CHAPTER 1

1 INTRODUCTION

Currently there is much interest in biofuel production driven by increasing awareness of the need to reduce CO_2 emissions and incentives to achieve this as formulated in the Kyoto Protocol (Caniëls & Romijn , 2008). The Global Warming and the issue of dependence on fossil fuels, leads the importance of this study in order to explore sustainable fuel options, contribute with the fight against Climate Change and study the challenges of using current mechanisms for developing countries to implement production and use of biofuels.

The aim of this study is to identify the potential of jatropha in the Clean Development Mechanism through the evaluation of potential activities that reduce GHG gases through jatropha plantation and the use of jatropha biofuel. The Clean Development Mechanism (CDM) is a mechanism established under the Kyoto Protocol to promote projects that can reduce greenhouse gas emissions. It aims at promoting cooperative measures between the industrialized and the developing countries. Thus, this dissertation explores opportunities and challenges of the CDM for the jatropha industry in Malaysia and Chile.

It was conducted considering an optimistic/conservative scenario analysis based in the yield of the jatropha's oil production (oil ha/year). For each of those scenarios was calculated the amount of GHG reductions and expressed in CERs. The greenhouse gas reductions achieved by CDM projects can be used to meet the developed countries' targets. In this case study New Zealand was considered to be the developed country. In addition, it was identified the suitable conditions for CDM projects in the countries studied (Malaysia, Chile and New Zealand).

Biodiesel is a clean burning alternative fuel, produced from domestic renewable resources. It contains no petroleum but it can be blended at any level with fossil diesel to create a biodiesel blend. It can be used in diesel engines with little or no modifications. Biodiesel is simple to use, biodegradable, non-toxic, and essentially free of sulphur and aromatics (Reynauld, 2009).

Jatropha curcas is emerging as the new crop of renewable energy proponents. It is a more viable and sustainable feedstock for biodiesel compared to other food related crops such as palm oil. Jatropha does not threaten food supplies because is not an edible crop, furthermore, it can be planted in marginal lands so does not compete for water and land with food crops.

Jatropha is not only capable of growing on marginal land, but can also help to reclaim problematic lands and restore eroded areas. As it is not a food or forage crop, it plays an important role in deterring cattle, and thereby protects other valuable food or cash crops.

The main product of jatropha is biofuel, obtained from the oil extracted by pressing the plant's fruit. This product has been used in different countries as a fuel in the transport industry. Furthermore, the biofuel can be used to generate electricity thus replacing the use of fossil fuels and avoiding greenhouse emissions.

Jatropha seeds can be pressed into bio-oil that can be used to run diesel engines and can also be the basis for soap making. The pressed residue of the seeds is a good fertilizer and can also be used for biogas production.

The use of biofuel and biogas can reduce the amount of greenhouse gases by replacing fossil fuel. On the other hand, forestation and afforestation activities can also help to reduce the amount of greenhouse gases in the atmosphere.

Forest plantation species also make as good carbon reservoirs as natural forests; therefore potential planters must seize every opportunity to play a more prominent role in the mission of reducing the country's carbon emissions using the Clean Development Mechanism (CDM).

The Clean Development Mechanism (CDM) promotes projects that can reduce greenhouse gas emissions and was established under Article 12 of the Kyoto Protocol. It aims at promoting cooperative measures between the industrialized and the developing countries.

The greenhouse gas reductions achieved by each CDM project can be used to meet the industrialized countries' targets. In return for the reduction, there will be a transfer of money to the project that actually reduces the greenhouse gases. The production and use of jatropha biofuel qualify as a CDM project because the project will reduce greenhouse gases replacing fossil fuel consumption. The emission reductions achieved by the CDM project are called CER (Certified Emission Reduction). The emissions can be traded on the carbon market.

The purpose of the CDM shall be to assist developing countries in achieving sustainable development and in contributing to the ultimate objective of the

Convention, and to assist developed countries in achieving compliance with their quantified emission limitation and reduction commitments.

Malaysia and Chile are eligible as developing countries that have ratified the protocol. They have no obligations to constrain their GHG emissions based on commitments to the Protocol of Kyoto, so the reduction from the CDM project in Malaysia or Chile can be traded in the carbon market as a CER. New Zealand is a developed country that ratified the Kyoto Protocol in 2002. Its commitment is to reduce emissions, using emission credits from its forest sink, buying emissions credits on the international market, or some combination of these approaches (OECD, 2007).

The scope of work of this research is Malaysia and Chile as the host countries and New Zealand as the developed country that will transfer the knowledge and equipment to produce biofuel from jatropha.

The few measures implemented in the energy conservation and climate change programmes in New Zealand are likely to be insufficient to meet the Kyoto target (ME, 2007). Therefore, a CDM in Jatropha biodiesel will help New Zealand to meet its reduction targets.

The Organization for Economic Cooperation and Development (2007) suggests that to ensure that the most cost-effective domestic emission control measures are implemented, sector targets should be clearly set, for example in the transport sector.

The extensive use of vehicles and fossil fuel is putting pressure on the environment and human health. The use of diesel creates exhaust emissions that affect air quality and greenhouse gas emissions from the combustion of transport fuels contribute to climate change. Hence, the use of jatropha biodiesel as a replacement for fossil fuel will reduce GHG emissions

The reduction in the GHG emissions through replacement of fossil fuel can be quantified. However, project activity emissions also should be taken into account. The final unit of reduction is the CER.

The purpose of conducting this work is to identify the potential of jatropha as a CDM project hosted by Malaysia and Chile as the developing countries. CDM contributes to technology transfer by funding projects that use technologies previously unavailable in host countries. In Addition, conditions of each country are identified to comply with the requirements of a CDM project. The general objective of this research is to evaluate the potential of jatropha, in the context of the Clean Development Mechanism. Some of the limitations of the study are related with the market and prices for biofuel which depend of current oil prices, policies and regulations, likewise prices for CERs are driven by the current market and supply and demand for carbon credits. There is also limitation in the data provided as the data collected is an expectation of what the company anticipates in terms of yield of jatropha oil and an estimation on the data supplied for the fossil fuel and electricity consumption. More of the numerical values are yet to be implemented nor quantified at the real time, which is common in a CDM project.

Specific objectives are:

1. To identify and evaluate potential activities that can reduce greenhouse gases through the use of jatropha biofuel and sub-products.

2. To evaluate the option of jatropha plantation as part of an afforestation or reforestation project activity under CDM.

3. To identify those conditions that make a CDM project suitable for developed and developing countries.

4. To estimate the amount of reduction emission or certified emission reduction (CERs).

CHAPTER 2

2 LITERATURE REVIEW

2.1 Biofuels

The feedstocks used for producing biofuels can be grouped into two basic categories: first generation, which are harvested for their sugar, starch and oil content and can be converted into liquid fuels using conventional technology, and second generation feedstocks, which are harvested for their total biomass and can only be converted into liquid biofuels by advanced technical processes (Institute, 2007).

Institute (2007) and Pahl & Watson (2008) mentioned different feedstocks that are currently used or can be potentially used as biofuels. They can be classified as follows:

€ Sugar crops

- Sugar cane
- Sugar beets
- Sweet sorghum

€ Starch crops

- Corn/maize
- Wheat
- Cassava or tapioca
- Sorghum grain

- Oilseed crops
    - Rapeseed/Canola
    - Soybeans
    - Palm oil
    - Jatropha

- Others
    - Sunflower
    - Safflower
    - Cotton seed
    - Peanut
    - Mustard seed
    - Camelina
    - Coconut
    - Castor oil or momona
    - Hemp
    - Algae/Micro-algae
    - Animal fats (cattle, pigs, fish or chicken)
    - Used cooking oil

Institute (2007) declares that from the sugar and starch crops, it is possible to produce bio-ethanol, while bio-diesel can be produced from the oils from seeds and animal fats. According to Pahl & Watson (2008) biodiesel can be blended with petro-diesel in any percentage from B1 (1% of blended biofuel with diesel) to B99 (99% of blended biofuel with diesel). That makes it a flexible fuel that can meet a wide variety of different needs.

According to Foundation (2006), to produce a generally usable biofuel for any diesel engine, the Pure Plant Oil (PPO) can be converted to biodiesel by a transesterification process.

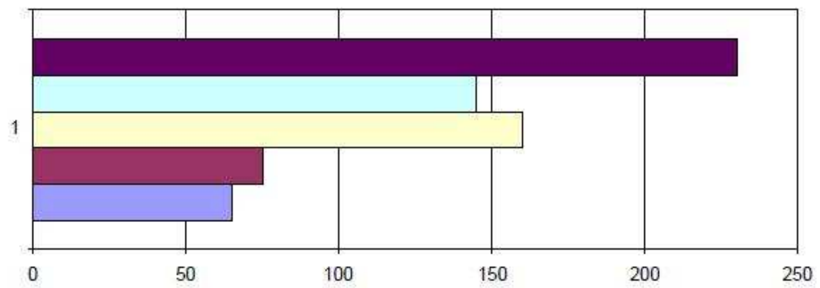
Transesterification is the process whereby the biofuel is converted to biodiesel. Vegetable oil, normally composed of three fatty acids and glycerol, is referred to as a triglyceride. Transesterification involves breaking every oil (triglyceride) molecule into three fatty acid chains, resulting in the removal of glycerin molecules from the vegetable oil, to make the oil thinner. During the alcohol process catalyst are added, and each of the fatty acid chains attaches to one of the new alcohol molecules (Foundation , 2006)

The products of the reaction are alkyl esters (biodiesel) and glycerin. Once separated from the glycerin, the alkyl ester chains then become a biodiesel (Pahl & Watson , 2008)

Foundation (2006) states that generally the diesel engine is well suited to run on pure plant oil and in fact, Rudolf Diesel designed his first engine to run on plant oil as well. Many types of diesel engines have indirect injection (IDI) with pre-chambers so PPO can be used freely in these engines, which are still commonplace in developing countries. Direct Injection diesels can also run on PPO, but some modifications have to be made to the engines. According to Pahl & Watson (2008), biodiesel can be used in any modern diesel engine without any modifications to the engine. It has excellent lubricating properties and will lubricate many moving parts in the engine, increasing the engine life.

The resulting biodiesel can be used in any diesel engine without adaptations, however Foundation (2006) states that there is an exception for pure rubber hoses which deteriorate after longer contact with pure biodiesel.

Biofuels contribute significantly to climate change mitigation by reducing CO_2 emissions (Gonsalves, 2006). Figure 2.1 shows a comparison of the CO_2 emitted by different combustibles during the life cycle analysis.



	1
Gasoline	230
Diesel	145
CNG	160
Ethanol	75
Biodiesel	65

Carbon dioxide emission, g/km

Figure 2.1: Carbon dioxide emission, life cycle analysis
Source: Planning Commission (2003)

Biodiesel has the lowest impact in terms of carbon dioxide emissions, as Figure 2.1 shows. Therefore, biofuels are a real option as an energy alternative in order to reduce green house gas emissions.

Biofuel can be an especially important alternative energy in oil-importing developing countries where landed petroleum costs are high due to a poor distribution infrastructure. Investing in a domestic biofuel industry could not only provide increased employment opportunities in rural areas, but it would allow developing nations to internalize a share of the economic value of the locally produced fuels (Institute, 2007).

Biodiesel is produced commercially in Europe and the USA to reduce air pollution and the net emission of greenhouse gas. Surplus edible oils, such as rapeseed oil and soybean oil, are used as raw materials for biodiesel. However, using edible oils to produce biodiesel is not encouraged because edible oils have to satisfy the consumption needs. Non-edible oil such as *Jatropha curcas* is attractive and the trees can grow in arid, semiarid and waste lands. It has a high-seed yield and high oil content (Houfang et al. , 2008).

