BIODIESEL VALUE CHAIN – Jamaica

Project No. 1215208-02

September 2012

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EXECUTIVE SUMMARY

The Ministry of Science, Technology Energy and Mining (MSTEM) has overarching responsibility for the development of the energy sector in Jamaica. The Ministry's Energy Division facilitates the development of strategies, programmes and projects to ensure the successful implementation of the National Energy Policy with a focus on the identification of new, renewable and alternative energy sources as well as the promotion of energy conservation and efficiency.

The Petroleum Corporation of Jamaica (PCJ) is an implementing agency of the Ministry and focuses on implementing the energy security and fuel diversification strategies including the cost-effective availability of petroleum products. The Centre of Excellence for Sustainable Energy Development (CESED), a division of PCJ, is providing leadership in research and development within this sector.

Jamaica's overall fuel imports have been growing at an average annual rate of two percent (2%) per annum over the past twenty eight (28) years. In 2010, Jamaica's energy mix remained dependent on the use of imported fossil/petroleum fuels with approximately 91% from oil imports and 9% from renewable energy sources. Over the past decade the transport sector is one of the primary demand drivers, with the expansion of the public bus fleet and the establishment of the transport sector modernization policy.

With the cost of fossil fuel energy increasing, alternatives to non-renewable sources of fuel are being sought.

The PCJ's CESED has determined the need for the development of a biodiesel value chain strategy for Jamaica at this time, in accordance with its mandate to introduce biodiesel blended automotive diesel oil into the transport sector.

Energy from biomass has been gaining significant traction as an alternative energy source or at least initially, a supplemental energy source that can reduce reliance on fossil fuels.

Common crops are being used to produce biodiesel globally including soybeans, palm, jatropha and castor. Additionally, waste vegetable oil can also be used on its own or in addition to the oils from crops to produce biodiesel.

Biodiesel feedstock cultivation has the potential to act as a development agent by enhancing livelihood opportunities for rural communities while reducing the fuel import bill of the country. The success of biodiesel in Brazil, the United States (US) and the European Union (EU) can serve as encouragement for the development of biodiesel in energy deficit countries.

Even though there is a global drive to identify alternative fuels such as biodiesel, experiences in some countries have shown that large-scale unplanned adoption of biofuels may also result in negative side effects.

Some of these include:

a. a negative impact on food security,
b. large-scale deforestation,
c. degradation of ecosystems,
d. environmental pollution and
e. displacement of rural populations.

In order to avoid adverse impacts, scaling-up biodiesel production requires proper understanding of the social benefits of biodiesel as well as the cross-sectoral implications.

In developing the biodiesel value chain strategy for Jamaica, there was impetus to carry out a variety of activities to garner a comprehensive perspective. Extensive literature research was undertaken and field visits were conducted to the PCJ/CESED pilot plots growing jatropha and castor. A close liaison was built with the CESED technical team and meetings were held with other agencies, such as Petrojam Ltd., MSTEM, RADA[1], the Bureau of Standards Jamaica, UTech[2] and data collected from entrepreneurs involved in growing oil seed crops and extracting oil. In particular, the following were integrated into the strategy document:

1. Literature research findings on the advantages and disadvantages of biodiesel production; the environmental and occupational health issues associated with its production; the by- and co-products produced; and options for reuse, recycling or disposal.
2. An examination of the various options for feedstock overseas and locally such as jatropha, castor, oil palm and pongamia.
3. Research findings regarding the biodiesel programmes in relevant countries such as Brazil and India paying particular attention to the successes, failures and lessons learnt.
4. An examination and comparison of Jamaica's National Energy and Biofuels Policies to those in relevant countries.
5. Inclusion of interim findings from the pilot projects at Bodles Agricultural Research Station and CARDI.
6. Costs obtained relevant to inputs at each stage of the value chain, where available.
7. Feedback from 2 stakeholder consultations held to gain insight into key challenges.
8. A gap analysis examining the policy, legislative and institutional frameworks essential to the success of implementing the biodiesel programme in Jamaica are presented as well as recommendations to close the gaps.

The research revealed that co-products and by-products can potentially be obtained from the production of biodiesel that tend to make production more feasible. Oil seed meal can be used as a fertiliser or animal feed in some cases and glycerine can be used as a raw material in animal feed and pharmaceuticals. This can serve to establish a value chain beneficial to stakeholders by making this initiative a more financially attractive and feasible business venture.

[1] RADA – Rural Agricultural Development Agency
[2] UTech – University of Technology

Examination of the cost of producing biodiesel on both the small and large scales reveal that the production cost for biodiesel is higher in both cases than the cost at which petroleum diesel is sold even with the added value of co- and by-products. This is expected to be the trend for some time yet as the cost of the main input to production which is the feedstock is still quite high. This is due to the high cost of cultivation of the oil seed crops.

The successful biodiesel producing countries have had the benefit of significant assistance from their Governments though a mix of incentives, tax relief and strong social programmes.

Lessons learnt from the implementation of biodiesel programmes elsewhere has shown that Jamaica has many fundamental structures and systems to establish before it is ready to embark on a sustained programme of biodiesel production.

1.0 Introduction

With the cost of fossil fuel energy increasing, alternatives to non-renewable sources of fuel are being sought. Energy from biomass has been gaining significant traction as an alternative energy source or at least initially a supplemental energy source that can reduce reliance on fossil fuels. Global diesel production increased six fold between 2004 and 2008, from 2 billion litres to more than 12 billion litres. The European Union (EU) contributed more than two-thirds of this production. The top producers in the EU are Germany, France, Italy and Spain. Besides the EU, the main biodiesel producers include the United States (US), Argentina, Brazil and Thailand.

The success of biodiesel in Brazil, the US and the EU should encourage the development of biodiesel in energy deficit countries. Biodiesel feedstock cultivation has the potential to act as a development agent by enhancing livelihood opportunities for rural communities while reducing the fuel import bill of the country. Global experiences have shown that large-scale unplanned adoption of biofuels may also result in negative side effects such as an impact on food security, large-scale deforestation, the degradation of ecosystems, environmental pollution and the displacement of rural populations. Therefore, scaling-up biodiesel production requires a proper understanding of the social benefits of biodiesel as well as the various cross-sectoral implications to avoid adverse impacts.

Common crops that are being used to produce biodiesel globally include soybeans, palm, jatropha and castor. However while this thrust for using crops to produce biodiesel gathers momentum, there are some concerns about the developments especially as it relates to the threat that it poses to food crops being used for the production of fuel oil. Strategies to secure the dual sustainability of local food and alternative energy sectors are therefore imperative particularly as biodiesel production alone is not a highly financially feasible activity. Establishing a value chain with several co-products and by-products obtained from the production of biodiesel would go a far way to enhance the financial profitability and business feasibility of the venture.

This strategy document will present the following salient information:

- required policy and legislative frameworks
- advantages and disadvantages of using biomass to produce biodiesel
- experiences in selected countries
- inputs and the associated costs
- environmental and safety concerns
- co-products and by-products generated as important elements of the biodiesel value chain.

2.0 Background

The Ministry of Science, Technology, Energy and Mining (MSTEM) has overarching responsibility for the development of the energy sector in Jamaica. The Ministry's Energy Division facilitates the development of strategies, programmes and projects to ensure the successful implementation of the National Energy Policy with a focus on the identification of new, renewable and alternative energy sources and the promotion of energy conservation and efficiency.

The Petroleum Corporation of Jamaica (PCJ) is an implementing agency of the Ministry and focuses on implementing energy security and fuel diversification strategies as well as providing the cost-effective availability of petroleum products. The Centre of Excellence for Sustainable Energy Development (CESED) in the PCJ provides leadership in research and development.

Jamaica's overall fuel imports have been growing at an average annual rate of two percent (2%) per annum over the past twenty eight (28) years. In 2010, Jamaica's energy mix remained dependent on the use of imported fossil/petroleum fuels with approximately 91% from oil imports and 9% from renewable energy sources. The transport sector is one of the primary demand drivers, with the expansion of the public bus fleet and the establishment of the transport sector modernization policy over the past decade.

PCJ's CESED, in accordance with its mandate, has determined the need for the development of a biodiesel value chain strategy for Jamaica at this time. This is based on a number of developments which have taken place in the energy sector over the past four (4) years. In fact, the PCJ/CESED has been the recipient of financial and technical support from other countries and donor agencies aimed at facilitating the development of a biodiesel strategy for Jamaica.

The first major assistance came through a Jamaica-Brazil-United States of America (USA) Tripartite Agreement. The original US-Brazil Memorandum of Understanding (MOU) on Biofuels Cooperation was signed on March 9, 2007. For Jamaica, the agreement was formalized on November 3, 2008, after accepting an invitation to join the US-Brazil Bilateral Memorandum of Understanding to Advance Cooperation on Biofuels. With the agreement in place, the Ministry of Energy and Mining established a Biofuels Taskforce in December 2008. This task force was a joint ministerial effort allowing the Ministry of Energy and Mining as well as the Ministry of Agriculture and Fisheries to identify obstacles to formulating a biofuels policy and strengthening intergovernmental cooperation. One success of this programme is the introduction in Jamaica of bioethanol (E10) in motor gasolines (87 & 90) over the period November 1, 2008 to November 1, 2009. Local standards for biofuels were developed by the Jamaica Bureau of Standards' Industrial Chemical and Allied Products Technical Committee through a series of meetings held in the financial year 2009-2010. These standards are aligned to the American Standards and Testing Methodology (i.e. ASTM 6751 for biodiesel).

The PCJ, as a member of the Ministry of Energy's Biofuels Taskforce, has implemented specific activities related to the development of the biofuels sector in Jamaica. The PCJ's Board and Management approved the Small-Scale Biodiesel Pilot Project (SBP) in July 2009. The SBP commenced with the signing of a Research Partnership Agreement (RPA) with the Ministry of Agriculture and Fisheries (Bodles Agricultural Research Station) on July 8, 2010 followed by the signing of a second RPA with the Caribbean Agricultural Development Institute (CARDI) on February 11, 2011. The programme is currently being implemented. The pilot projects seek to assess the viability of producing biodiesel from locally grown feedstock such as castor and jatropha as well as waste vegetable oil. This project is designed to advance the introduction of biofuels in Jamaica, guided by the Biofuels Policy and related legal and regulatory instruments, which are all based on appropriate commercial and economic models.

To support the SBP, the PCJ entered into an agreement with the United Nations Environment Programme (UNEP) Riso Centre in December 2009 to implement the project "Development of a Biodiesel Strategy for Jamaica to Ensure Compliance with Jamaica's Biodiversity Strategy".

Also, the PCJ was the recipient of technical assistance for biofuels development and policy support to Jamaica in May 2010 under the OAS funded Biofuels Technical Assistance programme. Winrock International was contracted to conduct a project designed to help the Government of Jamaica in its efforts to take advantage of biofuel technology and the island's agricultural resources to offset the cost of imported petroleum and reduce its impact on the local economy.

To establish a policy framework for the development of biofuels in Jamaica, the United States Embassy agreed in February 2011 to fund a biofuels consultant to provide technical assistance to the Ministry of Energy and Mining. A consultant from the United States Trade & Development Association (USTDA) provided strategic planning support for two (2) months and the deliverables included a draft policy, key performance indicators, a SWOT analysis and an action plan for locally grown biofuel feedstock.

This study includes a review of existing reports and data related to the pricing formulae for automotive diesel as compared with global biodiesel pricing trends. It is intended to support decision-making using local and international data that would be fundamental to considerations of starting and/or expanding a biodiesel project in Jamaica. This study is expected to assist in identifying existing and potential end-users of by-products (e.g. glycerine, fertilizer meal) of the biodiesel production process.

The study will also determine the positive and negative environmental effects associated with the use of the by-products, and assess the revenue and cost implications of the sale/disposal of the by-products. This is necessary to support the sustainability of fuel options and incorporate the resulting benchmarks into energy, agricultural, land use and trade policies.

The main objectives of this study are to:

1. Review existing reports and data related to the biodiesel value-chain and identify information gaps or development needs (e.g. Jamaica Bauxite Institute's Castor Cultivation Study 1980's).
2. Review the draft biofuels policy, strategy, SWOT analysis and standards that will support the definition and growth of a local biofuels industry.
3. Formulate a biodiesel value chain development strategy, which takes into account an assessment of the environmental impacts of potential by-products.

The Terms of Reference for this study are included in Appendix 1.

The development of the biodiesel value chain strategy will allow the PCJ to drive the development of the biodiesel sector in keeping with its role to implement fuel diversification strategies.

3.0 Methodology

In developing the biodiesel value chain strategy for Jamaica, an array of activities was undertaken. An extensive literature research was conducted in which the advantages and disadvantages of biodiesel production, the environmental and occupational health issues associated with its production, the by- and co-products produced and options for reuse, recycling or disposal were identified. Research was also done on the biodiesel programmes in other countries paying particular attention to the successes, failures and lessons learnt. National energy and biofuels policies were examined and compared.

Field visits were arranged to the PCJ/CESED pilot plots in collaboration with Bodles Agricultural Research Station (BARS) and CARDI growing jatropha and castor. Interim findings from the pilot projects were included. In addition, there was close liaison with the CESED technical team involving meetings and data collection regarding the growth of oil seed crops and oil extraction. The various options for feedstock were examined both overseas and locally. The cost of inputs at each stage of the value chain was obtained where available

Two (2) stakeholder consultations were held on biodiesel production. Invited participants included feedstock suppliers, biodiesel producers, representatives of stakeholder Ministries and Agencies, representatives of petroleum companies and academia. Discussion centred on the main issues related to biodiesel production in Jamaica. A listing of participants in the consultations is included in Appendix 2.

Persons and entities instrumental in providing information are listed in Appendix 3. Subsequently, from the literature reviews and information gathered, this biodiesel value chain strategy document was developed.

4.0 Terminology

4.1 First Generation Biofuels

First generation biofuels are made from the sugars and vegetable oils found in arable crops, which can be easily extracted using conventional technology.

4.2 Second Generation Biofuels

Second generation biofuels, also known as advanced biofuels, are fuels that can be manufactured from various types of biomass. Biomass is a wide-ranging term meaning any source of organic carbon that is renewed rapidly as part of the carbon cycle. Biomass is derived from plant materials, but can also include animal materials. Second generation biofuels are made from lignocellulosic biomass or woody crops, agricultural residues or waste, which makes it harder to extract the required fuel.

4.3 Biodiesel

Biodiesel is an alternative fuel similar to conventional or 'fossil' diesel. Biodiesel can be produced from straight vegetable oil (SVO), animal oil/fats, tallow and waste cooking oil. The process used to convert these oils to biodiesel is called transesterification and includes chemically reacting lipids (e.g. vegetable oil, animal fat/tallow) with alcohol and alkali producing fatty acid esters.

Biodiesel is a cleaner-burning replacement for petroleum-based diesel fuel, nontoxic and biodegradable. It has physical properties similar to those of petroleum diesel and is meant to be used in standard diesel engines and is therefore distinct from the vegetable and waste oils used to fuel *converted* diesel engines. Biodiesel can be used alone, or blended with petro diesel and can also be used as a low carbon alternative to heating oil.

4.4 Glycerine

The literature researched on this subject refers to glycerol, glycerin and glycerine. All these terms refer to the same substance. Additionally, according to the IUPAC[3] nomenclature, it is also called Propan-1, 2, 3-triol. Throughout this document the term ***glycerine*** will be used.

4.5 Co-Products, By-Products and Wastes

Co-products are produced along with the main product and have similar revenues as the main product.

By-products are produced along with the main product and have smaller revenues than the main product.

Residues/wastes are generated along with the main product and have no or negligible revenues.

5.0 Biodiesel Characteristics

Biodiesel is a liquid fuel whose colour varies between golden and dark brown depending on the production feedstock. It is practically immiscible with water, has a high boiling point and low vapour pressure. It is non-flammable, less toxic than table salt and biodegrades as fast as sugar. In order to ensure high-quality performance, strict specifications have been established regarding the characteristics of fuel-grade biodiesel. Biodiesel has physical properties very similar to conventional petroleum diesel, of which the following characteristics are the most distinctive.

5.1 Cetane Index

The benchmark for measuring the ignition performance of diesel fuels is the fuel's cetane number or cetane index. The higher the cetane index, the faster the fuel ignites, and the smoother the engine runs. Petroleum diesel in the United States typically has a cetane index

[3] IUPAC – International Union on Pure and Applied Chemistry

in the low 40s, European diesel typically in the low 50s. The main components of biodiesel are similar to cetane, and thus it naturally possesses a cetane index of 56 to 58 making it a high-quality fuel with excellent ignition performance, even without additives.

5.2 Lubricity

The lubricating properties are another important measure of diesel fuel as fuel injectors and some types of fuel pumps rely on fuel for lubrication. The problem with petroleum diesel is that it loses its lubricating qualities with lower sulphur contents, which in turn makes it necessary to blend it with synthetic additives. Biodiesel in contrast has particularly high lubricating qualities, even though it contains practically no sulphur at all. Lubrication tests revealed that the addition of 1% - 2% biodiesel to low-sulphur petroleum diesel improves lubricity substantially, thereby reducing by around 60% the wear and tear on engines and injection pumps. Biodiesel is therefore an environmentally friendly additive to petroleum diesel fuels.

5.3 Cold Filter Plugging Point

At low temperatures, diesel fuel forms wax crystals that can clog fuel lines and filters in a vehicle's fuel system. Firstly, it appears cloudy and at even lower temperatures, it becomes a gel that cannot be pumped anymore, resulting in possible engine failure. The temperature at which paraffin (petroleum diesel) or ester crystals (biodiesel) crystallise before injection, is measured by the cold filter plugging point (CFPP). For rape seed oil the CFPP lies between –12° and –14°C, for yellow grease between –2° and +2°C and for palm oil between +20° and +24°C. In general, the CFPP for biodiesel is higher than for petroleum diesel, which makes its performance in cold weather conditions markedly worse. Additives manufactured from certain raw materials are available for biodiesel use in such conditions. In tropical regions this is not a major concern. .

5.4 Fuel Economy

The performance of diesel fuels is also measured in terms of fuel economy, which as volumetric efficiency is usually expressed as kilometres travelled per litre of fuel. The energy content per litre of biodiesel is approximately 11% lower than that of petroleum diesel. Vehicles running on B20 are therefore expected to achieve 2.2% fewer kilometres per litre of fuel (20% x 11%). Though insignificant, biodiesel tends to reduce fuel economy.

5.5 Biodiesel Advantages

There are a number of advantages of using biodiesel as outlined below.

1. Energy Benefits
    a. Biodiesel fuel can be made from crops grown for fuel or from cooking oils recycled from restaurants. This means it is a renewable resource unlike petroleum-based diesel.
    b. Biodiesel improves domestic energy security. By using domestically produced, renewable fuels like biodiesel, some countries can reduce dependence on foreign countries for oil. Biodiesel has the highest energy balance of any domestic

renewable fuel. Every unit of fossil fuel it takes to make biodiesel results in 5.5 units of energy gain. Petroleum diesel has a negative energy balance of 0.88.

2. Environmental Benefits
   a. Biodiesel reduces emissions significantly. The use of biodiesel in a conventional diesel engine results in substantial reduction of unburned hydrocarbons, carbon monoxide, and particulate matter. Emissions of nitrogen oxides are either slightly reduced or slightly increased depending on the duty cycle and testing methods.
   b. The use of biodiesel decreases the solid carbon fraction of particulate matter (since the oxygen in biodiesel enables more complete combustion to CO_2), eliminates the sulphate fraction (as there is no sulphur in the fuel), while the soluble, or hydrocarbon fraction stays the same or is increased. Biodiesel works well with new technologies such as catalysts, particulate traps, and exhaust gas recirculation.
   c. Biodiesel exhaust is less offensive. The use of biodiesel and biodiesel blends results in a noticeable, less offensive exhaust odour that can be a real benefit in confined spaces. Some equipment operators have compared it to the smell of French fries. Users also report having no eye irritation. Since biodiesel is oxygenated, diesel engines have more complete combustion with biodiesel than with petroleum[4].

3. Safety
   a. Biodiesel is safer to use than petroleum diesel. The flash point (the point at which fuel ignites) for biodiesel in its pure form is a minimum of 93^{o}C versus about 52^{o}C for regular No. 2 diesel. This makes biodiesel one of the safest fuels to use, handle and store.

4. Economic and Operational
   a. Biodiesel fuel can be distributed through existing diesel fuel pumps. This is an advantage over other alternative fuels, which can be expensive to use initially due to high cost of equipment modifications or new purchases.
   b. Biodiesel provides almost the same energy per litre as petroleum diesel.
   c. Biodiesel operates in conventional engines. Just like petroleum diesel, biodiesel operates in combustion-ignition engines. Essentially no engine modifications are required, and biodiesel maintains the payload capacity and range of diesel.
   d. Biodiesel does not require special storage. In its pure form or in blends, biodiesel can be stored wherever petroleum diesel is stored, except in concrete-lined tanks. It handles like diesel and uses the same infrastructure for transport, storage and use.
   e. The lubricating effects of the biodiesel may extend the lifetime of engines.
   f. The absence of sulphur in 100% biodiesel should extend the life of catalytic converters.

[4]An Overview of Biodiesel and Petroleum Diesel Life Cycles; A Joint Study Sponsored by U.S. Department of Agriculture and U.S. Department of Energy; May 1998 http://www.nrel.gov/vehiclesandfuels/npbf/pdfs/24772.pdf and BioDiesel – America's Advanced Biofuel http://www.biodiesel.org/using-biodiesel/market-segments/general-interest

5. Social

Biodiesel production:

a. Provides new markets for agricultural producers that could stimulate rural growth and farm incomes
b. Provides jobs especially for rural farming communities
c. Contributes to energy security
d. Improves local access to energy in rural areas that can:
    - improve access to pumped drinking water i.e. clean water and cooked food to reduce hunger (95% of food needs cooking).
    - reduce the time spent by women and children on basic survival activities (e.g. gathering firewood, fetching water, cooking).
    - allow lighting for increased security thereby enabling the use of educational media and communication in school and home study at night.
    - reduce indoor pollution caused by firewood use, together with a reduction of deforestation.

5.6 Biodiesel Disadvantages

The disadvantages of using biodiesel include the following:

1. Economic
    e. Biodiesel is more expensive than petroleum diesel fuel
    f. Biodiesel is not distributed as widely as traditional petroleum diesel, but distribution infrastructure is improving.

2. Energy
    a. It takes energy to produce biodiesel fuel from crops, including the energy of sowing, fertilising and harvesting.

3. Social
    a. Biodiesel production may cause an increase in food prices if an oilseed feedstock that is used for food is used for biodiesel production making low income families who are net food-buyers vulnerable to hunger and malnutrition.
    b. Plantation developments have caused numerous land conflicts between large agricultural developers and indigenous people and other rural communities who rarely have formal land rights.
    c. Large plantation developers may not provide good working conditions for poor rural workers.

4. Operational
    a. Pure biodiesel is not compatible with natural rubber, sometimes found in pre-1994 vehicles. Because it is a solvent, biodiesel can degrade natural rubber hoses and gaskets as well as polyurethane foam materials. This is not a problem with B20 blends (20% biodiesel/80% diesel) and below.

b. Biodiesel cleans the dirt from the engine. This dirt collects in the fuel filter, which can clog it. Clogging occurs most often when biodiesel is first used after a period of operation with petroleum diesel, so filters should be changed after the first several hours of biodiesel use.

6.0 Biodiesel Production

The transesterification process, which converts crude vegetable or recycled oil (and fats) to biodiesel, is well established in Central America, Brazil, and the US. Several manufacturers deliver turnkey operations that can be run by a small number of trained staff members. The key types of expertise in biodiesel production are chemical (or related) engineering and chemistry, as it involves chemical reactions at elevated temperatures (50^{0}C -60^{o}C), the use of chemical reagents (methanol and alkali), and phase separation. Personnel with proper experience can be recruited from other chemical operations in Jamaica and from the country's academic and research institutions. Training provided by the equipment manufacturer should suffice to start, operate, and maintain a biodiesel production plant regardless of the feedstock used.

There are three basic routes to biodiesel production from oils and fats:

- Base catalysed transesterification of the oil
- Direct acid catalysed transesterification of the oil
- Conversion of the oil to its fatty acids and then to biodiesel

Most of the biodiesel produced today is done with the base catalysed reaction for several reasons:

- It is a low temperature and pressure process.
- It yields high conversion (98%) with minimal side reactions and reaction time.
- It is a direct conversion to biodiesel with no intermediate compounds.
- No exotic construction materials are required.

The chemical reaction for base catalysed biodiesel production is depicted below. In this process, 45kg of fat or oil are reacted with 4.5 kg of a short chain alcohol in the presence of a catalyst to produce 4.5 kg of glycerine and 45kg of biodiesel. The short chain alcohol, signified by ROH (usually methanol, but sometimes ethanol) is charged in excess to assist in quick conversion. The catalyst is usually sodium or potassium hydroxide that has already been mixed with the methanol. In the process diagram, R', R'', and R''' indicate the fatty acid chains associated with the oil or fat that are largely palmitic, stearic, oleic, and linoleic acids for naturally occurring oils and fats.

The Biodiesel Reaction

CH_2OCOR'''		CH_2OH		R'''COOR
|	Catalyst			|
CH_2OCOR'' +	3 ROH ------>	CH_2OH	+	R''COOR
|				|
CH_2OCOR'		CH_2OH		R'COOR
45kg	4.5kg	4.5kg		45kg
Oil or Fat	Alcohol	Glycerine		Biodiesel

The base catalysed production of biodiesel generally occurs using the following steps:

1. *Mixing of alcohol and catalyst*
    a. The catalyst (typically sodium hydroxide (caustic soda) or potassium hydroxide (potash) is dissolved in the alcohol using a standard agitator or mixer.

2. *Reaction*
    a. The alcohol/catalyst mix is then charged in a closed reaction vessel and the oil or fat is added.
    b. The system from here on is totally closed to the atmosphere to prevent the loss of alcohol. The reaction mix is kept just above the boiling point of the alcohol (around 71°C) to speed up the reaction that takes place. Recommended reaction time varies from 1 hour to 8 hours, and some systems recommend the reaction take place at room temperature. Excess alcohol is normally used to ensure total conversion of the fat or oil to its esters.
    c. Care must be taken to monitor the amount of water and free fatty acids in the incoming oil or fat. If the free fatty acid level or water level is too high it may cause problems with soap formation and the separation of the glycerine by-product downstream.

3. *Degumming*
    a. Unrefined vegetable oils (crude oil extracted from oil seeds) often contain phospholipid (gum) compounds that can make separating the glycerine at the end of the transesterification process more difficult. Small-scale biodiesel producers may benefit from degumming crude vegetable oil because it will enhance the quality of the final biodiesel product.
    b. Degumming is accomplished by mixing small quantities of water (3% to 5%) with the oil.
    c. The water combines with the gums and precipitates out after allowing the mixture to settle for approximately one hour, and the water then can be drained off the bottom of the oil.
    d. Several washings may be required to remove all the gums. Initially, the wash water appears milky-coloured. The degumming is complete when the water appears clear.
    e. Gum also can be removed from oil using an acid degumming process or simply by letting the oil sit in a tank for two to three weeks and draining it off the bottom of the tank or decanting the oil off the top, leaving gum behind as a sludge-type material at the bottom.
    f. Removing all the water from the oil before further processing is important because the presence of water will cause the fatty acids in the oil to form soaps rather than biodiesel.

4. *Separation*
    a. Once the reaction is complete, two major products are generated, glycerine and biodiesel. Each has a substantial amount of the excess methanol from the reaction. The reacted mixture is sometimes neutralised at this step if needed. The glycerine phase is much denser than the biodiesel phase and the two can be gravity separated

with glycerine simply drawn off the bottom of the settling vessel. In some cases, a centrifuge is used to separate the two materials faster.

5. *Alcohol Removal*
   a. Once the glycerine and biodiesel phases have been separated, the excess alcohol in each phase is removed with a flash evaporation process or by distillation. In others systems, the alcohol is removed and the mixture neutralised before the glycerine and esters are separated. In either case, the alcohol is recovered using distillation equipment and is re-used. Care must be taken to ensure no water accumulates in the recovered alcohol stream.
   b. Alcohol recovery is usually not practical for small operations.

6. *Glycerine Neutralisation*
   a. The glycerine co-product contains unused catalyst and soaps that are neutralized with an acid and sent to storage as crude glycerine. The salt formed during this phase may be recovered for use as fertilizer. In most cases the salt is left in the glycerine.
   b. Water and alcohol are removed to produce 80% - 88% pure glycerine that is ready to be sold as crude glycerine. In more sophisticated operations, the glycerine is distilled to 99% or higher purity and sold into the cosmetic and pharmaceutical markets.

7. *Biodiesel washing (Methyl Ester Wash)*
   a. Once separated from the glycerine, the biodiesel needs to be washed after the transesterification process to remove remaining catalyst, methanol, glycerine, soap and gums.
   b. Water should be sprinkled gently on top of the biodiesel; the water droplets will collect at the bottom of the tank for removal.
   c. If the unwashed biodiesel is agitated during this step, removal of the wash water may be difficult. Separation of wash water from biodiesel may be helped by adding sufficient acid to neutralise the catalyst. Suitable acids include vinegar and hydrochloric acid.
   d. The washing needs to be repeated until the wash water is clear.
   e. After washing, the biodiesel is heated to 120 ^{o}C (248 ^{o}F) for approximately one hour to evaporate any remaining water and methanol.
   a. The biodiesel is then dried, and sent to storage. In some processes this step is unnecessary. This is normally the end of the production process resulting in a clear amber-yellow liquid with a viscosity similar to petro diesel. In some systems the biodiesel is distilled in an additional step to remove small amounts of colour bodies to produce a colourless biodiesel.

8. *Product Quality and Registration*
   a. Prior to use as a commercial fuel, the finished biodiesel must be analysed using sophisticated analytical equipment to ensure it meets ASTM specifications. The most important aspects of biodiesel production to ensure trouble free operation in diesel engines are:
      - complete reaction
      - removal of glycerine
      - removal of catalyst

- removal of alcohol
- absence of free fatty acids

b. These parameters are all specified through the biodiesel standard, ASTM D 6751[5]. This standard identifies the parameters the pure biodiesel (B100) must meet before being used as a pure fuel or being blended with petroleum diesel.

c. The European standard for biodiesel is EN 14214, which is translated into the respective national standards for each country that forms the CEN (European Committee for Standardization) area e.g. for the United Kingdom, BS EN 14214 and for Germany DIN EN 14214. It may be used outside the CEN area as well. The main difference that exists between EN 14214 standards of different countries is the national annex detailing climate related requirements of biodiesel in different CEN member countries.

Appendix 4 and Appendix 5 present the ASTM D and EN standards. Jamaica will use the ASTM standard for biodiesel.

6.1 Processing Waste Cooking Oil into Biodiesel

Waste cooking oil collected from restaurants often contains solids, water, high levels of free fatty acids and dark colour. Removing the gum and water is the same process as removing them from crude vegetable oil. The solids can be removed using a screen or fabric filter.

Figure 1: Waste Vegetable Oil being Filtered

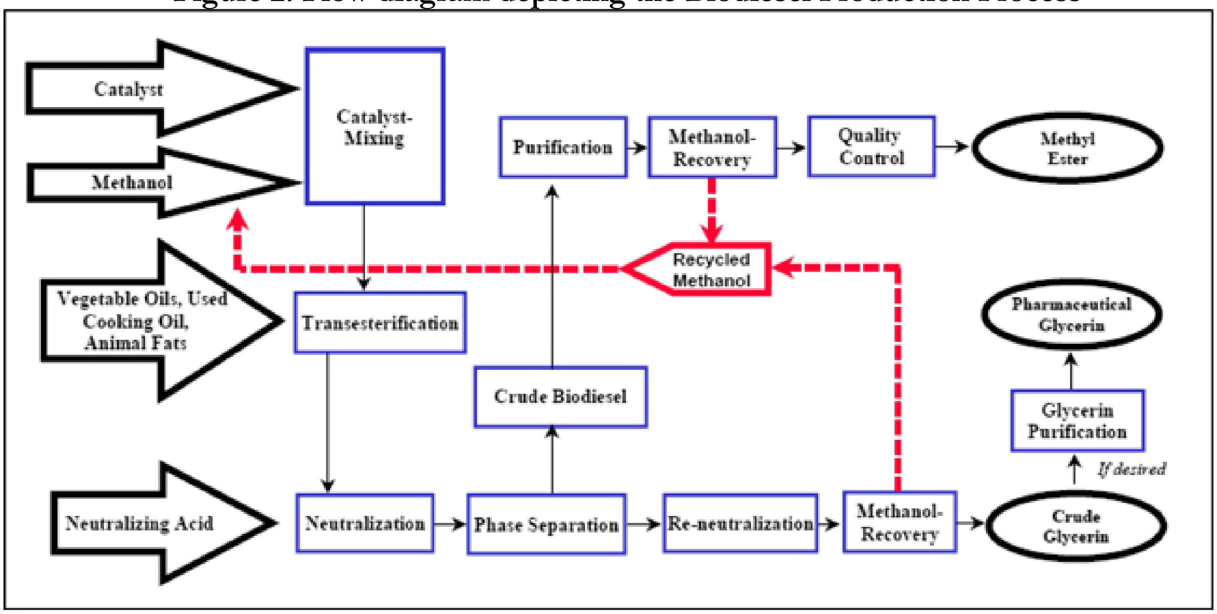
http://drdavesauto.com/Vegetable-Oil-Conversions.php

[5]ASTM D 6751 is available at www.astm.org

Waste cooking oil typically contains from 2% to 5% free fatty acids. Free fatty acid levels will increase with the amount of time vegetable oil has been heated. The presence of too high a level of free fatty acids will retard or stop the transesterification reaction. To ensure a successful conversion to biodiesel, determining the exact amount of catalyst needed to neutralise the acids by performing a titration test is worthwhile. Adding too much catalyst will result in excessive amounts of soap in the final biodiesel product. If too little catalyst is added, transesterification will not occur.

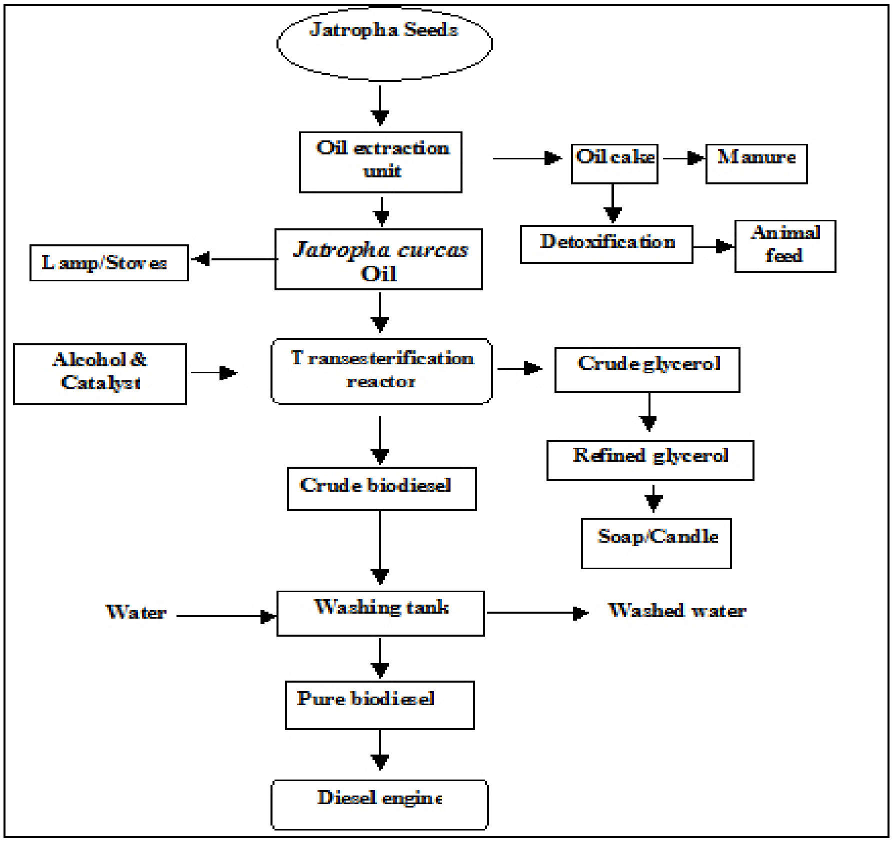
Figure 2 and Figure 3 show flow diagrams of the biodiesel production process as well as co- and by- products such as glycerine and fertilisers.

