priorities are and specifically what is to be done in the energy and renewable energy sector. The situation for a country like Jamaica with quite a few pressing problems other than renewable energy development earns understanding for the political reality.

The role of PCJ in the national renewable energy development is not clear. PCJ holds the exclusive right for the development of renewable energy sources. This was amended as a law in the year 2005 (formerly PCJ had the only right to explore and develop petroleum fuels). The Wigton Wind Farm is one example, where PCJ resp. a subsidiary in operating a renewable energy project. Biomass or bagasse can be deemed as renewable local energies and thus fall under the exclusivity of PCJ. However, in the past the sugar mills were using their bagasse for their own purposes. The difficulties arising now are the concepts for independent power plants (which are technically justified) attached to the sugar mills but with the function of mainly supplying electricity to the grid not only from bagasse but from additional biomass. The latter one could be a violation of that law from 2005. Otherwise it is not seen, that PCJ could operate power plants of that size and complexity, which are in cogeneration mode for the sugar industry for at least 6 months. There is a clarification needed for possible investors to what extent a biomass power plant could be operated in Jamaica under present law.

The Office of Utilities Regulation (OUR) is the regulator for the infrastructure, also responsible for the electricity generation. The function should be as an independent organisation ensuring a transparent and consumer oriented supply of services to the population. The high electricity prices are a reason for debate and protest in Jamaica and therefore interference is politically sensitive. Any attempt to introduce alternative energy production would be seen under the light of possible price increases to the customers and would be rejected if prices increase. On the other hand, the OUR should not be instrumented in blocking independent and new players in electricity generation. In fact, a liberalised market in such a small island like Jamaica needs close monitoring to prevent an apparent monopoly. The decisions made by the OUR sometimes lack transparency and more background information. The OUR could play a more active role in promoting renewable energy and independent power production, if the projects are in line with policies and no additional burden is foreseeable for the end customer.

Other Ministries with interest or responsibilities are mainly the Ministry of Agriculture (MoA) and partly the Forestry Department. The MoA houses the Sugar Transformation Unit STU, the entity set up for the privatisation strategy in the Jamaican Sugar Industry (with assistance from the EU). Field operations, agricultural extension, building of roads and local infrastructure to enable a competitive production are the key elements for agricultural development. The MoA would not be involved in designing and operating power plants, but they need to be involved in the production process for sugar cane and additional biomass. Especially, if new production methods and/or materials are introduced like energy cane or other fibre producing annual crops. Even perennial production methods like short rotation forestry would fall into the portfolio of the

MoA as long as this SRF would be performed on agricultural lands. Per definition the Forestry Department is responsible for the mountainous and non-agricultural areas in Jamaica. At a later stage there might be demand for additional biomass from forest lands (SRF on degraded lands) or from forestry directly (production of wood chips as a byproduct of forestry activity or as a main product from special species).

These above are the main political stakeholders. Some more departments and agencies are partly involved due to their responsibilities. The environmental legislation and execution is in the hands of NEPA, which would be involved in operating permits and emissions standards.

Finance has to differentiate between the banking sector and development/Government activities in finance and energy matters.

The Development Bank of Jamaica (DBJ) administers the Energy Fund, which was set up to provide finance for energy efficiency or energy projects. Renewable energy projects are eligible as well, but in case the proposal has to be forwarded through a commercial bank. The DBJ is not directly involved in the transaction. Maximum funding from the Energy Fund is limited to 100 mill. JD (equivalent to roughly 1.2 mill. USD) at an interest rate of 11%, the lending quota might be up to 70% requiring 30% equity. The JDB can offer consultations to the private banking sector.

Private banks are not well informed on the details of energy projects. This is only natural as only a limited number of renewable energy projects have been executed in Jamaica. The main difficulty for the banking sector is the appraisal of the projects in terms of the total investment and operating periods. Renewable energy projects (in general all resources like wind, solar or biomass) need extremely high investments, but operating costs are lower or near zero (if compared to a diesel generator with low initial investment but high fuel cost). The banks have to assess the risks for the high initial investment and tend to overemphasise security and viability of a loan. In addition, the pay back periods are also long, at least for 10 years. Taken all arguments together a commercial credit would be quite expensive, because the banks will increase interest rates for securing their lending capital. Without additional measures, be it incentives, collateral by other organisations or training of banking experts it would be difficult to secure financing for the envisaged projects. A first demonstration project would help to enhance the probability for a reasonable financing by the private banking sector.

8.2. RESEARCH AND DEVELOPMENT

There is only one major stakeholder, which is the Sugar Industry Research Institute (SIRI). SIRI under the private organisation of the sugar industry (SIA) is responsible for all research and development on the agricultural and processing side of sugar production. SIRI supplies new varieties to farmers and estates once the breeding programme has shown the suitability for Jamaican conditions. New varieties are supplied from Barbados, there is no breeding programme in Jamaica. The role of SIRI for the introduction of high fibre cane was already documented in chapters 2 and 5. Besides testing and distribution of varieties SIRI should be involved in the field operations as well. This includes the shift from burning cane to green harvesting and the possible collection of cane trash. Both ideas for increasing the biomass productivity from given resources, need demonstration and testing before the farmers would adopt the methods. Some opinions exist, that SIRI is not performing well to all of its obligations and duties. Nevertheless, there is no argument for creating a new agency or organisation especially for the energy matters of sugar cane. The performance of SIRI should be improved and new projects initiated to include the energy related questions in the overall R&D programme of SIRI. Besides field operation there is also demand for trials and testing at the factory level, for example the storage, the disintegration of bales and the feeding of the material to the boiler section. This should be taken by SIRI as well, although it is a bit more technology related. The power plant operation as such would be field, which is too wide for SIRI. As only a few power

plants would be erected in Jamaica there is no necessity to build up own research competence in this field, international cooperation could help to solve some of the relevant issues.

There are two major universities conducting research in several aspects of renewable energy. Biomass energy has attracted some more focus by UTECH (University of Technology, Jamaica). Some engineering and physics department at the University of the West Indies, Mona Campus (UWI) are also active in other renewable energy fields (solar). No specific research programmes have been running for the sugar industry and the aspects, which are examined in this study (e.g. baling, pre-drying of bagasse). These questions require an advanced research activity from a strong engineering perspective. The infrastructure for conducting that type of research is not available at the university level in Jamaica. On the campus at UWI there is an outpost of the Caribbean Agricultural Research and Development Institute (CARDI). Some of their fieldwork was visited and discussions held. The main focus was on reclamation of land in connection with forage production or possible biodiesel production from jatropha or other oil crops. Bt also CARDI is not engaged in research specifically for sugar.

The Center for Excellence for Renewable Energy (CERE) is a division of PCJ with two main units, one for renewable fuels and one for renewable electricity. The mission is to encourage and support renewable energy development through demonstration, R6D and cooperation. Main activities to date had been feasibility studies, coordination activities and international supported studies. No specific programme is active for sugar cane related questions. A national biomass energy assessment is underway and results should be available during the course of the year 2012. Some more important details could be taken from this study once completed.

8.3. PRIVATE SECTOR

There is a private sector present in Jamaica in different fields of activity, but in comparison to industrialised standards the private sector in general seems to be weaker, which is also due to the small size of specific national markets and relatively high local production cost.

For energy the main private sector stakeholders are the JPS (which was Government owned before) and some IPPs in the electricity production. There is some more generation of power for own consumption in the sugar, bauxite and some other industry. Liquid fuels are processed in local refineries and distributed by local or international traders.

In some niches one can find small and medium sized companies for renewable energy equipment. The focus is on solar energy (PV or SWH) and on some other applications (small wind), but there is no production of equipment in Jamaica. For biomass application at least on a larger scale (boiler, turbine) there is also no local production, but some representatives of international companies are active on the relative small market.

Private capital is available in the country, but the pay back periods for renewable energy projects are quite long, which reduces the attractiveness for capital. There are other business activities which offer a shorter pay-back period with also lower risks associated.

9. PROJECT APPROACHES

9.1. BARRIERS AND RISKS

The major obstacle is the setting of a feed-in tariff, which is fair to all concerned parties. A compromise is necessary between JPS as the buyer of electricity and the sugar sector as the producer of electricity. The OUR and the MEM in their capacities and duties should bring themselves and these two groups together. The objective must be to agree upon a tariff and guarantee that tariff for all applications. If no agreement can be reached and if the tariff is not near to 15 USct/kWh, all other activities can be suspended. The FIT is the main barrier for any project development and the biggest risk for a private investor.

Once interest is created by an attractive FIT, this alone would not lead to the construction of a power plant. The first project of its kind needs a special “incentive” to be started. The incentive could come either through an enthusiastic entrepreneur, who is taking the risk or through additional measures to make the first project quite attractive. The Government, however, is quite restricted in providing financial incentives because of the strict IMF rules and regulations.