2.2 Jatropha

Jatropha, the species employed for plantation and subsequent production of biodiesel is a plant that grows to between 3 metres (Foundation, 2006), (BioFuelsRevolution, 2009) and 8 metres in height (Van Eijck & Romijn, 2008). Jatropha produces seeds that contain an inedible vegetable oil that is used to produce biofuel. It can live up to 50 years and can produce seeds up to three times per annum.

Figure 2.2: Jatropha seeds

According to Institute (2007), *Jatropha curcas* is an oilseed crop that grows well on marginal and semi-arid lands. The bushes can be harvested twice annually, are rarely browsed by livestock and remain productive for decades. Jatropha has been identified as one of the most promising feedstocks for large-scale biodiesel production in India, where nearly 64 million hectares of land are classified as wasteland or uncultivated land. It is also particularly well suited for fuel use at the small-scale or village level.

When the nuts are pressed for oil the percentage of the oil obtained by extraction is about 20% to 35% of the nuts as mentioned in Foundation (2006) and Van Eijck & Romijn (2008) respectively. The rest remains as press cake which is the rest of the fruit and seed left over after extraction of the oil.

Amoah (2006) suggests that the yield of crude jatropha oil per hectare per annum is about 3.5 tonnes. Enthusiastic promoters of jatropha often claim that the yield can be as high as 8.0-10 tons per ha per year when the trees mature in 3-4 years. BioFuelsRevolution (2009) claims that 2500 plants (1 hectare) will produce around 10 tons of seeds which at 35% yield will produce up to 3.5 tonnes of biodiesel. The state-owned Philippine National Oil Company Alternative Fuels Corporation PNOC-AFC (2007) believes that a hectare of jatropha plantation can yield a minimum of 15 tonnes per year in the fifth year with a modified jatropha technology, crop improvement and scientific crop management.

Given these differences in the yield of jatropha oil, two scenarios are considered; the first is a conservative scenario with a production of 2.5 tonnes of oil ha/year; the second one is an optimistic scenario of 5 tonnes of oil per ha/year which is an average of the yield cited by the literature.

According to Pavitt & Bester (2007) jatropha has many benefits for farmers. It has a long life, is drought resistant and can be grown in a range of soil types including marginal soils with low nutrient content, sandy, saline, or otherwise infertile soil. It does not exhaust the nutrients in the land and it does not require fertilizers. It grows well on marginal land with more than 600 mm of rainfall per year, and it can withstand long drought periods.

Jatropha is considered a perennial crop and according to studies carried out by Institute (2007) these trees tend to deposit more carbon in the soil as roots, and the absence of tillage slows decomposition of soil matter.

The economic viability of biodiesel from jatropha depends largely upon the seed yields. To date, there has been a substantial variation in yield data for the plant, which can be attributed to differences in germplasm quality, plantation practices and climatic conditions. Several companies aiming to cultivate biodiesel in the developing world, have chosen jatropha as their primary feedstock owing to the plant's high oil content, its ability to tolerate a wide range of climates, and its productive lifespan of as long as 30 years (Institute, 2007).

In India, non-edible oil is the main choice for producing biodiesel, according to Indian government policy. Some development work has been carried out by Institutes and Universities in India with regard to the production of transesterfied non edible oil and its use in biodiesel. Generally a blend of 5% to 20% is used in India.

Several agencies promoting jatropha are projecting significantly improved yields as the crop is developed. In India, research has estimated that by 2012, as many as 15 billion litres of biodiesel could be produced by cultivating the crop on 11 million hectares of wasteland (Institute, 2007).

2.2.1 Uses of Jatropha

According to Foundation (2006) and Pahl & Watson (2008) the plant has many uses. It is capable of stabilizing sand dunes, acting as a windbreak or combating desertification. It can be grown as a hedge for erosion control, property boundaries and animal fencing. It naturally repels insects and animals. Jatropha is used to make lamp oil, soap, candles, poisons, and a wide range of folk remedies and the waste plant mass after oil extraction, “press cake” can be used as a fertilizer.

The plant also helps to stop local soil erosion, creates additional income for the rural poor, and provides a major source of energy both locally and internationally (Van Eijck & Romijn , 2008).

One of the advantages of using jatropha is that contrary to other biofuels made from oil seeds, jatropha does not displace food crops because the seeds and oil are non-edible and because it grows on land where food crops will not grow.

2.2.2 Jatropha and Greenhouse Warming

Amoah (2006) mentioned that the physic nut tree satisfies all the conditions set down under the UN Kyoto Convention as a positive sink tree that can be used for afforestation/reforestation projects to accomplish carbon sequestration (increasing the carbon stored by trees in a forest).

According to Hall, Woods, & House (1992) it is more efficient to use land to grow biomass for energy, offsetting fossil fuel use, than to simply sequester CO_2 in forests. Biomass energy strategies are preferable as they play much wider roles in coping with greenhouse warming.

The interest in using *Jatropha curcas* as a feedstock for the production of bio-diesel is rapidly growing. The properties of the crop and soil have persuaded investors, policy makers and clean development mechanism (CDM) project developers to consider this plant as a substitute for fossil fuels to reduce greenhouse gas emissions and to tackle the challenges of energy supply (Achten et al. , 2008).

Institute (2007) mentioned that jatropha biofuel has the potential to be carbon neutral over the life cycle, emitting only as much as the feedstock absorbs. The plant itself recycles 100% of the CO_2 emissions produced by burning the biodiesel.

Errázuriz (2008), mentioned in a seminar on jatropha conducted in Chile that with 12,000 hectares of jatropha, the amount of annual emissions reductions would be 80,000 tonnes of CO_2, considering an annual biodiesel production of 35,000 tonnes.

2.3 Clean Development Mechanism

To fight the global phenomenon that is climate change, two major agreements have been adopted by the international community, the United Nations Framework on Climate Change (UNFCC), adopted in 1992 in Rio, and more recently, the Kyoto Protocol, adopted in 1997.

In contrast to the UNFCC, the Kyoto Protocol sets quantified and binding commitments for limiting or reducing GHG emissions of anthropogenic origin for developed countries, or in the transition process towards a market economy, for the 2008-2012 commitment period. These countries are also referred to as Annex I parties. New Zealand is an Annex I country that has targets to comply with.

The developing countries do not have any legally binding targets under the Kyoto Protocol. The countries without any targets are referred to as non-Annex I parties. Malaysia and Chile are non-Annex I parties.

The Clean Development Mechanism is an economic instrument by which both countries, Annex I (or developed countries) and non-Annex I (or developing countries) can play a role in avoiding greenhouse emissions with the creation of new projects. The mechanism works as shown in Figure 2.3:

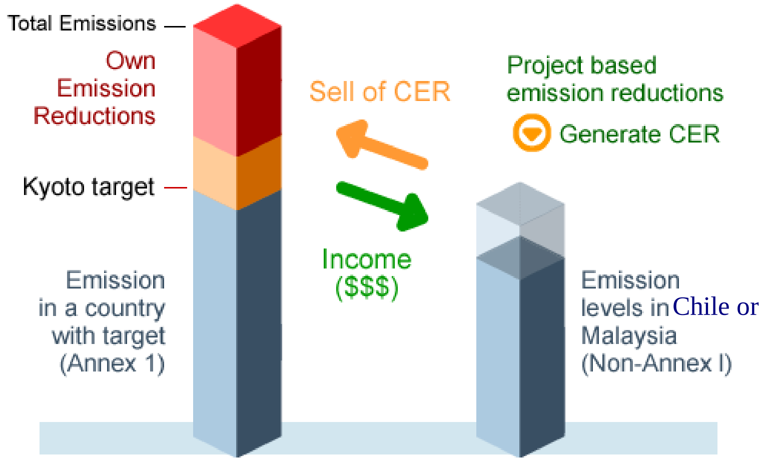


Figure 2.3: Clean Development Mechanism

Source : (PTM, NRE, & KTAK, 2005)

In Figure 2.3, the first bar represents the emissions from a developed country or (Annex I). Among the total emissions there are emissions that will be reduced in the same country and other emissions that can be reduced in developing countries helping to achieve the Kyoto target. The second bar corresponds to emissions from a developing country or (Non-Annex I). Among the total emissions, there are CDM project based emission reductions that will help a developed country to comply with the Kyoto target. The developed country will transfer income to the developing country. In response, the developing country will sell the Certificate of Emission Reduction (CER) to the developed country in order to comply with the Kyoto target.

The Kyoto Protocol states that developed countries can either meet their target through their own reductions, or by purchasing emissions credits from countries/firms that reduce their own greenhouse gases beyond their target level.

2.3.1 Project Cycle

The project cycle is usually initiated with the elaboration of a preliminary Project Idea Note (PIN) that summarizes a first concept and project structure. Figure 2.4 illustrates the project cycle. The next ones are officially required steps: Project design, Host country approval, Validation of project design, Registration, Monitoring, Verification, Certification and CER Issuance; the other boxes correspond to common, but not mandatory activities such as: Initial Project Idea, Preliminary Host Country Approval, Letter of Intention and Emission Reduction Purchase Agreement.

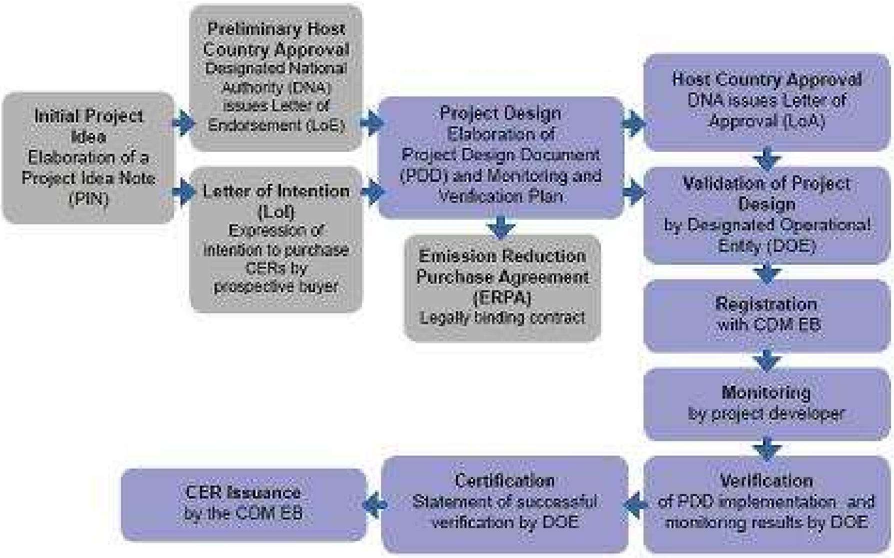


Figure 2.4: Overview of the CDM project cycle.

Source: (Neeff & Henders , 2007)

Figure 2.4 shows that the project cycle starts with the elaboration of the Project Design Document (PDD) which includes a description of the project activity, an estimation of the GHG reduction and a monitoring and verification plan of the GHG emissions. The project activity must be approved by the Designated National Authority (DNA) in terms of environmentally sustainable criteria. After that, the project must be validated by a Designated Operational Entity (DOE). In this stage, the project is registered under a CDM project category. The project developer in the host country should monitor the emissions reductions that will be verified by the DOE, together with the implementation of the PDD. The statement of successful verification brings the project to the certification step with the CER issuance.

Carbon trading has become the key response of the international community to the climate crisis, both in the forms of emissions trading and of trading in carbon credits (Bond Patrick, Dada, & Erion , 2006)

2.3.2 Afforestation and Reforestation (A/R)

The Kyoto Protocol establishes under Article 3.3 that greenhouse gas removals and emissions through certain activities, namely afforestation and reforestation since 1990 meet the Kyoto Protocol’s emission targets. Conversely, emissions from deforestation activities will be subtracted from the amount of emissions that an Annex I party may emit over its commitment period.