Figure 2: Flow diagram depicting the Biodiesel Production Process



Source: http://www.esru.strath.ac.uk/EandE/Web_sites/02-03/biofuels/what_biodiesel.htm

Figure 3: Biodiesel production process from Jatropha seeds as well as other Co- and By-Products



Source: http://www.lsbdholding.com/what-is-it/

7.0 Roundtable on Sustainable Biofuels (RSB) Certification System

The Roundtable on Sustainable Biofuels is an international initiative that brings together farmers, companies, governments, non-governmental organisations, and scientists who are interested in the sustainability of biofuels production and distribution. On August 13, 2008, the Roundtable developed a series of Principles and criteria for sustainable biofuels production. The Roundtable released "Version Zero" of its proposed standards for sustainable biofuels, which included twelve (12) Principles, each with several criteria for developing the Principle further. The Principles are:

1. Biofuel production shall follow international treaties and national laws regarding such things as air quality, water resources, agricultural practices, labour conditions, and more.
2. Biofuels projects shall be designed and operated in participatory processes that involve all relevant stakeholders in planning and monitoring.
3. Biofuels shall significantly reduce greenhouse gas emissions as compared to fossil fuels. The principle seeks to establish a standard methodology for comparing greenhouse gases (GHG) benefits.
4. Biofuel production shall not violate human rights or labour rights, and shall ensure decent work and the well-being of workers.

5. Biofuel production shall contribute to the social and economic development of local, rural and indigenous peoples and communities.
6. Biofuel production shall not impair food security.
7. Biofuel production shall avoid negative impacts on biodiversity, ecosystems and areas of high conservation value.
8. Biofuel production shall promote practices that improve soil health and minimise degradation.
9. Surface and groundwater use will be optimised and contamination or depletion of water resources minimised.
10. Air pollution shall be minimised along the supply chain.
11. Biofuels shall be produced in the most cost-effective way, with a commitment to improve production efficiency and social and environmental performance in all stages of the biofuel value chain.
12. Biofuel production shall not violate land rights.

In April 2011, the Roundtable on Sustainable Biofuels launched a set of comprehensive sustainability criteria - the "RSB Certification System." Biofuel producers that meet these criteria are able to show buyers and regulators that their product has been obtained without harming the environment or violating human rights.

The primary use of the RSB Standard is a certification system involving independent 3rd party certification bodies. The RSB certification model uses a risk management approach, which ensures security and robustness while remaining flexible for participating operators. To match the needs of operators, several "chain of custody" options are proposed (100% segregation, mass balance, etc.). It is also possible to certify groups of producers. The RSB aims to be the "one-stop shop" for compliance with various regulations and seeks to be recognised by market regulators, such as the European Union.

8.0 Environmental and Safety Information

8.1 Acute Oral Toxicity/Rates

Toxicity can be measured by using LD_{50} the standardized measure for expressing and comparing the toxicity of chemicals. Biodiesel is nontoxic. The acute oral LD_{50} (lethal dose) is greater than 17.4 g/kg body weight. By comparison, table salt (NaCl) is nearly 10 times more toxic.

8.2 Skin Irritation - Humans

A 24-hr. human patch test indicated that undiluted biodiesel produced very mild irritation. The irritation was less than the result produced by a 4% soap and water solution.

8.3 Aquatic Toxicity

Methanol

Methanol in high concentrations (>1%) in fresh or salt water can have short-term harmful effects on aquatic life within the immediate spill area.

Biodiesel

A 96-hr. lethal concentration for bluegill[6] of biodiesel grade methyl esters was greater than 1,000 mg/L. Lethal concentrations at these levels are generally deemed "insignificant" according to NIOSH (National Institute for Occupational Safety and Health) guidelines in its *Registry of the Toxic Effects of Chemical Substances*.

8.4 Biodegradability

Methanol

Methanol is readily biodegradable in both aerobic (oxygen present) and anaerobic (oxygen absent) environments. Methanol will not persist in the environment. The half-life for methanol in groundwater is just one to seven days. Since methanol is miscible with water and biodegradable, it is unlikely to accumulate in groundwater, surface water, air or soil.

Biodiesel

Biodiesel degrades about four times faster than petroleum diesel. Within 28 days, pure biodiesel degrades 85% to 88% in water. Dextrose (a test sugar used as the positive control when testing biodegradability) degraded at the same rate.

Blending biodiesel with diesel fuel accelerates its biodegradability. For example, blends of 20% biodiesel and 80% diesel fuel degrade twice as fast as No.2 diesel alone.

8.5 Flash Point

The flash point of a fuel is defined as the temperature at which it will ignite when exposed to a spark or flame. Biodiesel's flash point varies from a minimum value of 93ºC to over 149°C, well above petroleum based diesel fuel's flash point of around 52°C. Testing has shown the flash point of biodiesel blends increases as the percentage of biodiesel increases. Therefore, biodiesel and blends of biodiesel with petroleum diesel are safer to store.

8.6 Basic Safety Tips

The following is a general safety checklist that is provided for guidance only when manufacturing and handling biodiesel. Specific situations may require additional precautions as determined by a formal risk assessment process.

[6]The Bluegill (Lepomis macrochirus) is a species of freshwater fish.

Biodiesel

1. Biodiesel should not be made near children and chemicals used in its production should not be left around children.
2. Biodiesel should be made outside or in a well-ventilated area, if possible or if inside a building it is recommended that the biodiesel production work area be ventilated with a forced air extraction system to safeguard against inhalation of methanol fumes. It should be noted that a cartridge respirator does not offer protection against methanol fumes.
3. Electrical equipment must be explosion-proof to meet with national electrical code requirements.
4. Grounding is required for all equipment, including tanks, pipe racks, pumps, vessels and filters.
5. Lighting should be grounded. Tall vessels and structures should be fitted with lightning conductors that are securely grounded.
6. The Material Safety Data Sheets (MSDSs) for all chemicals (methanol, hydroxides, acids) must be kept readily accessible.
7. Positive pressure may be required for methanol-free areas such as control and switch rooms.
8. Running water must be available when mixing chemicals.
9. Long clothes and closed shoes must be worn.
10. No smoking is to be permitted around the biodiesel production areas.
11. Vehicle access should be strictly controlled.
12. Small production facilities should utilise dry powder fire extinguishers, but large facilities must consult the local fire department for assistance with fire fighting requirements.
13. Hydrants should be strategically placed with adequate hoses.
14. Biodiesel production will routinely produce rags saturated with oil or biodiesel. It is also common, though not recommended, for sawdust or other fibrous materials to be used as an absorbent for spilled biodiesel or vegetable oil. If rags are washed and reused more care must be exercised with their use as the lingering presence of oil could potentially increase the safety risk. These materials present an inherent fire risk as oily rags or sawdust can spontaneously combust. In 2007, a Pennsylvania barn burned to the ground when sawdust soaked with vegetable oil caught fire on a sunny day.
15. Used materials must not be allowed to accumulate in or around the workspace, including in open trash cans.
16. Oily rags should be kept in an air-tight metal container, a bucket of water, or sealed in evacuated plastic bags. After use, they all should be properly disposed of in the trash.
17. Free liquid should be squeezed into an appropriate container before disposal of saturated rags. When disposing of saturated sawdust in a dumpster, the material should be scattered to avoid any piles that may combust and cause a dumpster fire.

Methanol

18. Methanol (a flammable, toxic alcohol) is a hazardous chemical used in biodiesel production. Overexposure can cause neurological damage, blindness and other health problems.
19. The low flash point and wide explosive range require facilities to exercise caution when handling methanol. Methanol therefore presents a serious fire risk.
20. Large quantities of methanol should not be stored in residences. Where stored, methanol should be in steel containers with an earth strap connected to a spike in the ground or a water pipe.

21. Storage tank vents to the atmosphere should be sized for fire-heated emergency vapour release.
22. Aqueous Film Forming Foam of the alcohol-resistant type (AR-AFFF) with 6% foam proportioning (with water) equipment is advised for use on methanol fires.
23. Small spills should be remediated with sand, earth or other non-combustible absorbent material, and the area then flushed with water. Larger spills should be diluted with water and contained for later disposal.

Lye

24. Lye (a corrosive, caustic base) is a hazardous chemical required to convert feedstock into biodiesel. Lye can cause skin and lung irritation. Lye can cause eye damage or blindness. Rigorous precautions are necessary to avoid personal poisoning, and contamination of soil and water resources.
25. Strict adherence to the instructions on the Material Safety Data Sheet (MSDS) regarding the safety gear should be exercised when working with the hydroxides.
26. Use of a respirator is required when handling hydroxides to prevent dust from being inhaled and burning the lungs.

8.7 Methanol Fire Fighting Techniques

Methanol flames are almost invisible in daylight, producing no soot or smoke. They may be detected by the heat generated, a heat haze or the burning of materials in the affected area. Dry chemical powder, carbon dioxide (CO_2) and alcohol-resistant foam extinguish methanol fires by oxygen deprivation. Water will remove heat and dilute the liquid methanol. Fog or fine sprays will absorb methanol vapours, quench heat and provide a curtain shield for upwind advancement to a fire source.

Small fires can be extinguished using powder, CO_2, or foam in the early stages. It is possible for methanol to re-ignite spontaneously due to surrounding high temperatures that may exceed the auto ignition temperature. In addition to its cooling effect, water can be effective by diluting methanol to the point where it is no longer flammable. The amount of water required will be three to four times the volume of methanol.

Permanent sprinkler/drench systems are very effective in controlling potentially large fires at an early stage. Water cannons are generally installed in storage tank farms to cool adjacent structures and neighbouring tanks in the event of fire. Use of Alcohol-Resistant Aqueous Film Forming Foam (AR-AFFF) is effective for large-scale fires. Protein-based alcohol-resistant foams are also suitable.

8.8 Methanol Fire Fighting Personal Protective Equipment

Due consideration must be given to the hazards from chemical and heat exposure. Protective fire-fighting structural clothing is not effective protection from methanol fires. In addition to methanol vapours, fire-fighters may be exposed to combustion products such as formaldehyde and carbon monoxide that may form under conditions of depleted oxygen. Fire-fighters should wear full-face, positive pressure, self-contained breathing apparatus or an airline. Chemical protection may be provided with impervious clothing, gloves and footwear. Suitable materials include polyvinyl plastic, neoprene or rubber.

8.9 Methanol Spill Response

If a spill occurs, the following immediate measures should be exercised:
- Stop or reduce discharge of material if this can be done without risk.
- Eliminate all sources of ignition.
- Avoid skin contact and inhalation.
- Do not walk through spilled product.
- Stay upwind; keep out of low-lying areas.
- Prevent spilled methanol from entering sewers, confined spaces, drains, or waterways.
- Maximise methanol recovery for reuse.

Leaking methanol containers should be removed to the outdoors or to an isolated, well-ventilated area, and the contents transferred to a suitable container. Foam may be used for vapour suppression. Vapours can be knocked down using a water spray.

Whenever possible, contain land spills by forming mechanical or chemical barriers. Remove spilled product with explosion proof pumps or vacuum equipment. Treat the surface with sorbent materials, such as vermiculite or activated carbon, to remove the remaining methanol. Remove the sorbents after use. Soil contaminated with methanol should be removed and remediated.

Spills into large natural bodies of water, such as rivers and oceans, cannot be recovered. Whenever possible, contain spills to small surface waters using natural or mechanical barriers. Then remove the contained material with explosion proof pumps or vacuum equipment. Sorbents such as zeolite and activated carbon should also be considered for in situ clean up.

8.10 Treatment and Disposal

Possible treatment processes for spill countermeasures include biological degradation, reverse osmosis, carbon adsorption, steam stripping and air stripping. Large quantities of waste methanol can either be disposed of at a licensed waste solvent company or reclaimed by filtration and distillation.

Waste methanol, or water contaminated with methanol, must never be discharged directly into sewers or surface waters.

8.11 Spill Prevention

An effective spill prevention programme will include engineering controls, training, procedures, and spill response planning. Effective engineering controls include overfill alarms, secondary containment for tanks such as bunds to contain large spills, and hydrocarbon detectors within bunds. Workers must be trained to handle methanol in a safe manner. Systems and procedures that protect the employees, the plant and the environment should be implemented, especially the use of spill-response plans. Regular drills of the plan will ensure that workers know how to respond safely and effectively to a release.

9.0 Energy Balance

Considering the potentially devastating impacts of global warming, as well as the imminent global energy crisis due to the rapid depletion of fossil fuels, the focus of future energy development clearly must be changed towards renewable energy sources and on biodiesel, especially for transportation fuel.

Energy production, however, also requires an energy investment. Drilling for oil or building a wind power plant requires energy, and so do the production, distribution, and consumption of biodiesel. Altogether, the energy balance of biodiesel is determined by the amount of energy required for the manufacturing compared to the amount of energy released when it is burned in a vehicle.

9.1 Net Life Cycle Analysis

Biodiesel is generally considered "climate neutral" for some biodiesel crops like oil palms and castor beans because in addition to providing the raw material for production of biodiesel, they absorb carbon dioxide (CO_2) as they grow. During the production of biodiesel, CO_2 is converted to sugar, which is then used to make the final diesel fuel. When burnt in engines, biodiesel eventually releases approximately the same amount of CO_2 into the atmosphere as the plants absorbed during their growth (closed CO_2 loop). Based on this net life cycle (well-to-wheel), biodiesel reduces emissions of carbon monoxide (CO) by approximately 50% and CO_2 by 78% compared to petroleum diesel. The reason is that the carbon introduced from petroleum was sequestered in the Earth's crust before and not already existing in the atmosphere.

9.2 Debate over Energy Balance

The debate over the energy balance of biodiesel is on-going as various factors have been identified that reduce the greenhouse gas savings, which were believed to be achieved. The biodiesel produced in Asia, South America and Africa is far cheaper than biodiesel produced in Europe and North America, which drives up exports accordingly. From a worldwide perspective, most biodiesel is therefore not locally sourced. It is truly not a carbon neutral product in the current manner because large investments of energy are required before this biodiesel arrives at the petrol stations (well-to-wheel).

Other major concerns are related to deforestation and monoculture farming. Transitioning fully to biodiesel would require immense tracts of land if traditional crops are used, and most countries with high energy consumption do not have enough arable land. The prime concern in relation to the environment is therefore that countries will clear large areas of tropical forest in order to grow oil seed crops. The Philippines and Indonesia for example plan to increase their biodiesel production levels significantly using oil palm as the oil seed source, which would lead to the deforestation of tens of millions of hectares. Since these forests contain large quantities of carbon, which will be released if they are burnt down, and because forests, unlike biodiesel crops, also trap carbon in humus and soil, the deforestation to accommodate biodiesel production will eliminate all environmental advantages of biodiesel over petroleum diesel.

Deforestation on this large-scale will further lead to a significant loss of habitat, endangering numerous species of plants and animals, as is already happening to populations of orangutans on the Indonesian islands of Borneo and Sumatra.

Biodiesel plays a major role in tackling the effects of global warming as it is the only alternative diesel fuel that actually reduces major greenhouse gas components in the atmosphere. The climate neutrality of biodiesel can however be undermined by deforestation and by very long distribution channels for the fuel. Taking the potentially devastating effects of global warming into account, the ecological impacts of growing some oil seed crops such as oil palms may in turn be small compared to the potentially much larger impacts of unmitigated climate change.

10.0 Co-products, By-products and Wastes from Biodiesel Production

The biodiesel production process produces a number of other products:

1. Glycerine (co-product)
2. Methanol (by-product and raw material)
3. Wastewater (waste)
4. The occasional failed batch (waste)

Untreated biodiesel waste products are toxic, mostly because they contain methanol. In small plants biodiesel waste products are often not disposed of properly.

Several by-products and co-products from biodiesel production have economic value and options for their use are presented in this section.

10.1 Leaves, Branches and Seed Hulls

Oil-bearing trees not only produce seeds/fruits, but their leaves, latex and wood can also be used. The leaves of some oil bearing trees can serve as valuable organic fertiliser, and both the leaves and latex of some species are used for medicinal purposes. When trees or bushes are pruned, branches can be used as firewood or – like any other biomass – for biogas production. Fruit hulls may serve for several possibilities including uses mentioned above – as organic fertiliser, for burning, for medicinal purposes as well as for biogas production.

10.2 Seed Cake

Two other important by- and co-products of biodiesel production emerge during further processing i.e. seed cake and glycerine. After the oil is extracted, the remains are the particulate material of the kernel called seed cake, which can be used as an organic fertiliser. Since yields increase substantially when fertiliser is applied, the seed cake can be taken back to the field to be used to facilitate cultivation. It is also possible to produce biogas from the seed cake.

Theoretically, seed cake could also serve as fodder for animals. However, jatropha seedcake has to be detoxified since it contains toxins like curcasin and crucin and this detoxification process has proven successful only in the lab (Jongschaap et al. 2007). The process, if applied in the field, would currently be very expensive, so that jatropha seed cake as fodder would not be feasible in the market. The better option is to use the oilcake as a fertiliser.

Despite its high protein content, castor seed cake is not used as livestock feed due to the presence of toxic factors namely ricin, ricinine and allergen. Of the three, ricin is the most detrimental to animals. Detoxification of castor seed cake is done by treating it with calcium hydroxide, sodium bicarbonate and autoclaving after which it can be used as an animal feed. It contains proteins and carbohydrates, essential amino acids, potash minerals, nitrogen and organic matter.

Farmers evaluate oilseed profitability against other rotational crops. To plant oilseeds, a farmer must be convinced that the economic returns for these crops are at least as good as other alternatives. The value of oilseeds as a biodiesel feedstock depends on a number of factors:

- value of fossil diesel
- value of tax incentives
- value of seed meal
- value of glycerine (a co-product of biodiesel production)
- cost of crushing oilseed
- cost of processing seed oil into biodiesel

While all of these factors are important, the development of higher value seed meal markets may be the most significant. For example, canola meal is sold as an animal feed supplement but this market does not provide the economic returns needed by most growers to justify planting oilseeds. Instead higher value markets are needed from increasing the value of the meal as an animal feed, to using it as a high value fertiliser, a bio pesticide, as food for human consumption, or as a feedstock for other bio products. In particular, there is an increasing demand from organic dairies for high value organic meal.

10.3 Waste to Solid Fuels

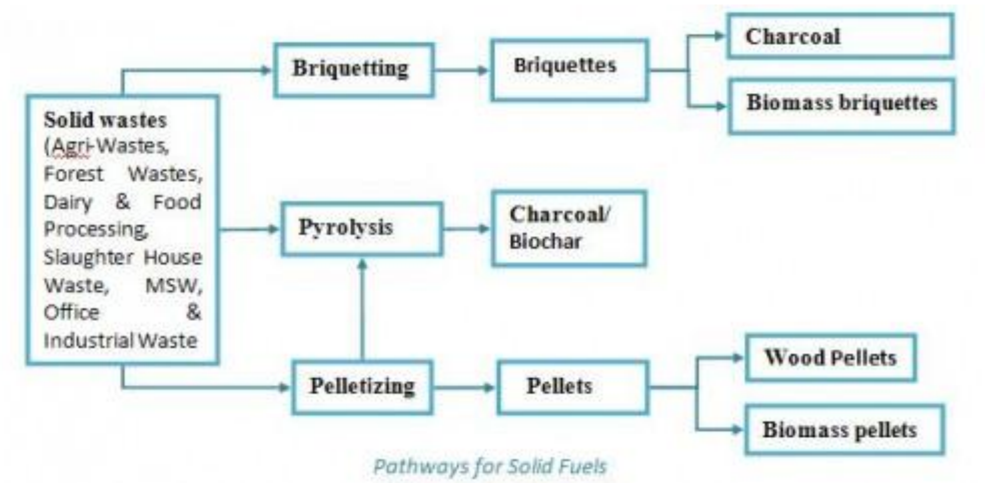
Solid waste can be converted into various types of briquettes, charcoal, biochar or pellets. Biochar is not a fuel, but its immense utility and market value is comparable to any solid fuel generated from waste. The Biochar market seems to have huge potential as it is an emerging industry unlike a well matured pellet industry. Briquettes and charcoal have relatively higher market value compared to pellets.

Figure 4 illustrates the various pathways in which these wastes can produce solid fuels.

Briquette/Bio-coal or white-coal is a solid fuel made from a variety of waste materials such as charcoal from low-density wood, agro-forestry waste material, domestic, municipal solid wastes and typically any type of biomass waste. A wide array of feedstock, including some that are not pelletable, can be briquetted such as agricultural residues and paper. Briquetting is the process which converts these low density biomass into high density and energy concentrated fuel briquettes.

Briquettes have Gross Calorific Value (GCV) of up to 4,200kcal/kg. About 2.2 kg of briquettes are equivalent to 1 litre of furnace oil. Briquettes made from charcoal dust are called charcoal briquettes and those made from crop wastes are biomass briquettes. Other types of briquettes include wax briquettes, coal- coke briquettes, sawdust briquettes, lignin briquettes and peat briquettes. Table 1 presents the value chain for solid wastes that can be converted to soil fuels.

Figure 4: Solid Wastes Converted to Fuels



Source: Altprofits -http://www.altprofits.com/ref/ct/wei/wtsf/waste_to_solid_fuels.html

Table 1: Value Chain for Solid Wastes Converted to Solid Fuels

	Pellets	Briquette	Charcoal
Calorific Value (MJ / kg)	17.64	12.5 - 20. 0	29.6 - 33.0
Market price ($ / ton)	170 - 200	400 - 500	340 – 400
Investments ($ / ton)	89	23	51.8
Operating cost ($ / ton)	54		75

Source: Altprofits - http://www.altprofits.com/ref/ct/wei/wtsf/waste_to_solid_fuels.html

Applications

Briquettes are widely used for any thermal application where coal can be utilised such as steam generation in boilers and for heating. They are used as a flammable material in brick kilns, paper mills, chemical plants, distilleries, pharmaceutical units, dyeing houses, food processing units and oil mills. Applications of briquettes in various industries are presented in Table 2. Each step in the briquette production value chain provides business opportunities for entrepreneurs, equipment and machine manufacturers as well as those in the service industry. The demand for fuel briquettes is huge and increasing every year

Table 2: Applications of briquettes in various industries

Textile process houses	Dyeing, bleaching etc.
Agro-products	Tobacco curing, tea drying, oil milling etc.
Clay products	Brick kilns, tile making, pot firing etc.
Domestic	Cooking and water heating
Gasification	Fuel for gasifiers
Charcoal	Suitable for making charcoal in kilns

http://www.altprofits.com/ref/ct/wei/wtsf/briquettes.html

10.4 Glycerine

The glycerine that comes out of the biodiesel process is laden with methanol and caustic chemicals (unless ethanol is used instead of methanol as a catalyst). Glycerine is probably the most problematic biodiesel waste product as it is hard to process without an investment in expensive equipment. The glycerine generated from biodiesel production contains about 40% glycerine. Purification to pharmaceutical grade is difficult. After processing, water, methanol and soaps are left.

For every 100 litres of biodiesel produced, there are 20 -25 litres of crude glycerine. This glycerine which can have up to 25% methanol content, should be considered a hazardous waste, and treated in the same way as pure methanol. All the handling precautions for biodiesel production are applicable to glycerine. Moreover, crude glycerine has a high pH due to a residual sodium or potassium hydroxide catalyst from the biodiesel reaction. If acid is added to the by-product to neutralise the pH, this may allow the recovery of some additional free fatty acids for processing into biodiesel. Salts such as sodium chloride or potassium phosphate (depending on acid and catalyst choices) will result from acidulation. Note, however, that this exercise may be considered waste processing and will require an environmental permit and licence from the National Environment and Planning Agency (NEPA).

Overall, glycerine is becoming so abundant with increased biodiesel production that the demand for it has dropped resulting in more pay-to-dispose scenarios. More value can be obtained by utilising pure glycerine as a raw material for another process or by its direct sale.

Glycerine Contaminated with Methanol

Currently no easily attained options for disposal of glycerine with methanol are allowed. Small-scale burning of glycerine is not recommended due to high toxicities plus fire hazards inherent in processing activities. High-temperature burning is imperative to avoid the formation of highly toxic acrolein that results from burning glycerine at temperatures less than 536^{o}F (280^{o}C). Acrolein, a suspected carcinogen, is dangerous to living things at concentrations as low as two parts per million. Some options are under investigation and may be allowed as more data become available. Options being examined include use as a feedstock for on-farm composting, anaerobic (biogas) digestion, as well as incorporation into landfills.

Acceptable disposal options include the following:

1. Further processing by big commercial biodiesel producers with the required capability.
2. Disposal at a toxic waste disposal facility.
3. Disposal to the natural environment via regular drains where the glycerine neutralised with acid meets local regulatory requirements.
4. Feeding it into anaerobic digesters for conversion to methane. The crude by-product has been added to anaerobic biogas (methane) digesters with success, including farm-scale manure digesters. In controlled anaerobic digestion, microbes decompose animal manures and/or human waste producing methane gas that may be used as a source of energy. These microbes are capable of breaking down methanol and glycerine into more benign compounds. The addition of glycerine may actually boost biogas production. The glycerine by-product typically has a high pH and a high carbon to nitrogen ratio, which may also make it attractive as a digester additive. Dilute additions of small amounts of glycerine by-product should be tested while carefully monitoring the response of the digester.
5. Glycerine by-product may be allowed for use as a blended fuel in industrial burners and boilers such as cement and lime kilns if it is classified as a co-product. Testing to ensure that the flash point exceeds 140ºF (60ºC) must be done on the waste material so that it is not classified as a hazardous waste. This classification would prevent its use in a fuel-using system not permitted for hazardous waste incineration. Approval for its use in this form would be required from the NEPA, in particular, compliance with the Natural Resources Conservation Authority (NRCA) Air Quality Regulations.

It should be noted that with options 1 and 2 are not readily available in Jamaica.

Glycerine after Methanol Recovery

It is best to consider recycling the wastes to make other products but it is important that the methanol is removed before conversion into another product. The easiest way to remove and recover methanol is through distillation. Once the methanol has been removed the glycerine is safer to handle and recycle into products such as soaps, hand cleaners and floor cleaners (Figure 4). Examples are provided as follows:

1. **Industrial Combustion:** Glycerine can be designated a co-product for use as fuel. Approval for its use in this form would be required from the NEPA. Compliance with the NRCA Air Quality Regulations will be required.
2. **Composting:** If glycerine is generated from biodiesel production using a potassium based catalyst, it can be composted in a large compost heap. After methanol removal, glycerine can be safely composted with reduced concern for environmental contamination. Glycerine by-product is a high-carbon, high-pH, wet feedstock and should be combined with a bulking agent (straw, hay, leaves) and nitrogenous materials (manures or fresh green yard wastes) for proper composting. Glycerine should be added to compost piles in dilute amounts to prevent wet saturation leading to anaerobic conditions. Frequent turning of piles will promote speedy aerobic decomposition and an

even distribution of glycerine into the mix. Glycerine compost piles should be constructed far away from any water source to prevent runoff contamination. Covering piles with commercially available compost fabrics will prevent water saturation and reduce runoff potential. Soils where compost is applied should be tested regularly for any salt build up from residual biodiesel catalyst in the glycerine by-product. Approval will have to be obtained from NEPA for disposing of glycerine in this manner. Until further research into the action of crude biodiesel glycerine in the compost pile can be conducted, it is not recommended to add glycerine to compost piles used to fertilise food gardens.

3. **Soap:** Glycerine can be processed into a crude hand or body soap using simple recipes. It is imperative that all methanol has been removed from the glycerine before making soap. To be certain, glycerine should be heated slowly to 212ºF (100ºC), which is the boiling point of water. If bubbling occurs in the glycerine pot before 212ºF (100ºC) is reached, then some methanol is still present. Heating should continue until no bubbling occurs at temperatures below 212ºF. When making soap, use only stainless steel, glass, or ceramic pots (no aluminium). Heating should occur outdoors over an electric burner to prevent any concentration of fumes or ignition of stray methanol vapours.
4. **Degreaser:** A simple but effective engine degreaser or floor cleaner can be made by making a 50/50 blend of water and glycerine after methanol removal. Individual biodiesel producers report a strong demand for glycerine degreaser in some locations.
5. **Dust Suppressant:** After methanol recovery is complete, glycerine by-product has been blended with water and sprayed on roads and dirt tracks as a dust suppressant. Glycerine tastes sweet to animals and may draw wildlife to roads, so caution is advised. Avoid spraying near any waterways to prevent contamination. Any land application of waste material must have permission from NEPA.
6. **Animal Feed Additive:** Early experiments show some success with adding glycerine to animal feed after methanol recovery. Glycerine is a sweet, high carbohydrate energy source that may be added to grain feeds in dilute quantities. Further research is needed to determine proper blending rates and the possible effects of potassium or sodium salts and high pH of the by-product.

Figure 5: Soap being made at Sammy's Farm, St. Catherine from Oil Palm

Environmental & Engineering Managers Ltd., 2012

Other options for using and recycling glycerine include:

1. Mixing 50% glycerine with kerosene to provide an excellent engine cleaner.
2. Converting glycerine into ethanol through fermentation with a strain of E. coli. This method of producing ethanol actually has higher yields than the traditional way of producing ethanol.
3. Combining glycerine with a harmless strain of E. Coli to form Succinate. Succinate is used to flavour food and drinks and is an ingredient in perfumes and dyes as well as in non-toxic plastic solvents. Succinate has a large market in the US.
4. Producing Formate from glycerine and E-coli strains. Formate is a common preservative in animal feed and is also used as an antibacterial agent.
5. Developing a form of lignin that can be used to manufacture glue, detergent and sealants.
6. Using glycerine to produce a hydrogen rich gas for use in fertilisers, food production and chemical plants.
7. Tests by a researcher to turn the resulting glycerine from the catalyst he developed into 1, 3 propanediol (1, 3-PDO). This is used as a base material for a substance used when making clothing, upholstery and fabrics.

10.5 Wash Water

Most processors also use water for fuel purification, and may generate as much as 12 litres of waste water for 4 litres of fuel produced. The wash water that is used to clean biodiesel will also be contaminated with methanol. As a biodiesel waste product this must be disposed of properly. The water from the first wash will contain significant quantities of methanol in it, making the wastewater toxic. It will also contain significant quantities of soaps and caustic chemicals.

Most small-scale biodiesel producers improperly dispose of the wastewater in the nearest (municipal) drain. Some wastewater treatment plants can accommodate some methanol as the bacteria in the plant thrive on it. However, it is always a matter of degree and trade effluent standards must be met before discharge of this wastewater. The wash water should never be disposed of in open drains or into ground water. Doing so can result in methanol contaminating surface and groundwater resources which could cause major pollution problems.

One way for small-scale operations to treat the wastewater is to neutralise it with acid. By adding enough acid to bring the pH to 7 the soaps making free fatty acids (FFAs) and biodiesel can be broken down. Residual oil can be removed by passing the wastewater through a grease trap and the effluent can be disposed of or used for irrigation. **This option of treatment and disposal can only be used if the resultant effluent meets local regulatory requirements for effluent discharge or irrigation**. The water will contain salts of some kind, depending on the acid used and the catalyst used. For example, if potassium hydroxide is used as a catalyst and sulphuric acid is used to neutralise the water, then the salt that precipitates will be potassium sulphate. After skimming off the biodiesel, oil and FFA layers by passing the wastewater through a grease trap, the remaining wastewater can be applied as a 0-0-50 fertiliser as needed. The wastewater being used for irrigation should be applied with care to prevent run-off to storm drain and surface water bodies.

Another option is to dry wash biodiesel. This will not use water, but dry washing will generate another waste stream that will need to be disposed of properly. However, this is usually easier to manage. Some dry wash examples include:

- Ion exchange resins
- Soda Keg Resins Tower Plan
- Magnesol
- Sawdust
- The GL Method
- Air washing

10.6 A Failed Batch of Biodiesel

With a failed batch of biodiesel, it is best to have a used oil processor collect it. For small-scale operations biodiesel waste can be composted by mixing in organic matter such as leaves, grass clippings, straw, and twigs. The mixture should be aerated by turning every couple weeks to aid in the decomposition. This will also allow any remnant methanol to evaporate. In a few months the compost can be used.

10.7 Remnant Methanol in Glycerine

Excess methanol can be distilled off the glycerine within a closed container and directed into a condenser. It can then be reused in the next batch of biodiesel production.

11.0 Crops used in Biodiesel Production

Energy from biodiesel is derived from biological carbon fixation and biomass conversion. Although fossil fuels have their origin in ancient carbon fixation, they are not considered biofuels by the generally accepted definition because they contain carbon that has been "out" of the carbon cycle for a very long time.

Cost-effective sourcing of feedstock is of paramount importance in the production of biodiesel as it can represent up to 80% of total production cost depending on the raw material used. The sources for biodiesel are quite numerous, ranging from oil palm, coconut, sunflower, soybean, rapeseed, canola, linseed, cottonseed, to waste vegetable oils and animal fats. Common biodiesel crops are soybeans, palm, jatropha, castor and canola. Typical oil extractable from oil bearing seeds by weight is presented in Table 3.

Table 3: Oil Extractable from Crops

Crop	Oil %
copra	62
castor seed	50
sesame	50
groundnut kernel	42
jatropha	40
rapeseed	37
palm kernel	50
mustard seed	35
sunflower	32
palm fruit	49
soybean	14
cotton seed	13

Source: http://en.wikipedia.org/wiki/Energy_crop (modified by EEM, 2012)

Preferences by region differ on the crops utilised, and crops offer different possibilities for gains.

Rapeseed: European production of biodiesel from energy crops has grown steadily in the last decade, principally focused on rapeseed used for oil and energy.

Soybeans: Soybeans are America's primary source of biodiesel feedstock (90% in 2006). They can produce 475 litres of oil per hectare (L/ha) (48 gallons of oil per acre).

Palm: Palm can produce an astounding 5,950 L/ha (635 gallons of oil per acre), has the highest oil yield of plants currently grown for biodiesel feedstock. It is mainly grown in Malaysia and Indonesia. It does pose some environmental concerns as increasing production is at the expense of tropical rainforests. Besides being havens of biodiversity, the world's tropical rainforests are the Earth's largest terrestrial carbon sinks. The production of palm oil, both as a food item and feedstock for biofuel plays a large part in the destruction of these environmental assets through the clearing of rainforests for the cultivation of palm oil and the introduction of a monoculture.

Jatropha: Jatropha seeds can contain up to 40% oil, producing an average of 1,818 L/ha (202 gallons of oil per acre). This plant can thrive in marginal lands and does not compete with food supply as the seeds are poisonous.

Castor bean: Castor beans have a relatively high oil content. In the case of castor seed, the oil content is close to 50% of the total by weight, that is, the castor bean contains 50-55% oil. The oil itself contains a number of fatty acids similar to those in cooking oils such as oleic acid, linoleic acid, stearic acid and palmitic acid. However, castor oil is distinguished by its high content (over 85%) of ricinoleic acid. No other vegetable oil contains so high a proportion of fatty hydroxyacids. Castor bean averages 1,430 L/ha (151 gallons of oil per acre).

Canola: Canola is a genetically modified type of rapeseed. It can produce an average of 938 L/ha (100 gallons of oil per acre). In 2008/2009, it was the third most produced vegetable oil in the world.

Other less common feedstock includes:

- Mustard seed: a type of rapeseed containing 25-40% oil. The meal left over after processing can be used as an organic pesticide.
- Radish: wild radish can contain up to 48% oil, and is drought tolerant.
- Sunflower: produces an average of 965 L/ha (102 gallons of oil per acre).
- Coconut: produces approximately 2,615 L/ha (287 gallons per acre).
- Moringa seeds: contain 30-40% oil and the rest of the plant can be used as food.
- Pongamia pinnata: can produce up to 40% oil per seed and can grow on malnourished soils with low levels of nitrogen and high levels of salt.

Oil yields for different oil bearing crops are presented in Table 4 and some advantages and disadvantages of different crops are presented in Table 5.