Another main barrier is the power purchase agreement. A standard PPA should be available and transparent to all parties. An investor for a 20 year lifetime power plant needs a secure contract with clear conditions to tailor the investment project.

Still a big risk is the adequate biomass supply. Up to here all potentials are theoretical, nothing had been demonstrated and shown in reality. This risk has to be taken into consideration, otherwise the situation ends up in permanent “hen and egg” – discussions. The proposed biomass power plant must create a market for additional biomass. If all theories are working, the increased market pull will lead to the formation of biomass suppliers. The cost per unit of biomass could only be estimated in this study, real costs would emerge after the initial activities have been started. Continuing research and testing under Jamaican condition will result in more realistic cost approaches.

9.2. SHORT TERM SOLUTION

In order for the Jamaican sugar industry to remain competitive it must focus on the modernisation of its existing infrastructure and on efficiency gains at all levels.

Increasing the availability of high-quality fibre while maintaining high productivity in field operations is critical to the success of the Jamaican sugar industry. A tiered programme for increasing the available fibre supply should be implemented. This recommendation should also be implemented in parallel with improvements in power generation technologies to ensure best use of available resources.

Increasing the amount of fibre available to the sugar factories should be carried out within the existing sugar cane operations as well as in developing new fibre sources.

Over the next two to five years, the amount of fibre made available for combustion should be increased by making alterations to sugar cane cultivation and harvesting. Specifically, elimination of burning cane fields through the widespread implementation of green cane harvesting and the adoption of high fiber varieties as soon as is practical. The implementation of these practices could provide as much as a 150% increase in the amount of cane fibre available for combustion applications. Additional measures, such as adopting dry cane cleaning methods, investigating methods for bagasse drying and upgrading to high pressure boilers, will contribute to efficient operations and maximize the use of fibre from sugar cane operations. Storage and

other logistical operations will need to be addressed to ensure a steady supply of high quality fibre.

In addition, an enhancement and/or coordination of grower outreach programmes should be considered. Specifically, coordination of activities between SIRI and STU to make sure that best cultural practices and availability of advanced sugar cane varieties are effectively communicated to industrial and private land owners growing sugar cane. Such coordination should focus on long term education and support programmes for growers to insure awareness and economic benefits of the STU programme and materials available from SIRI.

9.3. LONG TERM SOLUTION

Maximizing the production and use efficiency of sugar cane fibre can provide for a substantially increased fuel source within existing operations. However, reliance on sugar cane fibre will put severe limits on the amount of generation capacity available to Jamaica, create vulnerability in the fibre supply and limit the potential to developing high value products derived from sugar cane resources.

Over the next 10 to 15 years the fibre resource pool should be expanded to include dedicated energy crops such as trees, grasses, sorghum and fiber cane. This long-term plan includes a comprehensive land use plan, continued development of resources for forest plantations and consideration of additional fibre-based dedicated energy crops.

A solid basis for a long-term solution will involve a detailed land use plan. A land map of Jamaica is currently being updated and will provide a basis for classifying land to maximise sugar cane lands as well as identifying areas within an economical transport distance that can support growth of trees and other dedicated energy crops.

Research and development into tree plantations should be continued using the previous studies as a basis for further work. Determination of the long-term productivity potential of tree species in Jamaica on the available land along with growth and harvesting protocols will be critical to the long term success of a tree fibre industry. Additionally, tree breeding programmes and nursery operations to supply growers with superior planting stock should be considered as an investment into the success of this industry.

Dedicated energy crops such as grasses, sorghum and fibre cane should be considered for cultivation on marginal lands in the vicinity of the sugar factories. Crops that are compatible with the local environment and existing cultural practices in Jamaica should be emphasised. A review of potential environmental impact of these activities should be carried out as part of the selection process. Just as the sugar growers have a support system to learn about best cultural practices and to gain access to superior varieties of cane, a breeding and agronomic support system will need to be developed to support the growth of dedicated energy crops.

9.4. GENERAL REQUIREMENTS FOR A SUCCESSFUL IMPLEMENTATION

The chapters 9.2 and 9.3 gave an idea on how to develop the biomass supply in near and long term perspectives. However, the demand for additional biomass can only be created if the sugar industry builds and operates a bigger power plant with export capacity. This has been tried for some 20 years under different conditions and policies. There had been reasons why the industry or the investors were reluctant or not willing to take up the proposals although most of them came up with favourable technical and financial background. Even if all conditions seem to be optimal, a project does not go off the grounds. Reason is the uncertainty in the local markets, whether the conditions will prevail for the next 20 years and how big the overall risk will be. For the implementation of a successful project, these “apparent” risks must be reduced. The ultimate objective would be to get one biomass power plant installed as a kind of demonstration

project. Then the advantages and viability is shown and demonstrated on the local market and others could follow. But this first project needs special incentives to overcome the “reluctance” in the market. And the first operator should see a benefit for the risk taken. In essence, two sets of requirements can be formulated for a successful demonstration project, one set in general for all the potential installations and a special set for the first project.

The general requirements are:

- A feed-in tariff that allows a financially viable operation;
- A structured and transparent power purchase agreement;
- A PPA with at least 10, better 20 years of validity;
- A PPA including a formula for energy price escalating factors (on both sides for the buyer and the seller);
- A fair setting of conditions for the grid connection;
- Optimising investment with special credit lines, reducing import duties or offering tax incentives.

As discussed already several times, good framework conditions are sometimes not sufficient for the initiative to invest. The first project of its kind is the most complicated one. The special conditions for the first project could be:

- Investment subsidy to lower the initial risk for the investor;
- Special tax incentives for the starting period; or
- A premium paid for the FIT for a certain time period;
- Subsidising detailed engineering and project implementation.

9.5. CUSTOMISED PROJECT APPROACHES FOR INDIVIDUAL SUGAR MILLS

9.5.1. Appleton

The best candidate for the first biomass power plant is the Appleton sugar factory. A boiler system with 40 bar capacity is already installed, the boiler is separated locally from the sugar mill, which will demonstrate the IPP concept and allow the separate (in pure technical terms) production. The grid connection together with the frequency conversion can be solved and should not be an obstacle. The reduced investments allow a start of the project based on bagasse alone as the fuel and as a seasonal production. Gradually more and other biomass materials can be incorporated and used and experience collected on handling and logistics with that additional biomass. After a few seasons of successful operation this project can be used as the demonstration and reference case.

9.5.2. Golden Grove

This newly privatised sugar factory could be used as a showcase for a very efficient sugar factory with a high efficient power production. A completely new power plant would be designed and erected and specifically adopted to the requirements of the mill and the export orientation of the power plant. During the first few years it is expected that this power plant can operate only under financial losses unless the complete biomass delivery chain is functioning at the start of the project. To make that certain, several years of experience are necessary before tangible results are in the field. But the other option, waiting for the biomass supply chain to be established (without a demand), would delay construction of the power plant and loose opportunities. The risk needs to be taken and could hopefully be safeguarded with incentives or guarantees by the Government or other institutions. Also the planning of an integrated concept (sugar of different qualities, bioethanol and other sugar cane based products) for processing of alternatives coupled with a modern energy concept could be favoured at this location.

9.5.3. Everglades

The situation at this newly privatised mill is comparable to the previous case. Also here a new power plant must be designed and built. Size, capacity and design features would also depend on the framework conditions and the overall expected economic performance.

9.5.4. Potentials at the remaining mills

The two biggest[27] sugar mills Frome and Monymusk are under new ownership. It was not possible during the course of the mission to discuss the plans with the new management. But plans are published for a large power plant at Frome. According to a newsletter article[28] a completely new sugar factory should be built up at Frome for 1 mill. TC per year including a high pressure boiler system with 50 MW electrical capacity. No more details were given.

During discussions, the sugar mill at Worthy Park was not interested in a larger cogeneration project and in possible exports to the grid.

[27] *The maximum capacity for a biomass power plant at the sugar mill should be set at 15 MW to avoid a bidding process, which is required for capacities of more than 15 MW.*
[28] *Article in „The Observer" from 30. November 2011*

10. RECOMMENDATIONS

The different chapters of this study have analysed the situation under different aspects. Pros and cons had already been discussed in the chapters and also recommendations were formulated for the specific problems seen. A quick summary and an overview for several main areas are given below.

The starting point for the analysis is the present state of the sugar sector in Jamaica. For the sugar industry and their operation the following recommendations are formulated:

- Increase productivity at the sugar plant;
- Optimise the downstream processing steps for sugar manufacturing;
- Improve steam consumption in sugar processing;
- Evaluate the option to change steam driven mills to electrical motors;
- Reduce the import of electricity and fuel oil/diesel for operation;
- Aim for an energy self-sufficient factory.