Under Article 3.4 of the Kyoto Protocol, parties could choose additional human-induced activities related to LULUCF, specifically forest management, cropland management, grazing land management and re-vegetation, to be included in their accounting for the first commitment period (UNFCC , 1998).

An A/R CDM project activity is an afforestation or reforestation measure, operation or action that aims at achieving net anthropogenic GHG removals by sinks. An A/R CDM project activity could, therefore, be identical with, or a component or aspect of a project undertaken or planned (UNFCC , 2008).

2.4 New Zealand and Climate Change

New Zealand ratified the Kyoto Protocol in 2002, committing to return its net annual GHG emissions to 1990 levels during the first commitment period (2008-2012) by reducing emissions, using emission credits from its forest sink, buying emissions credits on the international market, or some combination of these approaches (OECD , 2007).

While New Zealand contributes only a tiny proportion of the world's emissions, per capita emissions are high by international standards. So reducing the emissions will not, by itself, make a major contribution to the global problem of climate change (ETS, 2007).

A report carried out by the OECD (2007) mentioned that the GHG intensity in the New Zealand economy is the fourth highest in the OECD, after Canada, the US and Australia. The report declares that New Zealand adopted as a target "to return net emissions of CO_2 to no more than the 1990 level by 2000 and maintain emissions at that level thereafter. Unfortunately, this domestic target, concerning a reduction of CO_2 emissions, was not met.

There are four main climate change challenges for New Zealand:

- To control its own greenhouse gas emissions and reduce them relative to the current growth trend
- To support international initiatives for multilateral action on greenhouse gas emissions, principally through maintaining momentum on the implementation of the Kyoto Protocol and ensuring this momentum is carried through into whatever agreements emerge for the period after 2012
- To prepare for, and adapt to, the impacts of changes in the physical environment, by responding to the risks and taking advantage of the opportunities they present
- To realize the above objectives at the lowest achievable long-term cost.

A climate change policy package adopted in late 2002 set out policies designed to make significant and permanent reductions in GHG emissions and enable New Zealand to meet its Kyoto target or take responsibility for any exceedance by purchasing emission reduction credits on international markets (OECD , 2007).

The Climate Change Response Act 2002 put in place a legal framework to allow New Zealand to ratify the Kyoto Protocol and to meet its obligations under the UNFCC and the Kyoto Protocol. The Act enables New Zealand to trade emissions units (carbon credits) on the international market, and establishes a registry to record holdings and transfers of units. The Act also establishes a national inventory agency to record and report information relating to greenhouse gas emissions in accordance with international requirements (ME , 2007).

The policy package set a national target of putting gross emissions of GHG on a downward path by 2012; it builds on laws, policies and strategies covering energy efficiency, transport, waste, growth and innovation, and sustainable energy. The Energy Efficiency and Conservation Act (2000) and Strategy (2001) in New Zealand, set economy-wide, non binding targets for 2012 to improve energy efficiency and develop renewable energy supplies, aiming to reduce New Zealand's CO_2 emissions by between 4.5 Mt and 20 Mt annually (OECD , 2007).

ME (2007) declares that global measures to reduce greenhouse gas emissions from transport, a major contributor to New Zealand's emissions, and one of the fastest growing emissions sectors, are likely to give added momentum on initiatives to improve fuel efficiency and increase the use of biofuels and alternative means of powering vehicles.

ME (2007) also declares that a number of sector specific initiatives and policies are underway to reduce New Zealand's greenhouse gas emissions. In addition, an economy-wide emissions trading scheme (ETS) has been announced to put a value on emissions.

The Government has decided in principle that New Zealand will use an emissions trading scheme as its core price-based measure for reducing greenhouse gas emissions and enhancing forest carbon sinks. The New Zealand Emissions Trading Scheme (NZ ETS) will operate alongside other policies and measures to reduce domestic emissions and achieve New Zealand's broader sustainability objectives.

As a developed country, New Zealand must reduce its GHG emissions during the first commitment period (2008-2012). The reduction commitment for New Zealand mentioned in Annex B of the Protocol of Kyoto is 100 (percentage of base year or period). That means, it will have to return the same amount of GHG emissions that it had in 1990, in other words, New Zealand is meant to show no increase from 1990 levels between 2008-2012.

2.5 New Zealand and Biofuel

Since 1996, the most significant increase in GHG emissions has come from the energy sector, mainly because of growth in CO_2 emissions from motor vehicles and power plants (OECD , 2007).

The motor vehicle fleet has expanded rapidly, partly through imports of secondhand cars. The vehicle ownership rate is now among the highest in the OECD (54 vehicles per hundred inhabitants), and CO_2 emissions from road transport have increased by nearly 60% since 1990 (OECD , 2007).

In 2003, oil represented about 48 percent of New Zealand’s total energy consumption. With dwindling reserves, the country imports more than five times the amount of oil it is able to produce domestically (Pahl & Watson , 2008).

The New Zealand Transport Strategy is the strategic framework for achieving the vision that by 2010 New Zealand will have an affordable, integrated, safe, responsive and sustainable transport system (ME , 2007).

The New Zealand Transport Strategy (NZTS) makes reference to the NEECS transport objectives, including increasing the use of low energy transport options, within the context of environmental sustainability. The strategy also recognized the importance of transport biofuels (MOT , 2008).

The Renewable Energy Target in the NEECS included an indicative target of 2 petajoules (PJ) by 2012 for the transport sector in order to signal the longer-term pathway required. The target is equivalent to about 1 percent of current transport energy use. It was set at this low level because of the lack of an established biofuels industry.

Consequently, the New Zealand Government has been looking at ways to encourage the greater production of biofuels encouraging voluntary uptake and promoting biofuels and a biofuel industry by applying consistent tax incentives" (MED, 2009).

Despite an indicative target under the National Energy Efficiency and Conservation Strategy for the uptake of transport biofuels since 2002 and a number of government initiatives to encourage voluntary uptake, there are no transport biofuels being used in commercial quantities in New Zealand. No biodiesel is produced commercially at present, but feedstocks are available in sufficient quantities to exceed the NEECS target (Ministry of Transport, 2008).

2.5.1 Use of Biofuel in New Zealand

In a recent newspaper article, Dye (2008) commented on Air New Zealand and the use of oil from jatropha nuts to fuel a test flight which was the first of its kind using a sustainable biofuel with commercial potential. By 2013 the fuel will provide it with one million barrels a year. Jatropha biofuel is cheaper than traditional jet fuel, emits less carbon dioxide and is socially responsible. It is grown on land unsuitable for food crops and which has not been forest land for at least 20 years.

Other cases mentioned in New Zealand newspapers are Virgin Atlantic powering a jumbo jet partly using coconut oil in February, and the Dutch airline KLM which plans a test flight this year with a biofuel made from algae.

2.5.2 Barriers to the Introduction of Biofuels

MOT (2008) identified the following barriers to the introduction of biofuels:

- Risk of vehicle damage: Some vehicle manufacturers' representatives are reluctant to accept more than 3% ethanol in second hand vehicles imported from Japan, on the basis that this is the regulated level in Japan. On the other hand, fuel companies are not interested in ethanol blends below 5% because they are not seen as economic. They are waiting for a clear signal from Japanese manufacturers that 5% ethanol is acceptable.

- The variation in the real price of oil. Fluctuating oil prices make it difficult to justify long term investment in biofuels. Although the high price of oil at present makes biofuels competitive, investment decisions for new facilities/expansions will also need to take into account possible future oil price decreases – so investment is unlikely.

- The externalities of mineral diesel are not accounted for. In the existing system, some environmental and social costs associated with mineral fuels are not fully accounted for in their pricing, and as a result, the price of biodiesel (and to a lesser extent ethanol) appears high relative to the price of diesel (and petrol). There is no feasible way to reflect the environmental benefits (other than via the carbon charge) from using biofuels, especially biodiesel.

The energy intensity of the industrial sector is high, and the carbon intensity of the electricity supply although still low, is increasing. Low taxation of motor vehicle fuels (or non existent in the case of diesel) translates into relatively low prices at the pump, giving little incentive to replace fossil fuel by biodiesel.

New Zealand’s Environment Minister, Mr. Brownlee declared: "To meet the biofuels obligation of the old law oil companies were required to blend 10 million litres of biofuel into petrol and diesel sold in New Zealand in a year.” This would mean much of the biofuel would have been imported before environmental sustainability standards had been put in place (MED ,2009). This declaration was done after the biofuel law was repealed, therefore removes the obligation on oil companies to sell a small percentage of their fuel blended with biofuels.

2.6 New Zealand and Forest

Carbon sequestration in forest is the amount of CO_2 captured by the biomass and sinks in carbon pools such as above-ground, below-ground, dead wood, litter and soil organic carbon. This key factor in New Zealand's GHG accounting since 1990 is likely to diminish over time as planted forests reach maturity, and government retention of forestry carbon sink credits may have contributed to the weakening of incentives to expand plantations (OECD, 2007).

In 2004 New Zealand's GHG emissions totalled 75.3 million tonnes of CO_2 equivalent (Mt CO_2e), 21.3 % above the 1990 baseline level (62 Mt CO_2e). The latest Government projections suggest that net emissions during 2008-2012 are likely to exceed 1990 levels by about 30%, although sequestration from forestry may offset 10-15% of these emissions (Ministerial Group on Climate Change, 2005; Mfe, 2006a).

The largest growth in emissions since 1990 has been in the energy sector (an increase of 9.9 million tonnes of CO_2e as declared by ME (2007). This growth has been offset by a concurrent increase in removals to forest sinks (5 million tonnes of CO_2 e, or 29 per cent since 1990).

Carbon sequestration from forest plantations will decrease towards 2020, however, as forests reach maturity and are harvested, and incentives to plant for carbon sinks may have contributed to the slowdown in the planting rate (OECD , 2007).

Plantation forests play a pivotal role in New Zealand's GHG accounting in the first Kyoto commitment period, during which protected indigenous forests are considered a neutral carbon reservoir that do not contribute to CO_2 removal. Removal of CO_2 is calculated from the growth of planted forests, and emissions from the harvesting of planted and privately owned indigenous forests (OECD , 2007).

According to MAF (2006) about 6,600 km^2 of plantation forest have been established since 1990. These plantations are known as "Kyoto forest" and count as carbon sinks. Carbon sequestration in plantation forest is the main domestic measure New Zealand uses to reduce net GHG emissions. Since 1990, new forest planting has added 423 km^2 per year, on average, but the annual net planting rate declined from a peak in 1994 (980 km^2) to a net loss of 10 km^2 in 2004 NZCCO (2005).

Annual CO_2 uptake by *Pinus radiata* is estimated at 26 tonnes per hectare (Trotter et al, 2004). Recognition of forests as useful carbon sinks has led to a range of policies favouring the plantation of forests (Rhodes and Novis, 2002). As the Kyoto forests near commercial maturity, however, it is increasingly realized in New Zealand that their sequestration of carbon is not a permanent solution.

In conclusion the New Zealand government recognizes the importance of the forests as carbon sinks and the role that they play in the Kyoto Protocol. However to combat climate change and meet the Kyoto target, sequestration of carbon is not enough. New Zealand has to diversify its environmental projects that reduce GHG in order to preserve forest and reduce its emissions.

2.7 Chile and Climate Change

Chile ratified the United Nations Framework Convention on Climate Change in 1994 and established a National Climate Change Advisory Committee in 1996. In 2001, a year after Chilean ratification of the Kyoto Protocol, the National Commission on the Environment was appointed as Designated National Authority. In January 2006 the CONAMA Governing Board approved a National Climate Change Strategy with a primary focus on mitigation of GHG (PROCHILE , 2007).