Table 4: Oil Yields for different Oil Bearing Crops

Source	Yield (litres/hectare)	Comparison of yields
Palm	5,950	1.00
Coconut	2,689	0.45
Jatropha	1,892	0.31
Castor	1,413	0.24
Rapeseed	1,190	0.20
Soybean	446	0.07

Source: Pahl, G. (2005). Biodiesel: Growing a new energy economy; Chelsea Green Publishing Company, White River Junction, Vermont, USA. 281 p.& http://en.wikipedia.org/wiki/Tble_of_biofuel_crop_yields

Table 5: Advantages and Disadvantages of Oil Crops

	Type	Advantages	Disadvantages
1.	Palm oil	• Plentiful	• US $850-990/tonne[7] • High cloud point • Food crop • Displacing rainforest
2.	Canola oil	• Low cloud point	• US $1,160-1,500/tonne[8] • Food crop • Limited supply • Drought susceptible
3.	Sunflower oil	• Plentiful	• US $1,250-1,300/tonne[9] • Food crop
4.	Soybean Oil	• Limited fertiliser required • Low cloud point	• US $1,110-1,160/tonne[10] • Food and industrial crop • Limited supply
5.	Jatropha oil	• Hardy • Fast growing	• US $800-1,000/tonne[11] • Toxic by-product • Requires manual harvest • Weedy species
6.	Pongamia oil	• Non-food tree crop • Limited fertiliser required • Hardy but non-weedy • Grows on marginal land • Broad geographic distribution • Low cloud point	• US $2-5/litre[12] • Early stage in domestication • Limited genetic database

Source: CILR ARC Centre of Excellence -http://www.cilr.uq.edu.au/UserImages/File/BiodieselWeb.pdf; modified by EEM, 2012

There are three (3) main crops grown for biodiesel production that are the focus within this study, namely:

1. Castor
2. Jatropha
3. Palm

These biodiesel sources have been developed in many countries each with their own advantages and disadvantages. Pilot plants have been implemented in Jamaica with castor bean and jatropha, and

[7] FOB 2012 prices - http://www.alibaba.com/showroom/crude-palm-oil-price.html
[8] FOB 2012 prices - http://www.alibaba.com/showroom/crude-canola-oil-price.html
[9] FOB 2012 prices - http://www.alibaba.com/showroom/crude-sunflower-oil-price.html
[10] FOB 2012 prices - http://www.alibaba.com/showroom/crude-degummed-soybean-oil.html
[11] FOB 2012 prices - http://www.alibaba.com/showroom/crude-jatropha-oil-price.html
[12] FOB 2012 prices - http://www.alibaba.com/showroom/pongamia-oil-supplier.html

there is an independent producer growing oil palm. Information on other crops is included to provide comparison and context.

11.1 Castor Beans *(Ricinus communis)*

Castor beans (ricinus communis) originated in Africa and grow wild in East and North Africa, the Yemen and the Near and Middle East. Cultivated in ancient Egypt as long ago as 4000 B.C., the castor bean was introduced into the New World shortly after Columbus. The castor plant is now naturalised in many tropical and subtropical countries.

Castor grows wild in many locations and is well adapted to poor soils, so it commonly appears as a weed among other crops. As such, the economic growth of this crop often needs more care than most farmers are willing to provide for the attainable return. For success, there needs to be a suitable fertilization programme, proper soil preparation, weed control and other good practices.

Castor oil is unique among all fats and oils. It has an unusual chemical composition of a triglyceride of fatty acids. It is the only source of an 18-carbon hydroxylated fatty acid with one double bond. The product uniformity and consistency of castor oil are significantly high for a naturally occurring material.

The chemical composition of castor oil is:
- Ricinoleic Acid (89.5%)
- Linoleic Acid (4.2%)
- Oleic Acid (3%)
- Stearic Acid (1%)
- Palmitic Acid (1%)
- Dihydroxystearic Acid (0.7%)
- Linolenic Acid (0.3%)
- Eicosanoic Acid (0.3%)

The ideal conditions for castor bean cultivation are tropical, at altitudes between 300m and 1,500m, with average temperature between 20°C and 30°C and annual rain between 500mm and 1,500 mm. Heavy rainfall and water-logging should be avoided. The best soils for its cultivation are rich and well drained soils such as sandy or clayey loams. In the USA the crop is grown with irrigation. Saline conditions are not tolerated.

The plant is an annual or short- lived perennial, but it can give a ratoon crop. It is cross-pollinated by wind and insects. The seed will maintain its viability for 2-3 years. The brittle testa is easily damaged and crushed seeds may cause clogging in mechanical planters. More even germination may be obtained by pouring boiling water on the seeds and leaving them to soak for twenty-four (24) hours. Some seeds may take up to seven (7) days to germinate, or even longer. The time to maturity may take from 140 - 180 days from the time of planting, according to the cultivar (variety).

If properly cultivated and with adequate rainfall and/or irrigation, the plant can produce two crops per year, since it takes somewhat less than 6 months to complete its cycle. The germination process is very dependent on water availability. Approximately two to three months after germination, flowering begins; a process that also requires adequate water. Harvesting, either manually or with coffee harvesting machinery, will be completed three to four months after flowering. Provided adequate water is available, under ideal conditions with appropriate equipment and technology, the oil content of the fruits can reach 60% and productivity 2,200 kilograms of oil per hectare. Due to the varying impacts tied to local conditions, field trials in the local area where castor is planned for commercial use are necessary in order to determine the best time for planting and the possibility of having two crops per year. The total required precipitation over the fruiting cycle is approximately 650 mm. Variations will influence the oil content.

Castor bean is a suitable crop for the production of biodiesel for the following reasons:

- No competition with food crops, as it can be grown on marginal lands that are not competing with food production lands.
- No competition with food grade oils.
- Its toxicity is sensed by animals and therefore not foraged.
- It is high yielding with as much as 350-650 kg of oil per hectare when no maintenance is applied to the crop e.g. fertilisers, to a high end yield where annual rainfall happens at the right times giving 1,000 – 1,500 L/ha.
- It has a very high oil content (approximately 50%).
- The oil seed is collected by hand, by picking the ripe pods from the plant.
- It requires only moderate rainfall (approximately 600mm) and can withstand long periods of drought, but will thrive under higher rainfall.
- It is an uncomplicated crop that requires little attention during its growing periods.
- It is ideal to replant marginal lands to prevent desertification and erosion due to its low demand on soil fertility.

Castor oil properties indicate very low pour and cloud points, which make this biofuel a good alternative in winter conditions. Also, mixtures of 20% (B20) and 10% (B10) biodiesel-petroleum diesel show good flow properties. It indicates that castor oil biodiesel also could be used as petroleum diesel additive improving both environmental and flow behaviour of the mineral fuel.

An unintended but important advantage to planting castor beans is that the plants absorb carbon dioxide, thereby reducing greenhouse gas accumulations in the atmosphere. The estimated carbon dioxide absorption level of castor bean plants is 34.6 t/ha, with two growing cycles per year.

Although volunteer plants of castor bean appear in many parts of Jamaica, in gullies, along road-sides, in ditches and on stony areas, the yields and habit of growth, whether tall or short vary considerably. They vary also in oil content, and the shattering habits of some make commercial production difficult. Over the years introductions of hybrids have been made and tested locally. These have not always performed in Jamaica as well as they have done in the source country. Conditions even within Jamaica vary considerably, as certain areas of high relative humidity are conducive to the development of fungus diseases. Control of these diseases may be expensive.

The Brazilian Experience with Castor

The Brazilian experience with castor is under quite different conditions from those found in Jamaica, but some lessons can be learned. In Brazil, castor is grown in areas with very pronounced dry and wet seasons. It is planted immediately before the rainy season to ensure germination and high oil content of the beans. The actual average yield is about 600kg/ha of beans with a 45% content of oil, but the potential with existing technologies is over 1.5t/ha. This is the yield considered as the "breakeven point" for economic analysis in Northeast Brazilian conditions. The oil content can also reach 48%. The average castor productivity in Brazil is 600 kg/ha, but it can reach 1.8 t/ha without irrigation using proper fertilization and cultivation practices. The potential yield in the field, projected by the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) (Brazilian Enterprise for Agricultural Research) for the next 15 years, reaches 5 tonnes of beans per ha. Productivities above 1.5 t/ha are now achieved in big biodiesel enterprises, but lower values remain typical for smaller scales of production. The costs of production are between US$200 and US$300/ha with limestone and fertilizer application as well as weed control.

Use of Castor by smallholders

Small farmers have many incentives to grow castor in Brazil. These include: special loans and "*bolsa familia*," an income support programme for families with incomes under $2,000/yr., which makes the Brazilian biodiesel costs appear lower than they would under conditions where similar incentives are not available. Brazilian biodiesel economics are not directly comparable to the Jamaican situation and may be misleading. The crop can be cultivated manually and can grow in areas with steeper slopes where higher fertility soils may prevail. It will not employ manual labour year round as an annual crop, unless irrigated. In Brazil, small farmers apply practically no consumable inputs and essentially leave the crop to grow wild.

Use of Castor for gradual development of biodiesel production in Jamaica

This crop can be used theoretically by small and big farmers, with different production systems, different yields and incomes. Subsidized castor cultivation can be an effective tool for social welfare, but sustainable production will need modern production technology and higher investments.

11.2 Jatropha (*Jatropha curcas*)

The idea of making biodiesel from jatropha has been met with excitement. Jatropha curcas has been cited by Goldman Sachs as one of the best candidates for biodiesel feedstock. Some advocates consider jatropha as the preferred oil plant for biodiesel due to its non-competitiveness as a food crop and its ability to be grown on poor soils, where other oil crops are not economical. On a worldwide basis, while some good results in field trials have been achieved, transferring these to larger scale commercial applications has proven generally elusive. Specific experience in Brazil thus far has not been conclusive.

Jatropha is a perennial crop that will grow in poor soils and withstand dry periods, but it responds well to better soil conditions and adequate water. It is suitable for manual labour and can be planted where mechanization is not possible. It grows in shady conditions, which means that it does not need total land clearing to plant it. Due to limited field trials, the tolerance of jatropha to pests and diseases is largely unknown, but it does seem to be generally resistant. It does leave a residue very rich in organic matter that can be used for energy purposes with the resulting ash recycled for fertilization with high phosphorus and potassium contents. The harvest occurs over about 6 months, but can be increased by the use of irrigation when regular rainfall is seasonal. Jatropha is very tolerant to salinity and salty water. The plant grows fast and helps in controlling erosion and desertification, and it can be used as a live fence (20 cm of spacing) for cattle, pigs and others. It can grow in combination with castor and leucena, and matches very well with apiculture for pollination. The plant flowers 3 to 5 times a year and produces celluloses from its cultivation. The produced oil does not contain sulphur and has superior yield in ester of about 90%. The theoretical production is of 5 tonne of beans/ha, with 38% of oil content or 1,650 litre of oil /ha and 3,200 kg/ha of residual cake. The actual average in Brazil is half of this value, and from some reports, the cost of production, which depends on hand labour for harvesting, appears to be decreasing with time.

Advantages

Jatropha is beneficial because:

- It is a perennial plant.
- It produces its first seeds within two years of being planted.
- It starts yielding from 9–12 months and the best yields are obtained only after 2 – 3 years
- Seeds are ready for harvesting around 90 days after flowering when the fruits have changed from green to yellow-brown.
- It produces seeds for an average of 50 years.
- With sufficient water and high temperatures, it can produce several crops throughout the year.
- The crop can thrive in poor soils.
- The seeds are poisonous and do not compete with the food market.

On average it produces 1,892 L/ha, more than four times the oil yield of soybean plants (Table 4).

Growing conditions for jatropha:

- It grows well in moderate and poor soils.
- It is drought tolerant surviving 7-8 months by dropping its leaves.
- It grows best in soils that drain easily.
- It grows best in soil with a pH between 6 and 9.
- It needs to be planted between the altitudes of 0 to 500 metres (0 - 1,640 feet).
- It requires at least 600 mm (23 inches) of rainfall.
- It prefers temperatures between 20-28°C (68 and 85°F).

Jatropha will likely be one of the leading sources of biofuel oil because it can be grown in areas that other crops would not survive.

Figure 6, Figure 7 and Figure 8 show pictures of jatropha at the Bodles Agricultural Research Station, St. Catherine, Jamaica.

Disadvantages

There are some concerns about the favourability of jatropha for the production of biofuels. These concerns were presented in a January 21, 2011 article entitled 'Biofuel "Wonder-Crop" Jatropha Fails To Deliver' BRUSSELS (BELGIUM)/ABUJA (NIGERIA).

The article stated that the much-touted biofuel crop jatropha is neither a profitable nor a sustainable investment according to a new report released by Friends of the Earth International. Jatropha is being promoted by investment companies as a profit-making panacea providing a source of biofuel that can be grown on marginal land across Africa, Asia and Latin America. However, research from Friends of the Earth International reveals that investments in large-scale jatropha plantations are failing due to the crop's poor performance, with increasing evidence of low yields on poor quality soils and even good soil. The report highlights jatropha companies such as D1 Oils and Flora EcoPower who have been unsuccessful, illustrating that the plant's economic viability is highly doubtful.

Jatropha is touted as a shrub with oil-producing fruits able to survive in arid conditions. Investors are being warned away from jatropha stating growing evidence that the crop is failing to deliver on its promises while simultaneously failing to prevent climate change or contribute to pro-poor development. It further states that contrary to claims by European investment companies that jatropha guarantees high returns on marginal soils, these promises are far from realistic. Many projects have already been abandoned because yields have stayed below expectations, even on good soils. Additionally, investments are reportedly fuelling land-grabs in Africa, displacing farmers and communities while competing with food production and water supplies. Large-scale jatropha plantations may be neither a profitable nor sustainable investment.

The Brazilian Experience with Jatropha

The field experience in Brazil to date has not demonstrated the many advantages claimed for jatropha. One important issue is the wide variation in the genetic material showing that this crop is not completely domesticated. When grown commercially in larger areas, wide variations occur in productivity. As yet there is inadequate information to draw conclusions concerning longer term potential.

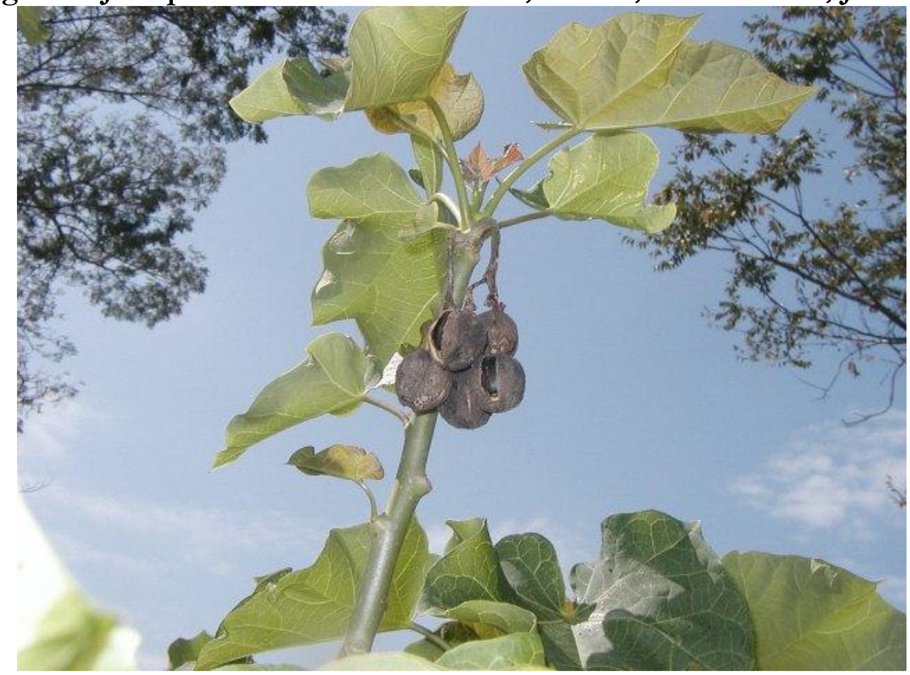
How Jatropha compares to Castor as an option

If all the advocates' reasons to plant jatropha are valid, the plant is potentially a better alternative to castor. In any case, it can be an option for marginal lands, including those with steep slopes, and trial plantings could be pursued in combination with castor in small hilly areas. As with castor, extensive field trails are needed over several years before deciding on introduction at large commercial scale.

Figure 6: Jatropha Plantation, Bodles, St. Catherine Jamaica

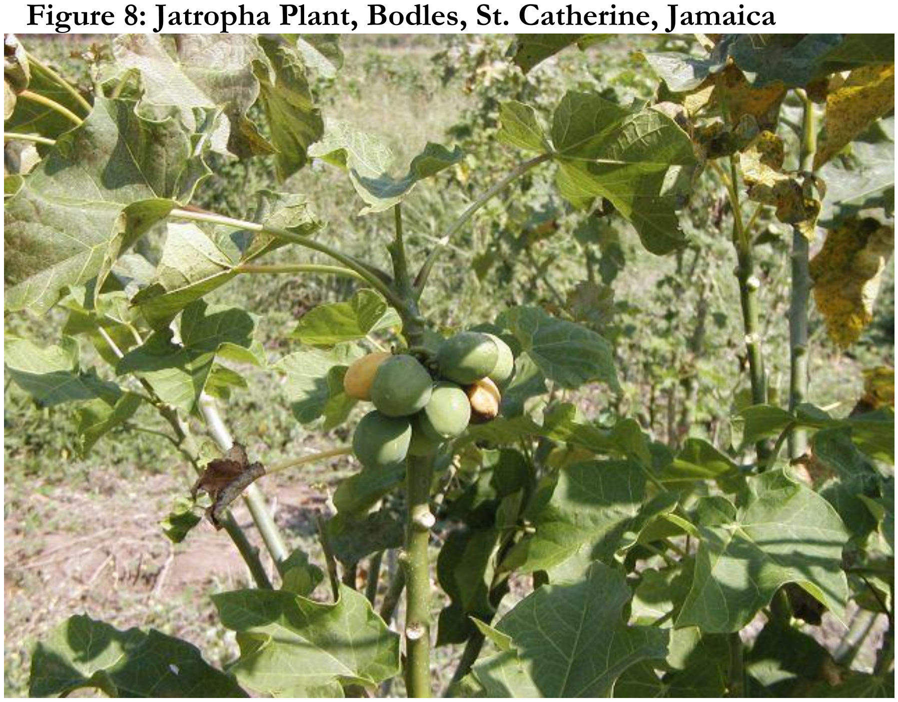
Source: Environmental & Engineering Managers Ltd., 2012

Figure 7: Jatropha Plant with dried seeds, Bodles, St. Catherine, Jamaica



Source: Environmental & Engineering Managers Ltd., 2012

Figure 8: Jatropha Plant, Bodles, St. Catherine, Jamaica



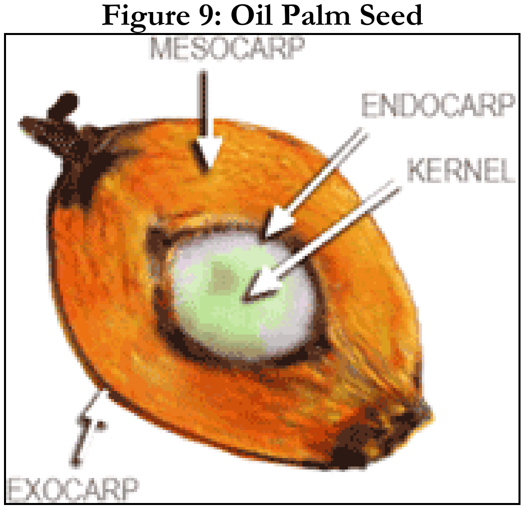
Source: Environmental & Engineering Managers Ltd., 2012

11.3 Palm Oil (*Elaeis guineensis*)

Palm oil is an edible plant oil derived from the mesocarp of the fruit of the oil palm (*Elaeis guineensis*). It is different from the palm kernel oil derived from the kernel of the same fruit. The pulp is yellow and when crushed it yields palm oil. Inside the shell of the seed is the kernel which yields palm kernel oil when crushed.

Because of its economic importance as a high-yielding source of edible and technical oils, the oil palm is grown as a plantation crop in many countries with high rainfall (minimum 1,600 mm/year) in tropical climates within 10° (degrees) of the equator. The palm tree begins to bear at the age of four to six years. The palm bears its fruit in bunches (Figure 10 and Figure 11) varying in weight from 10 to 40 kg. Individual fruit (Figure 9 and Figure 12) ranges from 6 to 20 g, and are made up of an outer skin (the exocarp); pulp (mesocarp) containing the palm oil in a fibrous matrix; a central nut consisting of a shell (endocarp); and the kernel, which itself contains an oil, quite different to palm oil, resembling coconut oil. A developed palm tree produces up to 100kg of bunches per year with each bunch containing more than 100 fruits. After the oil is extracted from a bunch, Crude Palm Oil (CPO) at room temperature (25°C) looks like a pasty red-coloured material. In order to produce a more finished product, fatty acids, colour and odour are removed through a refining and distillation processes.

Figure 9: Oil Palm Seed



Source: http://www.green-power.co.th/en/supply/sourcing-of-feedstock.php

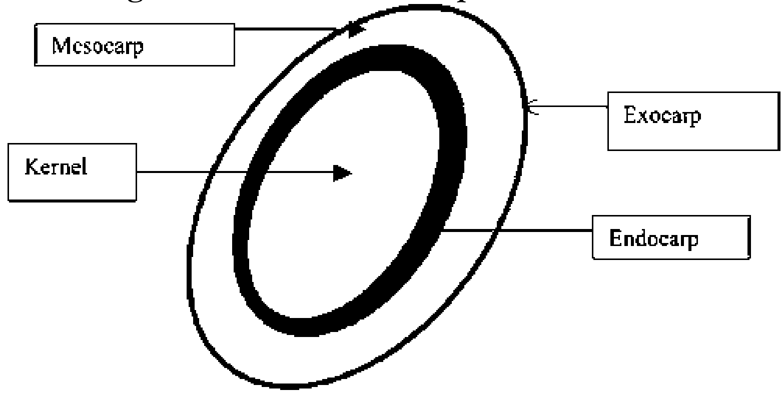
Figure 10: Palm Oil Fruit on a Tree at Sammy's Farm, St. Catherine, Jamaica

Source: Environmental & Engineering Managers Ltd., 2012

Figure 11: Oil Palm Plantation - Sammy's Farm, St. Catherine

Source: Environmental & Engineering Managers Ltd., 2012

Figure 12: Structure of the palm fruit



Source: www.fao.org/DOCREP/005/Y4355E/y4355e03.htm

Oil palm is a crop that can be grown in areas with higher slopes than 12%. It is considered semi perennial since it produces 3 years after planting and continues to produce up to 25 years with the peak of production happening after 7 to 9 years. It has many advantages in tropical areas because it can grow with other crops such as vegetables in inter-row systems during most of its cycle. It can be manually cultivated and can produce yields from 7 t/ha of fruits in the third year, increasing to 14 t/ha in the fourth year, and reaching 25 t/ha at maturity with stable production of 22 t/ha between 10^{th} and 20^{th} year before declining. These yields are currently achieved in Brazil by specialized farmers who use good agricultural practices to produce fruit with a 25% of oil content at average yearly costs of US$150.00/ha. Oil palm is not tolerant to flooding, and when this occurs, the trees show symptoms of yellowing, so good drainage practices are important. Its introduction into Jamaica must be done carefully because of diseases that might be prevalent.

Palm oil, as feedstock for biodiesel production, holds many advantages:

- They can be harvested all year.
- The entire plant has use value. The empty fruit bunches are usually returned to the plantations for use as organic fertiliser. The mesocarp fibre and broken shell can be burned to produce steam for the refining process.
- It has high oil content - the mesocarp of the seed contains 49% oil and the kernel contains 50% oil.
- It yields an average of 5,950 L/ha (635 gallons of oil per acre), significantly greater than other plant sources; almost 12 times as much as soybeans. This is the highest oil-producing crop. (Refer to Table 4 for the Oil Yields for different oil bearing crops).
- Palm oil has the lowest per-unit production costs of all vegetable oils; next in line is soybean, with a production cost that is 20% higher.
- The palm oil extraction process is a relatively simple one.
- The relative oxidation rate as measured by the Oil Stability Index (OSI) of palm oil at 37°C (98.6°F) is 40-65 OSI at 97.8°C, with a relative stability of 20, as compared with 13-15 OSI for soybean oil, with a relative stability of 6; and 16-20 OSI with a relative stability of 6 for rapeseed oil. As extensive oxidation can cause fuel quality to degrade during storage, the higher OSI of palm oil renders it more stable with respect to oxidation than other oils, which is an important advantage.

- Palm oil has a high ignition quality, which is a measure of how easily it will ignite in the engine.

Some of the downsides include:

- Palm oil has a high pour point of 15ºC (59ºF). That is the lowest temperature at which oil will flow.
- A higher cloud point, that is, the temperature at which dissolved solids in the oil begin to form and separate from the oil, means that the oil must therefore be kept at a temperature that is above the cloud point in order to prevent the clogging of filters.
- In blends of RSO (Refined Soy Oil) and palm oil, the palm oil addition is strongly limited by CFPP (Cold Filter Plugging Point) and viscosity. Furthermore, palm oil addition yields only limited price flexibility.
- Greenpeace and Friends of the Earth estimate that the destruction of peat-land and rainforests for the development of palm plantations releases more CO_2 into the atmosphere than burning biofuels can save. It is feared that certain species will become extinct due to habitat destruction.

There are new technologies that change the chemical/molecular structure of the oil to effectively address the above issues. Since the treated palm oil is identical to diesel, 100% of this material can be used as a replacement for diesel in all temperatures.

The Brazilian Experience with Oil Palm

In the last few years, major palm oil companies from Malaysia have set up large new palm oil plantations. In Brazil, palm oil is grown in the northeast, close to the rain forest, in conditions quite similar to some Jamaican areas. The average annual production of oil in Brazil is 5t/ha. The oil is very much appreciated as spicy oil for some typical foods, and this makes the price in the market more attractive for other purposes than fuel.

Potential lethal yellowing and other diseases

African oil palm in Brazil is susceptible to a disease similar to coconut yellowing. To ensure that other serious diseases are not prevalent, it is strongly recommended that trials should be conducted under local conditions before any large-scale planting of oil palm is undertaken in Jamaica.

How Palm compares to Castor as an option

Palm will produce more oil than castor, but disease prevention is a challenge that cannot be ignored. The risks of total loss of the crop by disease are high. All the knowledge of production systems for oil palm comes from its use for human consumption in restricted sites.

11.4 Pongamia Pinnata

Pongamia pinnata is a legume native to a number of countries including Australia, India, Malaysia, Indonesia, Taiwan, Bangladesh, Sri Lanka, Myanmar and Florida (USA). It has also been naturalised in parts of eastern Africa and northern Australia. There is now investment in using this as an alternative to jatropha in areas such as Northern Australia, where jatropha is classed as a noxious weed. Commonly known as 'Pongamia', the tree is currently being commercialised in Australia by Pacific Renewable Energy. For example, it is being grown in Central Queensland, Australia, for future biodiesel production. Expected use is as a diesel replacement for running in modified diesel engines or for conversion to biodiesel using 1st or 2nd generation biodiesel techniques, as well as for running in unmodified diesel engines.

Figure 13: *Pongamia pinnata* seeds in Brisbane, Australia

Source: http://en.wikipedia.org/wiki/File:Pongamia_Pinnata_Seeds.jpg

Pongamia pinnata has the following botanical features:

- It is a fast growing, medium sized evergreen tree.
- It is 7 - 10 m in height with stem diameter of 50 - 80 cm.
- It has smooth grey-brown bark with vertical fissuring.
- Leaves are compound, pinnate and alternate.
- Mature leaves are glossy dark green above and pale below.
- New leaves are pinkish-red.
- Flowers are white, pink or lavender pea-like blossoms, which bloom in late spring/early summer.
- Seeds are 1.5 cm long, light brown, oval and contained in clusters of brown, eye-shaped pods.
- The plant reproduces via seeds, but can be cultivated from root suckers.
- A single tree is said to yield 9–90 kg seed per tree, indicating a yield potential of 900––9,000 kg seed/ha
- The plant can produce up to 30-40% oil per seed.
- Approximately 50% of oil is C18:1, which is suitable for biodiesel production.
- Its chromosome number is 22.

Pongamia has a varied habitat distribution and can grow in a wide range of conditions. Typically, it is found in coastal areas, along limestone and rock coral outcrops, as well as along the edges of mangrove forests, tidal streams and rivers. It is hardy and can survive in temperatures from 5° to 50 °C and altitudes from 0 to 1,200 m. Due to its deep roots it also has a tolerance for drought and is found in areas with rainfall from 200 to 2,500 mm a year. It grows well in both full sun and partial shade and can grow in most soil types.

Pongamia has many uses including the following:

- Wood: used for stove top fuels, poles, and ornamental carvings.
- Bark: used for paper pulp, twine and as a medicine to reduce swelling of the spleen.
- Flowers: are considered good sources of pollen for honey bees, and have been described as having anti-diabetic properties.
- Leaves: used as cattle fodder; as an infusion to relieve rheumatism and coughing; as an extract to treat itches and herpes; and as a source of poison for Australian Aborigines for fish spears;
- Oil: extracted from the seeds has been used as lipids for commercial processes; as an ointment for skin diseases; as a liver medicine; as a lamp fuel in India; and for the production of biodiesel.
- Seed cake: leftover after oil extraction has been used as 'green manure' as it is rich in protein and nitrogen; and
- Whole plant: Due to its hardy nature Pongamia is often planted in urban streetscapes

Pongamia is a good source of biodiesel as it has high oil content (approximately 40%). It can grow on malnourished soils with low levels of nitrogen and high levels of salt. It is fast becoming the focus of a number of biodiesel research programmes. Some of the advantages of Pongamia for fuel are:

- it has a higher recovery and quality of oil than other crops.
- no direct competition with food crops as it is a non-edible source of fuel.
- no direct competition with existing farmland as it can be grown on degraded and marginal land.
- it is also able to fix its own nitrogen from the soil (as a legume), minimising the need for added fertilisers.

12.0 Seed Harvesting

12.1 Castor Beans

When harvested, the capsules are stripped from the dry seed clusters either by hand or by means of a slotted tin mug, pushing it under and upwards under the seed clusters. An adult can strip from 272 – 453 kg (600 - 1,000 lb.) per day. When harvesting is done manually, the right time to harvest is indicated by the spikes turning brown and the capsules just beginning to open, assuming a yellowish colour. The capsule is usually spiny and maybe troublesome to some harvesters. The spikes are cut with shears and put in a dry place protected from rain and moisture. The seed is then carefully extracted by gently beating with rods.

At the pilot Castor plot visited in March 2012 at CARDI in Manchester, Jamaica, the project supervisor indicated that harvesting of the castor beans could be challenging as all the trees with seeds do not ripen at the same time and if left too long the beans will shatter releasing the seeds to the ground. Once the beans look mature, they are harvested and allowed to dry under managed conditions.

In the semi-dehiscent cultivars (i.e. those with fruits open, but remain on the tree without releasing the seed), the castor bean harvest can be initiated when two-thirds of the fruits of the bunch are dry. The fruits open in a more intense way when the weather is hot and dry. To decrease the cost of the labour force in the harvest operation, it is important to do the lowest number of passages, observing if the fruits are opening and knocking down the seeds. Otherwise, the harvest can be postponed for a short period.

For mechanical harvesting it is usual to wait until the plants have lost their leaves.

12.2 Jatropha

The harvesting of the jatropha seeds is mainly done by hand as it is difficult due to the ripening characteristics of the fruit. There have been many attempts to improve this process by mechanisation, but only in pilot projects. The harvesting process is very labour intensive with a high impact on the production costs of jatropha oil. Harvesting is a significant aspect to consider in the entire production process. These high costs compared to other oil producing crops have a number of causes:

- The jatropha fruit ripens over a long period, requiring weekly picking for weeks up to many months a year.
- The uneven ripening of the fruit means only some of the fruit of a bunch can be harvested at one time: (e.g. yellow, brown and black fruits are ripe and can be picked).
- The fruit is small and requires a lot of time to harvest (e.g. 3 seeds in a fruit weigh about 2 g).
- The production of jatropha fruit on a hectare basis is moderate i.e. the density of fruits in the field is low, requiring more transport distances in the field.

12.3 Oil Palm

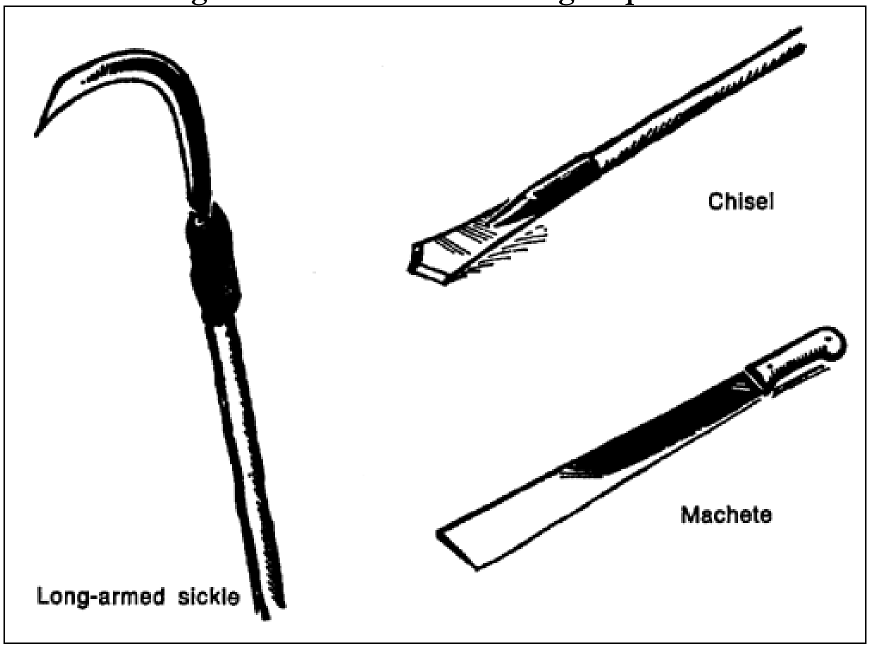
Harvesting needs much time and much care because only those fruit clusters that are cut at the right moment yield a lot of good-quality oil. The plantation has to be checked many times to pick the ripe clusters. A cluster is ripe for harvesting when the fruits begin to turn red, and when 5 or 6 fruits drop to the ground.

If harvesting is late it takes much more time, because all the fruits that have dropped to the ground must be collected. The fruits will also yield less oil, and the oil will be of a lower quality. If harvesting is done too early, the fruit will not be ripe enough. It will be more difficult to separate the fruits from the clusters and the clusters will yield less oil.

The clusters can be cut off with different tools (Figure 14):

- For oil palms 4 - 7 years old the clusters are cut with a chisel.
- For oil palms 7 - 12 years old the clusters are cut with a machete.
- For oil palms older than 12 years the clusters are cut with a long-armed sickle.

Figure 14: Tools for harvesting oil palms



Source: http://www.fao.org/docrep/006/T0309E/T0309E05.htm

If the clusters are too high up to be cut with the long-armed sickle, bamboo ladders can- be used or the tree will need to be climbed using a belt and spiked shoes for support. Any clusters that have dropped to the ground should be collected in a basket. Fruits that have come loose must also be picked up.

13.0 Seed Storage

13.1 Jatropha

An important consideration in selection of feedstock for biodiesel production is the content of free fatty acid (FFA) in the oil. However, the FFA is affected by the storage duration and condition of the feedstock before extraction. Jatropha seed moisture percentage must be below 6% for storage. Seeds should not be broken or damaged and they should be stored away from direct sunlight in a cool dry area. Seeds can be stored for up to a year without excessive loss of viability.

The quality of *Jatropha curcas* seeds should be maintained during storage, either as seeds for seedlings or oil production for biodiesel. The effects of water activity and duration of storage on quality (i.e. fungal population, lipid, fatty acid and free fatty acid contents and viability of seeds) have been investigated and the results showed that moisture content of seeds and total fungal population decreased at low water activities, and increased at high water activities (a_w).

- At a_w 0.64, at the beginning of storage and after 20 weeks of storage, total fungal populations were 5.4×10^3 and 1.8×10^2 cfu g^{-1} dry basis (db), respectively.

- At a_w 0.93, at the beginning of storage and after 20 weeks of storage, total fungal populations were 5.0 x 10^3 and 3.3x 10^6 cfu g^{-1} db, respectively.

At the beginning of storage, fungi infecting seeds were field fungi, i.e. *Cladosporium* sp., *Colletotrichum*sp, *Fusarium semitectum*, and *F. verticillioides*. The population of field fungi decreased with the increase in storage duration. They were replaced by post harvest fungi, i.e. *Aspergillus restrictus*, *A. penicillioides*, *Eurotium chevalieri*, *E. rubrum*, *Penicillium citrinum*, *P. implicatum* and *P. oxalicum*.

Lipid content and viability of seeds decreased with the increase of water activities and seed moisture contents, while free fatty acid contents increased with the increase of water activities and seed moisture contents during storage. Fatty acids of lipids were dominated by unsaturated fatty acids i.e. oleic and linoleic acids. It is recommended for the best results that the seeds are stored at a_w 0.64-0.75 for up to 8 weeks if they are to be used for seedlings or up to 16 weeks if they are be used for producing oil.

Generally:

a. Free fatty Acid (FFA) content of raw jatropha oil increases with time.
b. Higher FFA results in loss of more oil as precipitate while neutralising. It is therefore recommended that raw oil should not be stored for a long time.
c. Oil content of seeds decreases with time. Therefore, seeds should not be stored for a long time.
d. Cost of biodiesel is sensitive to storage time of seeds as well as raw oil.