The energy policy gas set targets and strives for implementation. The ambitious targets can be reached, but for the political and regulatory framework some measures are very important:

- Enforce political targets;
- Monitor targets and achievements and analyse the situation, make necessary alterations and shifts;
- Offer a fair feed-in tariff, which benefits producer, distributor and consumer;
  The question is still not answered, what exactly the FIT should be. At least, it must be in the range of 15 USct/kWh. A revised calculation of avoided cost may come up with a figure of 14.75 or 15.25 USct/kWh (as example). Whatever the results are, they should be used as the starting point. For the first project or during the first operating period a premium should be paid, which could be the difference between the new FIT and the actual avoided fuel cost (it would roughly be 5 USct/kWh at the moment at fuel cost of 20 USct/kWh). By this strategy one part of the FIT would be dynamic and could change according to the pace of development for new generating capacity in Jamaica, but allow some time for the power plant to establish additional biomass supplies;
- Offer standardised power purchase agreements and long term contracts;
- Offer incentives for the early market approach;
- Support necessary research and development activities.

It is more or less agreed that the new biomass power plants are a private sector activity. For potential investors in biomass power plants the following points are important:

- Evaluate the concept of an “IPP” attached to the sugar complex;
- Maximise electrical output during the crop season;
- Provide storage facilities for surplus bagasse and cane trash and other materials;
- Consider additional biomass production by the power plant operator itself or create a market for the private sector, which can deliver.

If biomass power plants should have an impact on the national energy production, they must be operated year-round and thus they need additional fuel, preferably from biomass resources. The production of biomass is seen under two different time horizons.

For short term success there should be an increase of fibre availability from sugar cane and related sources:

- Aggressively implement best practices for sugar cane agronomy;
- Require green cane harvesting on all suitable lands;
- Strengthen development of existing programmes to develop high fibre cane varieties;
- Implement methods to collect cane tops and trash;

- Adopt dry cane cleaning methods;
- Evaluate bagasse drying technology;
- Enhance grower outreach and education programmes.

In the long term, the main issue is the development of non-sugar cane fibre sources, which leads to following recommendations:

- Carry out a detailed land-use plan in the vicinity of the sugar factories and estates;
- Conduct an in-depth economic analysis for the development of dedicated energy crops in Jamaica;
- Select appropriate species for fibre production on marginal lands including both tree species and other dedicated energy crops;
- Develop a long term testing and breeding programme for dedicated energy crops;
- Implement a grower outreach and education programme.

11. ANNEXES

11.1. LITERATURE AND SOURCES

(ALMAZAN 1998) Almazan, O., L. Gonzalez and L. Galvez: The Sugar Cane, Its By-Products and Co-Products. Maurice Paturau Memorial Lecture, Food and Agriculture Research Council, Redui, Mauritius. pp.13, 1998

(ATKINSON 2009) Atkinson, C.: Establishing perennial grass energy crops in the UK A review of current propagation options for Miscanthus, Biomass and Bioenergy 33, 752–759, 2009

(AZAR 2000) Azar, C. and Larson, E.D.: Bioenergy and land-use competition in Northeast Brazil, Energy for Sustainable Development 4, 64-71, 2000

(BARRETT 1995) Barrett, David: Briquetting Biomass for Fuel, PCJ, Kingston, Jan 23, 1995

(BINGER 1982) Binger, Al: Brief Summary of Energy Cane project and feasibility study, SRC, Kingston, Jamaica, no year

(BINGER 2011) Binger, Al: Energy efficiency potential in Jamaica: challenges, opportunities and strategies for implementation, ECLAC, GIZ, Santiago de Chile, April 2011, also download from www.eclac.org/publicaciones/xml/1/43261/Lcw394i.pdf

(BUNDABERG 2005) Anonymous: Bagasse Storage, ASSCT Conference 3-6 May 2005, Bundaberg Bundaberg Sugar LTD., 2005

(CALLAGHAN 2010) Callaghan, George: Government of Jamaicas Sugar Adaptation Strategy, Ministry of Agriculture and Fisheries, June 2010, PowerPoint presentation download from Sept. 2011

(CARILEC 2010) Carilec: Position Paper on Regulation and Renewable Energy, March 2010, download from www.carilec.com

(CASTALIA 2011) Castalia: Options to bring down the cost of electricity in Jamaica, Final report, 23 June 2011

(DEEPCHAND 2005) Deepchand, K.: Sugar Cane Bagasse Energy Generation – Lessons from Mauritius, Parliamentarian Forum on Energy Legislation and Sustainable Development, Cape Town, South Africa, 5-7 October, 2005

(FAO 2010) Food and Agriculture Organisation, Forestry Department: Global Forest resources Asessment 2010, country report Jamaica, Rome, 2010

(FOREST 1988) Forest, Denise: Report on sorghum processing at Bernard Lodge Factory, Petronol (Jamaica) Limited, Research and Development Department of the Petroleum Corporation of Jamaica, 1998

(FOREST2MILL 2010) Anonymous: A Snap-Shot Comparison of Total Conifer Fibre Delivered Prices for U.S. Pulp and Paper Mills, September 2010 Forest2Mill Newsletter, Accessed Nov 2011, http://www.forest2market.com/f2m/us/f2m1/free/forest2mill-archive/story/2010-Sep-Conifer

(FRANCIS 1987) Francis, A. and Harrison, A: Sweet sorghums for sugar and biomass production at Bernard Lodge Estates, Report on variety trials, 1987

(FULMER 1991) Fulmer, M.E: Electricity-Ethanol Co-Production from Sugar Cane: A Technical and Economic Assessment, Master of Science Thesis, Princeton University, Princeton, NJ USA, pp. 317, 1991

(GALIK 2009) Galik, C.S., R. Abt, and Y. Wu: Forest Biomass Supply in the Southeastern United States—Implications for Industrial Roundwood and Bioenergy Production, Journal of Forestry 69-77, 2009

(GIBSON 2003) Sugar Corporation of Jamaica: Frome Cogeneration Project Pre-Feasibility study, Gibson Energy Ltd. Kingston, Jamaica, September 30, 2003

(GOJ 2009) Government of Jamaica: Jamaica Country Strategy for the Adaptation of the Sugar Industry 2006-2020, GOJ, August 2009

(GOJ/EU 2008) Jamaica-European Community: Country Strategy paper and national indicative programme for the period 2008 – 2013, November 2008

(GOODRICH 2011) information from www.goodrichsugar.com, accessed in September 2011

(HASSUANI 2005) Hassuani, S.J., M.R.L.V. Leal and I. de C. Macedo eds: Biomass power generation, Sugar cane bagasse and trash, PNUD - Programa das Nações Unidas para o Desenvolvimento CTC - Centro de Tecnologia Canavieira, Piracicaba, Brazil. pp. 217, 2005.

(HINCHEE 2009) Hinchee M et al.: Short-rotation woody crops for bioenergy and biofuels applications, In Vitro Cellular & Developmental Biology – Plant 45, 619-629, 2009

(HOBSON 2005) Hobson, P.A. and Mann, A.P: The prediction of heating and spontaneous combustion in bagasse stockpiles, An update on model capabilities, Bagasse Storage Workshop, ASSCT, May 2005.

(ISUE 2010) Anonymous: Miscanthus factsheet, Iowa State University Extension

(JPS 2011-1) Fuel rates. Download from www.myjpsco.com from 7.9.11

(JPS 2011-2) Jamaica Public Service Company Limited: Rate Schedule 2011, download from www.myjpsco.com from 7.9.11

(KUKKONEN 2009) Kukkonen, C. 2009: Giant King Grass An Energy Crop for Cellulosic Biofuels and Electric Power Plants, Biofuels and Jatropha Markets Asia, June 29-July 1 2009, Jakarta, Indonesia, 2009

(LANE 2010) Lane, Jim: Energy Crop Conundrum, http://www.biomassmagazine.com/article-print.jsp?article_id=3535 (Accessed March 15, 2010).