The general guidelines and priorities of the Chilean Government as defined by PROCHILE (2007) are as follows:

- The adaptation to climate change impact, where the government will determine the impacts and adaptation measures and formulate a national program and plans for adaptation.
- Mitigation of emissions where the government wants to update an emissions inventory, evaluate the country's potential for GHG mitigation, generate domestic mitigation scenarios, formulate a National Program and Plans for GHG emission mitigation and to create and build national climate change capacities.
- To create and build national climate change capacities, updating the emissions inventory, formulate a National Climate Change Education and Awareness Program and create a National Biodiversity and Climate Change Research Fund.

These guidelines establish a policy in Chile to deal with climate change and to arrange plans for potential GHG mitigation, linked by the participation of education and awareness programs.

Chile has established, as a strategic priority, diversification of the energy pool to promote renewable sources of energy replacing fossil fuel. This will allow future development of the country (Ministry of Energy Chile, Tokman, 2008).

Chile is the ninth most vulnerable country to climate change among the world. Some of the environmental concerns are: glacial melt; shifts in rainfall patterns; expanding deserts; greater frequency of El Niño impacting on the water supply; food production, tourism industry and migration. All of these potential problems will impact on Chile's socio-economic development and national security (UK , 2009).

While the prospect of becoming one of the world's largest victims to climate change approaches, Chile must find viable solutions to an ongoing energy crisis. Reality dictates that current coal based energy production and future affordable energy production projects are contradictory to the adoption of low carbon emission policies. Alternatively, Chile's native energy resources include renewable possibilities such as wind, solar or maritime (UK , 2009).

2.8 Chile and Biofuel

Chile imports most of the fuel it consumes. The Chilean Government has recently signed a pact with Brazil to help it identify areas of potential biofuel development and cooperation. In March 2007, the government announced the elimination of taxes on bioethanol and biodiesel in a bid to increase demand and help jump-start the industry (Pahl & Watson , 2008).

Chile needs to diversify the energy matrix both for environmental and strategy reasons and to achieve this, the agricultural sector is studying the best way to produce jatropha on a commercial scale. The production of jatropha biodiesel is considered to be one of the new energy alternatives to fossil fuels.

In the northern part of the country, the Government is working with the University of Tarapaca and the University of Chile to develop and validate plantations of jatropha to produce biofuel. The seeds were imported from Guatemala and currently the first plantations are growing well.

Chile appears to be making careful progress towards greater biodiesel use in its future energy. However, it is at a very initial stage as the studies are concerned just with the identification of suitable cultivation sites and the genetic improvement of the jatropha plant in Chile's soil conditions.

2.9 Chile and Forest

The Afforestation/Reforestation CDM Project Activities in Chile are usually divided into three categories: First, afforestation in small owner lands or indigenous communities through CONAF, NGO and/or other organizations; second, associative afforestation by share-partnership agreements between forest enterprises and small land owners, and the third is afforestation in eroded or degraded soils to recover productivity in any kind of land tenure and surfaces size (Neuenschwander , 2003).

Neuenschwander (2003) estimated that, between the years 2003 and 2012, about 200,000 hectares could be afforestated though Afforestation/Reforestation CDM project activities.

To establish the additionality of an Afforestation/Reforestation CDM project activity, it is preferable to do it through socio-economics impacts. The preliminary criteria for the Afforestation/Reforestation CDM project activities in Chile are classified under social, economic and environmental priorities.

Table 2.1: Classification of priorities for an Afforestation/Reforestation CDM project

Social Priorities	Economic Priorities	Environmental Priorities
-Increase employment through implementing economic activities. -Improvement of life conditions of land owners and indigenous communities associated with land.	- Establish forest plantation with high economic value. -Increment value of property through forest activities and additional incomes by CER. -Access to governmental incentive programs for plantations. -To minimize organizational costs and project administration.	-Recuperation of eroded and degraded soil with no cover vegetation. -Water supply sources protection, hydrographic basins, sloped lands and erosion risk. -Forest species adapted to local ecosystems. -Avoid natural forest replacement.

Source: (Neuenschwander .2003)

From Table 2.1 it can be concluded that jatropha plantation meets social, economic and environmental priorities in Chile. Increasing the employment levels in the north part of Chile will help poor communities to improve living conditions; in addition, the Chilean Government is supporting through investigation grants the development of jatropha plantations in degraded areas to help the environment.

Chile's forest has lost 4.5 million acres of native forest from 1985 to 1995 and, besides the forest, there is a loss of biological diversity. These forests were destroyed largely to make way for industrial tree farms and 90% of all wood exported from Chile comes from its non-native tree farms. Native forests will face increasing danger over the next 15 years as Chile's wood products industry pursues its plans to double plantation acreage from more than 5 million acres today to more than 10 million acres by the year 2020 (Forestethics 2009).

2.10 Malaysia and Climate Change

Malaysia is a party to the United Nations Framework on Climate Change and ratified the Kyoto Protocol on 4 September 2002. The Kyoto Protocol entered into force on 16 February 2005.

At the national level, Malaysia has set up a National Steering Committee on Climate Change to oversee and address all issues related to climate change, the Convention, and the Protocol. The Conservation and Environmental Management Division at the Ministry of Natural Resources and Environment is the Designated National Authority (DNA) for CDM projects in Malaysia (Norini et al, 2007).

Malaysia has been following the negotiations and development of climate change issues very closely owing to the numerous implications that can and will arise from the agreements achieved. As a developing country, Malaysia has no quantitative commitments under the Kyoto Protocol at present.

However, through the Clean Development Mechanism (CDM), Malaysia could benefit from investments in the GHG emission reduction projects, which will also contribute to the country's sustainable development goals, the overall improvement of the environment and result in additional financial flows.

CDM projects result in certified emission reduction (CERs) that can be traded on the international market. These CERs will provide mutually shared benefits between developing and developed countries (PTM, NRE, & KTAK , 2005)

According to (PTM, NRE, & KTAK , 2005) the CDM can provide a financial contribution to projects in reducing GHG emissions. Projects that have the potential to reduce GHG in Malaysia include amongst others:

- Renewable energy projects, including PV, hydro and biomass;
- Industrial energy efficiency;
- Supply and demand side energy efficiency in domestic and commercial sectors;
- Landfill management (flaring or landfill gas to energy);
- Combined heat and power projects;
- Fuel switch to less carbon intensive fuels (e.g. from coal to gas or biomass);
- Biogas to energy (from POME or other sources);
- Reduced flaring and venting in the oil and gas sector;
- Land-use, land-use change and forestry (LULUCF) projects (afforestation, reforestation, forest management, cropland management, grazing land management and re-vegetation)

Assuming an annual potential of 18 million CERs per year in 2010, there is a substantial CDM potential in Malaysia of up to 100 million tonnes of CO_2 equivalent for the period 2006 to 2012. At market prices of between US$ 3 and 10 per tonne, this corresponds to a total capital inflow to Malaysia from sales of CDM credits (CERs) in the range of RM 1.14 to 3.8 billion. Bilateral and multilateral CDM projects might typically leverage projects financing 3 to 4 times this amount, hence contributing substantially to foreign direct investment and technology transfer.

From the perspective of Malaysia, the success of the CDM rests upon the contribution it may make to national sustainable goals. Whether this will actually be achieved can be largely directed by the Government, because only projects that receive national host country approval can be officially registered as CDM projects and generate CERs. Without such an approval, no CERs can be generated. In the case that the Government does not want to support a certain type of project or technology, it can withhold national approval and thus prevent CERs from being generated and traded (PTM, NRE, & KTAK .2005)

2.11 Malaysia and Biofuel

The Malaysian National Biofuel government policy has as a goal to reduce the consumption of imported petroleum. In order to accomplish that, the policy has promoted greater production and use of blended palm-oil biodiesel in 5% (B5). Those supports have not been needed recently, since the demand for palm oil has soared and its price has doubled between 2006 and 2007, causing problems for biodiesel producers (Pahl & Watson, 2008)

Table 2.2 shows the biodiesel projects currently in operation. Another four plants with a combined capacity of 190,000 tonnes are expected to commence commercial production by the end of 2009.

According to USDA (2009), the Malaysian Government has started to look at a promising alternative feedstock jatropha. The Government has allocated funds to facilitate research and development of the crop and the Malaysian Palm Oil Board is tasked with carrying out performance tests on jatropha-based biodiesel. The Malaysian Rubber Board is to engage in seed breeding and the National Tobacco Board is to gauge the suitability of cultivating jatropha in the northern part of the country. A few private companies are planning to invest in jatropha cultivation but the impact on the biofuel sector will not be significant in the next two years.

Table 2.2: Biodiesel Plants in Operation in Malaysia

	Name	Location
1	Carotino Sdn.Bhd.	Pasir Gudang, Johor
2	Malaysia Vegetable Oil Refinery Sdn. Bhd.	Pasir Gudang, Johor
3	PGEO Bioproducts Sdn. Bhd.	Pasir Gudang, Johor
4	Vance Bioenergy Sdn. Bhd.	Pasir Gudang, Johor
5	Mission Biotechnologies Sdn. Bhd.	Petaling Jaya, Selangor
6	Carotech Bio-Fuel Sdn. Bhd.	Ipoh, Perak
7	Lereno Sdn. Bhd.	Setiawan, Perak
8	Golden Hope Biodiesel Sdn. Bhd.-Carey Island	Pulau Carey, Selangor
9	Golden Hope Biodiesel Sdn. Bhd.-Panglima Garang	Teluk Panglima Garang, Selangor
10	Zoop Sdn. Bhd.	Shah Alam, Selangor
11	Global Bio-Diesel Sdn. Bhd.	Lahad Datu, Sabah
12	SPC Bio-diesel Sdn. Bhd.	Lahad Datu, Sabah

Source: USDA (2009)

2.12 Malaysia and Forest

Forest Research Institute Malaysia (FRIM) indicated that selected species planted under forest plantation programmes are able to sequester carbon. The ranges of sequestration are from 3.5 t/ha/year for *Dipterocarpus* species to 14.6 t/ha/yr for *Eugenia urophylla* (Norini, et al. , 2007)

Following the 11th Session of the Conference of Parties (COP), Malaysia submitted its stand on the issue of deforestation in developing countries. Malaysia is aware of the importance of forest resources in providing environmental protection, especially with regard to climate change. Malaysia also is committed to managing its forests in a sustainable manner and will support global efforts to curtail deforestation. With regard to negotiation processes on deforestation, Malaysia would like very much to do this under the Kyoto Protocol and be considered under the second commitment period, i.e., after 2012 (Norini et al. , 2007)

The CDM mechanism mentioned earlier in the text refers to afforestation and reforestation projects on deforested land before 1990. With the Government's intention to increase the area under forest plantation, the potential of both reforestation and afforestation projects to be new sources of timber is highly likely.

Preliminary assessments carried out by researchers at FRIM indicated that forest plantation species also are good sequesters of carbon. For instance, *Acacia mangium* and *Acacia hybrid* have the capacity to absorb 6.39t/ha/yr and 6.22t/ha/yr of carbon, respectively. In fact, almost all of the species recommended for forest plantation are capable of sequestering carbon.

Table 2.3: Total carbon uptake increments of different plantation forests according to species.

Classification	Category	Carbon Uptake (t/ha/year)
Plantation Forest	*Acacia mangium*	6.39
	Pinus spp.	5.65
	Eucalypthus deglupta	11.68
	Dipterocarpus spp.	3.45
Plantation Industry	*Elaeis guineensis*	6.95
	Hevea brasiliensis	6.31

Source: (Norini et al. , 2007)

Table 2.4: LULUCF potentials of considered Non-Annex B countries – first commitment period (in tCO_2)

Project type	Malaysia		Chile	
	low	high	low	High
Plantations	55,000	82,500	275,000	550,000
Avoided deforestation	0	0	0	0
Agro-forestry	9,167	21,083	1,833	4,217
Regeneration	550,000	1,100,000	18,333	55,000
Total carbon	614,167	1,203,583	295,167	609,217

Source: (Jung , 2003)

According to Norini, et al. (2007) there are challenges in implementing the CDM in Malaysia. These can be classified as:

I. Methodologies, criteria and definitions need to be developed.

- National CDM criteria for forestry projects, particularly concerning the transfer of technology.
- Definition of forest and the calculations for above-ground carbon sequestration rates using local values.
- Methodologies for forestry CDM suited to Malaysian conditions.