13.2 Castor

The seed or bean should be handled with care to avoid breakage since broken beans have to be eliminated. The beans rapidly deteriorate with the oil being converted to glycerine and free fatty acid, which causes the production of highly coloured acid oil during the process of manufacture.

Ideally, castor beans should be stored at less than 6% moisture in a cool dark place until ready for use. When the castor bean seed is well stored, seeds for planting can remain up to 1 year or they can be stored for up to 2 years for those seeds destined for industry.

Castor beans before storage are dried to reduce losses due to fungus. Beans for commercial purposes can be dried quickly at air temperatures between 50ºC to 60ºC. High temperature drying also destroys disease causing fungus. Castor for seed purposes is dried at air temperature 30°C to 35°C. Once dried, oil content, seed viability and quality are not affected when stored for 2 to 3 years.

Figure 15: Castor Seeds

Source:
http://www.dovebiotech.com/pdf/CASTOR%20BEAN%20%28RICINUS%20COMMUNIS%29%20-%20BIODIESEL.pdf

13.3 Oil Palm

Oil palm kernels should be stored at a moisture content of 5% or less.

14.0 Pest Management

14.1 Castor

Seedling and germination difficulties can be prevented by treating the seed with the seed protectants used for peanuts. Diseases seldom do much damage e.g. leaf spot (*Cercospora reicinella*), rust (*Melampsora oricini*) and *Alternaria* leaf spot may occur. Leaf Spot caused by fungi occurs mainly when humidity is high. Caterpillars, stink bugs and midges should be controlled early and dust sprays applied at least 5 days before stripping of the seed.

14.2 Jatropha

The attack of pests and diseases is a limiting factor in achieving optimum production, and sometimes makes harvests fail. If *Jatropha curcas* is cultivated as fences or in intercropping systems, the problem of pests and diseases is not very significant, and can in this case be overcome easily. But if the cultivation is done in large-scale monocultures, pest and disease control is more important. There are several techniques to be adopted in pest and disease control such as mechanical, cultural, biological and chemical controls.

14.3 Oil Palm

Oil palm suffers from many pests and diseases that can have a serious impact on palm growth, yields and survival.

- Rodents (e.g. rats and agoutis), porcupines and wild boars attack very young palms and eat the terminal bud.
- Limacodidae insects (i.e. brightly coloured, highly urticant caterpillars) cause defoliation and subsequently yield losses.
- In Africa, oil palm vascular wilt is a major problem.
- In Southeast Asia, basal stem rot caused by *Ganoderma* is having an increasing impact in replantings.
- In Latin America, oil palm bud rot causes substantial losses and has even wiped out whole plantations in Colombia, Brazil, Suriname and Ecuador.

In terms of weeds, the base area of the oil palm plant should be kept free of weed growth through ring weeding especially for young palms whose roots are to be kept free from competition from weeds. Depending on the extent of weed growth and rainfall, hand weeding is carried out up to 4 times in a year during the early years of the plantation and is progressively reduced to 2 rounds per year.

Herbicide application has become common in recent years. Care must be taken in the choice of herbicide and its application to prevent the damage of young palms. It is recommended to preferably apply contact herbicides rather than translocated herbicides.

15.0 Experiences in Other Countries

Government support for locally produced biofuels exists in practically all biofuels-producing countries. It comes in various forms through policies and legislation at the local, regional, and national levels.

These policies include:

- Direct payments to producers or blenders of biofuels.
- Direct payments to farmers growing biofuel crops.
- Exemption from or reduction in fuel excise taxes for biofuels.
- Grants or low interest loans or loans guaranteed by the government for capital expenditures of biofuels facilities.
- Exemption from import duties of capital equipment for biofuel facilities.
- Exemption from or reduction in income taxes for biofuel producers for a period of time.
- Grants for biofuel research and development.
- Tariffs on imported biofuels.

This section examines the policies and strategies of various biofuel producing countries to provide context to the type of policy and legislative framework that could be adopted in Jamaica.

15.1 The EU biofuels policy and mandate

The European Union (EU) has been a pioneer in the promotion of biodiesel. The main drivers of biofuel adoption in the EU have been the targets set by European Commission Directives namely 2% and 5.75% blends of biofuels in petrol and diesel by 2005 and 2010 for member states. Tax relief is one of the main incentives used by member states to promote biofuel use in the EU. However, mandatory blending requirements along with tax relief have been used in conjunction with partial, but increasing levels of taxation on fossil fuels to promote the use of biofuels. Some countries are also using quota mechanisms and tendering. Although the programme started slowly, biofuel production picked up momentum in 2006 and 2007 with the share of biofuel touching 2.6% of road transport fuel in 2007. About 75% of the increase in biofuel use came from biodiesel.

Key policy initiatives: Tax relief for biofuels use, mandatory blending requirements and increasing levels of taxation for fossil fuel use.

15.2 Brazilian Biodiesel Programme

Brazil's National Programme for the Production and Use of Biodiesel (PNPB) appears to have four (4) main objectives:

- To structure the supply chain of biodiesel in Brazil;
- To produce biodiesel from different oil seeds (such as castor beans, cotton, peanuts, dendê oil, sunflower seeds and soybeans) from the diverse regions of the country;
- To promote social inclusion and regional development in underdeveloped areas; and
- To support the production of a new source of oil supply at competitive prices and with appropriate quality.

Brazil's PNPB is a near perfect reflection of the country's push for energy security and economic growth. The programme is an initiative of President Luis Inácio Lula da Silva's government (2003-2010) to integrate a drive for energy security in the electricity generation and transportation fuel sectors with sustainable rural development. It incorporates both large-scale agribusiness and family farms across the entire country. In many ways the PNPB represents the reconciliation, if not harmonisation, of divergent economic and environmental interests, both private and governmental, into a comprehensive national public policy that has already paid measurable dividends to all Brazilians.

The Early Years - Betting on Biodiesel

In the 1970s policymakers focused on the production of biodiesel as an important substitution strategy to lessen the national dependence on petroleum and its derivatives, including diesel.

In 1980 the Plan to Produce Vegetable Oils for Energy Use (Proóleo) was created by the National Council on Energy to foster research that could test the viability of producing and using vegetable oils in diesel cycle engines. In 1985 the private sector firm Proerg in the state of Ceará obtained the first patent for biodiesel. In that same year, the Industrial Secretariat of the Ministry of Industry and Commerce launched the National Program for Energy from Vegetable Oil (OVEG). However, the drop in world oil prices in the mid 1980s challenged the commercial viability of the nascent biodiesel sector and eventually forced the government to abandon its biodiesel policies and programmes. This initial experience demonstrated Brazil's interest and possible comparative advantages in biodiesel production, but also revealed that a simple import substitution strategy would not be sufficient to overcome the global market constraints imposed by cheap oil.

President Lula was determined to push Brazil forward with a mix of economic and social policies, including a government led effort to pump up biofuel production to achieve transportation fuel security in the midst of rising energy prices (Langevin[13] 2008, Langevin 2010). At the time, Brazil imported approximately 16.3 % of its diesel consumption at an annual cost of $1.2 billion (Caderno NAE 2004:12). An inter-ministerial working group, established by the government to study policy options issued a report to the Executive Inter-Ministerial Council, which would by 2004 endorse a full-fledged effort to seriously focus on biodiesel as an energy source. By the end of 2004, the National Programme for the Production and Use of Biodiesel (PNPB) was launched. The Minister of Mines and Energy at that time (now President) indicated that the biodiesel policy challenge required an integrated set of policies and programmes framed around coordinated production of a diverse set of vegetable oils in accord with regional variations in climate and soil conditions for viable and sustainable cultivation, guarantees of quality and supply for consumers, and competitive pricing in relation to petroleum diesel (Rousseff 2004). The timing was good as world petroleum prices were surging by 2004 just as the government's attention turned toward improving Brazil's trade balance by increasing exports and curbing petroleum product imports. In late 2004 the Lula government launched a comprehensive and fully integrated policy and regulatory framework that guaranteed biodiesel's commercial viability while weaving its production chain throughout all five regions of the nation and among both large and family-based producers of vegetable oils and animal fats.

One of the objectives of the PNPB was to rapidly expand biodiesel production and use by instituting a targeted set of fiscal incentives, financing, and blend ratio mandates. First, the PNPB mapped out a national production chain by region and cultivation to focus efforts on improving productivity and lowering costs in the long run. The strategy included incorporating each of Brazil's 5 regions into a national plan, and each region would feature a different set of vegetable oil production. As Table 6 indicates, soy, cotton, and sunflower crops were planned as the major sources of vegetable oils for biodiesel production in both the South and Southeast while the Northeast would focus on palm oil along with castor beans. The North would focus on palm oil along with soy and the Centre-west region, home to most of Brazil's soy cultivation and biodiesel production, would focus on soy, cotton, and castor beans.

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Table 6: Planned Vegetable Oil Sources for Biodiesel Production by Region/PNBP (2004)

Region	Vegetable Oil Source
South	Soy, Cottonseed, Sunflower seed
Southeast	Soy, Cottonseed, Sunflower seed
Northeast	Palm, Castor Bean
North	Palm, Soy
Centre-west	Soy, Cottonseed, Castor Bean

Source: Rousseff (2004) "Biodiesel: O Novo Combustível do Brasil. O Programa Nacional de Produção e Uso de Biodiesel."

This variation of cropping by region was framed by soil and climate conditions, and it was driven by the economic, political and social imperatives of incorporating family farms and small producers into the production of biodiesel while also expanding cultivation of palm oil, the most efficient biomass for biodiesel production in Brazil. Texeira de Andrade and Miccolis (2010) summarised existing research to conclude that palm oil, either for export or for use as biomass for biodiesel production and diesel substitution, makes a measurable contribution to a positive trade balance, contributes to an overall renewable energy portfolio, reduces greenhouse gas emissions, and retains capacity for carbon sequestration at over 35 tons of carbon per hectare. Indeed, the most important and driving factor is excellent yields coupled with the low production costs of palm oil as a biomass for biodiesel production, the only vegetable oil capable of competing head on with petroleum based diesel in Brazil. Recognising palm oil's comparative advantages, the PNPB encouraged expansion of its cultivation to improve the long term viability of Brazilian biodiesel, incorporating family farms, cooperatives, and small producers into the production chain throughout the North and Northeast.

Another of the PNPB's goals was social inclusion. This outcome was to be achieved by compelling biodiesel producers to buy vegetable oils from family farms and small producers. The Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (ANP) was made responsible for organising national sales of biodiesel to distributors through auctions in which participating sellers must offer legally established ratios of biodiesel made from family farm produced vegetable oil or animal fats and certified with the Social Fuel Seal (Selo Social). This ensures that biodiesel refiners encourage and contract with family farms as an essential producer of vegetable oils in the biodiesel production chain. As part of the PNPB, Law# 11.097 was enacted in 2005 to regulate biodiesel production, encourage the cultivation of vegetable oils in tandem with the National Program for the Improvement of Family Agriculture (known by its Brazilian acronym PRONAF), and guarantee a market for the family farms through the establishment of the Social Fuel Seal. The Social Fuel Seal mandates by region the required portion of family farm produced vegetable oil for biodiesel production. Initially the law required that 50% of all biodiesel produced in the Northeast and semi-arid regions be made from vegetable oils cultivated by family farms, 30% for the South and Southeast regions, and 10% from the North and Centre-west regions. Yet, as César and Batalha (2010) pointed out,

The initial mandatory raw material purchase quote of 50% from the family farms… to obtain the 'social fuel seal' prevented the success of the projects in the northeast and semi-arid regions of Brazil. In most cases the *fiscal incentives associated with the social fuel seal were not worth the efforts of the biodiesel producer companies...*

Hence, the Social Fuel Seal's first impact was to concentrate production around concentrated cultivations of soy in the Centre-west where the family farm quota of 10% was the lowest. However, in 2009 the Brazilian government enacted new family farm produced vegetable oil quotas for obtaining the Social Fuel Seal, reversing the distorting effects of the initial requirements. Today, 15% of family farm produced biomass is required for the North and Centre-west regions and only 30% for the Northeast, Semi-arid, South, and Southeast regions. The PNPB continues to feature the social fuel seal, but the family farm produced quotas of vegetable oil have been lowered to encourage greater investment in those regions, such as the North and Northeast, where palm oil production is highly incentivised by federal fiscal policies and favourable financing, and where more family farms would benefit from direct participation in the biodiesel production chain.

This programme has been challenging however, as it has been difficult to effectively insert small-scale family farmers into the supply chain of biodiesel, especially in the Northeast region, where the farmers are dispersed across the territory and thus far have not had a long-term engagement with market processes. To address this problem, the Brazilian government established a comprehensive policy and a set of economic incentives to foster stakeholder involvement in the biodiesel supply chain. The aim was to facilitate the provision of technical and financial support to family farmers, and to provide them with an assurance of price stability through formal contracts (Zapata and Nieuwenhuis, 2008). To date, despite immense political will, the programme has not integrated small-scale family farmers to the extent anticipated. Some have viewed it as a policy failure, because the initiative did not live up to the initial expectations but others realise that the programme needs to be interpreted in a more complex fashion. The analysis has to take into account not only the *number* of small-scale farmers incorporated into the programme, but also *how* the programme has affected the livelihoods of those who have taken part. Research to date indicates that in a short period of time, the participation of family farmers in the PNPB has led to a significant (20% in the current context) increase in their median yearly income. More systematic impacts, including those on poverty, are harder to track because these types of impact evaluations were not built into the programme design, and also because institutional modalities are still being refined.

In addition to the Social Fuel Seal, the PNPB offers a tax incentive framework that encourages the production of vegetable oil for biodiesel and the integration of family farms into regional production poles to advance the policy goal of social inclusion. When the PNPB was rolled out in late 2004 alongside Presidential Decree# 5.297, tax rates were adjusted to favour specific regions, cultivations, and family farms. Family farms that produced palm and castor bean oil for biodiesel production in the North, Northeast, and semi-arid regions were exempted from major federal taxation, while the federal tax obligation of intensive, agribusiness production in these specific regions was reduced by 32%. With the exception of the total exemption of palm and castor bean oil in the North, Northeast, and Semi-arid regions, federal taxation of family farm production of vegetable oils for biodiesel production was reduced by 68% across the nation. The strategy behind these tax cuts was threefold:

- Stimulate biodiesel production in the North and Northeast.
- Incorporate family farms into the production chain.
- Rapidly increase the use of palm and castor bean oil into the national production chain.

In addition to these fiscal incentives, Brazil's National Economic and Social Development Bank (known as the BNDES) introduced a special financing programme, the Financial and Investment Support Program for Biodiesel, offering up to 90% financing for projects obtaining the Social Fuel Seal and 80% for any biodiesel related project, including cultivation of vegetable oils, warehousing, logistics, capital goods acquisition, and the commercialisation of by-products from the biodiesel production process. Coupling fiscal incentives with special BNDES financing established the conditions necessary to rapidly increase production of biodiesel in Brazil, but it was the PNPB's blend mandate that guaranteed a national market for years to come.

The Blend Mandate

The PNPB established a graduated blend mandate schedule that guaranteed a growing national market for production. The mandate sought to quickly incorporate biodiesel production into a 2 percentage point mix with all diesel sold in Brazil, and then to gradually increase the biodiesel blend ratio. Initially the PNPB established benchmarks for production in 2 phases, the B2 and the B5 phases. The B2 phase, from 2005 to 2008, would feature 16 biodiesel production plants refining up to 840 million litres of biodiesel. The B5 phase, from 2008 to 2010, planned to increase the number of refineries to 43 and to produce 2.2 billion litres. During the first 5 years of the programme, national biodiesel production rose steadily, from approximately 70 million litres in 2005 to over 2.35 billion litres by 2010. According to the Brazil Oilseeds Annual Report for 2010, three quarters of all Brazilian biodiesel is produced from soybean oil, followed by animal fats and cottonseed oil, with palm and castor bean oil contributing the smallest portions. The 2010 soybean crop in Brazil was larger than expected. Yet, the disproportionate use of soybean oil for biodiesel production, largely concentrated in the Centre-west, also revealed that the planned increase in production of biodiesel from palm oil did not meet PNPB objectives. From production trends it is forecast that Brazil will be the second largest producer of biodiesel in the world, next to Germany and superseding the United States, after the B5 blend mandate takes a measurable effect on investment and production.

The government blend mandate guarantees the commercial viability of Brazilian biodiesel relative to world petroleum prices through the redistribution of costs to consumers and taxpayers. The PNPB holds out the possibility that national biodiesel production might one day compete with petroleum based diesel on a production cost basis.

The PNPB estimated that during Phase B2 the country would save some $160 million dollars by lessening diesel imports. With the B5 blend mandate enacted in 2010, it is likely that Brazil can save hundreds of millions of dollars in import costs by producing its own biodiesel and substituting an increasing share of imports. Petrobras, Brazil's state-controlled energy company, reported that diesel imports declined by 43% between 2008 and 2009 due to increased national production of diesel, including biodiesel. Goes, Araújo and Marra

(2010) reported that in 2009 biodiesel production substituted 1.1 billion litres of diesel imports, saving nearly a billion dollars from the trade ledger.

Brazil's recently discovered pre-salt hydrocarbon reserves could rapidly increase national petroleum-based diesel production in the coming decades (Langevin 2010). The improved trade balance achieved by producing biodiesel locally is a strong incentive to continue with the PNPB despite the potential of the pre-salt reserves.

Programme Successes

The PNPB has delivered impressive environmental benefits. Although the B5 blend mandate does not offer substantial reductions of emissions, it does play a modest role in Brazil's broader mitigation campaign in both the transportation and energy sectors. The PNPB is an important element in Brazil's voluntary commitments to reduce carbon emissions. Although the PNPB is a modest effort to mitigate carbon emissions, it represents a distinctively Brazilian model of development that attempts to reconcile national development goals with global governance. In this way, the PNPB deserves special attention by policymakers around the world.

Programme Challenges

The programme's implementation in the first few years faced several problems related to planning and execution, circumstances that became evident in *ex-post* evaluations. The economic-incentive instruments used did not successfully incorporate the anticipated number of small-scale family farmers, particularly in the poorer and more underserved areas of the Northeast. Several explanations were identified for this, including: the lack of adequate technical assistance; the distribution of low-quality seeds; low productivity that compromised family farmers' profitability; and difficulties caused by climatic, logistical and other factors related to small-scale farming in Brazil.

Institutional Challenges and Recent Developments

The requirements of the Social Seal certification stipulate that technical support was to be provided by the biodiesel refineries. Brasil EcoDiesel, the main producer in the Northeast until 2009, operated by hiring technical workers. The technical assistance provided, however, was less than adequate. What also appears to have been underestimated was the amount of time and commitment required to provide the type of stable and predictable engagement needed to help small-scale farmers make a transition from mostly subsistence production to engaging in a market process.

The programme has been transformed by a quiet, but profound rearrangement of roles on the part of major stakeholders with the small-scale family farmers. This has provided some flexibility to the initial policy implementation framework. In this context, it is important to estimate whether these changes have been effective. These changes are addressed below.

The New Role of Petrobras

One of the most crucial changes observed in the structure of the biodiesel programme has been the emergence of a new central stakeholder in the biodiesel supply chain i.e. Petrobras Biofuels (PBio). Petrobras, Brazil's state-owned oil company is emerging as the dominant player in petrol-derived fuels and bio-ethanol. A subsidiary company has been created to focus on the biofuels market and the firm has also made significant investments in the construction of biofuels refineries in the Northeast. It is also likely to become the largest producer of biofuels in the Brazilian market in the next few years.

The company has begun to establish itself in the market by addressing some of the inefficiencies of small-scale family farming, and by helping to ensure that the participation of farmers in the market takes place on a firmer footing than in the previous period. The firm has hired dedicated technical staff (i.e. 35,000 contracted workers), distributed seeds, and signed medium-term contracts with small-scale farmers, which provide for the payment of a minimum market price for castor beans. The firm is also fostering the creation of local farmers' associations and the use of several sources of biodiesel feedstock including soy, sunflower and castor beans, to include more farmers in the programme and diversify the source of fuel.

One of the firm's main objectives is to become a central player in the international market. The company sees its support to family farmers' participation in production for the domestic market as an opportunity to enhance its own participation in large international markets. In other words, the investment in small-scale family farmers aims to reduce the risk of relying solely on large-scale soy producers.

Since the negative social and environmental externalities related to the production of biofuels, especially in Asia, have created a negative image of biofuels in European markets (Transport and Environment, 2010), this engagement enhances the firm's image by demonstrating well-structured and effective "corporate social responsibility". A demonstration of the potential for incorporating small-scale farmers could help diffuse criticisms while enhancing the corporate social and environmental image of the Petrobras Group.

Petrobras has also played a special historical role in the development of new technologies and productive structures in Brazil. The firm's involvement is helping to correct some of the problems that surfaced earlier in the relationship between small-scale family farmers and large-scale refineries, especially in the Northeast region. Only time will tell if Petrobras can effectively incorporate small-scale family farmers into the supply chain of biodiesel. In other countries facing similar challenges, a public entity such as a marketing board or public-private partnership may be able to play this role.

In addition, two important technical issues need to be acknowledged with regard to the choice of feedstock to be produced by small family farmers. First, at the moment the castor bean bought by the firm is not turned into biodiesel because the product can command a higher price in the cosmetics and pharmaceutical industries. This makes the development of the value chain of castor for biodiesel sensitive to trends in these other markets. The investment in several sources of biodiesel - including soy, sunflower and castor beans - may help mitigate the risks of relying on a single type of feedstock and source of supply, and also provide additional options for family farmers. Second, Petrobras has become a monopsonist[14], posing long-term risks for small-scale family farmers - especially in the Northeast. It should be noted, however, that in the short run the participation of PBio has enhanced the participation of family farmers.

This experience points to a potential short-term win-win outcome because of a unique set of circumstances typical of Brazil. Even in Brazil, however, it is not clear whether it will be possible to establish a balance between fostering a competitive industry and supporting social inclusion through the production of biofuel feedstock, particularly in underserved regions.

The Biodiesel Production Centres: "Polos do Biodiesel"

One of the PNPB's main challenges has been the geographically scattered distribution of family farmers in the Northeast. Small-scale family farmers were unable to interact with their peers, and could not gain from economies of scale. The wide spatial dispersion of farmers also has a direct impact on the logistics of technical support, seed distribution and commercialisation. This was especially challenging in regions where farmers' organisations were weak or non-existent.

The "polos do biodiesel" serve to overcome these challenges by creating local centres of production. The Ministry of Agrarian Development (MDA) has invited two institutions to implement the poles; for the northeast regions and for the centre-west, southeast, south and north regions. Currently, 37 poles have been established across the country (Portal da Cidadania, 2010).

The biodiesel production centres are important because they can help small farmers overcome some of their difficulties in producing and trading in their production, as well as help them develop their entrepreneurial skills. Small-scale farmers' ability to organise themselves could lead to more profitable solutions for them.

Farmers' associations and/or cooperatives are important in enhancing the knowledge base of small-scale farmers, as well as their market participation through awareness-raising programmes and more cost-effective delivery of technical support. The associations also have the potential to increase farmers' bargaining power, and to move into more value-added activities such as processing, rather than having farmers integrated only into the lowest rung of the value chain. Cooperatives can build oil-producing facilities that will improve the income of small-scale farmers, since significant value-added is to be gained from processing oil.

To date, very few associations have had the entrepreneurial drive to invest resources and build oil-producing facilities. The association in Irecê, Bahia, is an exception in this regard, as it is now building the first cooperative-owned plant in the country.

[14]Monopsonist - one who is a single buyer for a product or service of many sellers

Consideration of a Broader Range of Biodiesel Feedstocks

The sources of biodiesel are crucial to structuring its supply, and to how small-scale farmers can be incorporated. The current feedstock supply for biodiesel production is dominated by soy oil because of its availability and scale advantages. In 2009, soybean accounted for 80% of biodiesel production, followed by beef tallow (which accounted for 15%). The rest came from other oilseeds such as palm, peanut, wild radish, sunflower and castor bean. Castor was produced by 51,047 small-scale farmers.

With the demand created by the accelerated blending targets (i.e. a shift from a 2% to a 5% biodiesel/diesel blend since January 2010), the federal government has increased its total investment funding for small-scale agriculture with a view to enhancing the inclusion of family agriculture into the biodiesel chain. The aim is to expand the share of biodiesel production from alternative oleaginous crops to 8%, as opposed to the present share of less than 1%. It should be noted that PBio is currently promoting a production model that fosters fuel-food integration (i.e. castor and beans). According to the technical assistance provided in the Northeast region, small-scale farmers are instructed to use an intercropping technique to plant castor and beans together. This improves the productivity of castor, and might provide the farmers with an additional source of income and additional food supply. Given these recent developments, however, it is important to understand that in the absence of technological advancement, feedstock diversification is still very much a work in progress. Several projects have been fostered by local governments to look at other sources of biodiesel including sunflower, cotton and soy. This may encourage more farmers take part.

Changes in the Use of the Social Label Certification Scheme

The Social Label scheme is a regulatory instrument to promote social inclusion and to foster the participation of small farmers in the biodiesel chain by giving a tax break to firms that buy at least the minimum stipulated amount from small-scale family farmers (PNPB, 2009). Recently, adjustments have been made to the minimum percentage of feedstock that has to be bought from family agriculture in order to secure certification. Arguably, this change can be accounted for by a better grasp of the real production capabilities of family agriculture, including its capacity to meet the targets set, as well as by regional social inequalities and the geographically specific agro-ecological potential for biodiesel feedstock production.

The contracts consisting of purchase-price criteria and adjustment of contract price have been negotiated, and there is now provision of quality and timely technical assistance, fertilisers and quality seeds. The MDA is seeking to ensure that the requirements of the Social Label are adhered to by tightening the industry-monitoring processes. For example, on 5 March 2010, MDA indicated that it had suspended the right to use the social fuel label for six biodiesel-producing units because the companies had failed to comply with the minimum amount of purchases from small-scale family farmers. This suspension prevents their involvement in 80% of biodiesel auctions overseen by ANP.

Change in the Programme's Political Salience and Adjustment of Aggregate Targets

The biodiesel programme was initially launched with much fanfare by the Brazilian federal government. In the media, the new policy instruments were proclaimed to be a great policy initiative for Brazil's rural poor, and were portrayed as a potential model for other developing countries to follow.

After the early years, however, the programme's political visibility appears to have been diluted, and the targets and institutional modalities are being revised in light of the experience gained. It is also important to point out that, despite the decline in the political salience of Brazil's biodiesel programme, the government has pushed forward the timeframe for meeting several of the programme's overall mandatory blending. In this respect, the programme fosters the increased participation of large-scale farmers with a view to enhancing the industry's competitiveness and its potential to produce at scale. Small-scale farmers lack a longstanding tradition of producing commercial crops, and they do not have the production infrastructure to match the mode and rate of production (blending targets) set by the PNPB.

Lessons learnt

The following policy lessons can be drawn from the recent institutional developments in Brazil's biodiesel programme.

Policies geared to including small-scale family farmers in internationally driven markets should take account of the structural weaknesses and the needs of those farmers.

In the case of Brazil's biodiesel programme, economic incentives such as the distribution of seeds, technical assistance and credit were used to insert small-scale farmers into the biodiesel supply chain. The Social Label scheme was used to ensure their integration and to guarantee a steady demand for their production. Initially, the policy seemed to overlook the characteristics of small-scale farming, including family farmers' lack of experience in taking credit. This situation led to credit defaults in the programme's early years and the difficulties they faced in achieving reasonable levels of productivity. The small quantities of biodiesel produced, and logistical issues involved in securing the output suggest that a different type of strategy was needed in the initial phase.

Small-scale projects might be a better start for nationwide policies that seek to include small-scale farmers in internationally driven markets.

This would provide the space for the programme approach to be tested and to be adapted to local realities and dynamics. The programme had been implemented without sufficient consideration of the challenges involved in integrating subsistence farmers. Most of the small-scale family farmers in question were distributed in sparsely populated areas of the country, areas that lacked proper transport and related infrastructure. Aside from that, few of them had experience with enhanced entrepreneurial activities. The longer-term engagement and participation of PBio has the potential to overcome some of these problems in the underserved regions, though it poses challenges of its own.

The Social Label certification scheme is a policy instrument that can guarantee demand for family farmers, but it needs further refinement.

Without this instrument, no small-scale family farmers would be involved in the production of biodiesel because the costs of a small-scale farmer producing castor beans are not competitive with those of large-scale soy producers. The recent adjustments in the percentage of feedstock to be bought from family agriculture takes into account the characteristics of small-scale agriculture, but the Social Label certification scheme has been shown to lack the disciplining power necessary to ensure widespread participation, as well as the flexibility to be adapted to different areas of the country.

For the programme to serve as an instrument of economic and social inclusion there should be a focus on integrating farmers into more value-added components through an enhanced role for producer organisations.

The associations of farmers have the potential to increase the organisation of farmers so that they can move to activities that will provide higher value-added (such as processing), rather having farmers integrated only into the lowest rung of the value chain. Forming cooperatives that foster oil-producing facilities can improve the income of small-scale farmers because there is significant value-added to be gained from processing oil. It is also important to have a monitoring and evaluation framework that can track the economic impacts for the farmers, and to assess how participating in biodiesel production compares to other economic activities and the production of food crops, as well as the matter of food security.

Overall Programme Achievements

In five short years the PNPB has proven successful as a national policy framework that overcomes a number of economic, environmental, and social challenges through an integrated set of policies and programmes directed in large measure by the Ministry of Mines and Energy. The PNPB has achieved its production goals, largely in compliance with the social fuel seal, and has guaranteed a stable supply to meet the demand generated by the B5 mandate. The programme has created new private sector opportunities; stimulated job creation; advanced research and development; contributed to a favourable trade balance; and incorporated a growing legion of family farms and small producers of vegetable oils into the national production chain at a modest cost to taxpayers and consumers. Indeed, the biodiesel programme demonstrates the Brazilian government's capacity to coordinate policies that redirect resources and transform production and consumption across both the private and public sectors and within a broad set of government ministries and agencies. However, the complete success of the PNPB requires additional efforts to expand sustainable palm oil production and incorporate greater numbers of family farms and small producers who labour at the margins of this production chain.

The approach taken in the programme's current stage seeks to overcome some of the problems encountered in the initial phase. More attention has been paid to solving pressing technical-support issues by setting up local biodiesel production centres. Petrobras' greater role can also be seen as addressing some of the challenges in commercialisation, as well as providing better management of logistical delivery systems. The programme has evolved, but the adequacy of castor and other alternative crops for the production systems of family agriculture is still open to question. A number of other important issues must also be addressed including the development of refinery technology, the potential to combine several different types of biodiesel feedstock (such as soy and castor), and technologies to improve soil fertility in areas with poor soils such as in the Northeast. This would allow small-scale farmers to produce at costs that are more competitive with those of other oilseed producers in the biodiesel chain.

A more comprehensive mechanism to enhance stakeholder participation is needed aside from the Social Label scheme. Ideally, this should be put in place at the start and not midway, as is the case of the biodiesel production centres, and should consider the needs and constraints of small producers.

Key initiatives: Targeted set of fiscal incentives, tax incentives, financing, and blend ratio mandates, guaranteed market for oil and technical assistance for small farmers.

15.3 Biofuels in India

Producing biodiesel from tree-borne oilseeds (TBOs) is seen by many as a win-win opportunity to solve two of India's most pressing problems.

First, India needs to stimulate rural development. Agricultural growth lags far behind growth in manufacturing and services, reflecting lack of investment and low productivity in the sector. Three quarters of India's poor people live in rural areas, and their prospects to overcome poverty are dim if agriculture remains decoupled from India's current economic boom.

Second, India needs energy. From 1990/91 to 2006/07, India's oil imports increased dramatically from 21 to 111 million tonnes. As economic growth continues to be strong and international energy prices quickly rise, the country's foreign exchange expenditures for oil imports are skyrocketing. Biodiesel could stimulate agricultural development and create employment and income for many of the rural poor. At the same time, it may satisfy a significant part of the country's fuel demand, increasing India's energy security and saving foreign exchange. Shifting to biodiesel could also reduce greenhouse gas emissions and urban air pollution. Also, as oil-bearing trees can be grown in semiarid regions, there is a potential to rehabilitate degraded lands, which are abundant in India.

At the same time, biodiesel production has come under heavy criticism for two reasons. First, critics claim that fertile agricultural lands will be diverted to cultivation of fuel crops at the expense of food production. Food scarcity and rising prices would especially hit the poor. Second, it has been shown that biodiesel production in some countries in fact *increase* greenhouse gas emissions because forests are cleared for their cultivation and high energy inputs are used to produce some of the fuel crops. Hence, important debates about the development impacts of biodiesel remain unsettled, and the specific trade-offs in the case of India need to be explored.

The biodiesel sector is in an early stage in India. Although a significant number of plantations and some processing plants have been set up in recent years, the first full yields are yet to be realised. Little is therefore known about the economics of biodiesel from TBOs, and it is still uncertain whether production will ever become economically viable. Likewise, it is not yet clear what its socio-economic and environmental impacts will be e.g. how much additional employment will be created and how big the undesired side-effects will be. Furthermore, little is known about how the different stages of the biodiesel value chain should be organised in order to achieve the best socio-economic and environmental outcome, and which policies are most appropriate to achieve this.

Feedstock

In India, Straight Vegetable Oil (SVO) is derived almost exclusively from oil-bearing trees. Several tree species can be selected for biodiesel production. More than 300 different species of oil-bearing trees exist in India. All of them are naturally growing wild species that have not yet been cultivated and harvested systematically for oil production on a larger scale. Some of the seeds have been traditionally collected by poor people for lighting. In small quantities, TBOs are used for commercial purposes in the paint, lubricant and soap industries.

According to the National Oilseeds and Vegetable Oils Development Board of the Indian Ministry of Agriculture (NOVOD), there are about ten species with economic potential for biodiesel production including jatropha curcas, Pongamia pinnata, Simarouba glauca, Azadirachta indica (Neem) and Madhuca indica (Mahua) as shown in Table 7. Proponents of biodiesel in India focus almost exclusively on jatropha and to a lesser extent on pongamia. Other species have not received much attention. The focus on jatropha is justified mainly on the basis of 2 arguments: First of all, jatropha is a shrub i.e. it does not grow into a tree, therefore, it is easier to harvest than large trees and has a much shorter gestation period.

Table 7: Characteristics of TBO's Grown in India

Jathropha	Pongamia	Simarouba	Neem	Mahua
Seeds and oil are toxic. The plant is not browsed as the leaves are not palatable for animals. Not useful as fire-wood.[b] Used as lubricants, soap and candle manufacturing.[h]	Non-toxic leguminous tree, fixing nitrogen into the soil and due to large canopy and nutritious leave and flower litter used for planting in pastures.[m] In villages leaves are used for protecting grains from insects.[m] Good as fire wood, leaf litter with high calorific value.[b]	Large root system, evergreen canopy and large amount of leaf litter (6-8t/ha); most suitable for wastelands reclamation and watershed development.[j] Sugar rich fruit pulp can produce ethanol (800-1000l/ha).[j]	Has a unique property of calcium mining, changing acidic soils into neutral. Famous as ecologically friendly biopesticide to control storage and field crop pests.[f]	Largest indigenous source for soap and bathing oil manufacture, medical purposes and animal feed.[i] Sugar rich flowers used as vegetable and for alcohol production (1 t flowers produce 405 l of alcohol).[i]

Source:
http://dspace.cigilibrary.org/jspui/bitstream/123456789/26015/1/Biodiesel%20in%20India.pdf?1

India's Biodiesel Policy

India initiated biofuel production nearly a decade ago to reduce its dependence on foreign oil and improve energy security. India commenced its biodiesel programme in 2003 with the formulation of the National Mission on Biodiesel. The programme called for mandating a 20% biodiesel target by 2011 -2012 using *jatropha curcas* as the primary feedstock. Although 400 non-edible oilseeds can be found in India, jatropha was selected for the programme because of its high oil content (o/e/ 40% by weight) and low gestation period (2-3 years) compared with other oilseeds. To meet the 20% blending target, the recommendation was to cultivate jatropha on 11.2 million hectares (ha) of underutilised and degraded lands. This was to be implemented in 2 phases, namely a research and demonstration phase from 2003-2007 (Phase I) and an implementation phase from 2007-2012 (Phase II). The main goals of Phase I and to enact a 5% blending target (B5). The programme would be expanded under Phase II to achieve a 20% blending target (B20) by 2011-2012. To support the programme, the Ministry of Petroleum and Natural Gas enacted a National Biodiesel Purchase Policy and set a price of Rs[15]25 per litre (US$0.48/L), subject to periodic review, effective November 1, 2006. The Ministry designated twenty (20) oil marketing Companies (OMCs) in twelve (12) states as purchase centres. The buyback programme remains in effect, but the price was raised to Rs26.50 per litre (US$0.50/L) in October 2008.