(LARSON 2001) Larson, E.D, R.H. Williams and M.R.L.V. Leal: A Review of Biomass Integrated-Gasifier/Gas Turbine Combined Cycle Technology and Its Application in Sugarcane Industries, With an Analysis for Cuba, Sustainable Energy Development 1, 54-76, 2001

(LOY 2005) Detlef Loy, Manlio F. Coviello: Renewable energies potential in Jamaica, ECLAC, GTZ, Santiago de Chile, May 2005,
also download from www.eclac.org/publicaciones/xml/3/24583/jamaica.pdf

(MACCASKILL 2011) Maccaskill, C., B. Gray and J. Sexton: Self-heating and drying in bagasse piles, http://www.maths.usyd.edu.au/u/charlie/modelling/macaskill_bagasse.html

(MACEDO 2001) Macedo, I.C., Leal, M.R.L.L., and Hassuani, S.J.: Sugar cane residues for power generation in the sugar / ethanol mills of Brazil, Energy for Sustainable Development 1, 77-82, 2001

(MCCUTCHEN 2008) McCutchen, B.F. and Avant, R.V. Jr: High-Tonnage Dedicated Energy Crops: The Potential of Sorghum and Energy Cane. In: NABC Report 20: Reshaping American Agriculture to Meet its Biofuel and Biopolymer Roles, 119-122, 2008

(MEM 2009) Primary and final energy balance for 2009, personal communication

(MEM 2010-1) Jamaica´s National Energy Policy 2009-2030, Our Citizen´s Guide Ministry of Energy and Mining, Nov-Dec 2010 Consultations, UNDP, 2010

(MEM 2010-2) National Renewable Energy Policy 2009-2030, Creating a sustainable future, Ministry of Energy and Mining, August 2010, download from www.mem.gov.jm

(MEM 2010-3) National Biofuels Policy 2010-2030, Ministry of Energy and Mining, October 2010, download from www.mem.gov.jm

(MEM 2011-1) Calculation of grid emission, from http://www.mem.gov.jm/PDF_Files/MEM_grid_baseline.pdf, access on 29.7.11

(MEM 2011-2) Ministry for Energy and Mining: Jamaica total alternative energy consumption, from www.mem.gov.jm

(MEM 2011-3) Ministry for Energy and Mining: Jamaica energy statistics 2010, from www.mem.gov.jm

(MEM/EU 2011) Ministry of Energy and Mining in Collaboration with the European Union: Position Paper on Generation Avoided Cost And Feed In Tariffs to Stimulate Development of Renewable Energy, 1.6.11 (Jaap Smink)

(MOA 2010) Ministry of Agriculture and Fisheries: Report of the sugar industry enquiry commission, September 2010

(MOA 2011) Ministry of Agriculture and Fisheries, Sugar Transformation Unit: Revised Sugar Area Development Programme: Multi-Annual Action Plan 2011/12 to 2014/15, March 2011

(MUKHERJI 2005) Petroleum Corporation of Jamaica: Options report for sugar industry ethanol study, Mukherji, Pune, India, May 2005

(NADIR 2009) Nadir, N. Mel, M., Karim, M.I.A. and Yunus, R.M: Comparison of Sorghum and Cassava for Ethanol Production by Using Sccharomyces cerevisiae, Journal of Applied Sciences 9, 3068-3073, 2009

(NEPA 2011) National Environmental Protection Agency: Environmental Standards, supplied on August 18, 2011

(NUNG 1995) Nung, H.V and Binh. L.H: Forage Productivity of Guinea Grass in Different Farming Systems, Food and Agriculture Organization of the United Nations, 1995

(OAS, 2011) Winrock International: Assistance for Biofuels Development and Policy Support in Jamaica, final report, May 24, 2011 for OAS http://www.mem.gov.jm/PDF_Files/Jamaica%20Biofuels%20Report%20Final.pdf, access on 29.7.11

(OSBOURNE 2004) Noel G. Osbourne, Energy Consultant: Woodchips combustion trials at Frome, May 2004, A report for the Sugar Industry Research Institute (SIRI)

(OUR 2008) Office of Utilities Regulation: Declaration of Indicative Generation avoided costs, OUR, June 2008 (including annexes)

(OUR 2010-1) Office of Utilities Regulation: Declaration of Indicative Generation avoided costs, OUR, December 2010

(OUR 2010-2) Office of Utilities Regulation: Generation Expansion Plan 2010, Office of Utilities Regulation, August 2010

(OUR 2010-3) Office of Utilities Regulation: Annual Report and Financial Statements 2009/10, download 25.8.11 from www.our.org.jm

(PANKHURST 2005) Pankhurst, C: Should sugarcane trash be used as a biofuel for cogeneration or left in the field for its long-term benefits to soil health and crop productivity? A report prepared for the Sugar Yield Decline Joint Venture, Australia, 30, 2005

(PCJ 1992) Ruth Potopsingh: Bioenergy Resources Assessment Study, PCJ, August 1992

(PCJ 2000) Petroleum Corporation of Jamaica, Energy Resources Division: Initial Findings of the Demonstration Fuelwood Project, Font Hill, St. Elizabeth, 1995-2000, November 2000

(PCJ 2007) Biofuel Production and its Regulatory and Economic Frameworks, Summary Report, PCJ, CERE, August 2007

(PERLACK 2011) Perlack, R.D. and B.J. Stokes (eds). 2011. U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry, U.S. Department of Energy ORNL/TM-2011/224, Oak Ridge National Laboratory, Oak Ridge, TN. pp 227, 2011

(PIOJ 2011) CDM Intro and OUR Avoided Cost Assessment and FIT Approach, PIOJ-MEM Review, July 2011

(REECE 2004) Reece, Niconor: Combined Heat and Power Generation in Jamaicas Sugar Cane Industry, Sugar Research Institute, Jamaica, year??, download August 2011

(RICHARD 2011) Richard, E. and T. Tew, R. Cobill, E. Dufrene, D. Garrison and S. Lingle: Sugar Cane as a Potential Energy Crop, USDA-ARS Sugarcane Research Laboratory, Houma, LA., Powerpoint presentation, downloaded 14 Oct 2011.

(RONCO/BECHTEL 1986) USAID and Ronco Consulting/Bechtel: Jamaica Cane/Energy Project Feasibility Study Volume 1 and Volume 2 B, September 1986 (Volume 2A??)

(SANDERSON 2008) Sanderson MA, Adler PR. : Perennial Forages as Second Generation Bioenergy Crops, International Journal of Molecular Sciences 9, 768-788, 2008

(SIA 2011-1) Sugar Industry Authority: Table Production 2005 to 2009, download from June 2011

(SIA 2011-2) Sugar Industry Authority: Annual Report 2009, Sugar Industry Authority, download from www.jamaicasugar.org/SIAIndex.htm from 7.9.11

(SIEMERS 2010) Siemers, W.: Greenhouse Gas Balance for Electricity Production from Biomass Resources in Thailand, Journal of Sustainable Energy & Environment 1, 65-70, 2010

(SMINK 2011-1) Jaap Smink: OUR Avoided Cost Assessment and FIT Approach and Fuel Mix potential, 16.8.2011, see also powerpoint from EU

(SOSA 2004) Sosa-Arnao, J.H. etal: Sugar cane bagasse drying-a review, Proceedings of the 14th International Drying Symposium (IDS 2004) São Paulo, Brazil, vol. B, pp. 990-99, 22-25 August 2004

(STEPPLER 1987) Steppler, H.A. and P.K.R. Nair eds. Agroforestry: A Decade of Development. 1987, International Council for Research in Agroforestry, ICRAF House, off Limuru Road, Gigiri P.O. Box 30677, Nairobi, Kenya, pp. 336, 1987

(STUBER 2011) Stuber, D: Roundwood Price Update: 3Q2011 Results, Forest2Market Watch, Accessed Nov 2011, http://blog.forest2market.com/2011/10/28/3q2011-results/

(TENPAGER 2011) Integrated Assessment of Trade-Related Policies and Biological Diversity in the Agricultural Sector in Jamaica: Transition Strategies for the Sugar Industry, Jamaica 10 pager.pdf, download from August 2011

(TPET 2011) Bagasse drier from http://www.tpet-engineering.com/?knowhow-sewage-salesletter-9, accessed in September 2011

(TRANSTEC 2011-1) Beaumont, Trevor: Technical Assistance for the management of wastewater from the rum and sugar industries, July 2011, EU Framework contract

(TRANSTEC 2011-2) Beaumont, T., etal: Technical Assistance for the management of wastewater from the rum and sugar industries, Final report, October 2011, EU Framework contract

(UNFCCC 2011) Information on CDM projects under http://cdm.unfccc.int/Projects/projsearch.html, access on 29.7.11

(VAN DEN BELT 1985) Van Den Belt, R.J., and J.L. Brewbaker eds: *Leucaena* Wood Production and Use – A Field Manual. Nitrogen Fixing Tree Association, P. O. Box 680 Waimanalo, Hawaii 96795, U.S.A. pp. 50, 1985

(WB 2006) The World Bank, GEF: Jamaica Demand-Side Management Demonstration Project, Post-Implementation Impact Assessment, Washington, 2006

(WIKI 2011) Jamaica on wikipedia.org, accessed on 13.12.2011

(WOMERSLEY 2010) Womersley, J: Managing impacts from the bulk storage of bagasse, Guideline, Department of Environment and Resource Management, Australia, 17 Sep 2010.