II. Stakeholders, Institutions & Regulations.

- The awareness and understanding among stakeholders
- To enhance the effectiveness of the process application and the proper advice to potential clients.
- Legal and institutional issues related to land tenure need to be addressed.

III. Future actions

- Identification of suitable lands that are eligible for afforestation/reforestation CDM in Malaysia.
- Forestry CDM should be viewed as an incentive to promote the establishment of forest plantation where it might not be profitable otherwise
- Rules and modalities for forestry CDM projects should be less strict in the next commitment period (2012).
- Avoiding deforestation and forest rehabilitation in developing countries should be considered for credits in future negotiations on suitable mechanisms.

2.13 Case Studies on Jatropha Biodiesel

There are various biofuel projects currently being submitted under the CDM, where the main reduction is caused by the replacement of fossil fuels. Some of these CDM projects that utilize biodiesel are as follows:

- Palm Methyl Ester – Biodiesel Fuel (PME-BDF) production and use for transportation in Thailand
- AGRENCO biodiesel project in Alta Araguaia, Brazil
- Sunflower methyl ester biodiesel fuel production and use for transportation in Thailand
- Biodiesel production and switching from fossil fuels petro-diesel to biodiesel in the transport sector, Andhra Pradesh, India
- Manufacturing of biodiesel from crude palm oil and jatropha oil Kakinada, Andhra Pradesh.
- Jatropha biodiesel from degraded land in Madagascar
- *Jatropha curcas* Cultivation in the Democratic Republic of Congo

Among the biofuel projects submitted to IPCC, the last three mentioned are jatropha projects. The rest have used other crops to produce biofuels.

The following are brief descriptions of jatropha projects submitted in IPCC that have claimed carbon credits from jatropha, either as a biofuel or as a reforestation/afforestation project.

2.13.1 Manufacture of Biodiesel from Crude Palm Oil and Jatropha Oil in Kakinada, Andhra Pradesh.

Natural Bio-Energy Limited (NBEL) is setting up a 300 tonnes per day biodiesel manufacturing facility at Kakinada, Andhra Pradesh. The plant is proposing to use Crude Palm Oil as a raw material during its initial operation and in due course jatropha oil will also be included along with the palm oil. NBEL is planning to import the raw material from Malaysia and the refining of raw material and manufacturing of biodiesel will take place at Kakinada. NBEL is proposing to use methanol for trans-esterification and sodium methaoxide as a catalyst. During the manufacturing process, the pharma grade glycerine will be produced as a by-product (Chalasani, 2007).

It is assumed that the bio-diesel generated from the project activity will replace liquid fossil fuel that would otherwise be used as fuel in mobile combustion engines for road and rail transport as well as in stationary combustions. The project activity proposes reductions in GHG emissions in both the production stage (transesterification as compared to pre-combustion emissions of baseline fuel) and the consumption stage (biodiesel consumption as compared to emission from combustion of baseline fuel) (Chalasani , 2007).

The project activity will contribute to the sustainable development of India in the following ways with respect to social, economic, environmental and technological well- being: the project promotes use of biodiesel, which is a renewable fuel and is clean, safe and biodegradable. Combustion of biodiesel reduces serious air pollutants such as soot, particulates, carbon monoxide, hydrocarbons and air toxics (Chalasani , 2007).

Efficient and effective production of biodiesel would significantly enhance the prospects of employment of native people, involving technical, semi-technical and non-technical human resources. Optimal deployment of oil extraction and crushing units would help in the sustainable business development of small scale industries. Usage of bio-diesel fuel would also help in improving the oil sector productivity, growth and linkages leading to a higher contribution to GDP. The annual average over the crediting period of estimated reductions is 60,012 tonnes of CO_2 e (Chalasani , 2007).

The project activity reduces greenhouse gas emissions by reducing the consumption of fossil energy in combustion engines in the transport sector or stationary electricity generation. As part of the project activity, a jatropha plantation will be established on 3,000 ha of wasteland. Oil presses and a biodiesel production plant will be set up on the site and biodiesel will be marketed domestically (Chalasani , 2007).

2.13.2 Jatropha Biodiesel from Degraded Land in Madagascar

The purposes of the project activity are the establishment of the oil seed producing plant *jatropha curcas* on extremely eroded, unused areas in Madagascar, the production of biodiesel (jatropha oil methyl ester) as a substitution for fossil diesel in Madagascar, the prevention of ongoing erosion, re-cultivation of the land for past project use and local employment benefits (Germain , 2008).

The proposed project activity is carried out as a small scale activity which is classified by the IPCC as a type of renewable energy project activity with an output capacity lower than an appropriate equivalent to 15 megawatts. The annual average of the estimated reductions for this project over the crediting period is 3828.3 tonnes of CO_2 e.

The project also reduces greenhouse gas emissions by reducing the consumption of fossil energy in combustion engines in the transport sector or stationary electricity generation. As part of the project activity, a jatropha plantation will be established on 3,000 ha of wasteland. Oil presses and a biodiesel production plant will be set up on the site and biodiesel will be marketed domestically (Germain, 2008).

The production of biodiesel from jatropha oil produced on degraded land will contribute to sustainable development in Madagascar through multiple effects:

- Land degradation, particularly erosion on long term deforested areas, is a serious threat to global food security. After completing the project land fertility and productivity will be significantly higher for further use.
- The enhancement of renewable energies is of high importance, particularly in the rapidly growing transport sector of many developing countries, to counter increasing greenhouse gas emissions and shortage of fossil oil resources.
- Socio-economic benefits will arise from the transfer of know-how and the promotion of project experience for sustainable domestic production of biofuels, enabling Madagascar to reduce its dependence on fossil energy imports by using its vast but currently largely infertile land resources. Short-term effects in the course of the project activity will occur through direct employment opportunities and income generation for the local project partners and population as well as demand for commodities and services at local suppliers.
- From an ecological point of view, the establishment of a jatropha plantation and the corresponding supply of organic matter to the soil ecosystem will entail a diversification as compared to the predominant occurrence of severely eroded soil and one or a few low-grade grass species.

2.13.3 *Jatropha curcas* Cultivation in the Democratic Republic of Congo

The project entitled Jatropha Cultivation in the Democratic Republic of Congo will allow the establishment of 187 *jatropha curcas* plantations covering an area of 14,000 hectares of mostly degraded soils. The intended objectives of this project are: sequestration of CO_2 by the cultivation of *jatropha curcas*; regeneration of degraded soils and protection against erosion; and empowerment of local communities (Carbon2green, 2008).

The planting schedule will be phased in over four years to sow the 14,000 ha and gradually include the 187 villages involved in the project.

The net sequestration of greenhouse gases by sinks associated with the implementation of this CDM afforestation project includes 35 million plants spread over 14,000 hectares and is estimated at 3,219,899 tonnes of CO_2 equivalent over a 30 year period.

The benefits of the jatropha plantation project are erosion control through plantings, improved soil fertility through the life cycle of jatropha, creation of new habitats for bees, birds and small animals, minimal disruption of existing natural habitats, restoration of biodiversity and improving the beauty of the landscape.

2.14 Summary of Chapter 2

Biodiesel can be produced from the oils from seeds and can be blended with petro-diesel to be used in any diesel engine.

Biodiesel has the lowest impact in terms of carbon dioxide emissions in comparison with different combustibles such a gasoline, diesel, ethanol and compressed natural gas (CNG), therefore biofuels contribute significantly to climate change mitigation by reducing CO_2 emissions.

Jatropha produces seeds that contain an inedible vegetable oil that is used to produce biofuel. It can grow well on marginal and semi-arid lands, has a long life, is drought resistant and can be grown in a range of soil types.

One of the advantages of using jatropha is that contrary to other biofuels made from oil seeds, it does not displace food crops because the seeds and oil are non-edible and because it grows on land where food crops will not grow.

The properties of the crop and soil have persuaded investors, policy makers and clean development mechanism (CDM) project developers to consider this plant as a substitute for fossil fuels to reduce greenhouse gas emissions. The Clean Development Mechanism is an economic instrument by which both countries (developed and developing) can play a role in avoiding greenhouse emissions with the creation of new projects.

New Zealand ratified the Kyoto Protocol, committing to return its net annual GHG emissions to 1990 levels during the first commitment period (2008-2012) by reducing emissions, using emission credits from its forest sink or buying emissions credits on the international market. Consequently, the New Zealand Government has been looking at ways to encourage the greater production of biofuels encouraging voluntary uptake and promoting biofuels and a biofuel industry

Chile is a developing country that ratified the Protocol of Kyoto. It has established, as a strategic priority, diversification of the energy pool to promote renewable sources of energy replacing fossil fuel. The production of jatropha biodiesel is considered to be one of the new energy alternatives to fossil fuels.

Malaysia ratified the Kyoto Protocol on 2002 which entered into force on 2005. As a developing country, Malaysia has no quantitative commitments under the Kyoto Protocol at present. Through the Clean Development Mechanism Malaysia could benefit from investments in the GHG emission reduction projects, which will also contribute to the country's sustainable development goals.

The Malaysian National Biofuel government policy has as a goal to reduce the consumption of imported petroleum. In order to accomplish that, the policy has promoted greater production and use of blended palm-oil biodiesel in 5%

An A/R CDM project activity is an afforestation or reforestation measure, operation or action that aims at achieving net anthropogenic GHG removals by sinks. In Chile has been estimated that, between the years 2003 and 2012, about 200,000 hectares could be afforestated though Afforestation/Reforestation CDM project activities. In the case of Malaysia, the country is aware of the importance of forest resources in providing environmental protection, especially with regard to climate change. Malaysia also is committed to managing its forests in a sustainable manner and will support global efforts to curtail deforestation.

There are various biofuel projects currently being submitted under the CDM, where the main reduction is caused by the replacement of fossil fuels. Projects that have used jatropha as the main biofuel are located in India and Congo.

CHAPTER 3

3 METHODOLOGY

The methodology to develop this research work consists of a literature review, observation, site visit, interviews and analysis of the data provided by the case study (project activity).

The research used data from a New Zealand biodiesel company which is planning to plant jatropha and produce biofuel. The name of the company is omitted as a part of a non-disclosed agreement in order to protect the confidentiality of the data provided.

The company studied expects to carry out a farming project on *jatropha curcas* in a developing country (project activity). It expects to grow up to 20,000 ha, gradually over a period of 10 years.

In order to achieve the objective of the study, primary and secondary data was required. Data was collected from the company in order to calculate the GHG emissions from the activity and also the GHG reductions. The data supplied by the company is: number of hectares, yield of jatropha oil expected, consumption of fossil fuel for machinery, consumption of electricity, amount of nitrogen fertilizers, amount of methanol used in the production of biodiesel. Other data such as the distance for ship voyages and the price of CERs was estimated.

The calculation of the GHG emissions from the activity and from the reduction was done using the equations provided by the IPCC Guidelines and similar CDM projects related to biofuel production/consumption. The equations include data supplied by the company and parameters that were sourced from IPCC Guidelines, DEFRA (Department for Environment, Food and Rural Affairs, UK) and NZ Guidelines.

The equations are used to calculate: the quantity of carbon capture by the plantation, baseline emissions, project emissions related to consumption of fossil fuel, project emissions related to other sources of GHG (nitrogen and methanol consumption).

In this work, Chile and Malaysia were selected as the case study and named as a “CDM host country”, which means the country in which the reduction project will take place.