Although the biodiesel blending targets were not codified, interest in jatropha rapidly accelerated after the introduction of the National Mission on Biodiesel. According to a global jatropha market survey, India was the world's leading jatropha cultivator in 2009, controlling approximately 0.93 million ha of plantations. Further, it was anticipated India would remain a leading cultivator and projected nearly 2 million ha would be under cultivation by 2015.

Despite India's initial progress in promoting jatropha, the industry has experienced setbacks because of declining international oil prices and the continued variability in the agronomic performance of the crop. To date, there remains considerable uncertainty surrounding seed yields, input and maintenance requirements for the crop, all of which have inhibited market development. Additional concerns surrounding land tenure and rural livelihood benefits have further stymied the industry. As a result, India's Integrated Energy Policy, released in 2006 recommended significant increases in research funding for jatropha and pongamia. Further, the 11th Five Year Plan recommended a blending target of 5% biodiesel by the end of 2012, a significant reduction from 20% target proposed under the National Mission on Biodiesel.

In September 2008, the Ministry of New and Renewable Energy (MNRE) resumed discussions on biodiesel and issued a draft National Biofuels Policy. The draft policy appeared to have backed off the country's exclusive promotion of jatropha and instead called for the use of any non-edible oilseeds grown on marginal, degraded or wastelands. The draft policy also recommended establishing 20% blending targets by 2012 for both ethanol and biodiesel.

[15]Rs – Indian Rupees; US$1 = Rs 52.5400

On December 24, 2009, the government adopted the National Policy on Biofuels. It established a 20% blending target by 2017 for both ethanol and biodiesel. Both targets will be phased in over time and until a phase-in schedule is finalised. There is no mandatory nationwide blending for biodiesel at present. Blending targets will be periodically reviewed and adjusted as needed. The policy proposes establishing a National Registry of feedstock availability to help monitor production potential and set blending targets.

The MNRE is tasked with coordinating the policy. Two new committees, the National Biofuel Coordination Committee (NBCC) and the Biofuel Steering Committee headed by the Prime Minister and Cabinet Secretary, respectively, were established on May 2010 to coordinate and implement the policy. As with previous biofuel policies, OMCs will be responsible for purchasing, storing, distributing and marketing biofuels. The policy includes the following components:

1. **Feedstock:** The new policy is not feedstock specific, as was the case with previous biofuel policies. Instead, the policy calls for using non-food feedstock's grown on degraded wastelands in order to avoid conflicts with food security. This provision will distinguish India's programme from other international biofuel programmes. This stipulation is aimed at biodiesel feedstock as the policy promotes the use of non-edible oilseeds cultivated on degraded land for biodiesel. The policy states that the government will assess the potential of over 400 tree borne non-edible oilseeds currently available in India.

2. **Mode of Production:** In order to avoid conflicts with food production, the policy promotes establishing plantations on government or community-owned wasteland and on degraded or fallow land. Both forest and non-forest land will be considered. Contract farming schemes will also be established in order to raise feedstock on privately owned wasteland and seed buyback programmes will be implemented to encourage contract farming. The policy specifically states plantations on agricultural lands will be discouraged. However, the policy does not provide any guidance as to how these provisions will be enforced.

3. **Policy Mechanisms**: The policy identifies several mechanisms that will be considered to promote biofuel production. The policy document contains few details on the specifics of each mechanism because, presumably, these items are still under development. The policy outlines mechanisms in the following areas: subsidies; preferential financing; fiscal incentives; research, development and demonstration (RD&D); and international collaboration.

4. **Other Policy Options:** There is convincing evidence that oil prices may trend higher over the next two decades and this would have a substantial negative macroeconomic impact for India. A 50% increase in oil prices between 2010-2030 would significantly reduce economic growth, real consumption and household income. Expansion of biodiesel is one policy response India can use to counteract the economic impacts of oil price hikes. Biodiesel intervention can significantly counteract these negative impacts. Combining supply-side energy solutions such as biodiesel development together with modest energy efficiency improvements and productivity improvements in agriculture will provide impressive results.

5. **Subsidies:** The primary government subsidies under consideration are price supports, land concessions, and labour subsidies. In terms of price supports the policy proposes establishing minimum support prices (MSP) for oilseed procurement, which will be paid by the OMCs. Additionally, the government will examine setting up a statutory minimum price (SMP) programme for oilseed procurement at biodiesel processing centres. The policy recommends modelling an oilseed SMP programme after the existing programme for sugarcane procurement. If implemented, this could greatly expand the number of buyback locations operating in the country. Currently, restricting buybacks to the 20 designated OMC locations has frequently been criticised. The government may also establish a minimum support price (MSP) for oil seeds. Oilseed plantations that qualify will be eligible to receive a subsidy for labour costs under the government's Mahatma Gandhi National Rural Employment Guarantee Act. The law guarantees 100 days of labour per year for Rs60/day (US$1.14) for adult members of rural households, living below the poverty line. The law typically applies to unskilled labour on publicly funded projects such as construction.

6. **Preferential Financing:** Recognising the need to create the necessary infrastructure to facilitate biofuel production, the policy calls for national finance institutions to develop preferential financing schemes for biofuel projects. The National Bank of Agriculture and Rural Development (NABARD) will provide loans to farmers to help with plantation costs. The Indian Renewable Energy Development Agency (IREDA), the Small Industries Development Bank of India (SIDBI) and various commercial banks will be encouraged to provide financing for all activities to develop biofuel value chains. The government of India will also seek financing from multilateral and bilateral lending institutions for investments in the sector as well as assistance for carbon financing opportunities. Finally, the government will also permit 100% foreign direct investment (FDI) in biofuel projects in order to attract international investment and joint ventures. However, FDI will not be allowed for plantation projects or for projects exporting biofuels. Therefore, FDI will likely be sought for processing and refining activities.

7. **Fiscal Incentives**: Additional subsidies and grants may also be considered to promote new and second generation biofuel production. The policy does not state the specific feedstock being considered under this category. If necessary, the government will create a National Biofuel Fund to provide financing for these efforts. The plan also calls for incorporating biofuels into other pre-existing central and state government financing schemes promoting renewable energy. However, the plan does not refer to specific policy schemes where biofuels should be integrated. The government will also reduce or eliminate taxes and duties on biofuels. The policy will maintain the current concessional excise duties on ethanol and biodiesel. Presently, the excise duty for ethanol is 16% while biodiesel is exempt from taxes. No further central government taxes or duties will be implemented for ethanol or biodiesel. The government will also reduce customs and excise duties for plant and engine technologies, but the precise reduction rates are not detailed in the policy.

8. **Research and Development:** The government will undertake research and development and demonstration to establish competitive domestic biofuel industries. Research and development (R&D) will primarily focus on establishing plantations, biofuel processing and production technologies, improving the efficiency of end-use applications and by product utilisation. Demonstration projects will be set up for both ethanol and biodiesel projects, which will focus on production and conversion technologies. The government will engage in public private partnerships (PPP) to support these initiatives.

   The government will fund research initiatives at academic, government, non-profit and corporate research institutions to support the R&D programmes. Multi-institutional research programmes with clearly defined objectives and timelines will also be established. The government will establish a research and development subcommittee under the Biofuel Steering Committee to oversee this. The subcommittee will be led by the Department of BioTechnology and include members from the Ministry of Agriculture, Ministry of New and Renewable Energy and the Ministry of Rural Development. The Ministry of New and Renewable Energy will coordinate the subcommittee as this Ministry is responsible for implementing the overall biofuel policy.

9. **International Cooperation:** India will also pursue strategic international partnerships to implement its biofuel policy and promote domestic biofuels industries. Priority areas for such collaboration will include technology transfer, joint research and technology development, field studies, pilot scale plants and demonstration projects. In February 2009, before the official announcement of its biofuel policy, India entered into a memorandum of understanding (MOU) with the US Department of Energy to promote biofuel cooperation. The goal of the MOU is to support the production, conversion, utilisation, distribution and marketing of biofuels in a sustainable and environmentally friendly manner in accordance with each country's respective strategies and goals. The MOU outlines cooperation in 8 specific areas, subject to revision and expansion

India's biofuel policy is comprehensive and gives a broad outline to all the major areas that need attention. These guidelines have to be translated into a biofuel programme with a series of projects to reap the potential benefits. The policy is further examined as follows:

1. **Potential for Producing Biofuels:** About 32 million hectares of wasteland are required for biodiesel production together with yield improvements to meet a 20% blending target with petroleum diesel. However, it is unlikely that India can achieve the 20% blending target by 2017 given the current infant stage of the biodiesel industry in the country.

2. **Food Security:** If confined to wastelands and using only limited irrigation during the establishment phase of the crops, biodiesel production will not have any adverse impact on the food sector.

3. **Technological Constraints:** The biodiesel supply chain is in its infancy and understanding the agronomy of the crops and development of nurseries and plantations with high yielding varieties are major constraints, which need to be removed for the sector to take off.

4. **Impact on Water:** Biodiesel crops most likely will not add to the water problems if confined to limited irrigation in the early stage of the crop establishment.

5. **Environmental Impacts**: Biodiesel crops have limited negative environmental impacts which can be easily mitigated using available technologies and regulatory measures. Biodiesel crops have a number of positive environmental effects and their carbon benefit potential is also large. There are no foreseeable negative social impacts of biodiesel.

6. **Financial Feasibility:** Biodiesel production is not financially feasible under the current pricing mechanism. The current administratively determined price of Rs26.5/L (US$0.50/L) needs to be revised to provide financial incentives along the supply chain.

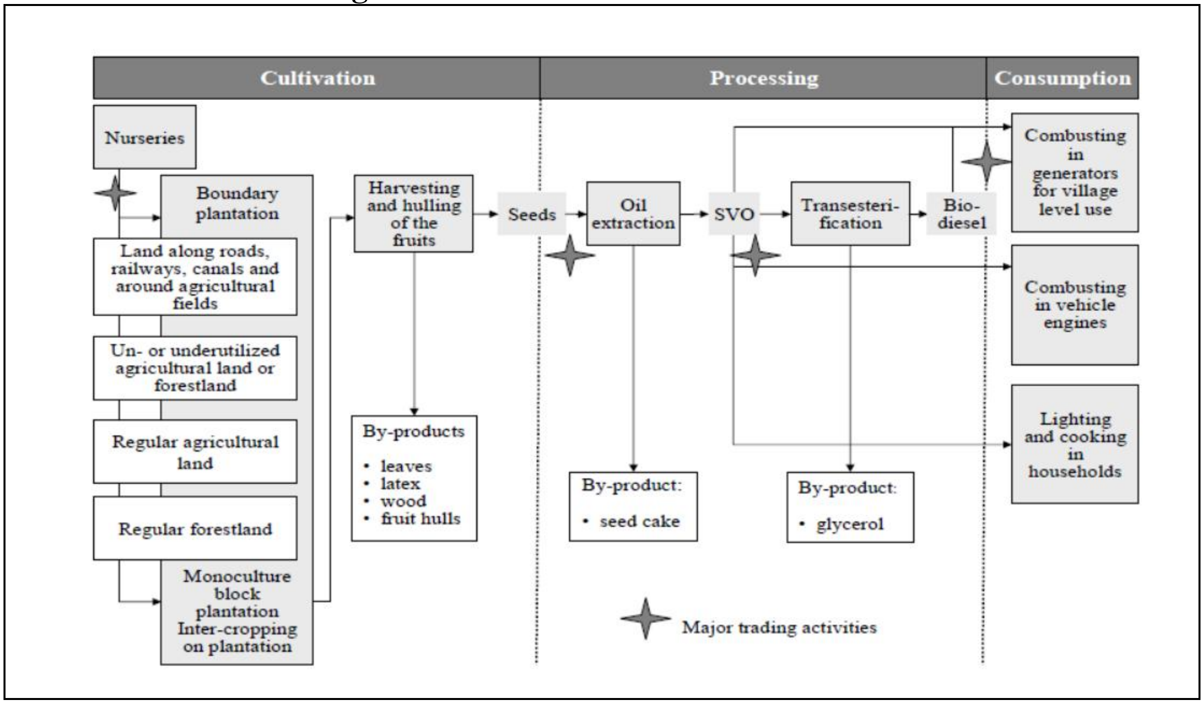
7. **Economy Wide Impact of Biodiesel:** The Indian general equilibrium model, with only biodiesel interventions, shows that biodiesel could provide India with an opportunity to enhance economic growth and the well-being of rural populations. The national biofuel programme has the potential to create a significant number of jobs with substantial real wage increases. Hence, it is a potential avenue for poverty reduction within an inclusive growth policy framework. The negative effect of the programme in terms of higher fiscal deficits does not seem to dampen the growth effect.

The Indian Biodiesel Supply Chain

The biodiesel value chain in India (Figure 16) shows the major trading activities from cultivation through to consumption.

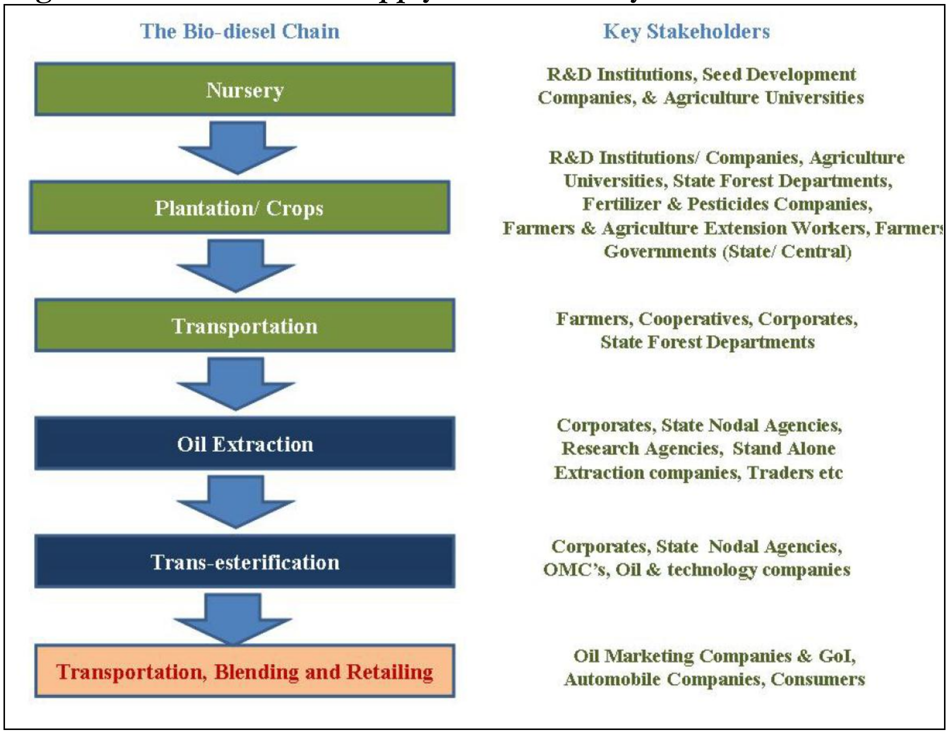
The biodiesel supply chain faces a number of challenges including the plantation component i.e. non-availability of high yielding planting material, cyclical supply shortages and gluts, high labour costs and a lack of knowledge about alternate feedstock. The various linkages in the biodiesel supply chain are illustrated in Figure 17. Biodiesel feedstock like jatropha and pongamia are still in their development phase. Both of these plants are relatively new when it comes to the mapping of their characteristics and genetics by scientists. Globally, 85% of jatropha cultivation is in Asia, mainly in countries such as India, Myanmar, China and Indonesia.

Figure 16: Biodiesel Value Chain in India



Source: http://dspace.cigilibrary.org/jspui/bitstream/123456789/26015/1/Biodiesel%20in%20India.pdf?1

Figure 17: The Biodiesel Supply Chain and Key Stakeholders in India



Source: http://www2.adb.org/Documents/Reports/Consultant/IND/42545/42525-01-ind-tacr-01.pdf

The critical bottlenecks impacting the development of the biodiesel supply chain are shown in Table 8.

Table 8: Critical Bottlenecks across the Biodiesel Supply Chain

Supply Chain Segments	Major Critical Bottlenecks Jatropha and Pongamia
Nursery	• Lack of high yielding varieties, quality planting material and high variation in yields
Plantations/Crops	• Land availability and allocation • Agronomic and management practices not fully developed • Absence or announcement of low minimum procurement price of seed • Long gestation period, no revenue in first few years • High labor cost of harvesting • Uncertainty about the future of the industry
Transportation	• High transportation costs especially if plantations are spread over a large area
Oil Extraction	• Higher cost of extraction due to low capacity utilization • Lack of adequate supply of seeds • Dispersed feedstock production limit the scale economy
Transesterification	• Higher cost of transesterification due to low capacity utilization • Shortage of feedstocks • Dispersed feedstock production limit the scale economy • Uncertainty of the biodiesel industry
Blending/Retailing	• Non-remunerative prices set by OMCs which are not revised regularly • Opposition of OMCs to direct retailing of biodiesel by others

Source: http://www2.adb.org/Documents/Reports/Consultant/IND/42545/42525-01-ind-tacr-01.pdf

Plantation Phase: The main bottlenecks afflicting the plantation phase of the biodiesel supply chain are described below:

1. **Non -availability of high yielding varieties**: The availability of high yielding varieties of seed for both jatropha and pongamia tree borne oilseeds (TBOs) is one of the biggest constraints in the development of a biodiesel value chain. The main reason for this is that although both of these TBOs have been around in the wild for a long time, systematic investigation and analysis has only recently been started on these two species. Most of the genome being used today is from the wild, which displays relatively low yields and high variability in those yields from location to location. The scientific recording of yields for both jatropha and pongamia was initiated only recently and limited data is available for seed yields. According to an FAO document, potential yields for jatropha in semi-arid conditions, have been forecast at around 1.0ton/ha. At this level of yield and the prevailing oil prices, large- scale commercial cultivation of jatropha and pongamia may not be viable. Therefore the key intervention required in the sector is the development of consistently high yielding jatropha and pongamia species.

2. **Lack of quality planting material:** Nurseries have to be developed using high yielding varieties and to make the seedling or saplings readily available. Even though some state governments are providing seedlings free of charge or at a nominal cost, the inaccessibility to high yield seedlings remains the key impediment in the development of biofuel crop cultivation. In addition, there is a need for the development of a set of agronomic and plantation management practices for jatropha and pongamia on a commercial scale.

3. **Relatively low minimum support price for jatropha seed**: The low minimum support price (MSP) for seeds being offered by most states is not high enough for seed collectors to earn enough to meet the minimum wage requirements for most states. Growers also find that the administratively set price is not adequate to make a profit. No seeds are being picked up in a large number of plantations because of this. At the same time the network for seed procurement is not organised and needs to be strengthened.

4. **Lack of experience in plantation development and management:** As both jatropha and pongamia are relatively new TBOs to be brought under commercial cultivation, no data or records exist of mature plantations. Therefore, the agronomy, pest and diseases, fertiliser responsiveness and irrigation water requirements at the field levels are not known.

5. **Availability of suitable land sites and their allocation**: In India, cultivation of biofuel crops is to be taken up on fallow or wasteland. The government will have to play a significant role in allocating this land as ownership lies with State Governments. However the identification and allocation of land is a long drawn out process as land in India is one of the most disputed and litigated of all commodities.

6. **Need for financing**: Jatropha and pongamia both have long gestation periods and have limited or no returns in early years of plantation. It is almost impossible for poor small scale farmers to take up the planting of these TBOs without adequate support in the first few years.

However, the variability of the yield along with the limited to almost no knowledge of the agronomy of the plantation means that financing is a big risk for farmers as well as for banks. Inter cropping has been practiced at some locations to partially overcome this bottleneck.

Processing and Blending

Seed processing infrastructure is one of the key requirements in the jatropha seed-based biodiesel value chain and is presently a major constraint holding back the development of the biodiesel sector in India. In most of the jatropha-growing areas, modern processing plants have not been established in sufficient numbers so far. This is because of two major reasons. Firstly, the government intends to bring private participation to build this capacity but the private players visualise potential risks in investing in this area because of uncertainty regarding the supply of sufficient feedstock and market demand for biodiesel. Secondly, the unavailability of processing capacity is causing farmers to down-scale their production and this poses a threat to even the existing processing plants. The cost of production of biodiesel increases substantially if the units are run under low economies of scale. The problem worsens with an increase in the price of seeds due to the involvement of middlemen and higher transportation costs when the seeds are sourced from distant places.

A number of challenges affect this phase in addition to low capacity utilisation because of poor availability of feedstock for processing and low procurement pricing. These are highlighted below:

1. **Dispersed feedstock production**: This limits economies of scale for setting up facilities for extraction and transesterification. Other issues of technology selection have a direct bearing on the cost of production such as whether to use solvent or mechanical extraction or batch or continuous processing. The early mismatch between production and capacity and the staggered build-up of plant capacities leading to attaining economies of scale are also issues that would need to be discussed while evaluating the viability of business models.

2. **Low prices for biodiesel**: Oil Marketing Companies (OMCs) were initially offering a procurement price of Rs25.00/litre (US$0.48/L) for biodiesel. When no supplier was forthcoming, this price was increased toRs26.50/litre (US$0.50/L). However, even this price was too low as the market price of seeds was significantly higher and as a result, until the present time, no biodiesel has been supplied to OMCs.

3. **Controlled markets**: The OMCs are reluctant to allow biodiesel producers the freedom to directly retail biodiesel to consumers. The OMCs state that all petroleum products come under the Ministry of Petroleum and Natural Gas (MoPNG) and can be retailed only by the OMCs.

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Biodiesel Distribution & Use

Presently, the biodiesel distribution does not follow any well-developed supply chain, even though several public sector undertakings and private companies have ambitious plans to enter into the sector in a big way. The consumers of biodiesel in the country include Indian Railways, Defence Research and Development Organisation (DRDO), state road transport corporations, some private companies, etc. Other than this, local consumption in tractors, trucks, diesel pump sets, etc. is also prevalent. Public sector oil marketing companies (OMCs) are in the process of setting up an extensive network of biofuel distribution chain connecting various processing industries and retail outlets across the country. However, presently they are concentrating more on developing jatropha plantations through contract farming arrangements with local governments and farmers.

Some efforts at establishing commercial links with private companies for setting up processing capacity are also underway. The Indian Railways have started using 5% blend of biodiesel. A separate body 'Indian Railways Organization for Alternate Fuels' (IROAF) instituted under the Indian Railways is building networks with potential biodiesel suppliers. Several state transport corporations have also started blending biodiesel with High Speed Diesel (HSD) in their fleet of buses. The Kolkata Police Department has made arrangements with Emami Biotech for regular supply of biodiesel to be used in their fleet.

Examples of biodiesel distribution in other Indian states include the following:

- In one state the only major jatropha oil processer utilises the produced oil only in its fleet of trucks due to lack of cost-effectiveness in production.
- The Rajasthan State Road Transport Corporation (RSRTC) is sourcing biodiesel from some local small-scale biodiesel units to conduct pilot runs in their buses.
- Some farmers are using Straight Vegetable Oils (SVO) made from jatropha in their tractors and diesel pumps.
- A processing plant in another state is supplying the biodiesel produced in its unit to Indian Railways, Defence Research & Development Organisation (DRDO), Mahindra and Mahindra Ltd.[16] and some transport companies; and
- Some village electrification committees are using biodiesel to contribute to the local electricity needs.

Addressing the Constraints

It is clear that the development of a commercial biodiesel industry based on jatropha and other non-edible oilseeds is at a very nascent stage in India at present. The farm surveys have suggested that the farmers are not happy with the current yield of the crop. To address this constraint, identification of superior germplasm with high-yield potential through systematic varietal improvement programmes is a pre-requisite to large-scale planting. A centrally coordinated breeding programme that replaces the current piecemeal approach in research can pay high dividends. It is also widely felt that jatropha is not a fully domesticated crop and cannot be grown successfully in all kinds of marginal lands.

[16]Mahindra and Mahindra Ltd.is an Indian multinational automaker headquartered in Mumbai, Maharashtra, India. It is one of the largest automobile manufacturers by production in India and a subsidiary of Mahindra Group conglomerate.

As most of the jatropha growing farmers are marginal, small or resource-poor, initial support in the form of subsidised seedlings and other inputs, technical assistance, buyback assurance and minimum support price (MSP) is of utmost importance for the success of biodiesel production. Unscrupulous planting irrespective of the geographical and climatic contours can only sabotage the programme. Premature withdrawal of support facilities may jeopardise the programme. Economic viability of jatropha plantations is critical in retaining the interest of the farmers. Higher prices of seeds are being realised presently because of the demand for seedlings of new plantings. However, once this phase is over, there is every chance of prices going down unless a jatropha seed market with both backward and forward integration evolves. The probability of the programme collapsing is higher if this transformation does not happen soon. The promoters of this industry including various government organisations, OMCs, private enterprises, and NGOs seem to be concentrating on increasing the area under the crop. But simultaneously, it is also vital to develop stable supply chains so that the feedstock produced is effectively marketed, processed and brought to the end-users. Even though some progress has been made in terms of area coverage, the processing infrastructure is way less than optimal. Moreover, most of the existing processing facilities are working under sub-optimal capacities. A critical assessment should precede investing in processing infrastructure so as to fully utilise the economies of scale in processing. Also, the demand for biodiesel is lacking due to poorly defined distribution channels. Since cost-effectiveness of biodiesel also depends on the revenue from its by-products like oilcake and glycerine, simultaneous expansion of by-product markets is also important.

Current Situation

It is too early to judge the success of India's biofuel programme though it was launched in 2003. There are too many unknowns at this stage particularly about the jatropha based biodiesel programme. Still, farm studies suggest that jatropha is a profitable crop in the long-run, provided, government support in the form of input subsidies and technical and marketing assistance is made available during the initial few years. The farmers consider jatropha as a supplementary crop, which can augment their income and employment to a certain extent, but are also concerned about the uncertainty regarding its yield potential, long-term economic viability essentially linked with a sustained demand for seeds and undesirable externalities like loss of common grazing land.

On the seed processing front, biodiesel can compete with petro-diesel if the processing plants are operated at sufficient economies of scale.

This can be realised by ensuring a stable supply of feedstock and consistent market demand of biodiesel and its by-products. Proper backward and forward integration at each level of the supply chain is therefore crucial in making the biodiesel industry operate at economically viable scale. So far, the participation of the corporate sector in developing the processing infrastructure and distribution channels has been feeble. Necessary steps have to be taken to bridge this gap. A centrally co-coordinated mechanism to supervise research, extension, development of processing and market infrastructure and various other assistance programmes should replace the existing piecemeal approach. Legal provisions to regulate a possible diversification of jatropha cultivation areas towards areas for food crop cultivation are also worth considering. To conclude, proactive orientation of all the stakeholders is critically important in sustaining the momentum of the programme and to contribute towards the efforts to find answers for the perennial concerns of energy security, environmental sustainability and poverty reduction in the country.

As can be seen from the analysis, biofuel supply chains show a high degree of complexity due to the fact that they are dependent on a wide variety of inputs from multiple stakeholders. Recognising that biodiesel is at an infant stage, nursery and plantation stages need immediate attention because without high yielding varieties and proper understanding of suitable agronomic practices, the industry cannot take off as a commercially successful, national scale venture. Processing and other downstream segments will quickly develop if the upstream issues and pricing issues are resolved.

Recommendations for Public Sector Support for Biodiesel

Another important factor in the implementation of a biodiesel programme is public support. The areas that have been identified for specific attention to improve public support include:

1. Land use mapping and land allocation study and for formulating a strategy for the necessary legal, institutional, and other provisions to make wasteland available for biodiesel production.
2. Revision of biodiesel and oil seed prices and provision of a stable policy environment for the biodiesel sector to develop.
3. Accelerated research programme on agronomy, selection and breeding, pest and disease control, other management practices, and the propagation of high yielding planting materials for plantation development.
4. Incentive packages for the private sector to mobilise private investment resources for the development of the biodiesel sector.
5. Further studies to examine the potential synergy between India's rural development programmes and biodiesel sector development particularly focusing on the long gestation period of biodiesel crops.
6. Establishment of a national agency with branches in relevant states to design and implement the above stated public support programme, oversee and monitor the biodiesel industry, periodically review the cost of production and prices, and design and recommend subsidies and taxes based on changes in oil prices.

15.4 Value Chain in Thailand

In 2005, Thailand began a campaign to promote biodiesel production and consumption to ease its reliance on fossil fuels.

Oil crops have become the most common raw material for biodiesel in Thailand because of its low cultivation cost and immense productivity. One (1) hectare of oil palm yields 10 to 12 times more fuel than the equivalent acreage of soybeans, which is widely used for biodiesel in the US, and 5 times more fuel than the equivalent acreage of rapeseeds, which is widely used in Europe.

Along with oil palm and used oil, *Jatropha curcas Linnaeus* (JCL) oil has been considered as a prospective feedstock for biodiesel production, particularly due to the possibility of cultivation in dry and marginal lands. More than 80% of the world's palm oil production comes from Malaysia (14 million tons per year) and Indonesia (12 million tons per year). Thailand's production output of crude palm oil is currently about 1 million tons per year or 2,740 tons per day. Approximately 200,000 tons per year or 550 tons per day are exported (Source: Food and Agriculture Organization, Agriculture Statistics Database).

Initial production of biodiesel was insignificant until February 1, 2008 when the Government adopted a policy requiring compulsory production of B2 biodiesel (high-speed diesel with the 2% of B100 content by weight). As of June 1, 2010, the government replaced the compulsory production of B2 with B3 as the government foresaw sufficient crude palm oil (CPO) production to implement this policy. According to an official in the Ministry of Energy, the government is on target to implement its plan to move towards compulsory requirement to B5 production by January 2011.

Under this scenario, it is estimated that demand for B100 palm oil biodiesel will increase sharply from 655 million litres in 2010 to 935 million litres in 2011, translating to an increased demand for crude palm oil (CPO) from 618,000 tons to 882,000 tons in 2011. The government has encouraged oil palm cultivation to meet its policy goals. However, new plantings have fallen short of the programme's goals. An analysis of the proposed policy indicates that, in order to meet demand, Thailand will need to import 200,000 tons of feedstock (CPO or stearin) in 2011. These imports would continue until 2015 when increasing domestic supplies are expected to meet the required demand. Insufficient domestic supplies could lead to escalating domestic prices that would affect other end-users such as cooking oil refining operations.

In order to attract B5 biodiesel utilisation, the government has created tax incentives to favour B5 production by making it cheaper than B2 and B3 biodiesel. In 2005, the Office of the Board of Investment (BOI) of the Ministry of Industry developed a framework in which tax incentives for B100 biodiesel processors were provided. These incentives waive import duties on machinery and accessories, and freezes corporate income tax for eight (8) years. In 2005, the Cabinet approved a budget of 1,300 million baht (approximately US$ 34 million) to promote palm production by providing low-interest loans tied in with a sectoral development plan. This plan was developed by a joint working group from the Ministry of Agriculture and Cooperatives and the Ministry of Energy, "Committee on Biofuel Development and Promotion" (CBDP), which aimed at expanding the palm growing area by 400,000 hectares from 2008 to 2012 or 80,000 hectares annually. Additionally, the committee set goals of increasing palm productivity from 19 tons/hectare to 22 tons/hectare, and the crushing rate of crude palm oil from 17% to 18.5% by 2012. To achieve the plan, the Royal Thai Government (RTG) provided low-interest loans to participating oil palm farmers.

However, increasing palm plantings to meet demand has been challenging. Harvested palm area reported by the Office of Agricultural Economics (OAE) increased by 33,600 hectares in 2008, 48,700 hectares in 2009, and an estimated 45,000 hectares in 2010, compared to the annual target of 80,000 hectares. The slow growth in fresh palm production led to concerns that supplies of crude palm oil (CPO) may not be sufficient to meet biodiesel consumption in the near future. An analysis of the outlook for biodiesel industry from 2009-2015 was reported in a recent GAIN report on Biodiesel Demand and Supply Outlook[17].

Production

The B100 biodiesel in Thailand is currently produced from feedstock from the palm oil industry i.e. crude palm oil (CPO), refined bleached deodorised (RBD) palm oil, and palm stearin. The B100 production is solely determined by domestic demand for blended biodiesel i.e. B2, B3 and B5. Thailand does not import and export B100. Despite irregular growth in total diesel sales, a compulsory B2 production policy has led B100 biodiesel production to increase ten-fold within two years from 68 million litres in 2007 to 448 million litres in 2008 and 610 million litres in 2009. Meanwhile, diesel sales dropped from 18,652 million litres in 2007 to 17,593 million litres in 2008 and rebounded to 18,360 litres in 2009. The B100 biodiesel production is forecast to grow sharply in 2010 (10%) and 2011 (42%), reflecting the changes in policy mandates for B3 in mid-2009 and B5 in 2010. Due to the response to government's incentives through the Board of Investment (BOI) provisions, 14 biodiesel processing plants were established from 2005-2009. The industry's rapid expansion created production capacities that far exceed actual B100 demand.

Industry sources reported that nearly all B100 producers have suffered continued losses since 2008 with at least 4 plants currently suspending their operations. The losses are attributed to high production costs as capacity is way under-utilised and an oligopolistic market structure that favours B100 buyers which consist of 7 petroleum oil refineries. Although production of B100 is closely adjusted to actual demand, which currently stands at 1.7-1.8 million litres per day, B100 producers are at disadvantage as the few petroleum refineries seem able to influence market prices. Trade sources cited that actual prices paid to CPO B100 producers are 2-3 baht[18]/litre and 3-4 baht for stearin B100 below reference prices. Prices for stearin B100 are sold at 1-2 baht/litre below CPO B100 due to a presence of "cloud point" appearance in stearin-derived B100. Due to this situation, producers sold their products below production cost for most of 2009. Some B100 producers who own feedstock processing plants (i.e. CPO crushing plants or cooking oil refineries) enjoy lower production costs than processors without feedstock processing. The latter group attempted to reduce their production costs by switching from CPO raw material to cheaper stearin in 2008. Nevertheless, this switch pushed stearin prices higher resulting in the disappearance of the price differential over CPO as prices increased from 14-15 baht/kg in late 2008 to 27-28 in mid-2009.

Consumption

The B100 biodiesel consumption, which is determined by the sale of the different blended ratios of biodiesel, increased from 62 million litres in 2007 to 446 million litres in 2008 and 609 million litres in 2009. The B100 consumption is anticipated to further grow to 655 million litres in 2010 and 935 million litres in 2011. In addition to a sharp growth in B100

[17]GAIN (Global Agricultural Information Network) Report is prepared by the United States Department of Agriculture (USDA) Foreign Agricultural Service and helps disseminate critical agricultural knowledge to USDA decision makers and the public.
[18]1 US$=30.83956 Thai baht

demand, there have been changes in the demand for the different blended biodiesel, as B2/B5 sales ratio rose from 2.45 in 2007 to 3.44 in 2008 due to the B2 production mandate in February 2008. However, the ratio dropped sharply to 1.23 in 2009 as the government eased the tax burdens and fees on B5 prices, making it 1.40-3.00 baht/litre (US 4-9 cents/litre) cheaper than B2 prices, as compared to a price gap of 0.50-1.50 baht/litre (US 1-4 cents/litre) in 2008. The B2/B5 sale ratio was expected to rebound in 2010 when the government increased the Oil Fund fee on B2 to lower a retail price gap following the possible negative impact of dry conditions on oil palm productivity.

Trade

Thailand has not imported or exported any B100 biodiesel products as the government practically restricts trade by not issuing import/export permits for these products. This is done to protect domestic palm growers.

Ending Stocks

The B100 biodiesel production is supplied to domestic petroleum oil refineries on a contract basis. The B100 producers try to keep their production limited to cover the contract amounts. As a result, the country's stocks held by either B100 producers or petroleum oil refineries are very low, and are currently at 10-15 million litres or about ten days of utilisation.

15.5 Jatropha in Mexico

Jatropha is native to Mexico and Central America and was likely transported to India and Africa in the 1500s by Portuguese sailors who were convinced it had medicinal uses. In 2008, recognising the need to diversify its sources of energy and reduce emissions, Mexico passed a law to encourage the development of biofuels that do not threaten food security and the agriculture ministry has since identified some 2.6 million hectares (6.4 million acres) of land with a high potential to produce jatropha.

Mexico continues to define its public policy strategy to establish a formal biofuels industry that will generate and distribute fuel additives derived from agricultural commodities, according to the USDA Foreign Agricultural Service. After the publication of the Biofuels Promotion and Development Law, the Government of Mexico (GOM) started work on the second stage of the definition of the legal framework related to bio-fuel generation, storage, distribution and final use.