(WRIGHT 2010) Raymond M. Wright: Energy The New Agenda, Kingston Jamaica, 2010

(YU 2011) Yu, T-H., J.A. Larson, B.C. English, S-H. Cho: Evaluating the Economics of Incorporating Preprocessing Facilities in the Biomass Supply Logistics with an Application in East Tennessee, Southeastern Sun Grant Center, University of Tennessee, Knoxville, TN. USA, pp.45, accessed 22 Sep 2011

11.2. CONVERSIONS AND UNITS

Btu	British Thermal Unit, 1 Btu = 1.055 J
psi	Pound per square inch, 1 psi = 0.0689 bar
ha	hectar, 1 ha = 10,000 m^2
bbl	barrel, 1 barrel = 159 L
lb	pound, 1 lb = 0.454 kg

Currency conversion at time of study/mission

1USD	84 JD
1 Euro	1.42 USD

11.3. WORKSHOP

A workshop had been planned as one element in the whole programme to enable stakeholder participation. The workshop was conducted on 7th December 2011 in Kingston at the Tera Nova Hotel. Unfortunately, due to the start of the crop season, participation by the sugar industry was not possible. However, the attendance presented a good selection of different stakeholders and interests. The questions after individual presentations and the discussion showed that the subject is of interest. The programme is shown on the following page.

A brief summary of the main issues and question raised is given here grouped into the three main sections of the workshop:

Introduction, overview on energy policy

- Comments and reactions from the sugar industry is needed for the different proposals;
- Objective is to diversify sugar production from rum and sugar only into energy, biomass, wastewater treatment and possibly ethanol;
- Possible cogeneration option had also been considered by the OAS financed Biofuel study;
- The true potential of biomass must be assessed and also seen under aspects of rural development and export oriented industries;
- Efforts should be coordinated to enhance investments.

Technical session

- Cogeneration is a site-specific planning process;
- The power plant should be separated from the sugar mill operation;
- The private sector is willing to invest, but the framework conditions must be right;
- For year round production the availability of biomass resources might still be an issue;
- The definition of cogeneration needs clarification, there might be better chances for cogeneration in the cement industry, for example, as compared to sugar;
- The direction of the Government energy policy is not clear to everybody;
- The methodology for “cost-sharing” between in-house cogeneration and export to the grid is not set or accepted by all parties.

Biomass, regulatory framework and economics

- The use of high fibre cane might increase operational difficulties in milling offsetting some of the advantages;
- Also high fibre cane might effect the sugar recovery and production cost;
- One alternative crop in the off-season could be lemon grass;
- There is a tendency for green product development or carbon footprinting of products;
- The reasons and benefits why Mauritius used coal in sugar cogeneration are not clear;
- If biomass production cost are too low, they do not stimulate an industry;
- The operators at the sugar mills are not familiar with climate change and carbon footprint;
- Besides energy and diversification it is still important to increase productivity in sugar;
- The wastewater treatment at mills and distilleries could produce biogas;
- The feed-in tariff or the base for avoided cost needs to be adjusted;
- There is regionally a competition on land availability;
- The process should be initiated by a pilot project.

A total of nearly 30 people registered for the workshop, as seen in the attached copy. The actual attendance varied as people were going in and out during the day. The guests were not interviewed systematically, but the general impression was, that the participants saw some benefits through attending and getting in touch with some more details.

Cogeneration and additional Biomass for increased Electricity Production in the Jamaican Sugar Industry Workshop

Date: Wednesday, 7th December 2011

Location: Tera Nova All Suites Hotel, Kingston

Time	Organisation/Person*	Subject
08:30 – 09:00		Registration
09:00 – 09:30	Fitzroy Vidal, MEM	Welcome and Introduction Overview of the National Energy Policy – Cogeneration Option
09:30 – 09:45	Pierre Luc Vanhaerverbeke, EEAS	EU Assistance for Jamaica in the Sugar Cane Industry
09:45 – 10:00	Hillary Alexander, Permanent Secretary, MEM	Opening address
10:00 – 10:30		COFFEE BREAK
10:30 – 11:00	Robert Marrett, Gibson Energy	Technical requirements for efficient power houses
11:00 – 11:30	Werner Siemers, LML/CUTEC	Technical Potential for Cogeneration and Energy Improvements
11:30 – 12:00		Discussion, Questions and Answers
12:00 – 13:00		LUNCH BREAK
13:00 – 13:30	Dr. Bob Kodrzycki, LML/	Availability and value chain for additional biomass feedstock
13:30 – 14:00	JaapSmink, MEM/	Framework and regulatory conditions for cogeneration
14:00 – 14:30	Werner Siemers, LML/CUTEC	Results of technical and economic evaluation
14:30 – 15:00		COFFEE BREAK
15:00 – 16:00	Round Table Discussion	Discussion with all participants on “Chances and threads for bioenergy development in Jamaica”
16:00 – 16:15	Dr. Betsy Bandy, MEM	Summary of seminar, conclusions
16:15		End of the seminar

MINISTRY OF ENERGY AND MINING

NOTES

BIOMASS CONSULTANCY WORKSHOP

HELD ON WEDNESDAY, DECEMBER 7 2011 @ 8:30 AM

TERRA NOVA ALL SUITES HOTEL



NAME	Organization
Mrs. Luz Edwards	Jamaica Private Power Company
Mr. Richard Walters	Jamaica Private Power Company
Phillip Farquharson	Jamaica Private Power Company
William Saunders	Past Chair-Biofuels Task Force
Leslie Simpson	CARDI
Owen Evelyn	Foresty Department
Trevor Beaumont	TTRANSTEC
Denise Tulloch	CERE, PCJ
Nardia Grant	MEM
Niconor Reece	CERE, PCJ
Charles Koomson	CERE, PCJ
Hylton Daley	DA Gibson Energy
Gladstone Taylor	Taylor Renewable Energy Enterprise (TREE)
Jaap Smink	MEM
Pierre-Luc Vanhaeverbake	EU Delegation
Andrea Jones Bennett	NEPA
Joan C Neil	OAS
Ruth Potopsingh	UTECH
Narrine O'Connor	Development Bank of Jamaica
Melroy Sterling	JIS
G. Angus	JIS
Steve Palmer	Jamaica Broilers
Fitzroy Vidal	MEM
John Carberry	JB Ethanol Ltd
Michael Kroener	German Embassy
Betsy Bandy	MEM
Marcia Anderson	MEM
Taniquea Callam	MEM

Programme planning

11.3.1. Short term programme for biomass supply

Proposed Short Term Planning Programme					
Activity		**Objectives**	**Description**	**Target Stakeholders**	**Leader of Activity**
Green Cane Harvesting				SIRI STU Ministry Agriculture Sugar Factories Private Growers	SIRI
	Evaluate Mechanical Harvesters	Identify best equipment for carrying out green cane harvesting.	• Evaluate available equipment on the market capable of handling green cane. • Contact equipment manufacturers to learn of new equipment designs • Arrange for on-site tests or travel to equipment trials		
	Harvesting logistics and cane delivery	Insure efficient use of fibre resource with change of harvesting protocol.	• Evaluate equipment needs for handling additional biomass. • Identify areas where equipment and handling protocols need adjustment. • Determine cost and resource changes needed to handle green cane.		
	Dry cane cleaning evaluation	Evaluate technology and costs for installation of dry cane cleaning.	• Identify technology and systems for dry cane processing. • Carry out site visits to observe dry cane cleaning operations. • Obtain cost estimates for dry cane cleaning system at selected sugar factories.		
Harvest Cane Trash				SIRI STU Ministry Agriculture Sugar Factories Private Growers	SIRI
	Carry out cane trash recovery experiments	Determine the amount of cane trash fibre available in Jamaican growth system.	Carry out tests to determine the proportion of cane leaves and tops generated by selected Jamaican cane varieties on selected sites.		
	Cane trash, trash plus bagasse combustion trials	Confirm the energy value of cane trash and mixed fuel.	Perform laboratory scale combustion trials on individual biomass components and mixtures.		
	Evaluate cane trash mixing with bagasse	Determine logistical solutions for a uniform supply of fuel and effective processing.	• Determine processing needed for size reduction, transport and storage of green cane components. • Evaluate methods for mixing bagasse and trash. • Determine storage requirements for trash and mixed fuels.		
	Fertility trials	Determine the amount of cane trash that should be left on fields and any changes to long term cane management necessary to insure productivity	• Conduct replicated multi-year field trials to determine effects of varying amount of cane trash left on fields. • Evaluate soil fertility, cane productivity, effect on field maintenance, weeds, and equipment operation. • Make recommendations for amount of cane trash to be left on fields to insure sustainable cane production.		
	Trash recovery trials	Evaluate methods and equipment for recovery of cane trash from fields.	• Identify methods for recovery of cane trash. • Contact parties that have carried out trials to verify results and determine best local solution. • Identify elements of supply chain necessary to recover trash including collection, transport, storage and processing. • Conduct local trials of trash recovery equipment.		