The reason for choosing Chile and Malaysia was because both are developing countries that can host CDM projects. New Zealand is an industrialized country that can transfer the technology and act as the buyer of CERs. The NZ company expects to plant jatropha biofuel in a developing country and produce biofuel.

Figure 3.1 represents the relationship of the countries studied in this work.

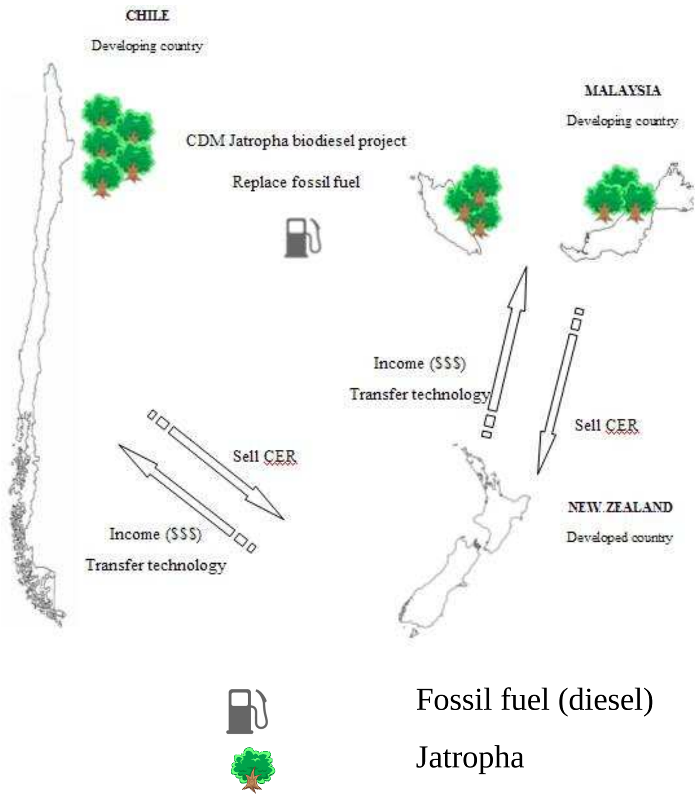


Figure 3.1: Relationship between Chile, Malaysia and New Zealand in the CDM.

As Figure 3.1 shows Chile and Malaysia are developing countries in which the jatropha plantation will be carried out .As a developed country, New Zealand acts as a provider of technology to produce jatropha biofuel. The reduction project and replacement of fossil fuel are placed in either Malaysia or Chile. As a result, New Zealand can either buy the carbon credits (CERs) generated for that reduction or participate as an investor at the very beginning of the project.

For each objective the methodology will be:

1. To identify and evaluate potential activities that can reduce greenhouse gases through the use of jatropha biofuel and sub-products.

In order to identify potential activities for CDM projects, at this stage the literature research will be considered. It will include relevant information and similar cases overseas, through library research and internet reviews on the UNFCC website. It will include an assessment of the registered, rejected and ongoing CDM projects regarding biofuel.

2. To evaluate the option of a jatropha plantation as part of an afforestation or reforestation project under CDM.

   The conditions necessary for a jatropha plantation to comply with the requirements for becoming a CDM project in terms of a greenhouse sink in an afforestation and reforestation scenario will be evaluated. There will be field trips to jatropha plantations as well as a literature review. The information will be obtained from a literature review of theses, dissertations, project proposals, project design documents under registration by the UNFCC and secondary information available, including articles, website and internet sources.

3. To identify conditions that make a CDM project suitable for developed and developing countries.

   It will identify the conditions necessary to make a CDM project successful in terms of the volume of CO_2 reduced, the number of hectares planted, agreement between the owner of the plantation and the biofuel manufacturer, sustainability of the project and the final consumer of the biofuel.

4. To estimate the amount of reduction emission or certified emission reduction (CERs).

   In this study, the amount of CERs to be earned will be estimated, either by increasing the activities that can reduce greenhouse gases or sinks by the jatropha plantation itself. The most suitable methodology for the data collected will be used, using the data available and parameters from the Country studied.

CHAPTER 4

4 RESULTS AND DISCUSSION FOR QUALITATIVE FINDINGS

4.1 Identification and Evaluation of Potential Activities that Reduce Greenhouse Gases through the Use of Jatropha Biofuel and Sub-products.

The most common uses of jatropha are mentioned in Figure 4.1:

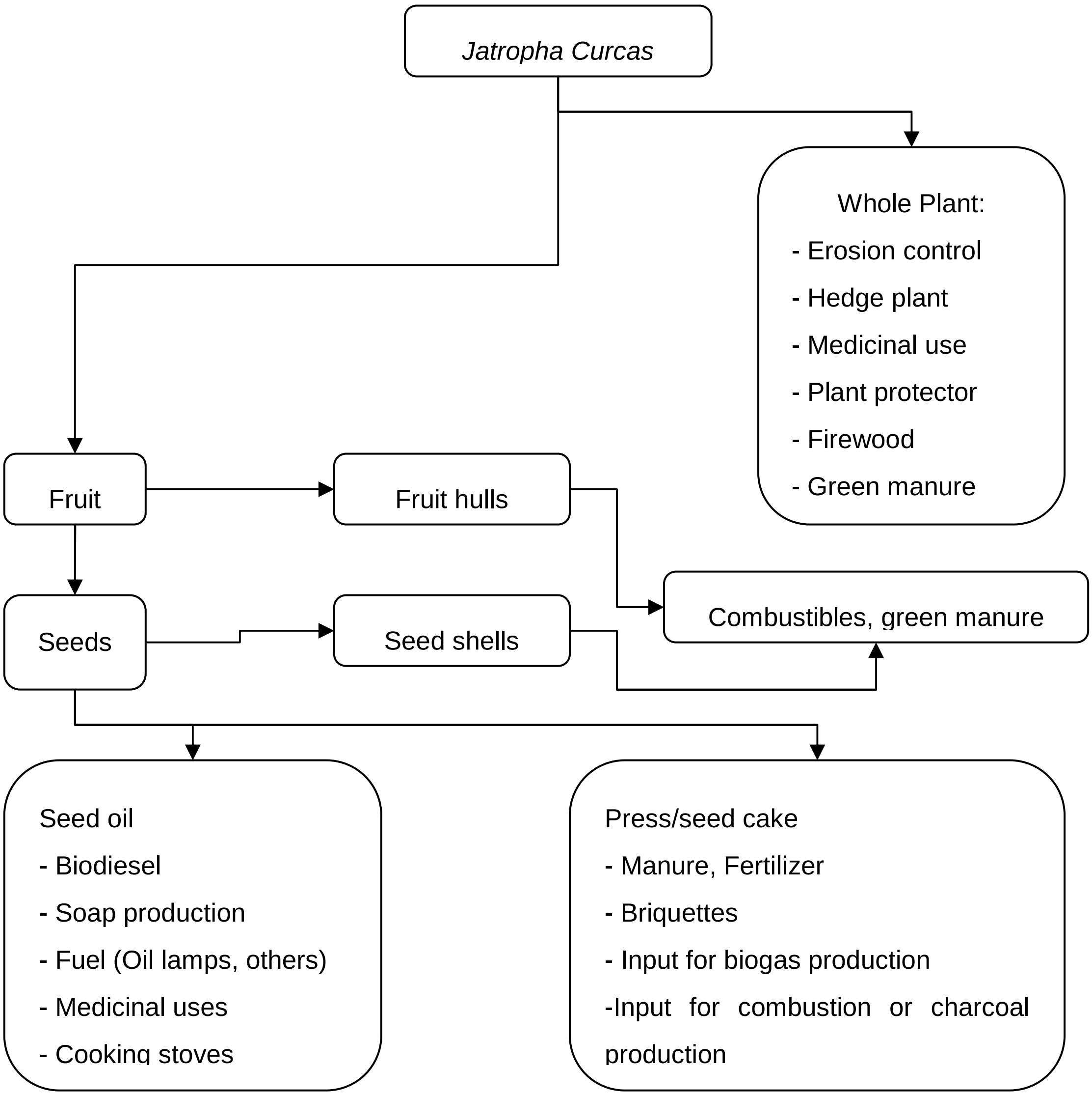


Figure 4.1: Different uses of Jatropha

Source: Van Eijck & Romijn (2008) , Heller (1996)

Figure 4.1 shows that the jatropha plant has many uses in erosion control, hedges and medicine. The products generated from the plant are firewood, green manure, fruit and seeds. During the pressing process, fruit hulls and seeds shells are generated and they can also be used as a combustible and green manure.

At the end of the process, seeds generate oil and an organic waste product is obtained as a residue of pressing the nuts called “press cake” or “seed cake”. The by-products from the seed oil are biofuel and soaps. The by-products from the press cake are fertilizer, briquettes and biogas.

Among all these jatropha sub-products, the ones related directly to the reduction of GHG are the seed oil and press cake. The reduction of GHG from seed oil is because the oil generated can replace fossil fuels. In the case of the press cake, it contains a considerable amount of energy owing to the oil content which can be recovered either by digesting it and producing biogas or converting it into briquettes for fuel as conducted in a study by Achten, et al. (2008).

Figure 4.2 shows inputs and outputs in the cycle of by-products and how they can be used either as a fertilizer or digested to produce biogas (CH_4). The inputs are CO_2, H_2O and sunlight in order to grow the crop and the fruit. There are two outputs: the first one is the biodiesel as a product of the seed oil; the second output is the biogas generated by the fermentation of the seedcake.

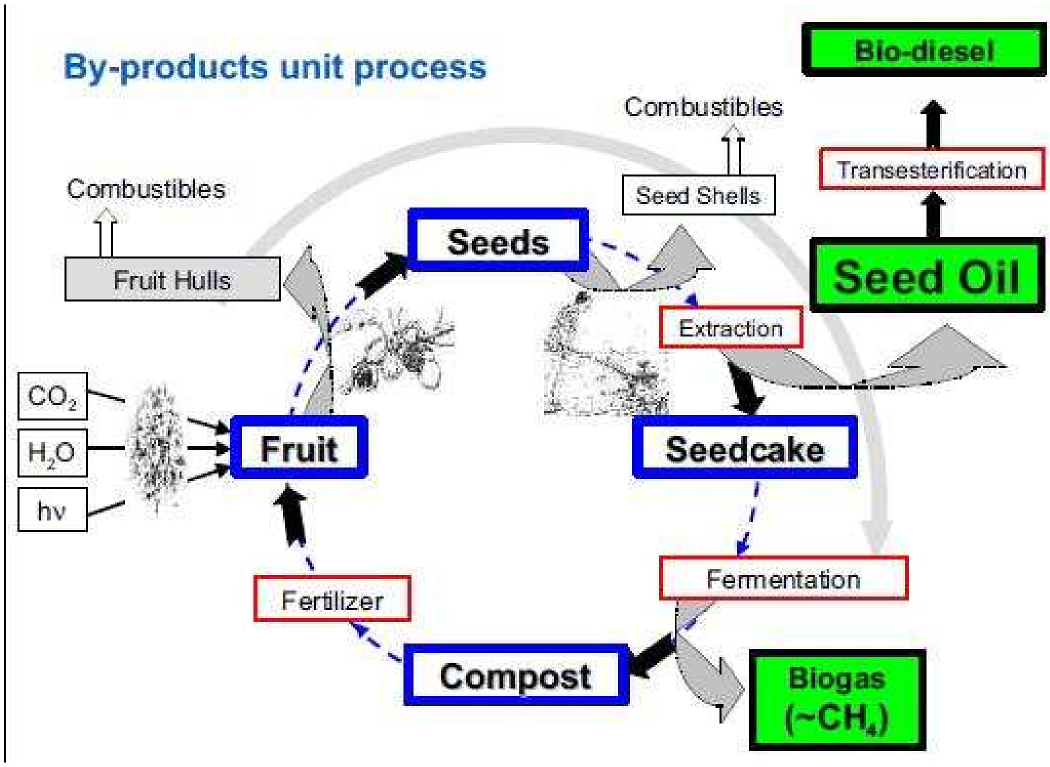


Figure 4.2: By products unit process

Source: Henning, 2003

The cycle that Figure 4.2 shows represents different processes such as extraction of oil from seeds, transesterification from the seed oil in order to produce biodiesel and fermentation of the seedcake to generate biogas (CH_4).