Mexico's biofuel public policies are based on three elements:

1. The potential for renewable energy sources in Mexico to reduce fossil-fuel dependency, and address unpredictable changes in oil prices. Ironically, Mexico is a large crude oil producer, but imports a large amount of oil-derived products, so diversifying energy sources represents a critical task for the Government.
2. The need to reduce gas emissions related to fossil fuels by using "cleaner" environmentally friendly fuels. The use of ethanol as a substitute for gasoline

additives such as Methyl Tertiary-Butyl Ether (MTBE) in order to reduce pollution in Mexico's metropolitan areas has been a recurrent request by environmental NGO's.

3. Promotion of rural development, a very sensitive element of the Mexican economy. Since biofuels use agricultural commodities as inputs, the relationship with agriculture is inevitable, and there is significant political pressure to use biofuels to promote rural development without creating a "fuel vs. food" dispute.

Recent notable successes related to the promotion of the use of biodiesel in Mexico include:

1. On April 1, 2011 Interjet completed the first Mexican aviation biofuels test flight on an Airbus A320. The fuel was a 70:30 traditional jet fuel biojet blend produced from jatropha oil provided by three Mexican producers. One of these producers operates the largest jatropha farm in the Americas.
2. On August 1, 2011 Aeromexico, Boeing, and the Mexican Government participated in the first biojet powered transcontinental flight in aviation history. The flight from Mexico City to Madrid used a blend of 70% traditional fuel and 30% biofuel (aviation biofuel). The biojet was produced entirely from jatropha oil.

15.6 Pilot Projects in Jamaica

There have been many biodiesel studies and pilot projects in Jamaica from as far back as 1952. Key stakeholders in these studies include the Scientific Research Council (SRC), Bodles Agricultural Research Station and the PCJ. The main studies undertaken are presented below:

1. **1952*:*** Castor bean varieties were introduced from Costa Rica, USA and South Africa and tested at Orange River, Charlton, Grove Place and Bodles. They included both tall and dwarf varieties. Those that yielded best were at Bodles. The dwarfs Cimmaron (U.S.A.) and the Brazilian variety introduced from Colombia, yielded about 672 kg/ha (600 lb. seed per acre).

2. **1953*:*** Eight (8) varieties were tested including the Local 42 which along with the Brazilian Dwarf took 240 days to mature. The USDA 34, 35, Baker Dwarf 36, 38 and 39 took 134 days while Cimmaron took 194 days to mature. These were planted in June at Tinson Pen. They took 5 days to germinate, and as their recorded time to maturity varied (134 to 204 days), reaping was carried out at intervals when the capsules were mature. Irrigation was applied sufficiently to prevent wilting. It was proved that the removal of the main terminal bud did not increase yield or make maturity more uniform. The Local 42 selection shared with the other varieties non-shattering, non-dropping characteristics, vigorous growth and drought resistance, but had the disadvantage of being too tall (2.4 m) for easy reaping, not genetically pure and had a strong perennial tendency. The Brazilian Dwarf and Cimmaron, a semi dwarf, were the best suited to local conditions.

3. **1969**: Nine (9) varieties received from the USDA were planted in January, February and March in six (6) ecological areas to test their resistance to disease, namely Bodles, Orange River, Grove Place, Caenwood, Sunning Hill and Lyssons. The varieties tested

included Baker Hybrids 44, 296, 22, 55 and 6 as well as Lynn, Cimmaron, Hale and Dawn. The results indicated that:

- At Grove Place, in North Manchester under rainfed conditions, Dawn and Baker Hybrid 55 grew well and although drought affected showed reasonable resistance to *Alternaria ricini* (Leaf Spot) and *Sclerotinia ricini* (grey mould and virus).
- At Bodles the tested varieties Baker Hybrids 44 and 296 showed virus as well. Irrigation was available.
- At Caenwood (Portland), Baker Hybrid 6, a late flowering dwarf under the wet conditions only showed Leaf Spot.
- At Lyssons (St. Thomas) the hybrid dwarf variety Hale yielded well and was only attacked by Leaf Spot.
- In the wetter Sunning Hill (St. Thomas) Cimmaron showed both Leaf Spot and Grey Mould.
- At Orange River (St. Mary) the damp conditions resulted in both Leaf Spot and Grey Mould.

4. **1975**: Observations were made at Lawrencefield and Bodles (St. Catherine) of thirteen (13) hybrids and one local selection. The hybrids were from Industrial Chemicals Company, California and from the Weizmann Institute of Science, (Israel). Baker 72 gave good yields at both stations and also gave the best oil content, viz.58-64% as the Israel 22 gave 39.2%. These results were obtained from the Scientific Research Council. The Iodine and Saponification tests were consistent with the standards of imported castor oil.

5. **1976**: The varieties tested in 1975 were cut back to stump to test their ability to yield well as a ratoon. The best response to this was shown by Baker Hybrid 72.

6. **1977**: In 1977 the Scientific Research Council (SRC) conducted trials with castor beans at different elevations. Approximately twelve (12) acres of Baker Hybrid 72 were planted at Lawrencefield as a Crossing Block to provide female parent material for possible commercial production and for return to the Company which supplied the seed. This acreage was isolated from other varieties and was planted in the fall.

   While this acreage was growing, 0.6 ha (1½ acres) of the male parent was planted at the Agricultural Development Corporation (ADC) property at Amity Hall in Clarendon, but the field selected was patchy and the soil proved too alkaline (pH 9.0). Alternative isolated sites were difficult to find.

   Also, 0.6 ha (1½ acres) of local seed were grown and some hybrids of Baker 72 for comparison were planted at Warminister and at Teak Pen in collaboration with the Bauxite Company on mined-out land. Under rainfed conditions they suffered from drought and when the rains came weeds soon took over.

7. **1977/1978**: Early in 1977 (under the same SRC Project) it became evident that the Grey Mould disease was present in the Crossing Blocks at Lawrencefield and particularly so on the heads of the female parent. This became so widespread that the decision was taken after discussion with the consultant to cut back the entire area and to remove and burn

the material. The fungicide Benlate was then applied at the recommended rate and the regrowth of the hybrid produced 2,250 kg (in hulls). In addition 675 kg was yielded from the male parent grown at Bodles to make up for the deficit. The second planting had grown well.

At Denbigh Kraal a 1.2 ha (3 acre) plot had to be abandoned due to irrigation problems and planting had to be delayed until May. Rather late in the programme it was learnt that the Hybrid 72 is a poor pollinator and requires inter-planting with an acceptable pollen bearer. The choice was limited as seeds could not be imported from countries that might supply such material because of the quarantine regulations that dictated the barring of material from coffee growing countries where coffee rust was found. Thus it was proposed to use seed produced in the male rows of crossing blocks as pollen bearers, mixing 10-15% of male.

At the end of 1978, 2,250 kg of hybrid seed in hulls awaited the installation of a mechanical huller imported by the SRC. The Bauxite lands at Warminister and Teak Pen planted with castor in 1977 with local seeds showed spasmodic maturing and shattered excessively on reaching maturity. Also 1.2 hectares (3 acres) of Baker 72 was planted at Denbigh Kraal but irrigation problems followed by heavy weeds gave such a poor standard that it had to be abandoned.

8. **1978/1979**: In 1978 four (4) herbicides, were tested at Lawrencefield. All gave good control of weeds excepting Nut Grass and White Top.

9. **2000**: A pilot project carried out by the Bauxite Lands Department of the Jamaica Bauxite Institute (JBI) and supervised by the Agricultural Research and Development Office evaluated the agronomic requirements of local castor bean varieties from several bauxite communities in central Jamaica. A grant of J$370,000.00 from the Bauxite Community Development Programme through the Jamaica Bauxite Institute was made available to plant 4 ha (10 acres) of castor bean in Hyde Park, St. Ann (Kaiser), Moneague, St. Ann (WINDALCO), Cockpit, Clarendon (WINDALCO), and Kendall, Manchester (WINDALCO). Lands were prepared including bushing, ploughing and furrowing in April 2000 and seeds were planted in May 2000.

   Reaping of local varieties posed a problem as they dehisced when dry and therefore had to be reaped when they were mature instead of dry. Reaping was by hand and represented the major share of the production cost.

10. **2008**: In March 2008, the PCJ embarked on a Biodiesel Experiment (BE) to cultivate biodiesel feedstock at the PCJ's Font Hill Farm site. The experiment involved cultivation, harvesting and processing of biodiesel feedstock. The experiment plot chosen was based on the available land at the time. The area utilised was based on the quantity of seeds that were received for cultivation. The plot was part of an old nursery, indicating that the soil was fertile. The cultivation included drip irrigation.

    The primary objectives of the castor experimental plot were to:

    a. Ascertain the yield and oil content for the plot.

b. Build knowledge capacity regarding the growing of biodiesel feedstock on marginal lands.
c. Investigate the financial costs and benefits of biodiesel farming and small scale bio-oil production.
d. Inform policymakers of the local opportunities and challenges of pursuing biodiesel production, arising out of this experiment

The specifications of the castor bean planted were as follows:

Variety of castor bean: Nordestina
Quantity of seeds: 2.7kg or 6lbs
Area planted: 2,430 sq. m. (26,136 sq. feet) (0.60 acres)
Planting dates: March 19 & 26, 2008
Germination: Approximately 80%

Testing

Dimensional and weight testing of the castor oilseeds were conducted by the Jamaica Bureau of Standards (BSJ) during the period October - November 2008. The test results are outlined in Table 9.

Table 9: Test results for Castor Oil Seeds done by the BSJ

Tests	Results	Units
Oil content (hexane extract)	45.83%	(% by mass)
Crude Fibre Content	23.95	(% by mass)
Seed Moisture Content (for volatile matter @ 130^{0}C)	4.97	(% by mass)
Average weight for a sample of 20 castor seeds	0.596123	g
Average seed dimensions for a sample of 200 castor seeds, Length, Thickness and Width	L:15.8527, t:6.88075, w:11.8231	mm
Germination 7 and 14 days counts average respectively	63& 66 respectively	%

Source: Jamaica Bureau of Standards, 2012

Cost of the Experiment

The summary of actual costs is outlined in Table 10.

Table 10: Cost of Pilot Exercise

Cost Item	Actual Cost (J$)	% of Total
Planting	30,000	16
Weeding	112,500	61
Testing	38,000	20
Fertiliser	5,000	3
Total	**185,500**	**100**

Source: Jamaica Bureau of Standards, 2012

11. **2011:** Pilot projects were implemented at Bodles, St. Catherine and CARDI in Manchester. Jatropha and Castor beans are under cultivation at both locations. The suggested yields by seed suppliers are presented in Table 11. Of note is that there is no yield provided for the Local Large and Small varieties.

Table 11: Yield Reported by Seed Supplier

Crops	Source Country	Av yield/ plant(g)	Av yield (kg)/hectare @ 2000 plants/ha castor & 1000 plants/ha jatropha	Seed Oil (%) BSJ	Seed wt. (g)
Zibo 5	China	1,000	2,000	47.6	0.33
Zibo 8	China	1,000	2,000	43.8	0.33
Nordestina	Brazil	1,200	2,400	45.8	0.59
Jamaica Local Large	Jamaica	-		33.8	1.01
Jamaica Local Small	Jamaica	-		39.6	0.29
Jatropha	Brazil	3,952	3,952	16.7*	0.70
*Seed supplier suggests approximately 50%					

Source: PCJ CESED, July 2012

Table 12 shows the preliminary local yields from the first reaping of four varieties of castor on four experimental blocks at the Bodles Site in St. Catherine, Jamaica. Each crop is reaped several times and there are two crops produced within the year. Results are reported based on yield per plant rather than yield per hectare as planting density may vary per hectare. Planting distance will ultimately be developed based on the experimental results. The planting density used for the experiments was 3m x 1.8m and this would result in 1,851 plants per hectare.

Table 12: Yields in Jamaica from Four Experimental Plots at Bodles, St. Catherine

Bodles Research Station	Block 1 grams (g)	Block 2 grams (g)	Block 3 grams (g)	Block 4 grams (g)	Average Yield/Plant (g)	Average oil yield %	Average oil yield (g)
Jamaica Local Large	397	165	329	747	409	43.17	176.75
Zibo 5	1591	436	79	88	549	43.16	236.82
Zibo 8	2008	899	762	294	991	43.16	427.58
Nordestina	343	997	1129	923	848	43.58	369.55

Source: PCJ CESED, July 2012

Results for jatropha are not yet available given that this is the first year and commercial yields are not until the 3-4 years. However, a conclusion that can be drawn from the CARDI pilot project so far, is that jatropha has not thrived on mined out bauxite lands in Manchester. However, the full slate of reasons for this is still being compiled.

Conclusion

While there have been many projects over the past 70 years, and the Baker Hybrid72 variety has been identified as one of the best cultivars, it was not possible to use any of the oil seeds from previous studies for the current pilot projects being undertaken by PCJ/CESED in collaboration with Bodles and CARDI. In order to develop a sustainable feedstock, certified varieties must be used. Since the earlier studies were done in the distant past, it was not possible to identify certified local seeds.

Other varieties such as the Zibo 8 and 5 out of China together with Nordestina from Brazil (which was the subject of research in 2008) and local varieties (Jamaica Local Small and Large) are being used in the pilot projects.

These varieties are certified except for the Local Small and Large. It is possible that the local small and large being used could be off-shoot from the earlier trials, but this would have to be verified.

16.0 Jamaica's Biodiesel Policy Framework

The development of biodiesel as an energy source to offset fossil fuel use in Jamaica must be done within an established policy and legislative framework. This is evident from the experience in other countries that have already implemented biodiesel as an energy source successfully. It is critical that the policy is developed with stakeholders from key Government ministries such as Energy, Industry, Investment, Finance, Transportation and Agriculture together with private sector interests such as the oil marketing companies. To this end, Jamaica has developed a National Biofuels Policy.

Jamaica's National Biofuels Policy 2010-2030 is one of six (6) sub-policies under the National Energy Policy 2009– 2030, and is intended to support the achievement of the goals of the National Energy Policy. The objective of the National Energy Policy is to provide "affordable and accessible energy supplies with long-term energy security."

Jamaica's National Biofuels Policy is designed to achieve:

A modern, efficient, diversified and environmentally sustainable biofuels sector that contributes to Jamaica's long-term energy security and socio-economic development.

The development of this policy was a specific response to the National Energy Policy, which calls for the development of the energy sector, especially in areas related to renewables, diversification fuels, biofuels and waste-to-energy. This policy will also support the attainment of the vision set out in the National Renewable Energy Policy 2009 – 2030, which is expected to create a *"well developed, vibrant and diversified renewable energy sector that optimally utilizes indigenous renewable energy resources."*

This Biofuels Policy will guide the operations and processes associated with the development of the biofuels sector with specific focus on bioethanol and biodiesel. This will involve partnerships among the energy and agriculture sectors as well as linkages with other sectors such as transport, finance and planning. The Policy establishes a strategic framework – goals and a mix of short to medium term as well as long term strategies to support the development of the biofuels sector.

The development of this policy was guided by a Task Force comprising representatives of key government ministries and agencies (see Appendix 6 for the members of the Task Force). The Policy also benefitted from the input of key stakeholders in the agriculture sector, various stakeholders in the public and private sectors as well as from non-governmental and civil society organizations.

The National Energy Policy has set targets for renewable energy and the percentage diversification of energy supply as presented in Table 13 below.

Table 13: Targets for renewable energy and energy supply percentage diversification

Indicator	2009	2012	2015	2030
Percentage of renewables in energy mix	9%	11%	12.5%	20%
Percentage diversification of energy supply	9%	11%	33%	70%

Source: National Energy Policy 2010-2030

16.1 Goals of the National Biofuels Policy

There are four (4) goals in this policy which, when achieved together, will realise the vision of providing *a modern, efficient, diversified and environmentally sustainable biofuels sector that contributes to Jamaica's long-term energy security and socio-economic development.*

Goal 1: The economic, infrastructural and planning conditions conducive to the sustainable development of the biofuels sector, supported by intersectoral collaboration
Goal 2: Innovative and clean technologies facilitating a secure supply of biofuels into local and national distribution systems
Goal 3: A well-defined governance, institutional, legal and regulatory framework for the development of the biofuels sector
Goal 4: Jamaicans have the technical capacity and knowledge for the development, deployment, management and use of biofuels

Goal 1
The economic, infrastructural and planning conditions conducive to the sustainable development of the biofuels sector, supported by intersectoral collaboration

The further introduction of biofuels will depend on the existence and availability of appropriate infrastructure. Achieving this goal will ensure that existing infrastructure is retrofitted or refurbished, new infrastructure is built to facilitate and expand capacity in line with renewable targets, and systems can handle the physical transportation and possible environmental and human health hazards that may be associated with more widespread use of biofuels across the island.

This goal involves the establishment of a national enabling environment for the development of the biofuels sector. The focus will be on establishing the national and sectoral systems within which biofuels developers and implementers will function and the incorporation of biofuels initiatives within the relevant components of the national energy system such as the electricity grid and transportation fuel distribution. This will include creating opportunities for private sector investment as well as public-private sector partnerships.

Strategies and Actions for Goal 1

1. Create an enabling environment for private sector investment for the biofuels sector.
2. Develop government industry partnerships that consider tax incentives, net metering and power wheeling, carbon trade policy, and low interest loans to create a viable business platform for sustainable indigenous biofuels production.
3. Explore the implementation of tax credits tied to efficiency targets for biofuels production plants.
4. Provide incentives that encourage the parallel development of sugar, molasses, ethanol and cogeneration for own use and to supply excess electricity to the grid in the sugar cane industry.
5. Leverage diplomatic relations with trading partners to ensure that the existing trade agreements are maintained or improved to Jamaica's benefit.
6. Align biofuels initiatives with the Clean Development Mechanism (CDM) to facilitate the sale of carbon credits.
7. Finalize and adopt standards for the formulation of B100 and pursue development of standards for other biodiesel combinations such as B5.
8. Establish national and local systems to facilitate the sale of liquid fuel generated from biofuels.
9. Retrofit service stations to facilitate the dispensing of biodiesel.
10. Create a framework for net metering that allows electricity produced from biofuels facilities to be sold to the national grid.
11. Assess the infrastructural requirements for the transportation of biofuels across the island.
12. Develop port and land-based storage facilities at strategic locations across the island to reduce the frequency of transporting biofuels across the island.
13. In order to reduce harvesting and cultivation costs of sugar cane lands used for biofuels production, promote the development of alternatives for sugar cane farmers with farms below a certain size to be helped to find alternative crops that are economically more attractive. To determine the size below which alternative crops should be encouraged, undertake a full country assessment of land use combined with land ownership. This will allow a better estimate of the total land suitable for sugar cane and the selection of viable block sizes.
14. Develop protocols for handling local spills, leakages and other hazards associated with biofuels that are consistent with those developed for renewable energy as a whole
15. In the process of divesting government-owned sugar estates, include stipulations in the estate sales agreements binding the new owners to production of ethanol and power
16. Meet with new factory owners and estate management to assess business plans for ethanol production, power generation for sale to the grid and timelines. Evaluate national indigenous production goals and revise as needed.
17. Determine appropriate pricing regime for sugarcane to act as an incentive for increased production and a multi-product industry

Key Implementing Agencies and Partners

- Ministry of Science, Technology, Energy and Mining
- Ministry of Agriculture
- Ministry of Transport and Works
- Petroleum Corporation of Jamaica
- Office of Utilities Regulation
- Office of the Prime Minister
- Ministry of Finance and the Public Service
- Jamaica Public Service Company Ltd.
- JAMPRO (Jamaica Trade & Invest)
- Bureau of Standards, Jamaica

Goal 2

Innovative and clean technologies facilitating a secure supply of biofuels into local and national distribution systems

Under this goal, Jamaica will be able to implement a key aspect of its renewable energy policy by ensuring that it has identified high quality biofuels feedstock. The country will have to ensure that biofuels sources are adequate to provide stable energy supplies that are consistent with end-user demand and that do not jeopardize local food security or human and environmental health. Increasing the portion of energy obtained from biofuels will contribute to the achievement of Jamaica's targets of renewables in the total energy mix of 11% by 2012, 12.5% by 2015 and 20% by 2030.

Over the medium to long term, biofuels development is expected to ensure reduced dependence on fossil fuels for energy consistent with available commercially viable technological advances that are affordable to the end-user.

Strategies and Actions for Goal 2

1. Utilize a systems approach to feedstock production that addresses:
    a. Feedstock development and production
    b. Logistics/material handling
    c. Infrastructure
    d. Processing- products and co-products
    e. End-use
    f. Waste management
2. Introduce and enforce effluent discharge standards at sugar mills and distilleries and biogas facilities
3. Manage final waste generated in the production of biofuels to minimize potential adverse impacts on health and the environment
4. Adopt precision agriculture and real-time yield monitoring on mechanical sugar cane harvesters
5. Facilitate the production of E10 towards meeting local demand and for export from locally grown feedstock through the production of ethanol from locally grown sugarcane and the modernization of the sugarcane agro-industry

6. Satisfy the demand in the transport sector for the biodiesel mixture B5 through the production of locally grown feedstock and recycled vegetable oil
7. Develop biofuel "packages" - including the use of biodigesters that can provide energy in the medium term - that can be implemented at the household level using biomass that avoid pollution concerns
8. Promote power cogeneration from generated biomass in conjunction with bagasse cogeneration operations
9. Continue assessment of extent and effectiveness of domestically and internationally produced biofuels in the Jamaican energy sector and determine the best biofuel sources for Jamaica
10. Continuously review options for biofuel use that may have improved based on technological advances and integrate new advances into the public's awareness
11. Facilitate the expansion of current agricultural producers to convert their biowaste/biomass into biofuels either for cogeneration or for on-selling to the grid
12. Support the Government of Jamaica Country Strategy (JCS) and the Sugar Industry Research Institute in implementing strategies to increase sugar cane production while minimizing the environmental impact
13. Develop partnerships in research and development for development of biofuels, including biodiesel crops and technologies, new cane varieties and production systems and cogeneration options
14. Implement variety and field trials of potential crops to validate potential yields for biodiesel production under Jamaica's growing conditions, avoiding the introduction of invasive species. Crops with potential for biodiesel production other than castor and jatropha include coconut (which would tie in with Jamaica's existing well-established coconut industry), sunflower (which has benefits and a rotational crop in sugar plantations) and oil palm
15. Develop demonstration pilot programmes for small scale biodiesel production, trans-esterification, marketing and distribution
16. Promote best agricultural practices in growing biofuels feedstock crops to:
    a. Optimize the use of all available water resources between competing interests and minimize water use through more efficient irrigation/drainage systems
    b. Increase yields
    c. Optimize use of fertilizers
    d. Minimize use of pesticides and biocides and use organic methods where feasible and cost-effective
17. Promote green cane harvesting
18. Conduct water and energy audits of existing sugar estates to determine the most effective way to conserve water and energy and increase efficiency
19. Design and assist with development of sugar mills and ethanol plants to provide electricity to the grid year round. This will generally require some additional energy to that of the bagasse. The additional energy can come from a combination of sources including biogas from effluent treatment, cane trash, energy crops and other residues

Key Implementing Agencies and Partners

- Ministry of Science, Technology, Energy and Mining
- Ministry of Agriculture
- Sugar Industry Research Institute

- Petroleum Corporation of Jamaica / Centre of Excellence for Renewable Energy
- Environmental Management Division
- National Environment and Planning Agency
- Scientific Research Centre
- Bodles Agricultural Research Station / Centre of Excellence for Advanced Technology in Agriculture
- Caribbean Agriculture Research and Development Institute

Goal 3

A well-defined governance, institutional, legal and regulatory framework for the development of the biofuels sector

Achievement of this goal will result in a coherent policy and regulatory framework that will enable the development of a successful biofuels sector. This will require collaboration among institutions and systems related to energy, agriculture, transport, finance, environmental management and planning, among others to remove inconsistencies and create mutually beneficial policies, goals and strategies. This goal will focus also on ensuring that the institutions with responsibility for guiding this sector have the requisite capacity and protocols.

Strategies and Actions for Goal 3

a. Develop a coordinated, integrated approach to the use of land to generate biofuel feedstock in the context of the broader energy policy and other national plans relating to agriculture and food security
b. Ensure that biofuels development is included in the formalization of the Agricultural Land Use Policy that is being developed. The policy will specify how agricultural lands are to be utilized
c. Review the National Land Policy to be aligned with the Biofuels Policy to ensure that biofuels development is included in the directives for deciding optimum use of marginal or idle lands and that lands used for biofuels production do not disrupt the functioning of the local ecosystems or impact negatively on the availability of lands for food production
d. Align proposed national spatial plan with biofuels policy to address issues related to land use for the development of biofuels.
e. Ensure that the transportation policy facilitates the continued introduction and sustainability of biofuels in the transportation sector
f. Ensure that the motor vehicle policy sufficiently incentivizes and prescribes an increased ratio of flexible fuel automobiles to regular petroleum using vehicles
g. Reconcile issues related to the railways in regard to the Highway 2000 Programme to ensure access by biofuels producers to rail transport

Key Implementing Agencies and Partners

a. Ministry of Science, Technology, Energy and Mining
b. Ministry of Agriculture
c. Ministry of Transport and Works
d. Office of the Prime Minister
e. National Land Agency

f. Office of Utilities Regulation

Goal 4
Jamaicans have the technical capacity and knowledge for the development, deployment, management and use of biofuels

Achievement of this goal will ensure that the country is well aware of biofuels options as alternatives to their traditional forms of energy and will require continuous demonstration of the viability and stability of the various alternatives that are being promoted to end-users as contributing to diversification of the energy mix. This goal also addresses the building of capacity among professionals in the energy and agriculture sectors regarding the development and implementation of new and existing biofuels technologies. This goal supports the enhancement of the Sugar Industry Research Institute (SIRI) as a national asset in supporting scientific input to sugar cane potential for renewable energy and the Jamaica sugar industry development and viability.

Strategies and Actions for Goal 4
1. Support the development of early action first generation biofuels plants by setting-up a group of biofuels experts who are available to provide information about feedstock production practices, process options to maximize overall returns and related issues and to facilitate the transfer of lessons learned in other countries to help entrepreneurs in Jamaica make informed choices
2. Implement a comprehensive education and outreach programme to raise awareness of biofuels among key stakeholders and to garnish support and overcome key technical and social barriers to biofuels development
3. Build the capacity of the Rural Agriculture Development Agency to enable the organization to raise awareness among farmers regarding biofuels
4. Provide education and technical support on following ISO 14000 Environmental Management in biofuels plants
5. Increase visibility of the Sugar Industry Research Institute to potential investors and enable it to become an integral part of the national effort to develop the biofuels sector by providing guidance to farmers, supplying cultivars, and disseminating information on "best practices" from other countries
6. Develop a biofuels resource registry to capture information on usable biofuels
7. Seek opportunities to develop local expertise and knowledge of emerging biofuels technologies through scientific exchange, international industry and government internships, sabbaticals, and professional seminars and conferences
8. Promote international and multidisciplinary research into agricultural practices and advanced biofuels production

Key Implementing Agencies and Partners
- Ministry of Science, Technology, Energy and Mining
- Petroleum Corporation of Jamaica / Centre of Excellence for Renewable Energy
- Sugar Industry Research Institute
- Rural Agriculture Development Agency

- Bodles Agricultural Research Station / Centre of Excellence for Advanced Technology in Agriculture

16.2 Policy Implementation and Institutional Framework

The Ministry of Science, Technology, Energy and Mining will lead and facilitate the implementation of the Biofuels Policy in collaboration with the Ministry of Agriculture and other Government Departments and Agencies, the private sector and NGOs. The successful implementation of this policy will require that linkages be made between the energy and agriculture sectors as well as other aspects of the economy and society including, but not limited to, transport, environment, finance and education.

The key players in the implementation of the National Biofuels Policy and their roles and responsibilities are described below.

1. The **Ministry of Science, Technology, Energy and Mining** will be responsible for the overall implementation of the Biofuels Policy and will provide expert advice and guidance. The **Petroleum Corporation of Jamaica**, which is an agency of the Ministry, and its **Centre of Excellence for Sustainable Energy Development (CESED)** will be involved in facilitating the implementation of biodiesel initiatives.
2. The **Ministry of Agriculture** and its agency the **Rural Agricultural Development Agency (RADA)** is responsible for the management of agriculture and will have significant responsibility for the implementation of this policy as it relates to suitable lands for biodiesel feedstock and feedstock varieties.
3. The **Environmental Management Division** within the Ministry with portfolio responsibility for the environment will provide expert advice and guidance on the environmental impacts of all biofuels production programmes. The Department will facilitate proposals for consideration of projects to benefit from the Clean Development Mechanism.
4. The **National Environment and Planning Agency** (NEPA) will have the responsibility of ensuring that biofuels production facilities operate in such a way that human health and the environment are protected from harmful emissions.
5. The **Office of Utilities Regulation** (OUR) will have oversight responsibility for the regulatory framework guiding biofuels initiatives. That office will protect the interest of both the consumer and investor in the provision and utilization of public utility services. The OUR will work with the **Jamaica Public Service Company** (JPSCo) to create net metering arrangements with biofuels facilities to sell electricity to the national grid.
6. The **Ministry of Finance and Planning** will be responsible for establishing any financial or tax incentives or disincentives for the development of the biodiesel sector.
7. **Local universities** will play a key role in keeping abreast of research in biodiesel technologies and uses for by- and co-products as well as linkages between biodiesel facilities and impact on human health and the environment, thereby ensuring environmental sustainability.
8. Agricultural Research bodies such as **Bodles Agricultural Research Station / Centre of Excellence for Advanced Technology in Agriculture** and **Caribbean Agriculture Research and Development Institute (CARDI)** will need to

continue to examine and develop the best varieties of feedstock for biodiesel production with the objectives of increasing yields and minimizing pests and disease while optimizing inputs such as labour (planting and harvesting), water requirements and the use of agrochemicals such as pesticides and fertilizers.

16.3 Monitoring and Evaluation

The Ministry of Science, Technology, Energy and Mining is accountable for monitoring and evaluating the implementation of the Policy. The proposed indicators for monitoring the biodiesel strategy are derived from the indicators outlined in the National Biofuels Policy 2010-2030. This is to ensure that the strategy is in keeping with the four (4) policy goals outlined earlier and will, in turn, contribute to the achievement of the related goals as set out in the National Energy Policy 2009-2030 and Vision 2030 Jamaica, National Development Plan.

CESED will continuously monitor and evaluate the implementation of biodiesel policy goals while the Ministry of Science, Technology, Energy and Mining will conduct broad stakeholder consultations periodically to review and assess the effectiveness of the Policy using the indicators identified below as a guide. The results of the assessment including recommendations will be published in an annual report for submission to the Cabinet.

Proposed Indicators

The proposed indicators for biodiesel specifically contained in the National Biofuels Policy over the period 2010-2030 are presented in Table 14. These indicators are the building blocks of the Monitoring and Evaluation programme. Targets will be set in collaboration with the key implementation partners.

Table 14: Biofuels Indicators and Targets

Indicator	**Baseline**	**Targets**		
	2010	**2012**	**2015**	**2030**
Percentage of energy from renewable energy sources generated from biodiesel				
Volume of biodiesel produced (litres)				
Number of farmers/employees involved in biodiesel production				
Land utilized for biodiesel production (ha / % total agricultural land)				
Average biofuels feedstock yield for each crop (tonnes/ha)				

Source: Environmental and Engineering Managers (EEM) 2012

16.4 Policy Gaps

The National Biofuels Policy has a strong focus on first generation biofuels such as ethanol production from sugarcane. There is insufficient focus on oil seed crops (food and non-food) that produce biodiesel. With the increasing global focus on second generation biofuels, more specific policy directives are required. It was found that combining the policies for ethanol and biodiesel production was a disadvantage as each has specific requirements that are not necessarily the same.

Based on a review of the policies in other countries the following are noted as gaps in the policy on second generation biofuels:

1. **Time based blending targets**

Time based, graduated blending targets must be established together with the relevant incentives to facilitate the cultivation of the oil seeds and the establishment of biodiesel production facilities.

2. **Social programmes to facilitate production of biodiesel feedstock**

The social aspects of the programme must be well designed to ensure that the farmer is able to make a profit from his/her involvement in the value chain. At the end of the day the farmer should be economically better off by investing in biodiesel value chain.

3. **Quality control mechanisms**

A system of quality assurance and quality control is integral to the success of a biodiesel programme and must be developed simultaneously with all other aspects of the programme.

4. **Occupational Health requirements**

There are a number of occupational health hazards associated with the production of biodiesel that must be taken into consideration. The Ministry of Labour's Occupational Health Department would need to be a stakeholder in the development of the biodiesel sector.

5. **Tax waivers and incentives to farmers and biodiesel producers**

The incentives and tax structure applicable to this sector and how it interfaces with other sectors will play a key role in the success of developing the biodiesel sector.

Additional indicators will be required to monitor these policy issues not covered in the National Biofuels Policy and others such as compliance with environmental legislation and the extent to which the social and economic situation of farmers and rural folk improve.

17.0 Draft Biodiesel Standard

The Bureau of Standards Jamaica has developed a draft Jamaican standard specification for biodiesel fuel. The standard specifies the requirements for diesel fuel oils suitable for various types of diesel engines and Biodiesel blends up to B5. This specification covers biodiesel [B100] grades for use as a blend component with most current Automotive Diesel Oil specification. The standard excludes requirements for Biodiesel blends B6 – B20.

Based on the draft standard biodiesel is defined as a fuel comprised of monalkyl esters of long chain fatty acids derived from vegetable oils or animal fats, designated B100. Biodiesel blend (BXX), is defined as biodiesel fuel with diesel oils. In the abbreviation BXX, the XX represents the volume percentage of biodiesel fuel with diesel fuel oils.

In April 2012, the Bureau of Standards Jamaica recommended to the Minister of Industry, Investment and Commerce that he seek ministerial approval from the Minister of Energy and Mining to amend the Petroleum Quality Control Regulations (1990) for the specifications for distillate fuel (Automotive Diesel) to include up to 5% B100 (B5 diesel). As indicated in the policy gaps however, there is still the need for a graduated blending timetable for biodiesel.

18.0 Land Suitability

Various studies indicate that Jamaica has potential for jatropha and castor bean production. Specifically, following several filtering steps, the total land area of varying suitability for jatropha and castor bean cultivation is 280,277 hectares. Even though this large acreage has varying suitability, approximately 42,797 hectares are deemed "suitable" and "very suitable" for jatropha and castor cultivation. The vast proportion of the land that is potentially available is classified as "moderately suitable" and "marginally suitable."

The projected land requirement for castor and/or jatropha cultivation is approximately 27,000 hectares with marginal yields to meet a B5 biodiesel blend for the transport sector. The potential available lands would adequately meet this requirement. It is acknowledged that the accuracy of these suitable areas has the potential to be greatly increased, as the data is based on a 1998 assessment and significant developments have occurred in Jamaica over the past thirteen years that may have impacted land use nationally.

Moderately suitable and marginally suitable lands for castor and jatropha cultivation provide the greatest opportunity in terms of available lands island wide. These lands fall within the broader objective of expanding biofuels crop production without competing for arable lands used in food crop production. It should be noted, however, that the use of marginal lands may pose significant limitations that may affect the productivity and subsequently the economic viability of a biodiesel programme. As pointed out by Harry Stourton of Sun Biofuels, marginal lands produce marginal yields.

The pilot crop production currently under way at the Caribbean Agricultural Research and Development Institute (CARDI) demonstration farm in Knockpatrick Manchester and The Ministry of Agriculture and Fisheries Bodles Research Station in Old Harbour St. Catherine, are both being carried out on lands that are categorized as "marginally suitable for castor and jatropha cultivation". The results of this pilot study will give a good indication of the types of yields that can be expected when the crops are grown under these conditions.

19.0 Biodiesel Initiatives in Jamaica

Recognising the inherent value of using biodiesel as a fuel, there are two (2) companies in Jamaica that have made the move to use this fuel in their fleets. One entity is a public sector organization and the other a private sector company.

In 2009, the National Solid Waste Management Authority (NSWMA) implemented an experimental programme to use biodiesel to fuel some of the garbage trucks in its fleet. The state minister in the Office of the Prime Minister with responsibility for local government, at the time, Robert Montague, was reported in the Jamaica Daily Gleaner newspaper dated October 29, 2010 as saying that he told

Parliament that the experiment appears to be bearing fruit and that "Early indications are that savings are somewhere in the region of 20% in both fuel and operational costs associated with biodiesel". He alluded to lower maintenance costs because of the lower sulphur content than the normal diesel.