High Fibre Cane Programme Enhancement				SIRI STU Ministry Agriculture Sugar Factories Private Growers	SIRI
	Continue SIRI testing plan	Insure effective selection of high quality varieties.	• Support current SIRI programme to identify high fibre cane varieties. • Identify areas where variety development can be accelerated and enhanced.		
	Evaluate and acquire field equipment	Determine equipment needs to support identification and distribution of high fibre cane to growers.	• Identify equipment needed by SIRI to insure that high fibre cane variety development can continue effectively. • Acquire needed equipment		
Bagasse Drying				SIRI STU Ministry Agriculture Sugar Factories Private Growers	Selected Sugar Factory
	Combustion trials	Confirm the fuel value of bagasse at different moisture levels.	• Obtain bagasse samples at selected moisture levels. • Conduct laboratory scale experiments to determine fuel value (BTU/kg)		
	Economic analysis	Determine if bagasse drying is cost effective given capital investment needed.	• Identify and determine cost of technology needed for large scale bagasse drying. • Perform and economic cost/benefit analysis of bagasse drying for fuel. • Make recommendations for leading drying technologies if justified.		
	Mixing with cane trash	Evaluate methods of mixing of dried bagasse with trash.	• Determine processing needed for size reduction, transport and storage of green cane components. • Evaluate methods for mixing bagasse and trash. • Determine storage requirements for trash and mixed fuels.		
	Storage system analysis	Determine best method for storage of dry fuel.	• Evaluate storage needs of dried and mixed fuels. Identify cost effective technologies for storage and handling.		
Grower Outreach Programme				SIRI STU Ministry Agriculture Sugar Factories Private Growers	SIRI / STU
	Planning coordination between SIRI and STU	Insure a coordinated effort in revitalizing the sugar industry.	• Conduct planning meeting between SIRI and STU to identify areas of overlapping interest. • Develop plan to insure coordination of efforts to insure success and a consistent message to stakeholders.		
	Develop marketing materials	Communication with stakeholders.	• Indentify target audience for the coordinated SIRI/STU outreach. • Determine best medium for communication. • Prepare materials for each appropriate communication medium.		
	Develop educational plan	Insure growers have access to ongoing training and information.	• Engage experienced personnel or organizations in carrying out outreach programmes. • Determine best method for long term communication and education of stakeholders. • Identify areas where there are concentrations of cane growers. • Recruit and/or train personnel for education programme.		
	Implement outreach programme	Communication with stakeholders.	• Conduct on-going communication and education programmes with growers and other stakeholders.		

11.3.2.Long term approach for dedicated energy crops

Proposed Long Term Planning Programme					
Activity		**Objectives**	**Description**	**Target Stakeholders**	**Leader of Activity**
Land Use Study				Ministry Agriculture Dept of Forestry Sugar Factories Private Growers MEM PCJ	Dept of Forestry
	Evaluate land use data	Planning for crop programme implementation.	• Obtain latest land use survey data. • Identify sugar factories and define surrounding area by distance. • Quantify land types within defined distances from sugar factories.		
	Identify transportation zones	Identify economically feasible haul distances.	• Determine cost to operate hauling equipment. • Calculate the maximum economic haul distance based on value and amount of product.		
	Make recommendations for suitable lands	Identify land suitable for agriculture.	• Classify land for various uses within different economic haul zones. • Match potential energy crops to specific sites based on land type and economic analysis.		
Develop Business Model for Dedicated Energy Crops				Ministry Agriculture Dept of Forestry Sugar Factories Private Growers MEM	Agriculture / MEM
	Verify productivity estimates for selected species	Establish reasonable goals for productivity.	• Obtain productivity data for target energy crops from Jamaican studies and scientific literature. • Make estimates of potential yields based on land use study.		
	Economic modelling of production and harvesting systems	Determine if value of crop and production rates will be justified by cost of production.	• Obtain best estimate for fuel value for each of the candidate energy crops. • Develop economic model for candidate energy crops based on input / output economic factors, capital required, breakeven point, etc. • Make recommendations for energy crops within transportation zones that could be profitable businesses.		
	Develop marketing plan for dedicated energy crop production	Recruitment effort to develop new rural business.	• Develop marketing materials detailing the economics and business opportunities for energy crops • Identify private landowners within target transportation zones with suitable land for energy crops. • Conduct public campaign to educate public and stakeholders regarding the benefits and business opportunities for energy crops. • Hold seminars to educate potential investors and landowners on energy crop opportunity.		

Woody Biomass Fibre Supply				Ministry Agriculture Dept of Forestry Sugar Factories Private Growers MEM	Dept of Forestry
	Verify data from previous tree plantation studies	Establish starting point for programme.	• Obtain available data for tree plantation growth. • Cross reference data and species to the suitable land identified in the land use study. • Identify available land for tree plantations within transportation zones.		
	Determine resources needed to carry out growth trials and ongoing support programme.	Quantify resource needs.	• Determine personnel needs and recruit to carry out growth trials. • Determine land and equipment resources needed to carry out trials. • Identify support personnel in Jamaican agencies, universities and stakeholder companies. • Form advisory boards of qualified personnel to advise and insure that stakeholder needs are addressed.		
	Establish and conduct growth trials	Collect data and make recommendations for sustainable fibre supply.	• Obtain land and equipment needed to conduct growth studies. • Obtain plant material to establish studies. • Start on-going trials to test performance of varieties under various growth regimes. • Conduct regular interactions with stakeholders to exchange information.		
	Establish breeding and nursery programme	Continued improvement of planting stock.	• Determine land and equipment needs to establish genetic improvement programme. • Recruit qualified personnel to carry out program.		
	Establish outreach programme to recruit and educate growers and stakeholders	Long term support for growers and stakeholders.	• Maintain close relationship with personnel carrying out growth trials. • Maintain communication with stakeholders.		
Other Energy Crops Fibre Supply				Ministry Agriculture Dept of Forestry Sugar Factories Private Growers MEM	Ministry of Agriculture
	Verify data from previous studies on selected crops	Establish starting point for programme.	• Obtain available data for growth of dedicated energy crops. • Cross reference data and species to the suitable land identified in the land use study. • Identify available land for dedicated energy crops within transportation zones.		
	Determine resources needed to carry out growth trials and ongoing support programme.	Quantify resource needs.	• Determine personnel needs and recruit to carry out growth trials. • Determine land and equipment resources needed to carry out trials. • Identify support personnel in Jamaican agencies, universities and stakeholder companies. • Form advisory boards of qualified personnel to advise and insure that		

			stakeholder needs are addressed.
	Establish and conduct growth trials	Collect data and make recommendations for sustainable fibre supply.	• Obtain land and equipment needed to conduct growth studies. • Obtain plant material to establish studies. • Start an ongoing trials to test performance of varieties under various growth regimes. • Conduct regular interactions with stakeholders to insure exchange of information.
	Establish breeding and nursery programme	Continued improvement of planting stock.	• Determine land and equipment needs to establish genetic improvement programme. • Recruit qualified personnel to carry out programme.
	Establish outreach programme to recruit and educate growers and stakeholders	Long term support for growers and stakeholders.	• Maintain close relationship with personnel carrying out growth trials. • Maintain communication with stakeholders.

11.3.3. Tentative programme planning

Programme	Short Term					Long Term									
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Green Cane Harvesting															
Evaluate mechanical harvesters															
Harvesting logistics and cane delivery															
Dry cane cleaning evaluation															
Harvest cane tops and trash															
Carry out cane trash recovery experiments															
Cane trash, trash + bagasse combustion															
Evaluate cane trash mixing with bagasse															
Fertility trials															
Baling tests															
High Fiber Cane Programme Enhancement															
Continue SIRI plan develop high fiber cane															
Evaluate and acquire field equipment															
Bagasse Drying															
Combustion trials															
Economic analysis															
Mixing with cane trash															
Storage															
Outreach to Growers															
Planning coordination SIRI and STU															
Develop marketing materials															
Develop educational plan															
Implement outreach programme															
Land Use Study															
Evaluate land use data															
Identify transportation zones															
Make recommendations for suitable lands															
Develop Model for Dedicated Energy Crops															
Verify productivity estimates for crops															
Economic modeling production/harvesting															
Develop marketing plan for production															
Woody Biomass Fibre Supply															
Verify data from previous tree studies															
Determine resource needs															
Establish and conduct growth trials															
Establish breeding and nursery programme															
Establish stakeholder outreach programme															
Other Energy Crops Fibre Supply															
Verify data from previous studies on crops															
Determine resource needs															
Establish and conduct growth trials															
Establish breeding and nursery programme															
Establish stakeholder outreach programme															

11.4. PERSONS AND INSTITUTIONS

Table 11.1: Chronological list of contacts, interviews and meetings by Consultant´s team[1]