4.1.1 Press/Seed cake

In order to fully use the energy characteristics of the press cake, the New Zealand Company studied should utilize the press cake generated in order to replace a fossil fuel and reduce greenhouse gases. The amount of biomass from seedcake is estimated to be around 65,000 tonnes, from a plantation of 20,000 ha over a period of 10 years and a yield of seeds of 5 tonnes/ha/year according with the production plan of the Company. This estimation was according to studies carried out by BioFuelsRevolution (2009), where 10 tonnes of seeds will produce 6,500 kg of biomass from the oiled seedcake.

The following are ways to use the waste plant mass or press/seed cake after oil extraction. With all these options there is a reduction in greenhouse gases as explained as follows:

- Using it as organic manure (fertilizer): The press cake retains all of its minerals and nutrients, so it can be used as an organic fertilizer. The nitrogen content is similar to other manures and ranges from 3.2 to 3.8 % as supported by Heller (1996). The reduction of GHG is carried out through the replacement of chemical fertilizer that emits N_2O which is considered a GHG under the Protocol of Kyoto.

- Converting it into biogas: The seed cake still contains oil; hence it still contains energy that can be used for biogas production. The cake can be converted into biogas by digestion in biogas tanks, together with other input materials such as dung, leaves etc. When the biogas is used for cooking, lighting, or to produce energy/electricity there is a replacement of fossil fuels that is considered to be a reduction in GHG. Furthermore, if these activities are implemented in a rural area, it can help to combat the poverty and improve the living conditions of low income families in remote areas.

- Using it directly as a fuel : Seed cake can be processed into pellets, briquettes or be converted into charcoal. They can be used for direct combustion as a fuel in wood stoves or ovens. The replacement of fossil fuel for this fuel produces a GHG reduction, in addition, using this fuel avoids deforestation problems and preserves carbon sinks (forest).

These options above for using seedcake are supported in several studies carried out by Foundation (2006), Foundation (2008) and Van Eijck & Romijn (2008).

4.1.2 Seed Oil

A potentially major use is the fuel obtained from the oil after it is chemically treated by the transesterification process. The oil produced by this crop can be easily converted to liquid biofuel, which meets the American and European standards as commented by Achten et al. (2008). When Jatropha oil is converted into biodiesel, vehicles require almost no modification (only the fuel hose needs to be resistant to biodiesel).

The sectors where jatropha biofuel can replace fossil fuel and reduce GHG are: energy industries, manufacturing and construction and transport industries. The vast majority of the world's heavy transport sectors are diesel-powered including automobiles, fleets, mass transit, trucks and heavy equipment, farm equipment, boats, trains, electrical generators and aircraft. Jatropha biodiesel can be used for diesel-powered vehicles and therefore reduce GHG emissions by replacing fossil fuels.

Therefore the transport sector is where fuel is most likely to be replaced by jatropha biofuel since the engines are fed with diesel. As mentioned before, diesel engines do not need to be modified to use biodiesel. Jatropha oil could also be blended with normal diesel fuel and sold at petrol stations for private vehicles, or be used to feed airplanes or marine transport.

One environmental advantage of using biofuel instead of diesel in marine transport is to avoid the pollution from a potential diesel spill into the sea. Diesel engines can cause considerable environmental damage, especially in the case of a petro-diesel fuel spill. This is supported by tests carried out by Pahl & Watson (2008), who concluded that biodiesel is not harmful to fish, and that when spilled in water, biodiesel will be 95 percent degraded after 28 days as compared with only 40 percent for petro-diesel in the same time period.

4.1.3 Examples of Transport using Jatropha Biofuel

In the case of Chile and Malaysia there is no industrial production of jatropha biodiesel. Nevertheless in New Zealand, its airline company Air New Zealand, on 5th January 2009, successfully completed the world's first test flight running on jatropha-based biofuel engines. The jatropha oil was refined utilising a technology to produce jet fuel from renewable sources that can serve as a direct replacement for traditional petroleum-based fuel.

Another example of transport fed by jatropha biofuel is the Indian Railways in both northern and southern India. This move is part of a long term policy decision to reduce dependence on fossil fuels and move to less expensive alternatives. Among the developing countries, India is leading the production of jatropha and it is being promoted by the Indian government (Brink, 2008).

4.1.4 Conclusion of Objective 1: Identification and Evaluation of potential activities that reduce GHG through the use of jatropha biofuel and sub-products

In conclusion, jatropha has the potential to help combat the greenhouse effect through different products generated, but mainly from seed oil (biodiesel) and press/seed cake.

The jatropha biofuel process generates a remaining biomass that can be used either as a fertilizer, or is combustible (firewood, leaves, branches, fruit hulls, seed shells etc.)

The seed/press cake obtained from the pressing process can be used either as a fertilizer, as a fuel or in a bio-digestion process to produce methane. In the first case, the reduction of GHG is through the avoidance of N_2O from synthetic fertilizer. The reduction in GHG from the rest of the options take place when fossil fuels are replaced.

The seed oil can be used as a biodiesel in diesel engines, oil lamps and cooking stoves. In all these ways the reduction in GHG takes place when fossil fuels are replaced by biofuel.

4.2 To Evaluate the Option of Jatropha Planting as Part of an Afforestation (A) or Reforestation (R) Project under CDM

The Clean Development Mechanism includes projects to sink GHG in a forest through afforestation or reforestation increasing the removal of greenhouse gases from the atmosphere. Owing to the characteristics of the jatropha tree and the climate conditions where the tree is planted, there is a potential option of becoming an (A)/(R) project under CDM.

Photosynthetic processes provide environmentally sustainable mechanisms for the removal of CO_2. Biological systems produce biomass which can act as a reservoir of carbon or as a direct substitute for fossil fuels, as is supported by studies carried out by Hall et al. (1992).

The definition of "Forest" is part of the glossary of CDM terms given by UNFCC (2008). A forest is a minimum area of land of 0.05-1.0 hectares with tree crown cover (or equivalent stocking level) of more than 10-30 per cent with trees with the potential to reach a minimum height of 2-5 metres at maturity *in situ*.

A forest may consist either of closed forest formations where trees of various heights and undergrowth cover a high proportion of the ground or open forest. Young natural stands and all plantations which have yet to reach a crown density of 10-30 per cent or tree height of 2-5 metres are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention, such as harvesting or natural causes, but which are expected to revert to forest.

From the definition given, it can be concluded that Malaysia and Chile, as they are not Annex I countries, may host an A/R CDM project activity if the plantation of jatropha complies with the next eligibility criteria:

a) A minimum land area value between 0.05 and 1 hectare; and

b) A minimum tree crown cover value between 10 and 30 %; and

c) A minimum tree height value between 2 and 5 metres.

d) Is either an open or a closed forest

The initial land area of the project activity that the New Zealand company is expecting to carry out is 2,000 hectares. The tentative plan of the company is to gradually expand to 20,000 hectares in a period of 10 years that will warrant setting up a modern oil extraction mill close to the plantation site.

A comparison between the requirement to qualify as a A/R CDM project activity and the current features of jatropha given by the New Zealand company are shown in Table 4.1

Table 4.1: Features of Jatropha

Feature	**Requirement to qualify as a A/R CDM project activity**	**Project studied**
Land area	Between 0.05 and 1 hectare	20,000 ha
Tree crown cover	Between 10 and 30 %	over 30%
Height value	Between 2 and 5 metres	3-6 metres

Source: Adapted from UNFCC (2008)

The data provided by the New Zealand company coincides with the bibliography data collected from different authors such as Foundation (2006) and Heller (1996) who describe the feature of jatropha. In terms of height, crown cover and land the jatropha CDM project reaches the requirement to be considered as a forest.

Activities in the Land Use, Land Use-Change Forest (LULUCF) sector are scoped for afforestation and reforestation projects. These activities are defined by UNFCC (2009) in the Report of the Conference of the Parties 16/CMP.1, Annex, paragraph 1 as follows:

- Afforestation is the direct human-induced conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding and/or the human-induced promotion of natural seed sources.

- Reforestation is the direct human-induced conversion of non-forested land to forested land through planting, seeding and/or the human-induced promotion of natural seed sources, on land that was forested, but that has been converted to non-forested land. For the first commitment period, reforestation activities will be limited to reforestation occurring on those lands that did not contain forest on 31st December 1989.

From the definition given above, it can be concluded that the afforestation and reforestation projects for jatropha either in Malaysia or Chile, depend on the land converted in order to establish the plantation.

It will qualify as an afforestation project if it can be demonstrated that for at least 50 years vegetation on the land has been below the thresholds adopted by the host country for the definition of forest; otherwise it will be classified as a reforestation project if the land was not forest before 31st December 1989.

Plantations could be established in degraded or deforested lands in Chile or Malaysia. With good land management and with a sustainable production, a jatropha plantation can be an environmental sustainable option and therefore be used for CDM afforestation and/ or a reforestation project.

The project proponent will be represented by the Chilean or Malaysian company who own the land and plantation. The project proponent should be able to demonstrate that the land is an "eligible land" that meets the requirements of the "eligible project" activity mentioned in the previous paragraph. For this purpose, the Executive Board of the IPCC has developed procedures to demonstrate the eligibility of lands for A/R CDM project activities as mentioned by UNFCC (2007).

In order to demonstrate that the land is 'eligible land' in Chile or Malaysia, the project proponent must demonstrate at the time the project starts that the land does not contain forest, by providing transparent information that:

a) Vegetation on the land is below the forest thresholds

The project proponent in Malaysia or Chile has to demonstrate that the land used to plant jatropha was not a forest before. In order to prove this statement, the owner can provide evidence such as aerial photographs or satellite imagery complemented by ground reference data.

b) All young natural stands and all plantations on the land are not expected to reach the minimum crown cover and minimum height

   The land used to plant jatropha cannot reach the same values of crown cover and height chosen by the host country (Malaysia or Chile). Evidence of the land use or land cover information from maps or digital spatial datasets are acceptable as proof of this requirement, for example, land cover information can be retrieved from government agencies related with land use.

c) The land is not temporarily unstocked, as a result of human intervention such as harvesting or natural causes

   The condition of the land cannot be conditioned by human intervention. The project proponent has to demonstrate the status of the previous land presenting land use or land cover information from permits, plans, or information from local registers such as cadastre, owners' registers, or other land registers.

If it is not possible to obtain these, project participants may submit written statements attesting to the eligibility of the lands. If options (a), (b), and (c) are not available/applicable, project participants shall submit a written testimony which was produced by following a Participatory Rural Appraisal methodology or a standard as practised in the host country.

4.2.1 Risk of Reversibility:

The longevity of the jatropha tree is about 50 years. In the context of a sink project, the carbon credits can be projected along this period of time.

There are forestry risks that can reverse the carbon stock; the risks can be classified as biotic risks (pests, etc.), abiotic risks (wind, fire, etc.) and anthropogenic risks (illegal encroachment of plantations by local population, illegal fuel-wood collection, etc.).

In the case of pests, there is a high chance that the tree will die; therefore there will be a loss of biomass and the forest will reduce its capacity to capture CO_2. In the event of a fire, loss of biomass can be massive; furthermore, the combustion of biomass will release huge amounts of CO_2. Among the biotic risk, wind and storms can destroy branches from the trees and lose biomass that was able to sink CO_2. Anthropogenic risks threaten the amount of biomass capable of sinking $CO_{2,}$ due to either illegal wood collection to be used as fuel or encroachment of plantations.