According to him, the NSWMA experimented with the use of 3,650 litres of bio-fuel in 20 trucks owned by the Agency at an initial investment outlay of J$273,000.00, in partnership with Jamaica Biofuels. Waste vegetable oil collected from hotels and restaurants by the NSWMA was provided to Jamaica Biofuels, where it was converted to biodiesel at a 96% conversion rate of oil to biodiesel.

The Sunday Gleaner dated March 4, 2012 reported on the initiative taken by National Bakery to use biodiesel-diesel mix for their fleet of delivery vehicles. The fuel used is a combination of diesel and biodiesel, which has been processed at the company's Osborne Road, St. Andrew, premises.

For the past five years, National Bakery has been using the leftover vegetable oil in which some of its products - such as peanut and cashew - have been cooked, to supplement the fuel for its fleet. It now has a pump dedicated to biodiesel and there have been times when the company CEO has used the more environmentally friendly fuel in his personal vehicle.

The company is able to process an average of 40 gallons (151 L) of biodiesel every 36 hours and this is used in six of the trucks in a 50:50 mix with the regular diesel.

The Fleet Manager admits that the fuel-production process is somewhat time-consuming because of the need to extract the water from the mixture. In fact, the process can take from 24-36 hours, and much of this time is spent doing the necessary tests during the process.

20.0 Biodiesel Value Chain

The research has shown that feedstock prices are a significant part of the biodiesel production costs and as such an important component in the economic viability of production. If the intention is to promote economic and social development in rural communities, supportive measures in the agriculture sector to ensure good yields need to be led by the government and/or in cooperation with potential investors.

Farming skills need to be developed and technical assistance provided to help maximize yields. As such, good accessibility to on-farm technology through use of high yielding varieties, access to training and irrigation, are key factors in achieving high productivity of feedstock and reducing biodiesel production costs.

Other challenges that can hinder development of biodiesel production chains include limited rural infrastructure - transportation (roads, rail and); potable and industrial water provision agro-processing and biodiesel plants) and rural electrification, to effectively support and service the rural industrialization.

20.1 Biodiesel Production Economics

A small-scale biodiesel producer will not use some of the equipment and steps involved in large, commercial biodiesel production because of costs and scale of operation.

A mechanical cold press can be used to extract the oil. The presses are produced by several manufacturers worldwide and are available with different capacities and cost. In this example, a small oilseed screw press manufactured in Europe at a cost of US$7,500 is used. It has an hourly throughput of about 62 pounds (28 kg) of seed and can be run automatically for long periods of time. Other equipment associated with oil extraction, such as oil tanks and containers for meal, is about US$1,500.

After oil extraction, typically one of two processes is conducted to remove gums from the vegetable oil. The amount of gums can be reduced naturally by allowing the oil to settle for one or three weeks or the vegetable oil can be "washed" one or more times, as needed, and then "dried." In either case, the oil can be filtered to further remove impurities.

The next step is transesterification. Several turnkey small-scale systems are available for purchase. In this example, a system to make 50 gallons per batch (189 L/batch) is used at a cost of $4,000. This analysis assumes that the on-farm small-scale biodiesel producer already has storage and moving equipment for oilseed and a building to house the oilseed press and biodiesel processing equipment. No fixed cost for these items is calculated. Also, no cost or benefit from the unrefined glycerine co-product is assumed.

Table 15 indicates that the cost of making biodiesel is $1.37 more per gallon than the price of No. 2 petroleum diesel if canola seed is valued at 14 cents/pound and diesel at $2.40/gallon (excluding excise taxes). The biodiesel must meet ASTM standards but unfortunately, the cost of tests to substantiate that the quality meets ASTM standards may be cost-prohibitive for a small biodiesel producer.

Table 15: Example budget for small-scale biodiesel production, 50 gallon per batch

Direct Cost	**Amount**	**Unit**	**$/Unit**	**$/Batch**	**$/Gallon**
Oil Extraction					
Canola seed[19]	1,105	Lbs.	0.14	154.70	3.09
Electricity				3.50	0.07
Maintenance and supplies				2.50	0.05
Labour	1	Hr.	12.00	12.00	0.24
Listed direct costs				**172.70**	**3.45**
Fixed costs of oil extraction equip[20]				**13.84**	**0.28**

[19] Seed required for 50 gallons of oil, assuming 43% oil content, 80% oil extraction efficiency and 7.6 pounds of canola oil per gallon.

[20] Investment in oil extraction equipment is $9,000 and for biodiesel processing equipment it is $4,000. Assumes 10-year life, 10% salvage value, straight-line depreciation, 6% opportunity charge on average annual investment and annual production of 80 batches (4,000 gallons).

Direct Cost	Amount	Unit	$/Unit	$/Batch	$/Gallon
Total listed costs				**186.54**	**3.73**
Credit for meal (13% oil)	725	Lbs.	0.07	-50.75	-1.01
Cost of oil				135.79	2.72
Processing Oil to Biodiesel[21]					
Canola oil (from above)	50	Gal	2.72	135.79	2.72
Methanol	10	Gal	2.60	26.00	0.52
Sodium hydroxide[22]	3	Lbs.	1.20	3.60	0.07
Electricity				2.50	0.05
Maintenance and supplies				2.50	0.05
Labour	1	Hr.	12.00	12.00	0.24
Listed direct costs				**182.39**	**3.65**
Fixed costs of processing equip[20]				**6.15**	**0.12**
Total listed costs of biodiesel production[23]				**188.54**	**3.77**
Price of No. 2 diesel w/o excise taxes					2.40
Gain or loss relative to No. 2 diesel					-1.37

North Dakota State University Extension Services, October 2007
http://www.ag.ndsu.edu/pubs/ageng/machine/ae1344.pdf

The main variables in the economics of biodiesel production are the cost of oilseed and the price of petroleum diesel. Biodiesel production would become profitable at certain levels of oilseed and diesel prices. For example, using Table 16 biodiesel production would break even at a canola price of $0.105 per pound if the price of diesel (excluding excise taxes) was $3 per gallon.

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[21] Process uses five parts canola oil to one part methanol. Output is approximately five parts biodiesel and one part unrefined glycerol of no value.
[22] Can vary by titration test
[23] Biodiesel has about 8% less energy than No. 2 diesel, but has better lubricant qualities. Divide by .92 to adjust to No. 2 diesel energy equivalent.

Table 16: Gain (loss per gallon) from small-scale biodiesel production, excluding tax credits, per gallon, at different canola and No. 2 diesel prices

	Canola ($/lb.)						
Diesel $/Gal	**0.09**	**0.10**	**0.11**	**0.12**	**0.13**	**0.14**	**0.15**
(no tax)							
1.00	(1.67)	(1.89)	(2.11)	(2.33)	(2.55)	(2.77)	(2.99)
1.50	(1.17)	(1.39)	(1.61)	(1.83)	(2.05)	(2.27)	(2.49)
2.00	(0.67)	(0.89)	(1.11)	(1.33)	(1.55)	(1.77)	(1.99)
2.50	(0.17)	(0.39)	(0.61)	(0.83)	(1.05)	(1.27)	(1.49)
3.00	**0.33**	**0.11**	(0.11)	(0.33)	(0.55)	(0.77)	(0.99)
3.50	**0.83**	**0.61**	**0.39**	0.17	(0.05)	(0.27)	(0.49)

North Dakota State University Extension Services, October 2007
http://www.ag.ndsu.edu/pubs/ageng/machine/ae1344.pdf

Table 17 shows the cost of biodiesel production when only direct costs are considered. After the machinery and equipment necessary for biodiesel production have been purchased, ownership costs will be incurred whether or not production occurs. In theory, until biodiesel producers divest themselves of the biodiesel equipment, they are better off continuing to produce biodiesel if all direct costs and any portion of fixed costs are covered.

Table 17: Cost per gallon of biodiesel, excluding labour and fixed costs[1]

	US$/gallon
Cost excluding fixed costs	3.37
Cost excluding labour costs	3.29
Cost excluding fixed and labour costs	2.89

[1] Assumes total cost of $3.77 per gallon, 40 cents per gallon fixed costs and 48 cents per gallon labour cost.

North Dakota State University Extension Services, October 2007
http://www.ag.ndsu.edu/pubs/ageng/machine/ae1344.pdf

Table 17 also shows the cost of biodiesel production when a charge for operator labour is not considered. Some producers of biodiesel may be motivated by more than business purposes. They may feel satisfaction in producing their own fuel and reducing the reliance on imported oil. Biodiesel could be considered a worthwhile hobby that does not need to show a return to labour.

20.2 The US Department of Agriculture Economic Model

The US Department of Agriculture, Agricultural Research Service has developed a computer model to estimate the capital and operating costs of a moderately-sized industrial biodiesel production facility.

The major process operations in the plant were continuous-process vegetable oil transesterification, and ester and glycerol recovery. The model was designed using contemporary process simulation software, and current reagent, equipment and supply costs, following current production practices. Crude, degummed soybean oil was specified as the feedstock.

- Annual production capacity of the plant was set at 37,854,118 L (10 x 10^6 gal).
- Facility construction costs were calculated to be US$ 11.3 million. The largest contributors to the equipment cost, accounting for nearly one third of expenditures, were storage tanks to contain a 25 day capacity of feedstock and product.
- At a value of US$ 0.52/kg (US$ 0.236/lb.) for feedstock soybean oil, a biodiesel production cost of US$ 0.53/L (US$ 2.00/gal) was predicted. The single greatest contributor to this value was the cost of the oil feedstock, which accounted for 88% of total estimated production costs.

An analysis of the dependence of production costs on the cost of the feedstock indicated a direct linear relationship between the two, with a change of US $ 0.020/L (US$ 0.075/gal) in product cost per US$ 0.022/kg (US$ 0.01/lb.) change in oil cost.

Process economics included the recovery of the co-product glycerine generated during biodiesel production, and its sale into the commercial glycerine market as an 80% w/w aqueous solution, which reduced production costs by approximately 6%.

The production cost of biodiesel was found to vary inversely and linearly with variations in the market value of glycerine, increasing by US$ 0.0022/L (US$ 0.0085/gal) for every US$ 0.022/kg (US$ 0.01/lb.) reduction in glycerine value.

The model is flexible in that it can be modified to calculate the effects on capital and production costs of changes in feedstock cost, changes in the type of feedstock employed, changes in the value of the glycerine co-product, and changes in process chemistry and technology.

20.3 A Tanzanian Economic Assessment

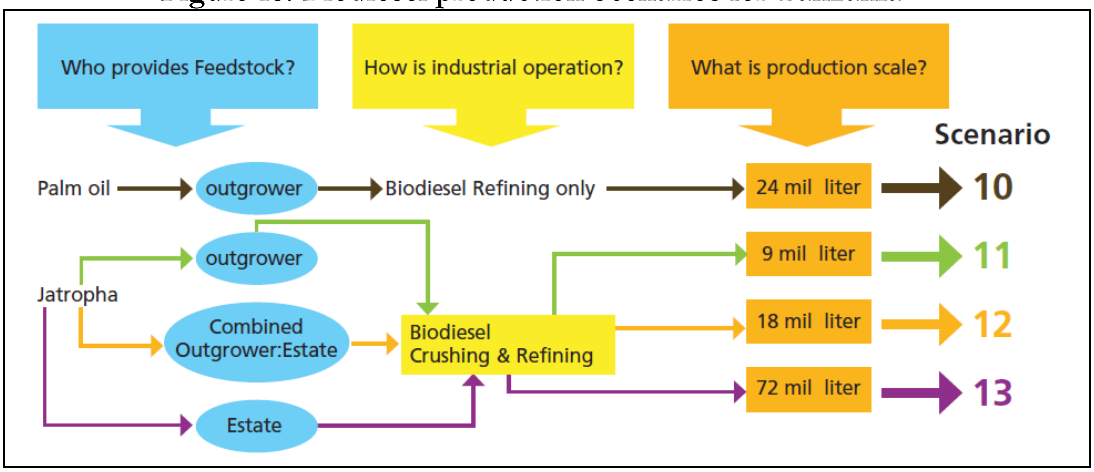
In a study done sometime between 2009-2010, biodiesel production was assessed from two feedstock palm oil and jatropha. Palm oil was limited to one scenario since there was already concern about the use of palm oil for fuel when Tanzania is already a net importer of palm oil for food. In the case of jatropha, three scenarios representing potential investments were simulated (Table 18 and Figure 18). Outgrowers refer to small-scale farmers and estate refers to commercial farmers.

Table 18: Characteristics of biodiesel scenarios

Scenario	Features
Scenario 10	• Stand alone refinery facility only (no oil extraction), small scale. • Palm oil produced from outgrowers.
Scenario 11	• Combined facility oil extraction and refinery, small scale. • Jatropha from outgrowers (10,000 ha).
Scenario 12	• Combined facility oil extraction and refinery. • Jatropha from estate (10 000 ha) and outgrowers (10,000 ha).
Scenario 13	• Combined facility oil extraction and refinery larger scale. • Jatropha from estate (80 000 ha)

http://www.fao.org/docrep/012/i1544e/i1544e05.pdf

Figure 18: Biodiesel production Scenarios for Tanzania



http://www.fao.org/docrep/012/i1544e/i1544e05.pdf

Considering the production costs estimated for conventional proven technology for biodiesel production in the country, the lowest cost for production of biodiesel is obtained from jatropha ranging from as low as US$ 0.66 per litre to as much as US$ 0.95 per litre (Table 19). In the case of jatropha biodiesel, results indicate that the most significant factor is the origin of the feedstock. Scenario 11, which is based on feedstock from outgrowers, has the least cost of production, followed by Scenario 12, whereby feedstock comes from a combination of estate and outgrower production and the highest production cost is estimated for estate production in Scenario 13. Jatropha is a very labour-intensive crop and as such commercial plantations will spend substantial amount of money in hired labour. The difference between Scenarios 11 and 13 is remarkable; it costs 30% more to produce biodiesel from estate production than outgrowers. This indicates that integrating outgrowers in the jatropha biodiesel supply chain is a more economically attractive option.

These results in Table 19 indicate that changes in technology have savings on processing inputs and utility costs but these are relatively small compared to the effect of feedstock price. In the case of palm oil the import parity price of crude palm oil was taken to be US$626 per ton and the price of jatropha US$164 per ton (at 4 ton per hectare) for outgrowers and US$270 per ton for estate[24]. These values were provided by the World Bank in Tanzania.

Therefore, for both palm oil and jatropha biodiesel production, feedstock rather than technology is most significant to the cost of production.

Table 19: Biodiesel production costs at plant gate based on scenario and technology level US$/L

Scenario	**Technology level**		
	1 Conventional Technology	**2 Combination of Conventional Technology and Advanced Technology**	**3 Advanced Technology**
Palm Oil			
Scenario 10	0.8302	0.8101	0.8011
Jatropha			
Scenario 11	0.7439	0.6865	0.6687
Scenario 12	0.8172	0.8171	0.7850
Scenario 13	0.9551	0.9361	0.9274

http://www.fao.org/docrep/012/i1544e/i1544e05.pdf

Production costs of jatropha biodiesel using conventional technology (Level 1) in Tanzania are higher than those estimated for India (US$0.602 per litre)[25] but somewhat lower than the cost estimated for Zambia (US$0.95 per litre)[26] and closer to those estimated for Mozambique (US$0.780 per litre)[27]. Level 2 is a hybrid of both conventional technologies with new improved technologies which are more efficient and Level 3 is advanced technologies that may not be commercially available yet.

In the case of palm oil biodiesel, the production costs are higher than the production costs reported in Malaysia which are estimated at US$0.69 per litre when the market price of crude palm oil is at US$670 per ton[28]. The European biodiesel market projects a lower production cost for biodiesel (US$0.58 -US$0.62 per litre) but as the main feedstock is rapeseed oil this

[24] Information for feedstock was collected in the country. The Palm Oil Parity Cost was provided by Mngeta, a potential biodiesel investor. The jatropha buying price from outgrowers was provided by Prokon, a biofuel investor in the country. The jatropha price in commercial (estate) production was assumed to be the production cost. The production cost for jatropha at commercial (estate) scale was based on values provided by the World Bank in Tanzania.
[25] Production cost for India came from publication by D. Ramesh *et al.*, titled Production of biodiesel from *jatropha curcas* oil by using pilot biodiesel plant.
[26] Presentation from Oval Biofuel Limited, September 2009.
[27] The production costs for Mozambique are taken from the Mozambique Biofuel Assessment prepared by Ecoenergy International Corporation in May 1, 2008.
[28] The production cost for Malaysia came from publication by Gregore Pio Lopez and Tara Laan entitled Biofuels - at What Cost? Government support for biodiesel in Malaysia. In the study the production cost is reported in energy equivalent. This value was adjusted to have cost on volume basis to be able to compare to production cost obtain in this analysis.

is closely linked to the vegetable oil market and could be even higher if the prices of vegetable oil commodities increase[29].

The biofuel processing cost includes capital and operating costs. The capital costs were estimated based on the scale as set by the level of production and adjusted for each of the production scenarios as necessary. Capital costs were based on global average equipment prices incorporated in the commercial simulator Aspen Plus. The operating costs were obtained from national statistics data and used in the simulation. Operating prices are the same for all scenarios and modified according to consumption as required by each of the production scenarios.

- The local prices reported for processing chemicals needed for biodiesel production were US$811 per ton for methanol and US$1,250 per ton for sodium hydroxide.
- Labour costs were based on the 2006 Tanzania Labour Survey and were estimated to be US$0.29 per hour for unskilled and US$0.44 per hour for skilled labour.
- The price of electricity was estimated to be US$0.03796 kilowatt hour and water price was estimated to be US$0.00038/cubic metre. Both water and electricity prices came from the prices stipulated by the Energy and Water Regulatory Commission.
- The tax rate was assumed to be 30% per period. The depreciation period was ten years.
- Construction costs were estimated based on assumed firm clay soil conditions.
- Maintenance and plant overheads were assumed to be 3% and 50%, respectively.

This analysis assumed 30% of the crop production cost for feedstock transport costs from farm to plant gate and was included in the feedstock price.

As there is no current biofuel production in Tanzania, the distribution of biofuel to end markets was estimated based on transportation costs for the sugar-cane industry and estimated from the sugar sector study carried out by the Federal Agricultural Research Centre Institute of Farm Economics. The base cost for rail was estimated based on average cost of US$0.017 per litre and the transport costs from Dar es Salaam to Rotterdam Port CIF were estimated to be US$0.08 per litre. The cost for road transport was estimated based on petrol distribution and provided by the Energy and Water Regulatory Authority. Road transport per litre of biofuel was based on 10 Tanzanian Shillings per 30 km per litre.

From the assessment for Tanzania the following information was gathered:

- The feedstock price is a significant part of the production cost and as such an important component in the economic viability of biodiesel production.
    - In the case of jatropha biodiesel production, feedstock supplied by outgrowers represents a more attractive option than commercial (estate) production.
    - In the case of palm oil the price is very unstable and closely linked to vegetable oil global markets. This severely affects and puts too much risk on the development of the use of palm oil for biodiesel production. Biodiesel production from palm oil is not recommended as this is not economically viable.

[29] The production cost for biodiesel in the EU came from report on Techno-economic analysis of Biodiesel production in the EU: a short summary for decision-makers, Report EUR 20279 EN, May 2002. ftp://ftp.jrc.es/pub/EURdoc/eur20279en.pdf

- Limited market accessibility to chemical inputs necessary for the biodiesel production process (such as methanol and sodium hydroxide) contribute to higher production costs.
- It should be noted that the estimated production costs for jatropha biodiesel are very uncertain due to issues surrounding the feedstock availability, the need to better understand the agronomy and concerns with potential risks presented by jatropha to cassava mosaic disease. Therefore at the present time a significant potential of jatropha should be limited to small-scale production and in particular encourage energy uses for local or self-consumption. One such option is the use of raw vegetable oil in power generation for domestic use in rural communities.
- It is important for Tanzanian to explore the possibility of developing other oilseed crops for biodiesel production such as moringa, castor bean, and cotton among others.
- If biodiesel production is desired the viability of this should be promoted first at the small-scale rather than at the large scale and for domestic uses rather than export markets.

21.0 Biodiesel Value Chain in Jamaica

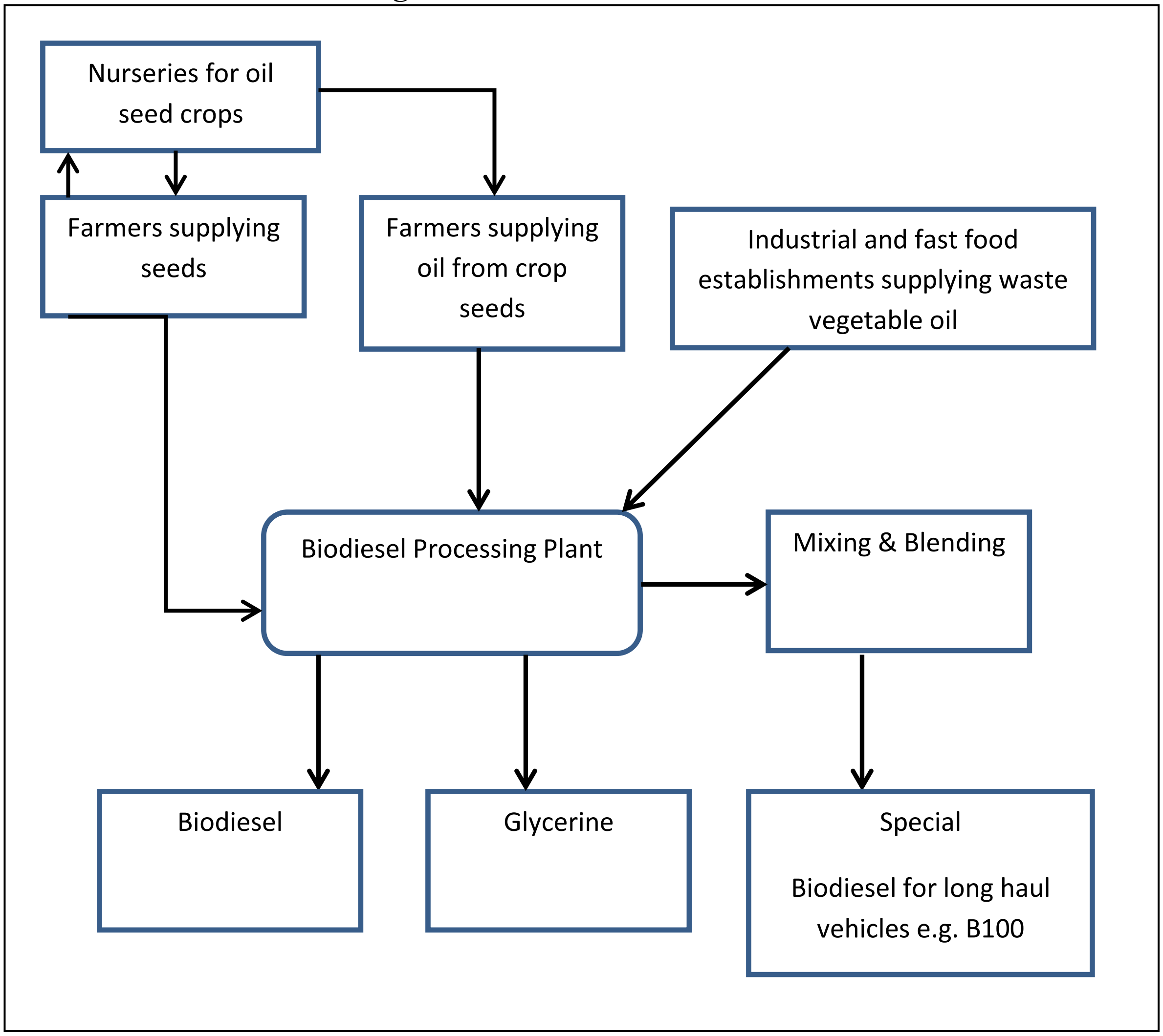
Large-scale production could be at the national level where one or two processing plants are established to receive the seeds and/or oil from farmers. Large-scale production can also be for dedicated use by a vehicle fleet. For example a company that generates significant amount of waste vegetable oil that also has a large vehicle fleet can process the waste vegetable oil into biodiesel for use in their own fleet.

The former framework has the advantages of establishing a guaranteed buyer for seeds or oil produced by small farmers. The ripple effect is that there are economic and social benefits in the communities where the seeds and raw oil are produced through the creation of jobs and increased commerce due to greater spending power. However, there will need to be incentives to attract investors to set up a biodiesel manufacturing facility. The operator of such a facility will also be challenged by ensuring that quality seeds and oils are purchased. This will require testing.

The latter option has the advantage that the biodiesel production will be for a targeted fleet.

The value chain for biodiesel can be presented simplistically as shown in Figure 17. Each will be discussed in this section.

Figure 19: Biodiesel Value Chain



Source: Environmental and Engineering Managers (EEM) 2012

21.1 Nurseries

Farmers can establish nurseries to produce good quality, high yielding seedlings for farmers who cultivate oil seed crops for biodiesel production. Nurseries play an important role in contributing to the quality and the yields of seeds and oils.

Inputs to nurseries would include:
1. Seeds
2. Land
3. Greenhouse
4. Water
5. Fertilisers
6. Pest and disease control
7. Labour

The price at which seedlings can be sold will ultimately depend on the cost of biodiesel. Farmers can also supply nurseries with compost made from trash and hulls from the shelling of seeds so that they can be utilised as soil conditioners in their nurseries.

21.2 Farmers supplying seeds

Farmers can supply seeds or oils to a Biodiesel Processing Plant and/or seeds to nurseries for new plants. It is important, however, to grow high yielding varieties of the oilseeds that have the lowest input costs. These high yielding cultivars can only be identified through research and experimental or pilot plots. Pilot studies past and present are helping to inform on the best varieties suited for cultivation in Jamaica.

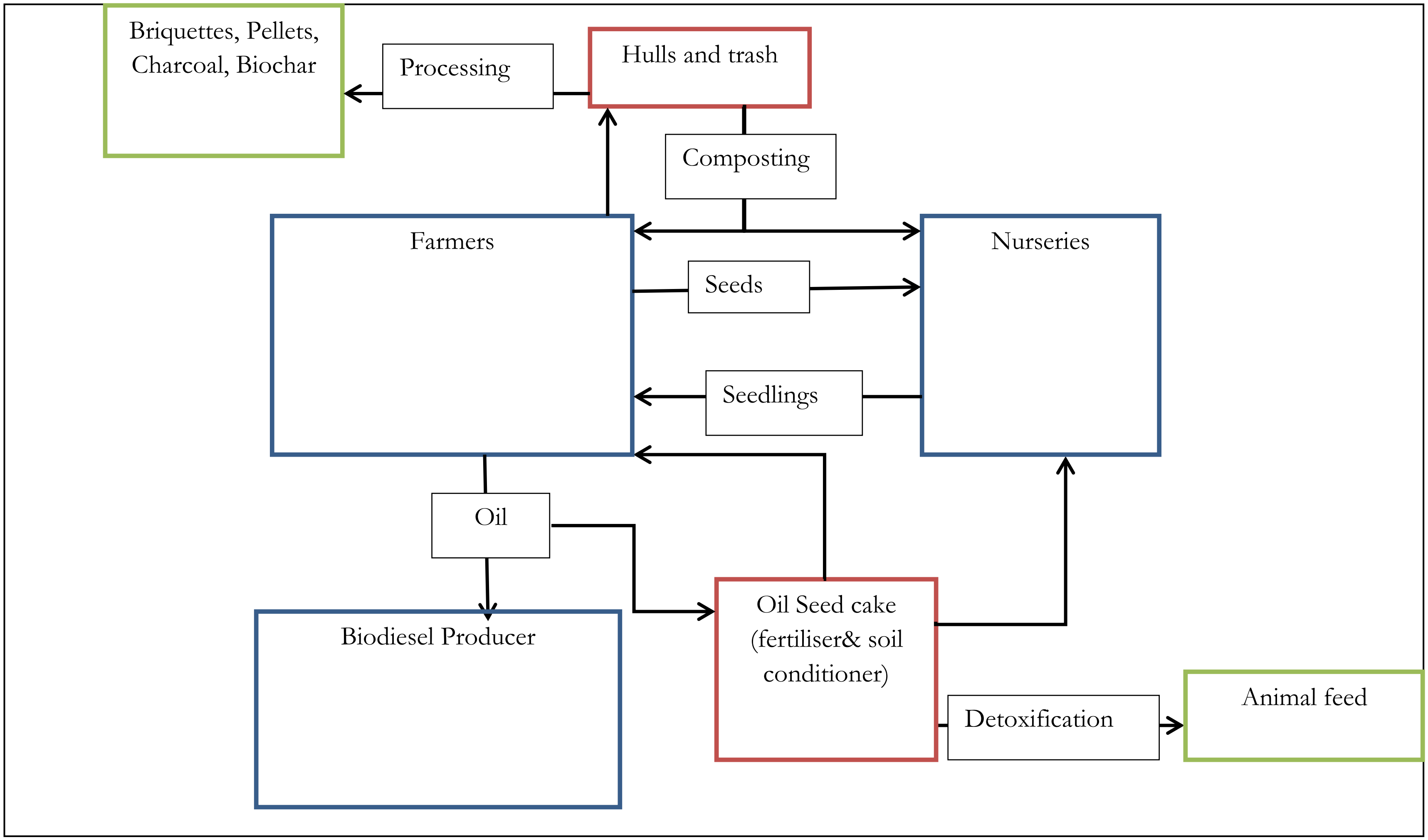
The price at which oil seeds are sold will depend on the oil content and ultimately on the cost of biodiesel. Since farmers cannot depend on income from only the sale of seeds, the trash and hulls from the oil seeds can be composted and used as mulch and soil conditioner, reducing the fertiliser inputs to the cultivation process. The actual savings from doing this have not been quantified.

Further experimental work is required locally to determine the minimum land requirements for feasible biodiesel production, the best cultivars, the amount and type of fertiliser to be applied and the average yield per hectare, among other things. The inputs by the farmer necessary for oil seed production are listed below.

Inputs for farmer for seed production:

1. Land
2. Seeds
3. Farm equipment
4. Fertiliser
5. Weed control
6. Pest control
7. Irrigation
8. Labour for:
    i. Sowing
    ii. Irrigation
    iii. Fertilizing
    iv. Pest and disease control
    v. Fencing arrangements
    vi. Weeding
    vii. Harvesting
    viii. Hulling
    ix. Drying
    x. Packing
9. Seed drying area
10. Seed storage area
11. Bags to store seeds prior to husking
12. Bags to store seeds after husking
13. Vehicle and petrol to transport seeds to Biodiesel Plant

Figure 20: Value Chain between Oil Seed Farmers, Nurseries and Biodiesel Producers



Source: Environmental and Engineering Managers (EEM) 2012

21.3 Farmers supplying oil

Oil production from jatropha, castor and palm oil seeds by small farmers based on the literature will not be an economical process unless it is a part of a national biodiesel production value chain as there must be guaranteed buyers of the oil as well as incentives for the farmer. Additionally the small farmer will need to consider the co- and by products that can be made to improve the feasibility of seed oil production.

Farmers supplying raw oil to biodiesel producers will need to invest in oil extraction equipment. The waste oil seedcake can be used directly as fertiliser and soil conditioner for crops thereby offsetting inorganic fertiliser costs. If the feedstock is jatropha or castor, the oil seedcake or meal will have to be detoxified before it can be used as animal feed but seedcake from oil palm can be used as animal feed. Since the process of detoxification of jatropha derived oil seedcake is not simple, and is likely to be costly unless there are sufficient economies of scale, farmers may not want to undertake this process. As such, they would not benefit from the recycled waste for use as animal feed.

Inputs for farmers or small scale operators for raw oil production include:

1. Oil extracting equipment
2. Bottles/containers for oil storage
3. Vehicle and fuel to transport oil to Biodiesel Plant
4. Safety equipment
5. Biodiesel quality testing equipment

Waste:

1. Hulls that can be used directly for mulch and/or animal feed after detoxification

Note: Detoxification of seed cakes is not recommended for small scale enterprises as it is a challenging and costly exercise.

Farmers supplying raw oil will have to ensure that the quality meets the requirements of the processor and must therefore have testing equipment on hand or source testing services from accredited laboratories. It is expected that the latter will be more cost effective for the farmer as acquiring and maintaining lab equipment and testing oil to the requisite international standards would be very costly.

Farmers may also find that there is a demand for castor oil in the health food and beauty sectors and could find it economically viable to supply raw oil to these sectors. The biodiesel policy and pricing will influence to whom the farmer will sell his/her raw oil.

21.4 Biodiesel Production

Biodiesel production will be dependent on a consistent supply of quality seeds and oil. It can be undertaken on a small scale or large-scale.

Small-scale biodiesel producers generally use a press extraction method because it is a simpler, less expensive and safer process (Figure 21). This is a process of mechanical separation of the oil from the oilseed. This process produces a crude oil and a cake meal that contains approximately 10% or more of the oil content of the original seeds. Crushers are used to extract oil from oilseeds. Processors sometimes heat the seeds prior to processing to decrease the energy required to extract the oil from the seeds. The heated seeds can be crushed and flaked to further enhance oil extraction, or seeds simply can run through a cold press, also referred to as expeller pressing, to remove the oil.

Figure 21: Expeller Press

Photo by John Nowatzki
http://www.ag.ndsu.edu/pubs/ageng/machine/ae1344.pdf

Large crushing operations use petroleum distillate to recover virtually all of the oil. However, such plants require costly safety features for operator and environmental protection, and are not recommended for small-scale extraction.

21.4.1 Small Scale Biodiesel Production

It is common for new producers to underestimate the time required to invest in the myriad aspects of fuel production. An analysis can be performed of the cost of inputs versus the resultant value of the fuel produced. If biodiesel is being manufactured as income-generating work there are a number of input costs that must be considered to determine the viability of the undertaking.

Costs to consider in determining the economics of small scale biodiesel production include:

- Capital investment in equipment: purchasing new equipment and acquiring a location to produce and store the biodiesel. Capital costs maybe lower if production is done in an existing well-ventilated space.
- Feedstock acquisition: production of oil seeds from farming, procuring the seeds or the oil.
- Chemicals: bought in bulk or small quantities.
- Disposal cost: by-products, where they are not utilised
- Regulatory: planning and environmental approvals
- Electricity/energy: including the electricity to run the process, but may also include ventilation for the facility
- Labour

Other inputs to consider include:

1. Storage for feedstock (raw seed oil, waste vegetable oil).
2. Secondary containment for all above ground chemical and fuel tanks and chemical storage areas in accordance with the requirements of the National Environment and Planning Agency (NEPA).
3. Storage of hazardous by-products and wastes in accordance with the hazard they pose and if in a liquid state with appropriate secondary containment for spills.
4. It is strongly recommended that all biodiesel producers incorporate methanol recovery systems into plant designs. Methanol recovery has some inherent safety concerns and should only be carried out by advanced producers who fully understand the safety issues involved with handling methanol and hot liquids.
5. Treatment of wastewater to meet the Natural Resources Conservation Authority's (NRCA's) Trade Effluent standards. Under no circumstances should wastewater containing the following substances in excess or above standards be disposed of into the environment or sewers:
   a. sodium or potassium hydroxide
   b. methanol
   c. glycerine containing methanol
   d. spoilt batch of biodiesel
6. Management plan for air emissions from methanol
7. Fire prevention and fire fighting equipment
8. Safety gear for biodiesel production and handling chemicals such as sodium or potassium hydroxide and methanol
   a. Chemical-resistant gloves (butyl rubber is best for methanol and lye)
   b. Chemistry goggles (indirect vented)
   c. Face shield
   d. Dust mask or cartridge respirator
   e. Eyewash station
   f. Small spray bottle with vinegar for neutralizing lye spills
   g. Access to running water
   h. Telephone in case of emergency and emergency telephone numbers
   i. Fire extinguishers (20-lb ABC)
   j. Absorbent material and spill-containment supplies

9. Access to quality testing equipment or services. A small producer must ensure that the biodiesel made meets the required ASTM standards (Appendix 4). Careful attention to production chemistry and oil-quality is critical.

The main challenge that small scale biodiesel producers will face is the disposal of glycerine. It is expensive to undertake glycerine purification on a small scale and in the absence of hazardous waste disposal facilities (particularly if methanol is used in the production process). A large-scale biodiesel production facility can purify the glycerine, and should be better able to manage associated wastes and related costs. Small scale biodiesel production should not be encouraged unless the facilities exist for the management of glycerine waste as serious health and environmental impacts can results if the waste is improperly disposed of.

Since costs and availability of feedstock vary, production costs should be compared to quality commercial biodiesel fuel before a decision is taken to embark on small-scale biodiesel production.