Date	Subject	Participants	Organisation
August 15, 2011	Introduction, briefing	Hillary Alexander	MEM, Permanent Secretary
		Fitzroy Vidal	MEM
		Dr. Betsy Bandy	MEM
		Gerald Lindo	MEM
		Frederico Berna	EEAS Kingston
		Pierre-Luc Vanhaeverbeke	EEAS Kingston
		Werner Siemers	Consultant
		Bob Kodrzycki	Consultant
August 16, 2011	Meeting and discussion	Denise Tulloch	CERE, PCJ
		Niconor Reece	CERE, PCJ
		Ava Whyte	CERE, PCJ
		Charles Koonsom	CERE, PCJ
August 17, 2011	Meeting and discussion	George Callaghan	Ministry of Agriculture, Sugar Transformation Unit
August 18, 2011	Meeting and discussion	Dr. Delza Riley	SRC
August 18, 2011	Meeting and discussion	Andrea Bennett	NEPA
August 18, 2011	Meeting and discussion	Mr. Malung	Meteorological Service, Climate Change Office
		Mrs. O Reggio	Department for Environment
		Jaap Smink	Consultant
August 19, 2011	Meeting and discussion	Aubyn Hill	SDE, Sugar Divestment Enterprise
August 22, 2011	Site visit	Nicki Jones	Golden Grove Sugar Estate
		George Morrison	Sugar Factory
		Noel Mc Lean	Sugar Factory
		Winston Chatrie	Sugar Factory
		Tracy-Ann Steele	Sugar Factory
		Alton Davis	Sugar Factory, Field
		Nicholas Duke	
August 23, 2011	Meeting and discussion	Bill Saunders	Retired from PCJ
August 24, 2011	Site visit	Mr. Mc Pherson	SIRI
		Mr. Green	
August 25, 2011	Meeting and discussion	Dr. Leslie Simpson	CARDI
August 25, 2011	Meeting and discussion	Hopeton Heron	OUR
		Cedric Wilson	OUR
		Peter Johnson	OUR
		Andrew Lewis	OUR
August 26, 2011	Meeting and discussion	Michael Kroener	German Embassy
August 30, 2011	Meeting and discussion	Trevor Beaumont	Consultant
		Johan Verink	Consultant
August 30, 2011	Meeting and discussion	Dr. Ruth Potopsingh	UWI
August 30, 2011	Meeting and discussion	Byron Thompson	CEO, Seprod Ltd.
August 31, 2011	Site visit	Albert Fearon	CARDI
		Dr. Leslie Simpson	CARDI
September 1, 2011	Meeting and discussion	Lawrence Nelson	MoA, Forestry Department

September 1, 2011	Meeting and discussion	David Banmiller	Everglade Farms
		Mr. Banmiller	Everglade Farms
		Mr. Banmiller	Everglade Farms
September 7, 2011	Site visit	Steve Palmers	Jamaica Broilers
		Conrad Miller	
		John Carberry	JB Ethanol
September 9, 2011	Meeting and discussion	Dr. Joan Neil	OAS
September 12, 2011	Meeting and discussion	Stephanie Muir	Development Bank of Jamaica
		Christopher Brown	DBJ
		Lennox Williams	DBJ
		Carmen??	DBJ
September 12, 2011	Meeting and discussion	Marilyn Headley	MoA, Forestry department
		Keith Porter	MoA, Forestry department
September 12, 2011	Site visit	Winston Watson	PetroJam
September 14, 2011	Meeting and discussion	Ambassador Heaven	SIA
		Dr. Earle Roberts	SIRI
September 14, 2011	Site visit	Robert Clarke	Worthy Park
September 15, 2011	Site visit	William Kelly	Everglades
		James Dawkins	Everglades
		Dalton Brown	Everglades
		Thomas Hall	Everglades
			Everglades
September 20, 2011	Meeting and discussion	Trevor Beaumont	Consultant
		Jaap Smink	Consultant
September 21, 2011	Site visit		Font Hill, PCJ
September 21, 2011	Meeting and discussion	Dr. Earle Roberts	SIRI
		Trevor Fallon	SIRI
		Mr. ,,,	SIRI
September 21, 2011	Site visit	Mr. Mc Pherson	SIRI
		Mr. Green	SIRI
September 26, 2011	Site visit	Mark Elliott	Appleton Estate
		Richard Bryan	Appleton Estate
September 27, 2011	Meeting and discussion	Sam Davis	JPS
		Dionne Nugent	JPS
November 21, 2011	Meeting and discussion	MEM staff	MEM
November 22, 2011	Meeting and discussion	Robert Marritt	Gibson Energy
November 28, 2011	Meeting and discussion	Joan Neill	OAS
November 30, 2011	Meeting and discussion	Mr. Beck, Mr. Kroener	German Embassy
December 13, 2011	Site visit		Golden Grove
December 14, 2011	Site visit, meeting		Everglades
December 19,2011	Site visit		Appleton

1 The consultant`s team usually consists of Dr. Betsy Bandy, Werner Siemers, Bob Kodrzycki and partially Gerald Lindo, Charles Koonsom

11.5. ADDITIONAL INFORMATION RELATED TO INDIVIDUAL CHAPTERS

11.5.1.Chapter 1

Primary energy balance 2009 (MEM 2011-3)

Energy Balance - 2009

Barrels of Oil Equivalent (KBOE)

Source / Flow	Coal	Crude Oil	Petroleum products								Renewables							Electricity	Total
			Gas	Diesel Oil	Turbo, Aviation, Jet Fuel Kerosene	Fuel Oil	LPG	Feed stock	Other Non-Energy Products	Total Petroleum products	Fuelwood	Charcoal	Hydro	Wind	Bagasse	Solar	Total		
1.0 Primary Energy Requirement																			
1.1 Local production										-	571	191	98	31	1,049	-	1,939	129	**1,939**
1.2 Imports	167	8,700	2,916	2,807	610	3,670	566			10,569	-	-	-	-	-	-	-	-	**19,436**
1.3 Re-exports and bunkering				(177)	(1,249)	(2,071)				(3,497)	-	-	-	-	-	-	-	-	**(3,497)**
1.4 International Bunkering										-	-	-	-	-	-	-	-	-	**-**
1.5 Stock change / Statistical error	92		(134)	(308)	(6)	1,939	(60)			1,431	-	-	-	-	-	-	-	-	**1,523**
Total Primary Energy Supply	**259**	**8,700**	**2,782**	**2,322**	**(645)**	**3,538**	**506**	**0**	**0**	8,502	**571**	**191**	**98**	**31**	**1,049**	**0**	1,939	**129**	**19,400**
2.0 Transformation Sector																			
2.1 Electric Generation											-	-			-	-	0		**0**
2.11 Public Utility (JPS)				(1,770)		(3,354)				(5,123)	-	-			-	-	0	1,688	**(3,435)**
2.12 IPP's				(2)		(1,688)				(1,690)	-	-	-	-	-	-	0	791	**(898)**
2.14 Other Self Generation										0	-	-	-	-	-	-	0		**0**
2.2 Oil Refinery		(8,126)	985	1,285	662	5,113	81			8,126	-	-	-	-	-	-	0		**0**
2.3 Conversion Losses		(574)								0	-	-	-	-	-	-	0		**(574)**
2.4 Power plant's own use										0	-	-	-	-	-	-	0	(131)	**(131)**
2.5 T&D Losses JPS										0	-	-	-	-	-	-	0	(576)	**(576)**
2.6 Non-Energy Use										0	-	-	-	-	-	-	0	0	**0**
Net Available for Final consumption	**259**	**(0)**	**3,767**	**1,836**	**17**	**3,609**	**587**	**0**	**0**	9,815	**571**	**191**	**0**	**0**	**1,049**	**0**	1,811	**1,901**	**13,786**
3.0 Final Consumption by Sector																			
3.1 Manufacturing sector											-	-	-	-	-	-			
3.12 Cement Production	259					13				13	-	-	-	-	-		0	42	**314**
3.12 Sugar Production			3	23		14				39	-	-	-	-	1,049		1,049	11	**1,100**
3.12 Other Manufacturing			4			116	15			135	-	-	-	-	-	-	0	175	**310**
3.2 Agriculture			69	134						203	-	-	-	-	-	-	0	11	**214**
3.3 Construction			51	110						161	-	-	-	-	-	-	0	18	**179**
3.4 Mining/Bauxite			6	272		3,466				3,744	-	-	-	-	-	-	0	455	**4,199**
3.2 Transport sector			3,634	1,259						4,893	-	-	-	-	-	-	0	0	**4,893**
3.4 Household					9		308			317	571	-	-	-	-	-	571	509	**1,396**
3.3 Services				38	8		264			310	-	191	-	-	-	-	191	679	**1,180**
Total Final Consumption	**259**	**0**	**3,767**	**1,836**	**17**	**3,609**	**587**	**0**	**0**	9,815	**571**	**191**	**0**	**0**	**1,049**	**0**	1,811	**1,901**	**13,786**

Petroleum imports for the recent 5 years (MEM 2011-3)

Jamaica Total Petroleum Imports (2006 – 2010)

	2006		2007		2008r		2009r		2010p	
	Volume (barrels)	Value (US$)	Volume (barrels)	Value (US$)	Volume (barrels)	Value (US$)	Volume (barrels)	Value (US$)	Volume (barrels)	Value (US$)
REFINERY										
Crude & Spikes	7,479,715	447,072,431	8,361,103	515,413,276	8,259,071	771,264,734	8,700,166	498,230,443	8,373,980	627,666,214
Refined Products	9,994,857	620,729,000	9,511,142	699,359,616	9,299,676	911,504,239	7,964,366	524,213,262	7,284,898	605,453,568
Sub - Total	17,474,572	1,067,801,431	17,872,246	1,214,772,892	17,558,746	1,682,768,973	16,664,532	1,022,443,705	15,658,878	1,233,119,782
MARKETING COMPANIES										
Refined Products	3,669,410	307,542,425	3,358,512	332,112,427	2,516,459	335,377,369	2,424,728	181,979,892	1,926,806	176,436,969
Lubricants	89,797	15,721,104	73,754	16,017,072	37,161	8,630,700	36,719	10,768,020	30,358	9,133,229
Sub - Total	3,759,207	323,263,529	3,432,266	348,129,499	2,553,621	344,008,069	2,461,447	192,747,911	1,957,164	185,570,198
NON - BAUXITE TOTAL	21,233,779	1,391,064,960	21,304,512	1,562,902,391	20,112,367	2,026,777,042	19,125,979	1,215,191,616	17,616,043	1,418,689,980
BAUXITE COMPANIES										
Bunker C	7,344,159	343,339,011	6,569,111	343,834,169	6,908,380	512,568,667	985,209	38,761,313	785,216	53,292,558
Low Vanadium	2,282,260	103,097,899	2,056,526	101,064,780	2,110,982	167,379,421	2,122,419	109,282,613	2,146,150	147,879,915
Sub - Total	9,626,419	446,436,910	8,625,637	444,898,949	9,019,362	679,948,088	3,107,628	148,043,925	2,931,366	201,172,473
GRAND TOTAL	30,860,198	1,837,501,870	29,930,149	2,007,801,340	29,131,729	2,706,725,130	22,233,607	1,363,235,541	20,547,409	1,619,862,453

Electricity generation and consumption for the recent 5 years (MEM 2011-3)

ELECTRICITY GENERATION (MWh)

	2006	2007	2008	2009	2010p
Steam & Slow Speed Plants	1,543,881	1,671,219	1,701,220	1,725,785	1,673,386
Gas Turbines Plants	988,487	968,888	1,016,117	1,001,221	968,752
Hydro	166,255	159,819	158,205	140,118	151665
JPS Net Generation	**2,698,623**	**2,799,926**	**2,875,542**	**2,867,124**	**2,793,803**
JPS Purchases	1,344,431	1,278,844	1,257,658	1,346,899	1,346,496
Total Net Generation	**4,043,054**	**4,078,770**	**4,133,200**	**4,214,023**	**4,140,299**
Losses	*939,523*	*903,564*	*1,006,735*	*980,869*	*902,116*

ELECTRICITY SALES (MWh)

Category	2006	2007	2008	2009	2010p
Rate 10 (Residential)	1,096,595	1,075,120	1,032,181	1,091,901	1,106,955
Rate 20 (General Service)	643,598	659,523	650,425	670,030	673,471
Rate 40 (Power Service)	757,209	771,338	748,893	777,591	750,289
Rate 50 (Large Power)	500,246	567,435	584,791	594,626	602,248
Rate 60 (Street Light)	65,669	66,421	69,407	70,388	71,029
Other	24,655	24,185	27,609	26,875	31,240
TOTAL	**3,087,972**	**3,164,022**	**3,113,306**	**3,231,411**	**3,235,232**

11.5.2.Chapter 6

Details of assumptions for economic model

Financial Data

Sources of funds	Value	Unit
Loan	70%	%
Equity	30%	%

Interest and Exchange Rates	Value	Unit
Minimum loan rate MLR	11.00%	% p.a.
Additional loan rate on	1.50%	% p.a.
Real loan rate	12.50%	% p.a.
Maturity time on Bank Loan	10	Years
Lifetime of equipment	20	Years
Commercial interest rate	14%	% p.a.
Currency conversion	84.00	JD/USD
Currency conversion	1.42	USD/EUR
Currency conversion	119.28	JD/EUR

Tax Payment	Value	Unit
Tax in the first .... Years	0%	%
Tax after year	15%	%
Tax after year	30%	%

Carbon Credits	Low	High	Default	Unit
as per ETS	5	25	10	EURO/t CO2
Jamaica grid emission			0.6927	t CO2 / MWh
Jamaica biomass power plant substition			0.6300	t CO2 / MWh

Energy data

Fuel Prices	Low	High	Default	Unit
Crude oil	50	150	130.00	USD/barrel
Import Coal	80	180	120.00	USD/ton
			4.69	USD/MBTU
Natural gas	5	12	9.00	USD/MBTU
			30.71	USD/MWh
Bunker oil/fuel oil	4	25	17.00	USD/MBTU
			649.38	USD/ton
Diesel	7	30	23.00	USD/MBTU
			0.77	USD/L
Imported biomass			11.40	USD/MBTU
			140.47	USD/ton
Bagasse nominal price		20	7.00	USD/ton
			1.01	USD/MBTU
Field residues, tops and trash		30	20.00	USD/ton
			2.11	USD/MBTU
Energy crop, annual		40	30.00	USD/ton
			2.64	USD/MBTU
Energy crop, perennial	12	15	15.00	USD/ton
			1.13	USD/MBTU
Municipal solid waste			-50.00	USD/ton
			-6.59	USD/MBTU

By-products Prices	Low	High	Default	Unit
Cane delivered			3,000.00	JD/ton
Molasses	5000	20000	10,000.00	JD/ton
Ashes, fertiliser	100	2000	500.00	JD/ton
other materials	0	100	50.00	JD/ton

Unit price of water			20.00	JD/m3
			0.23809524	USD/m3

Unit price of electricity and steam	Low	High	Default	Unit
JPS industry tariff			29.00	USct/kWh
Firm power to grid			10.05	USct/kWh
including RE		11.56	11.56	USct/kWh
Energy only to grid			9.33	USct/kWh
including RE			10.73	USct/kWh
Short term, dump			18.00	USct/kWh
Fuel cost JPS			27.00	USct/kWh
Recommended bying rate for Cogen Sugar		16.5	15.00	USct/kWh
Unit price of steam (internal use)			0.00	USD/t
Unit price of steam sold	3	7	3.00	USD/t
Unit price of steam (internal use)			0.00	USD/MWh
Unit price of steam sold			4.00	USD/MWh

Price Escalation Factors	
Fuel cost	0.00%
Raw Water cost	0.00%
Other consumption-linked costs	0.00%
Salary and Adm. Costs	0.00%
O&M cost	0.00%
Insurance cost + other cost	0.00%
Revenue from electricity (internal use)	0.00%
Revenue from steam (internal use)	0.00%
Revenue from electricity sales	0.00%
Revenue from steam sales	0.00%
Revenue from byproduct sale	0.00%
Revenue from CER trading	0.00%

O&M cost	4.00%
O&M cost as a % of EPC cost (year 1-5)	3.50%
O&M cost as a % of EPC cost (year 5-10)	4.00%
O&M cost as a % of EPC cost (year 11 onwards)	4.50%

Insurance cost as a % of EPC cost	1.50%
Import duty as a % of EPC cost	3.00%

Monthly salaries	JD/month	USD/year
Worker	40,000	5,714
Office	50,000	7,143
Engineer	100,000	14,286
Management	200,000	28,571
Farmer	60,000	8,571
part time labour	30,000	4,286
Average	70,000	10,000

Conversion Factors		
BTU into kJ	1055	MJ/MBTU
MBTU into MWh	0.2931	MWH/MBTU
lb into kg	2.205	lb/kg
Calories into J	4.186	kJ/kcal
1 toe	42.244	GJ
1 barrel	159.00	L
Natural Gas	9.8	kWh/m3

Lower Heating Value (NCV), fuel data		
Bunker or fuel oil	40.30	MJ/kg
density	930.00	kg/m3
Diesel	42.50	MJ/kg
density	830.00	kg/m3
Imported coal	27.00	MJ/kg
Natural Gas	10.00	kWh/m3
Biomass general	13.00	MJ/kg
Bagasse	7.30	MJ/kg
Tops and trash	10.00	MJ/kg
Energy crop, annual	12.00	MJ/kg
Energy crop, perennial	14.00	MJ/kg
MSW	8.00	MJ/kg
Wood chips fresh		
Steam in general	2,700	kJ/kg
steam parameters		
15 bar, 350 C	3,148	KJ/kg
20 bar, 350 C	3,138	KJ/kg
40 bar, 450 C	3,330	KJ/kg
70 bar, 520 C	3,483	KJ/kg
backpressure		
2 bar, 135 C	2,738	KJ/kg
15 bar, 350 C	3,072	KJ/kg
Condensate		
130 C	550	KJ/kg
70 C	290	KJ/kg
30 C	125	KJ/kg