Time commitment

To responsibly operate a small-scale biodiesel facility, time should be allocated for:
1. Fabrication and maintenance of biodiesel equipment
2. Oil collection
3. Securing chemicals
4. Fuel processing
5. Methanol recovery
6. Water washing of the fuel or other finishing techniques
7. Quality testing
8. Disposal of waste products
9. Record keeping

Due to the nature of the operations, it is likely that oil spills and leaks will occur. It is important to include time and labour to maintain the production area in a clean state.

21.4.2 Large-scale Biodiesel Production

The Biodiesel Processing Plant can take in seeds, raw seed oil, waste vegetable oils from industrial and fast food facilities and biodiesel from small scale production for use as feedstock.

Inputs include:
1. Production facility (land and building)
2. Biodiesel production equipment
3. Equipment to test if seeds, raw seed oil, waste vegetable oil and biodiesel supplied by others meet the required quality standards
4. Equipment to test final biodiesel product meets ASTM standards (Appendix 4)

5. Secondary containment for chemicals and fuels (raw materials, finished products and wastes) stored in above ground tanks in accordance with NEPA's requirements
6. Safe and secure storage of chemicals with appropriate secondary containment
7. Safety gear
8. Fire prevention and fire fighting equipment such as dry chemical powder, carbon dioxide (CO_2) and alcohol-resistant foam Fire extinguisher
9. Ventilation system
10. Methanol recovery system
11. Wastewater treatment system
12. Spill clean-up equipment
13. Trained labour

For viability it will be necessary to determine the quantity of waste vegetable oil that can be collected as supplementary feedstock for biodiesel production.

Large biodiesel production facility should be equipped to purify the glycerine co-product that is generated. Glycerine is used locally in the pharmaceutical industry and if quantities are sufficient it could be exported as well. However it must also be noted that worldwide production of glycerine has skyrocketed due to the increase in biodiesel production so there could be an oversupply in the market that would tend to depress prices.

21.5 Strategies for attracting investors

Before investors can be encouraged to invest in biodiesel production plants, the policy gaps identified at Section 16.4 will have to be addressed. One of the greatest drivers for investment is clear policy and legislative frameworks. After defining the biodiesel policy and legislation, the production of a sustainable source of oil will be most important. The investor may be invited to either invest in production and processing of biodiesel or just the production of biodiesel.

In the first option the investor could be offered a package where sufficient land is provided so that he/she can guarantee the amount of oil that will be supplied to the production process. He/she will be able to control the quality of the oil that is used in the production process in this option. However, this option has pitfalls which have been highlighted in other countries where there can be clear cutting of forested lands or a takeover of lands used for food crops which have serious social, environmental and ultimately economic repercussions. Sometimes large investors do not pay rural works well so the ultimate objective of improving the social well-being of rural folk is not realised. The government would have also had to establish the graduated blending timetable so that appropriate projections can be made by the investor about return on investment.

In the second option, the investor in the biodiesel production facility will need guarantees that a minimum supply of oil will be provided on a monthly or annual basis to maintain the viability of operations. The investor will have no control over the quantity and quality of the seeds or oil produced. There will be far more onus on the farmers to ensure good seed yields and good quality oil in order to fetch a good return. The farmers will require significant assistance and guidance on the best farming practices and varieties of oil seed crops to use to obtain the best yields, minimise input costs of labour, water as well as pest and disease control. Where farmers will produce oil for sale, the input costs for oil extraction will have to be assessed in relation to the cost that the oil can be sold for to determine viability.

As seen from the experiences in other countries, in the early stages of biodiesel production there is really no profit generated. The government will be required to make an investment to reap long term benefits. The investment on the part of the government will include tax waivers and incentives to both farmers and biodiesel production plant operators as well as extension services to farmers in the early development stage of oil seed crop production.

22.0 Jamaican Cost information

It is the cost of the various inputs that will help the farmer/entrepreneur to determine if the investment is feasible. This section provides some cost information that will be helpful but it is by no means exhaustive. It is recommended that the farmer/entrepreneur undertake a feasibility assessment before investing. Costs provided in this section are based on 2012 nominal prices.

22.1 Cultivation Costs

Seeds

Information obtained from local oil seed farmers on the cost of seeds is presented in Table 20.

Table 20: Castor and Jatropha seed costs

Type	lbs./acre	J$ Cost/lb.	Comments
Castor seed	2 (large) 1.5 (small)	140 -200	Equivalent to 1 quart
Jatropha Seed	1.5	140-200	Cost varies with demand may go as low as $100

Source: Interviews with Local Farmers 2012

Pilot Plot Costs

The cost of the pilot plots at Bodles, St. Catherine and CARDI Manchester are presented in Table 21. At this time it is only possible to report the overall costs associated with the experimental plots. The cost of the jatropha plot was J$783,374.00 and the cost of the castor plot was the same. There are no itemised costs for inputs such as chemicals and herbicides at this time. The costs presented were for the first seven months of the experiment.

Table 21: Costs associated with Experimental Plots

Activities	Cost (J$/ha)
Cultivation	230,910.00*
Harvesting & Prod.	100,018.00
Drip Irrigation	373,584.00
Fencing	78,862.00
Total	**783,374.00**

Source: Petroleum Corporation of Jamaica, CESED, 2012

The cultivation costs obtained from local farmers is presented in Table 22.

Table 22: Cultivation costs for oil seeds in Jamaica

	Inputs	Unit	J$ Cost
1.	Chemicals	acre	20,000.00
2.	Manure	annum	10,000.00 – 15,000.00
3.	Insecticide and fungicide	annum	12,000.00
4.	Tools	Lump Sum	5,000.00
5.	Labour per person	day	1,200.00
6.	Other equipment e.g. Tarpaulins, bags, drying house	Lump Sum	50,000.00
7.	Fencing	Lump Sum	75,000.00

Source: Interviews with Local Farmers 2012

22.2 Processing Costs

For small scale operations, the typical cost of equipment to shell, press oil and process biodiesel is presented in Table 23.

Table 23: Biodiesel Production Equipment Typical Costs

	Equipment	J$ Cost
1.	A typical nut sheller with capacity 100 to 200 kg/hr.	200,000.00 to 300,000.00
2.	Oil press with 1 ton per day capacity	300,000.00 to 500,000.00
3.	Biodiesel processor with capacity 200L to 400L per day	400,000.00 to 800,000.00
4.	Methanol recovery equipment capacity 25 gallon per 8hr day. Springboard Biodiesel	1,800,000.00
	TOTAL	**Up to 3,400,000.00**

Source: Petroleum Corporation of Jamaica, CESED, 2012

It is expected that biodiesel will be manufactured to Biodiesel ASTM specifications. However, the test for the full slate of parameters is not currently available locally. Petrojam can however test some key parameters at a cost of J$28,000.00.

22.3 Option of Menthol versus Ethanol in Biodiesel Production

The choice of alcohol in the production of biodiesel can make a difference in cost as there are far less adverse environmental impacts associated with handling ethanol waste. Based on data collected by the Petroleum Corporation of Jamaica (PCJ) the following information indicates that the cost of chemicals is comparable for both the single and dual reaction processes using either methanol or ethanol. Since there are fewer environmental concerns about ethanol based wastes from the biodiesel process, it is better to select ethanol as the alcohol catalyst where the price is reasonable for 99.9% pure ethanol.

Methanol

The following outlines the methanol used per litre of biodiesel produced and the cost of methanol (per litre) using the Dual Reaction (Acid/Base) Process and the Single Reaction (Base) Process, according to SpringBoard Biodiesel Processor recently acquired by PCJ.

0.2 litre of methanol is used for every 1 litre of biodiesel produced. The local cost of industrial grade methanol is J$23,449 + GCT[30] per 209L drum (55 gallons). Other inputs include:

- caustic soda at J$2,528.40 per 25kg bag (+ GCT) the process requires approximately 8 grams per litre biodiesel produced
- sulphuric acid at J$2,954.23 (+GCT) per 2.5 L - the process requires approximately 1mL per litre of biodiesel produced.

There may be need to use acetic acid (vinegar) in the wash water depending on the alkalinity level. Vinegar sells for J$200.00 per gallon and the process would require about 28mL per litre of biodiesel produced.

The Dual Reaction Process is used for the biodiesel being produced for the Pilot Projects being implemented by the CESED at Bodles and CARDI. Table 24 shows the typical costs for the input chemicals for the Dual Reaction Process.

The total cost of chemicals for processing 1 litre of biodiesel using the Dual Reaction (Acid/Base) Process is J$30.18. (Table 24)

If the Single Reaction (Base) standard process is used; 0.1 litre of methanol is used for every 1 litre of biodiesel produced.

Local cost of industrial grade methanol is J$23,449 + GCT per 209L drum (55 gallons). Other inputs include:

- caustic soda at J$2,528.40 per 25kg bag (+ GCT) - the process requires approximately 6.5 grams per litre biodiesel produced.

[30]GCT – General Consumption Tax – 17.5% sales tax

There may be need to use acetic acid (vinegar) in the wash water depending on the alkalinity level. Vinegar sells for J$200.00 per gallon and the process would require about 28mL per litre of biodiesel produced.

Table 24: Cost of methanol and other chemicals to produce 1 L of Biodiesel - Single and Dual Reaction Processes

	Single Reaction Process	**Dual Reaction Process**
Chemical	**Cost J$**	**Cost J$**
Caustic soda	0.77	0.95
Methanol	13.18	26.37
Sulphuric Acid	0	1.39
Acetic acid (vinegar)	1.48	1.48
TOTAL	**15.44**	**30.18**

Source: Petroleum Corporation of Jamaica, CESED, 2012

The total cost of chemicals for processing 1 litre of biodiesel using the Single Reaction (Base) Process is J$15.44 (Table 24).

The cost of chemicals for the Dual Reaction Process is twice that of the Single Reaction Process. Small biodiesel producers tend to use the single reaction process while larger producers use the Dual Reaction Process.

Ethanol

The following outlines the ethanol used per litre of biodiesel produced and the cost of ethanol (per litre) using the Dual Reaction (Acid/Base) Process and the Single Reaction (Base) Process, according to SpringBoard Biodiesel Processor recently acquired by PCJ.

For the Dual Reaction (Acid/Base) Process, 0.288L of ethanol is required per litre of Biodiesel produced.

For the Single Base reaction, 0.144L of ethanol is required per litre biodiesel produced.

It is recommended that 99.9% pure ethanol be used in the biodiesel process. The price of industrial grade ethanol at 99.9% purity from Petrojam is currently at $19,067.57 per 55 gallon (209L). The costs were calculated for the dual and single reaction processes including and excluding GCT on ethanol (Table 25 and Table 26).

When compared to the 1 litre production costs using methanol, the costs are comparable.

Table 25: Cost of ethanol and other chemicals to produce 1 L of Biodiesel - Dual Reaction Process

Chemical	Cost J$(including GCT on Ethanol)	Cost J$(excluding GCT on Ethanol)
Caustic soda	0.95	0.95
Ethanol	30.87	26.27
Sulphuric Acid	1.39	1.39
Acetic acid (vinegar)	1.48	1.48
TOTAL	**34.69**	**30.09**

Source: Environmental and Engineering Managers (EEM) 2012

Table 26: Cost of ethanol and other chemicals to produce 1 L of Biodiesel - Single Reaction Process

Chemical	Cost J$(including GCT on Ethanol)	Cost J$(excluding GCT on Ethanol)
Caustic soda	0.77	0.77
Ethanol	15.44	13.14
Acetic acid (vinegar)	1.48	1.48
TOTAL	**17.69**	**15.39**

Source: Environmental and Engineering Managers (EEM) 2012

22.4 Comparative cost of Biodiesel production from Castor versus Petroleum Diesel

Using a similar format to that developed by North Dakota State University Extension Services (October 2007), the various input costs based on local prices were used to calculate the cost of producing biodiesel. Three (3) scenarios were assessed; small and large scale production with castor oil only and large scale production with castor oil and waste vegetable oil (Table 28). Table 27 shows the criteria used to assess small scale and large scale production.

Table 27: Criteria Used to Assess Small and Large Scale Biodiesel production

	Small Scale Biodiesel Production	Large Scale Biodiesel Production
1.	Grower cultivated seeds	Oil seeds purchased
2.	No building costs	Building costs
3.	1.5 hour per batch operation	24 hour operation
4.	Single Reaction Process	Dual Reaction Process
5.	No Waste Vegetable oil	Waste Vegetable oil
6.	Ethanol	Methanol
7.	-	Methanol recovery equipment
8.	-	Glycerine refining equipment (pharmaceutical grade)
9.	Meal reused on farms	Meal sold
10.	Crude glycerine sold	Pharmaceutical grade glycerine sold

Table 28: Comparative Cost of Biodiesel production and Cost of Petroleum Diesel

	Scenario	Cost of Biodiesel production (US$)	Gain or Loss compared to cost of Petroleum diesel (US$)
1.	Small scale of 200L/batch	4.05	(3.01)
2.	Large scale of 24,000L/day	4.53	(3.48)
3.	Large scale of 24,000L/day with 15% WVO	3.92	(2.87)

The assumptions used in the calculations are included at Appendix 7.

Appendix 8 shows that the cost of biodiesel production on a small scale of 200L/batch is US$4.05 which is US$3.01 higher than the cost of petroleum diesel (before tax) based on the average 2011 price from Petrojam.

Appendix 9 shows that the cost of biodiesel production on a large scale of 24,000L/day is US$4.53 which is US$3.48 higher than the cost of purchasing petroleum diesel (before tax) based on the average 2011 price from Petrojam.

Appendix 10 shows an improvement in the cost of producing biodiesel in a large scale operation using 15% waste vegetable oil (WVO) with the cost being US$2.87 higher than petroleum diesel.

Sensitivity analysis showed that if the cost of the castor bean feedstock was a quarter of the current cost and the WVO was increased to 25% of the total feedstock oil, the production of biodiesel would breakeven with the cost of petroleum diesel.

These findings are consistent with assessments done in other countries and as stated in literature on the subject which shows that the cost of the feedstock is a significant factor in the high cost of producing biodiesel.

23.0 Recommendations and Conclusions

There are many challenges associated with successfully developing and implementing a biodiesel value chain in Jamaica. It is important to learn from experiences in other countries and adapt them to the Jamaican situation.

Based on information at the PCJ web site, total fuel consumption for road and rail transport was 5.8 million barrels in 2008. Of this about 4.3 million barrels was unleaded gasoline, leaving 1.5 million barrels (63 million gallons) of diesel, which represents a nationwide market of roughly 3 million gallons per year of plant methyl esters for B-5. This small volume may not justify a national campaign to introduce the blend, but an advantage would lie in the contribution of the plant esters to fuel lubricity, which is more difficult to achieve at 15 ppm sulphur levels projected for three years from now.

Another alternative market sector would be truck fleets, which could consume B-100. Diesel trucks represent nearly 90% of the 20,727 diesel vehicles on the island and no doubt a higher percentage of the fuel consumption. If a number of large fleet operators were to convert to B-100, as a trash collector has apparently proposed, biodiesel could displace a larger fraction of the 63 million gallons than the 5% upper limit of B-5.

Stationary engines represent an even larger market. Just over 6 million barrels (252 million gallons) of petroleum, including heavy fuel oil and auto diesel, are consumed for electricity generation. Assuming the 2.4 million barrels of auto diesel remaining after subtracting transport fuel from total production is for power generation that would represent 100 million gallons per year of potential market for B-100 for stationary diesel engines and combustion turbines. Biodiesel could also displace bunker C fuel, but the value would be reduced.

In any case, the August 19, 2010 price of auto diesel at the Petrojam refinery gate was US$95.86 per barrel, or US$2.28 per gallon. Accounting for the 10 % lower calorific value, the equivalent value of biodiesel would be US$2.05 per gallon.

Developing the biodiesel industry will be challenging as the agricultural infrastructure for feedstock production does not exist in Jamaica. While castor beans and jatropha are considered the most promising feedstock, practices in Central and South America indicate that African palm has the highest oil yield, whereas castor beans are cultivated extensively only in Brazil. Moreover, there is no large-scale commercial experience with jatropha anywhere in the world, hence developing a national programme based on this crop, regardless of its promise, entails high risk and significant investment.

On the positive side, capital requirements for new biodiesel production facilities are approximately US$0.26/L (US$1.00 per gallon) of biodiesel capacity, including storage tanks for feedstock, chemicals, and product. Biodiesel plants generally are modular allowing for easy capacity expansion at any time.

Recommendations for the further development of the biodiesel value chain are outlined below.

1. Despite the policy position stated in the National Biofuels Policy, the Government will need to decide on whether it has the fiscal space to make the investment in biodiesel recognising that the returns may 10 years or longer to be realised.

   The research has clearly indicated that the State is the driver for biodiesel programmes and that tax waivers and incentives from a major part of successful programme implementation.

2. Resuscitate the Biofuels Task Force to lead the biodiesel development programme.

   The Task Force has been dormant for some time and needs to become active once more.

3. Address policy, legislative and institutional gaps specifically for biodiesel.

   Separate the policy objectives, goals and strategies for the development of biodiesel from other biofuels as there are specific requirements for biodiesel production which are not relevant to other biofuels.

4. Continue research into the best varieties of oil seeds and the best locations for cultivation.

   Insufficient information is at hand to assess the best suited oil seeds since the Bodles and CARDI pilot projects on castor and jatropha are still being implemented

5. Keep abreast of global trends in preferred oilseeds for biodiesel production.

   Research is constantly taking place globally to identify the best oilseed to use for biodiesel production. Care must be taken not to invest in an oilseed that other countries, particularly those similar to Jamaica, are experiencing problems or where expectations are not being met. Careful consideration should be given to whether long term investment in jatropha is well suited for Jamaica especially since there are concerns in other countries about how well it actually performs. Partnerships should be forged with Universities locally and overseas to investigate the potential of other oilseeds e.g. pongomia, which is being heavily researched in Australia as a potential replacement for jatropha as a biodiesel feedstock.

6. Develop markets for co and by-products.

   It is expected that farmers will make use of trash and hulls from oil seeds as fertiliser and soil conditioner. It is unlikely that oil seed cake from castor and jatropha will be detoxified for use as animal feed at the level of the farmer due to the complexity of that process. If the economies of scale are very large however, it may suit one or two investors to look into the possibility of establishing the facilities to undertake this venture. One critical issue that will determine the viability of such a venture would be the ability to collect the oil seed cake from various locales in an efficient way. The same is true for developing a market to manufacture briquettes from the trash and hull.

   The most promising co-product that can be developed from the biodiesel production is glycerine. Glycerine is used in the pharmaceutical manufacturing industry in Jamaica and at least one local pharmaceutical manufacturer has to import it from overseas. While a feasibility study would be required, the purification of the glycerine by product of biodiesel production could very well be a viable undertaking. It also has the huge benefit of converting a hazardous waste, which has significant costs associated with handling and disposal into a useful product.

7. Collect currently unavailable information on input costs to refine the biodiesel value chain.

   As has been the experience in other countries, significant experimental work has to be undertaken before farmers can be encouraged to invest in the cultivation of oil seed crops. Good data will need to be collected to demonstrate the viability of production and to help establish the incentives that should be implemented in the early years of the programme until a breakeven point is attained. The best suited cultivars for different growing locations will need to be determined as well as planting distances, fertiliser requirements, water requirements and other inputs. The average oil yield per hectare is critical information that will be required by the potential farmer as well as the government.

8. Develop and implement an integrated plan for biodiesel production.

   This plan should consider the following:

a. the financial instruments to encourage local farmers and investors to participate in the biodiesel value chain
b. the institutional systems required to support social programmes that will be required to facilitate farmers

It is difficult at this stage without more information available on the amount of oil that the country can produce for biodiesel production and how much it will cost, to determine the viability of a biodiesel production facility. Much more data will have to be collected before this can be done.

9. Develop institutional framework for monitoring and evaluating all aspects of the biodiesel value chain.

   The correct indicators must be selected and data collected for effective evaluations to be done. It is only from the results of monitoring that it can be determined if objectives are being met and if changes need to be made.

10. Review and amend the strategy as situations dictate.

    Another feature of successful programmes has been the ability to amend target and policies when the intended objectives have not been met.

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Appendix 1: Terms of Reference (TOR) For Biodiesel Value-Chain Development Strategy through a Participatory Process

1.0 Background

PCJ-UNEP Consultancy Contract

In December 2009, the PCJ entered into an agreement with the United Nations Environment Programme (UNEP) Riso Centre to implement the project "Development of a Biodiesel Strategy for Jamaica, to Ensure Compliance with Jamaica's Biodiversity Strategy". The results of this UNEP project are expected to support the PCJ's Small-Scale Biodiesel Pilot Project (SBP), which was approved in July 2009.

Small-scale Biodiesel Pilot (SBP) Project 2009

The SBP, which is in its first year of implementation, is seeking to assess the viability of producing biodiesel from locally grown feedstocks such as castor and jatropha. This project is designed to advance the introduction of biofuels in Jamaica, guided by the Biofuels Policy and related legal and regulatory instruments, which are all based on appropriate commercial and economic models. The project is being developed collaboratively with the Ministry of Agriculture & Fisheries (MoAF) Bodles Agricultural Research Station (BARS) and the Caribbean Agricultural Development Institute (CARDI).

Value Chain Assessment for Jamaica

The consultancy services are geared towards reviewing existing reports and data related to the pricing formulae for automotive diesel as compared with global biodiesel pricing trends.

The consultancy is to support decision-making using local and international data that would be fundamental when considering starting and/or expanding a biodiesel project in Jamaica. The study is expected to assist in identifying existing and potential end-users of bi-products of the production process (e.g. glycerin, fertilizer meal, etc.).

The study should also determine the positive and negative environmental effects associated with the use of the bi-products. The consultant will assess the revenue and cost implications of the sale/disposal of the bi-products. This is necessary to support the sustainability of fuel options and incorporate the resulting benchmarks into energy, agricultural, land use and trade policies.

2.0 Objectives

The main objectives of this consultancy are to:

i. Review existing reports and data related to the biodiesel value-chain and identify information gaps or development needs (e.g. Jamaica Bauxite Institute's Castor Cultivation Study 1980's).

ii. To review the draft biofuels policy, strategy, SWOT analysis and standards which will support the definition and growth of a local biofuels industry.
iii. Formulate a biodiesel value chain development strategy, which takes into account an assessment of the environmental impacts of the potential bi-products.

3.0 Specific Inputs to Be Made by Environmental and Engineering Manager ltd

The assignment will include the following activities:

Review the biodiesel value chain (BVC) in other countries:

- Identify the structure of the BVC
- Identify existing & potential users in these benchmark countries.
- Assess the potential identified for extension of the value chain.
- Identify and create a listing of potential users in Jamaica based on the review of the BVC in other countries.

Formulate Biodiesel Value Chain (BVC) Strategy through Participatory Process

- Meet with relevant stakeholders for each of the above mentioned activities in Section 1.
  - Document concerns, comments, suggestions etc.
  - Develop strategies to address identified issues

Determine the positive and negative environmental effects associated with the biodiesel production process including the by-products.

- Review existing documents on the experiences in other countries.
  - Identify impacts.
  - Indicate best practices and management techniques.
- Assess the impacts based on the Jamaican situation (e.g. based on the Small-scale Biodiesel Experiment or other project).

- Make recommendations on best management techniques that would be most suited to local conditions.

Identify existing and potential end-users of by-products of the production process
(e.g. glycerin, fertilizer meal, etc.).

- Develop a survey to identify needs and requirements of the potential end-users and competing suppliers of the by-products.
- Conduct survey.
- Make recommendations on how potential end-users could be best engaged

4.0 Methodology

The following methodology will apply:

1.0 Review existing reports and data related to the Biodiesel Value Chain (BVC) and identify information gaps or development needs:

a. Jamaica Bauxite Institute's Castor Cultivation Study 1980's
b. The draft biofuels policy, strategy, SWOT analysis and standards which will support the definition and growth of a local biofuels industry.
c. Existing documentation related to BVC in other countries based on the use of castor and jatropha as raw materials.
d. Information on the value chain for diesel fuel in Jamaica

2.0 Meet with the relevant stakeholders to be identified by the Centre of Excellence for Renewable Energy (CERE) to obtain additional information which will inform the development of the BVC

3.0 Assess the environmental and social impacts of the biodiesel process from cultivation through to processing including the by-products.

4.0 Conduct desk study to review the BVC in other countries.

5.0 Conduct survey of potential end-users and competing suppliers of the by-products

6.0 Formulate a BVC development strategy.

7.0 Prepare draft and final reports

Appendix 2: Participants in the Stakeholder Consultations

BIODIESEL VALUE CHAIN DEVELOPMENT STRATEGY CONSULTATIONS MEETING

ATTENDANCE SHEET

MARCH 2, 2012

NO.	NAME	COMPANY	SIGNATURE
1	Todd Swagerty	Springboard Biodiesel	[illegible]
2	Charles Koomson	PCJ.	[illegible]
3	Ramon James	Ethand Consulting Ltd.	[illegible]
4	Kimballe Campbell	Environmental and Engineering Managers Ltd	Campbell
5	Ianthe Smith	"	[illegible]
6	Dennis Zulloch	P.C.J.	[illegible]
7	Nicholas Reece	PCJ	[illegible]
8	R. Karl James	Ethand Consulting	[illegible]
9	Tarik Felix	Valiant Trading	[illegible]
10	Nilza Justiz-Smith	University of Tech. Jamaica	[illegible]
11	Sahlu Baker	University of Technology	[illegible]

Meeting at the Petroleum Corporation of Jamaica
March 6, 2012 at 2:30 p.m.
Meeting: Biodiesel Value Chain Development Strategy

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Appendix 3: Organisations and Persons who provided information and data

	Name	Organisation
1.	Mr. Sammy	Sammy's Farm - Palm oil farmer and small scale soap manufacturer
2.	Princess Sheba	Local castor oil producer
3.	Carl and Ramon James	Ethanol Consulting Ltd Bernard Lodge Castor Bean Farm
4.	Rohan Smith	CARDI, Manchester – Castor and Jatropha Pilot Projects
5.	Marsha Thomas	Bodles, St. Catherine - Castor and Jatropha Pilot Projects
6.	Joy Angulu	Federated Pharmaceutical
7.	Shaneile Thomas	Federated Pharmaceutical

Appendix 4: ASTM D 6751-07b Standard

Biodiesel Standards		ASTM D 6751-07b	PETROLEUM DIESEL
Specification	Units		EN 590:1999
Applies to		FAAE	Diesel
Density 15°C	g/cm^3		0.82-0.845
Viscosity 40°C	mm^2/s	1.9-6.0	2.0-4.5
Distillation	% @ °C	90%,360°C	85%,350°C - 95%,360°C
Flashpoint (Fp)	°C	93 min	55 min
CFPP	°C		* country specific
Cloud point	°C	* report	
Sulphur	mg/kg	15 max	350 max
CCR 100%	%mass	0.05 max	
Carbon residue (10%dist.residue)	%mass		0.3 max
Sulphated ash	%mass	0.02 max	
Oxid ash	%mass		0.1 max
Water	mg/kg	500 max	200 max
Total contamination	mg/kg		24 max
Cu corrosion max	3h/50°C	3	1
Oxidation stability	hrs;110°C	3 hours min	N/A (25 g/m3)
Cetane number		47 min	51 min
Acid value	mgKOH /g	0.5 max	
Methanol	%mass	0.2 max or Fp <130°C	
Ester content	%mass		
Monoglyceride	%mass		
Diglyceride	%mass		
Triglyceride	%mass		
Free glycerol	%mass	0.02 max	
Total glycerol	%mass	0.24 max	
Iodine value			
Linolenic acid ME	%mass		
C(x:4) & greater unsaturated esters	%mass		
Phosphorus	mg/kg	10 max	
Alkalinity	mg/kg		
Gp I metals (Na,K)	mg/kg	5 max	
GpII metals (Ca, Mg)	mg/kg	5 max	
PAHs	%mass		11 max
Lubricity / wear	µm at 60°C		460 max

Appendix 5: European Standard for Biodiesel -EN 14214

Property	Units	lower limit	upper limit
Ester content	% (m/m)	96.5	-
Density at 15°C	kg/m^3	860	900
Viscosity at 40°C	mm^2/s	3,5	5.0
Flash point	°C	> 101	-
Sulphur content	mg/kg	-	10
Carbon residue remnant (at 10% distillation remnant)	% (m/m)	-	0.3
Cetane number	-	51.0	-
Sulphated ash content	% (m/m)	-	0.02
Water content	mg/kg	-	500
Total contamination	mg/kg	-	24
Copper band corrosion (3 hours at 50 °C)	rating	Class 1	Class 1
Oxidation stability, 110°C	hours	6	-
Acid value	mg KOH/g	-	0.5
Iodine value	-	-	120
Linolenic Acid Methylester	% (m/m)	-	12
Polyunsaturated (>= 4 Double bonds) Methylester	% (m/m)	-	1
Methanol content	% (m/m)	-	0.2
Monoglyceride content	% (m/m)	-	0.8
Diglyceride content	% (m/m)	-	0.2
Triglyceride content	% (m/m)	-	0.2
Free Glycerine	% (m/m)	-	0.02
Total Glycerine	% (m/m)	-	0.25
Group I metals (Na+K)	mg/kg	-	5
Group II metals (Ca+Mg)	mg/kg	-	5
Phosphorus content	mg/kg	-	4

Appendix 6: Members of the Biofuels Task Force October 2010

REPRESENTATIVE	MINISTRY/AGENCY
Dr. Betsy Bandy (chair)	Ministry of Energy & Mining
Mrs. Yvonne Barrett-Edwards	Ministry of Energy & Mining
Mr. Adrian-Charles Stewart	Ministry of Agriculture
Mr. George Callaghan	Ministry of Agriculture
Ms Shernette Sampson	Ministry of Transport & Works
Ms Monifa Blake	Ministry of Transport & Works
Mr. Vivian Blake	National Environment & Planning Agency
Mr. Anthony McKenzie	National Environment & Planning Agency
Mr. Jerome Smith	Office of the Prime Minister (Environmental Management Division)
Mr. Niconor Reece	Petroleum Corporation of Jamaica – Centre of Excellence for Renewable Energy
Mrs. Denise Tulloch	Petroleum Corporation of Jamaica – Centre of Excellence for Renewable Energy
Miss Felicia Whyte	Petroleum Corporation of Jamaica – Centre of Excellence for Renewable Energy
Mrs. Seveline Clarke-King	Planning Institute of Jamaica
Mr. Richard Kelly	Planning Institute of Jamaica
Ms Elaine Manning	Sugar Industry Research Institute
Mr. Lancelot White	Sugar Industry Research Institute
Dr. Nilza Justiz-Smith	University of Technology, Jamaica
Prof. Ralph Robinson	University of the West Indies
Mr. Richard Walker	-
Mr. William Saunders	-
Mr. Brad Rein	US Department of Agriculture

Appendix 7: Assumptions used in Calculations of Small and Large Scale Biodiesel Production Costs

General Assumptions

1. Castor Oil Bulk Density is 0.961kg/L
2. The castor seeds have 43% oil content
3. All costs are listed in US$

Small Scale Assumptions

1. The cultivation cost of the seed for the small producer is $1,300/tonne seed
2. This is a batch process. One batch consists of 1.5 hours of crushing and 1.5 hours of biodiesel processing
3. One crusher will be used each which rated at 10 HP.
4. Residual content in meal is 20%.
5. One person is required per batch
6. The castor meal will not be sold but will instead be re-used by the farmer as fertilizer
7. Crushing electricity costs were estimated using the equipment rating.
8. Biodiesel production facility is 200 L/day
9. The capital cost for the equipment is $13,000
10. Biodiesel processing electricity costs estimated using $0.066 kWhr /litre oil
11. Maintenance costs were assumed to be $2.5/batch
12. Crude grade glycerine will be sold at a cost of $200/MT

Large Scale Assumptions

1. Manufacturers will purchase seed from farmers at a cultivation cost of $1,300/tonne seed with a 20% margin
2. This is a continuous process.
3. Two crushers will be used each with a 50T/day (5,000 gals oil/day) rating.
4. Residual content in meal is 10%.
5. Each crusher is rated at 85HP for the screw and 20HP for the hopper arm.
6. One person is required per eight (8) hour shift of the twenty four hour (24 hr.) operation
7. The castor meal will be sold as fertilizer for $150/tonne
8. Crushing electricity costs were estimated using the equipment rating.
9. Biodiesel production facility is 24,000 L/day
10. The capital cost of a large scale biodiesel production facility is estimated at $0.26/litre biodiesel
11. The biodiesel equipment is rated at 32kW and produces 1,000L/hr. of biodiesel. Its efficiency rating is 0.022kWhr/litre.
12. Maintenance costs were 3.8% of the cost of the production facility
13. Pharmaceutical grade glycerine will be sold at a cost of $1,350/MT

Appendix 8: Cost of Biodiesel Production from Castor Oil (Small Scale Plant 200/L Batch)

Direct Cost	**Amount**	**Unit**	**$/Unit**	**$/Batch**	**$/L (oil)**
Oil Extraction					
Castor seed	560	kg	1.3	728.00	3.64
Electricity				2.50	0.01
Maintenance and supplies				2.5	0.01
Labour	1.5	Hr.	4.56	6.84	0.03
Listed direct costs				**739.84**	**3.70**
Fixed costs of oil extraction equip				**13.84**	**0.07**
Total listed costs				**753.68**	**3.77**
Credit for meal (13% oil)	367.36	kg	0	0	0.00
Credit for crude glycerine	0.08	kg/L	0.2	-3.17	-0.02
Adjusted Cost of oil				750.51	3.75
Processing Oil to Biodiesel					
Castor oil (from above)	200	L	3.75	750.51	3.75
Methanol				34.44	0.17
Sodium hydroxide				1.71	0.01
Acid				3.33	0.02
Electricity				5.28	0.03
Maintenance and supplies				2.5	0.01
Labour	1.5	Hr.	4.56	6.84	0.03
Listed direct costs				**804.62**	**4.02**
Fixed costs of processing equip				**6.15**	**0.03**
Total listed costs of biodiesel production				**810.77**	**4.05**
Price of No. 2 diesel w/o excise taxes					1.048
Gain or loss relative to No. 2 diesel					-3.01

Appendix 9: Cost of Biodiesel Production from Castor Oil (Large Scale Plant 24,000L/day)

Direct Cost	**Amount**	**Unit**	**$/Unit**	**$/Day**	**$/L (oil)**
Oil Extraction					
Castor seed	67,000	kg	1.56	104,520.00	4.36
Electricity				1,008.00	0.04200
Labour	24	Hr.	6	144	0.00600
Listed direct costs				**105,672**	4.40
Fixed costs of oil extraction equip				**0**	0.00
Total listed costs				**105,672**	4.40
Credit for meal (13% oil)	41,071	kg	0.15	-6,160.65	-0.26
Credit for pharmaceutical grade glycerine	0.08	kg/L	1.35	-2,567.75	-0.11
Adjusted Cost of oil				96,943.60	4.04
Processing Oil to Biodiesel					
Castor oil (from above)	24,000	L	4.04	96,943.60	4.04
Methanol				4,133.33	0.17
Sodium hydroxide				205.33	0.01
Acid				400.00	0.02
Electricity				211.2	0.01
Labour	24	Hr.	12	288	0.01
Listed direct costs				**102,181.46**	**4.26**
Fixed costs of biodiesel prod facility					**0.26**
Maintenance and supplies					**0.01**
Total listed costs of biodiesel production					**4.53**
Price of No. 2 diesel w/o excise taxes					1.048
Gain or loss relative to No. 2 diesel					-3.48

Appendix 10: Cost of Biodiesel Production from Castor Oil & WVO (Large Scale Plant 24,000L/day)

Direct Cost	Amount	Unit	$/Unit	$/Day	$/L (oil)
Oil Extraction					
Castor seed	57,000	kg	1.56	88,920.00	3.71
Electricity				1,008.00	0.04200
Labour	24	Hr.	6	144	0.00600
Listed direct costs				**90,072**	3.75
Fixed costs of oil extraction equip				**0**	0.00
Total listed costs				**90072**	3.75
Credit for meal (13% oil)	34,941	kg	0.15	-5,241.15	-0.22
Credit for pharmaceutical grade glycerine	0.08	kg/L	1.35	-2,567.75	-0.11
Cost of WVO					0.01
Adjusted Cost of oil				82,263.10	3.43
Processing Oil to Biodiesel					
Castor oil + WVO (from above)	24,000	L	3.43	82,409.76	3.43
Methanol				4,133.33	0.17
Sodium hydroxide				205.33	0.01
Acid				400.00	0.02
Electricity				211.2	0.01
Labour	24	Hr.	12	288	0.01
Listed direct costs				**87,647.63**	**3.65**
Fixed costs of biodiesel prod facility					**0.26**
Maintenance and supplies					**0.01**
Total listed costs of biodiesel production					**3.92**
Price of No. 2 diesel w/o excise taxes					1.048
Gain or loss relative to No. 2 diesel					-2.87