Actions to reduce or eliminate the reversibility of GHG reductions as a result of these risks must be taken by the owner of the plantation either in Chile or Malaysia. The area subjected to biomass burn from the natural or anthropogenic influences shall be assessed. The ex-ante estimation of fire risk can be assessed from the historic data on fire occurrence in the region.

The owner of the Afforestation/Reforestation CDM project should list any actions taken to reduce the risk of reversibility and how they were incorporated into the estimates of a project's GHG reduction and state whether these actions will fully or only partially avoid the reversal of carbon storage.

Performing good practices in designing and operating the forestry project are usually the best mechanisms to ensure the sink. Management practices such as planting or seeding, thinning, fertilization, harvesting, and replanting cycles must be part of a Management Forest Plan in order to address the forest operation and to control water quality and quantity, soil quality, pesticide and nutrient use, wildlife habitat, forestry and waste management.

4.2.2 Commercialization of Carbon Sink Credits

In the carbon trading systems there are different ways to off-set for activities that contribute to climate change. A company that has to reduce its own emission will buy carbon credits in the market. Those carbon credits can come either from a reduction in emissions due to an efficient energy program, from renewable sources of energies such as wind, solar, wave, tidal or geothermic projects, collecting methane from landfills, use of biomass or for storing carbon.

Carbon sink credits generated from stored carbon in jatropha trees are being traded in the voluntary carbon market. Deforestation can be avoided either by paying directly for forest preservation, or by using offset funds to provide substitutes for forest-based products with social and economic benefits.

Examples can be seen in the CarbonCatalog, (2009) where there are two providers offering carbon offset from jatropha projects. The first project is a fuel substitution project in the Philippines. The project aims to plant Jatropha trees and produce biofuel. The company involved in the project is GroPower which sells the oil harvested from the trees to biofuel refineries. The second project is a Forestation project in Kota Kinabalu, Sabah, Malaysia, consisting of a nursery for jatropha with a total plant capacity of 139,000 trees per month. The operator of the project is Trees4Good Sdn Bhd which works with biofuel feedstocks that will actively enrich the degraded soil with the long term view of the soil being able to support the regeneration of the indigenous plant life.

4.2.3 Conclusion of Objective 2: Option of Jatropha planting as a part of an Afforestation/Reforestation project under CDM.

In conclusion, the jatropha tree satisfies all the conditions set down under the UN Kyoto Convention as a positive sink tree that can be used for afforestation/reforestation CDM projects to accomplish carbon sequestration.

The land used to plant jatropha should be degraded land in order to comply with land requirements.

However, A/R CDM projects are unlikely to be accepted by IPCC owing to the uncertainties of the methodology to calculate carbon storage and the risk of reversing the carbon stock in the forest projects. Nevertheless, emission reductions of non CDM projects can be traded in the voluntary market of GHG as a way to offset the emissions.

4.3 To Identify those Conditions that Make a CDM Project Suitable for Developed and Developing Countries.

For this objective the suitable condition of New Zealand as an industrialized and developed country was analyzed. In the context of the Clean Development Mechanism, New Zealand may transfer technology to produce jatropha biodiesel to countries such as Malaysia and Chile as explained in Figure 3.1. Therefore, Chile and Malaysia were considered to be the developing countries that can host the production and use of jatropha. Conditions which make a CDM project suitable in both countries were analyzed.

According to the 12th article in the Kyoto Protocol, emission reductions resulting from each project activity shall be certified by operational entities to be designated by the Conference of the Parties serving as the meeting of the Parties to this Protocol, on the basis of:

(a) Voluntary participation approved by each Party involved;

(b) Real, measurable, and long-term benefits related to the mitigation of climate change; and

(c) Reductions in emissions that are additional to any that would occur in the absence of the certified project activity.

This situation means the investors should focus on developing projects in developing countries to receive carbon credits from them and meet the targets of the Kyoto Protocol.

Identified in this objective were: the sustainability of the project, additionality criteria, the monitoring process, and ownership of the credit. Furthermore, there is a discussion about some opinions from detractors of the CDM project that can make the certifications of emission reduction from jatropha biofuel difficult.

4.3.1 Additionality:

The Kyoto Protocol declares that the purpose of the clean development mechanism shall be to assist Parties not included in Annex I in achieving sustainable development. Furthermore, one of the requirements of a CDM project is to demonstrate the additionality of the project. It must be clearly explained and indicated why registration of the project as a CDM is required to make the project feasible.

Emissions reductions are additional if they occur because of the presence of incentives (carbon credits or CER). This criterion relates to whether the project has resulted in emission reductions or removals in addition to what would have happened in the absence of the project.

If the project reduction is used as an offset, the quantification procedure should address additionality and demonstrate that the project itself is not the baseline and that project emissions are less than baseline emissions. It means showing that the emissions reductions are not “business as usual” or emissions “baseline”.

Additionality can be demonstrated using a tool comprising five steps given by UNFCC (2008). The methodology has five steps to identify whether the project activity meets the requirement and was carried out taking the situation of Chile and Malaysia into consideration.

4.3.1.1 Current Laws, Policy and Regulations

In Chile and Malaysia currently, petrol diesel is used in transport. At the moment there is no enforcement of applicable laws or regulations about the use of biofuels, so it is not compulsory to use blender biofuels.

Policies supporting production and use of biofuels in Malaysia are at present on hold. The policy mentions a mandatory blend of 5 percent of palm methyl esters in diesel in the domestic market. The Government of Malaysia wants to address several impediments first in order to ensure its success. Major issues to be addressed include logistics, infrastructure cost and blending facilities.

In Chile, since 2006 there has been a renewable energy policy that encourages the usage of new sources of energy in order to be more independent in terms of fuel importation. However, since May 2008, the use of biodiesel in percentages of 2% and 5% blended with petrol has been approved. The use of this biofuel is voluntary.

4.3.1.2 Barrier analysis

In this stage, barriers that would prevent the implementation of the proposed project activity will be identified. These exist in the implementation of the project activity in both developing countries and include:

I. Investment and Technological barriers:

There are investment barriers as the project is not profitable in itself. Although commercial production of biodiesel is becoming popular, the potential producers are still not convinced to take the risk.

In Chile, biodiesel related researches have been successfully carried out by the University of Chile, but investors are not yet sufficiently convinced to take the market risks in this sector.

In Malaysia, the low cost of diesel makes any business with biofuel unprofitable, and currently, palm oil has a better yield than jatropha. However some companies such as Sime Darby, Platinum Energy Sdn Bhd and Nandan Biomatrix Limited have carried out some research.

The production of biofuels is a relatively new technology in Malaysia and Chile, with which more experience is necessary to create confidence among project developers and investors. Based on financial investment analysis biofuels will be cost-effective only in rare cases.

On the other hand, the transesterification process cost (chemical conversion of jatropha oil into biodiesel) increases the price of the jatropha oil in comparison with fossil diesel oil. In areas where fossil diesel is widely and easily available the blending option is not yet financially attractive. Jatropha blended biodiesel can be 30–50% higher in price than conventional diesel.

In conclusion, the biggest barrier presently is its high cost; the cost of producing biofuel, which includes the cost of the transesterification process and the cost of the technology required, is an economic barrier that must be taken into account. Therefore, for this new technology to produce jatropha biofuel, it can be assumed that use of CDM is required to make the project financially viable and feasible for investors.

Economic/financial barriers:

The price of fossil fuel is a very important factor at the moment when discussing renewable technologies and especially biofuels. The variation in the real price of oil or fluctuating oil prices make it difficult to justify long term investment in biofuels. Although the high price of oil at some periods makes biofuels competitive, investment decisions for new facilities will also need to take into account possible future oil price decreases, so investment is unlikely.

In this case of study, it is expected that the jatropha biofuel can be used either in Malaysia or Chile replacing fossil fuels. The price of the biofuel requires a more detailed economic evaluation, but it is certainly related to the prices of fossil fuel in the markets. Table 4.4 shows the price of diesel in the countries studied:

Table 4.2: Prices of Diesel in Chile, Malaysia and New Zealand (US$/ m^3)

Country	**2006**	**2007**	**2008**	**2009**
Chile*	521.82	603.15	844.46	411.21
Malaysia**	437.49	496.64	646.50	300.12
New Zealand***	717.26	673.56	955.07	----

* Source: ENAP (2009)

** Source: Petronas (2009)

*** Source: MED (2009)

The price of diesel in Malaysia represents the monthly average calculated based on the weekly pricing submitted to the Asian Petroleum Price Index. This data was supplied by Petronas (2009).

In Chile, the data supplied by ENAP (2009) also represent a monthly average calculated based on the weekly pricing according to the price on the international market. The value is the price given to the suppliers and does not include the cost of logistic, transport and storage nor the tax and the stabilization grant supplied by the Government.

The data supplied by Ministry of Economic Development in New Zealand were weighted daily averages in nominal New Zealand cents per litre. The data was converted to US$/ m^3. The prices do not reflect all the variations due to regional pricing differences and discounts available to bulk diesel customers.

From Table 4.2, it can be concluded that Malaysia has the cheapest price of diesel because the country has its own sources of fossil fuel.

In the other hand, New Zealand has the highest price of petrol among the other countries. This price of fossil fuel would be closer to the potential price of the jatropha biodiesel, however to be able to claim carbon credits for the replacement of fossil fuels, the host country must be a developing country.

The data on the price in Chile do not include the cost of logistic, transport, storage; tax and the stabilization grant that is supplied by the government. If the final consumer price is considered, then the price can increase around 50% of the price as shows in Figure 4.3.

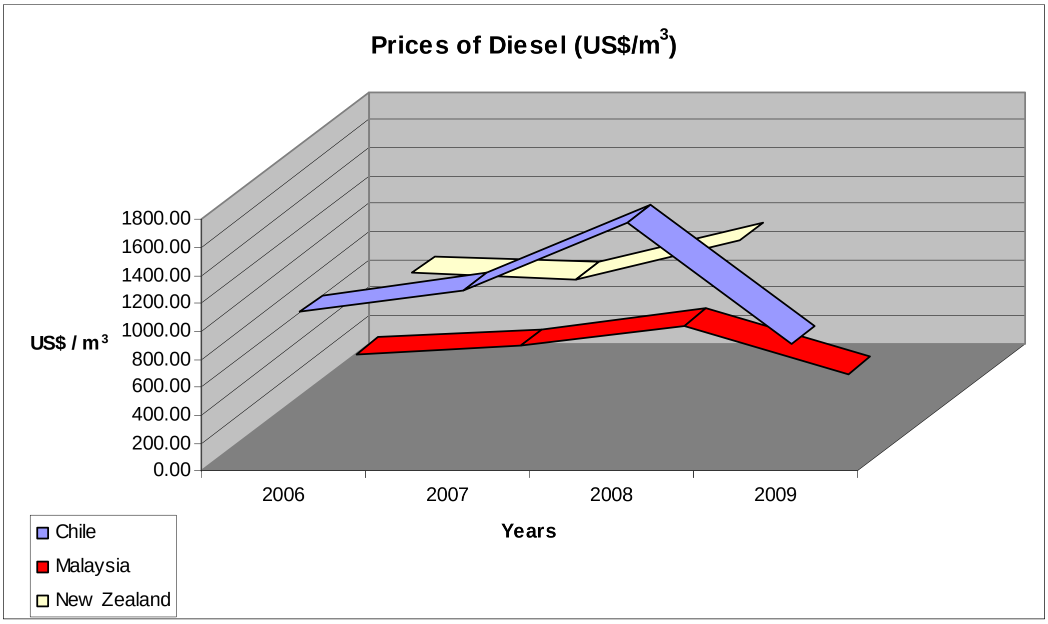


Figure 4.3: Prices of Diesel in Chile, Malaysia and New Zealand (US$/ m^3)

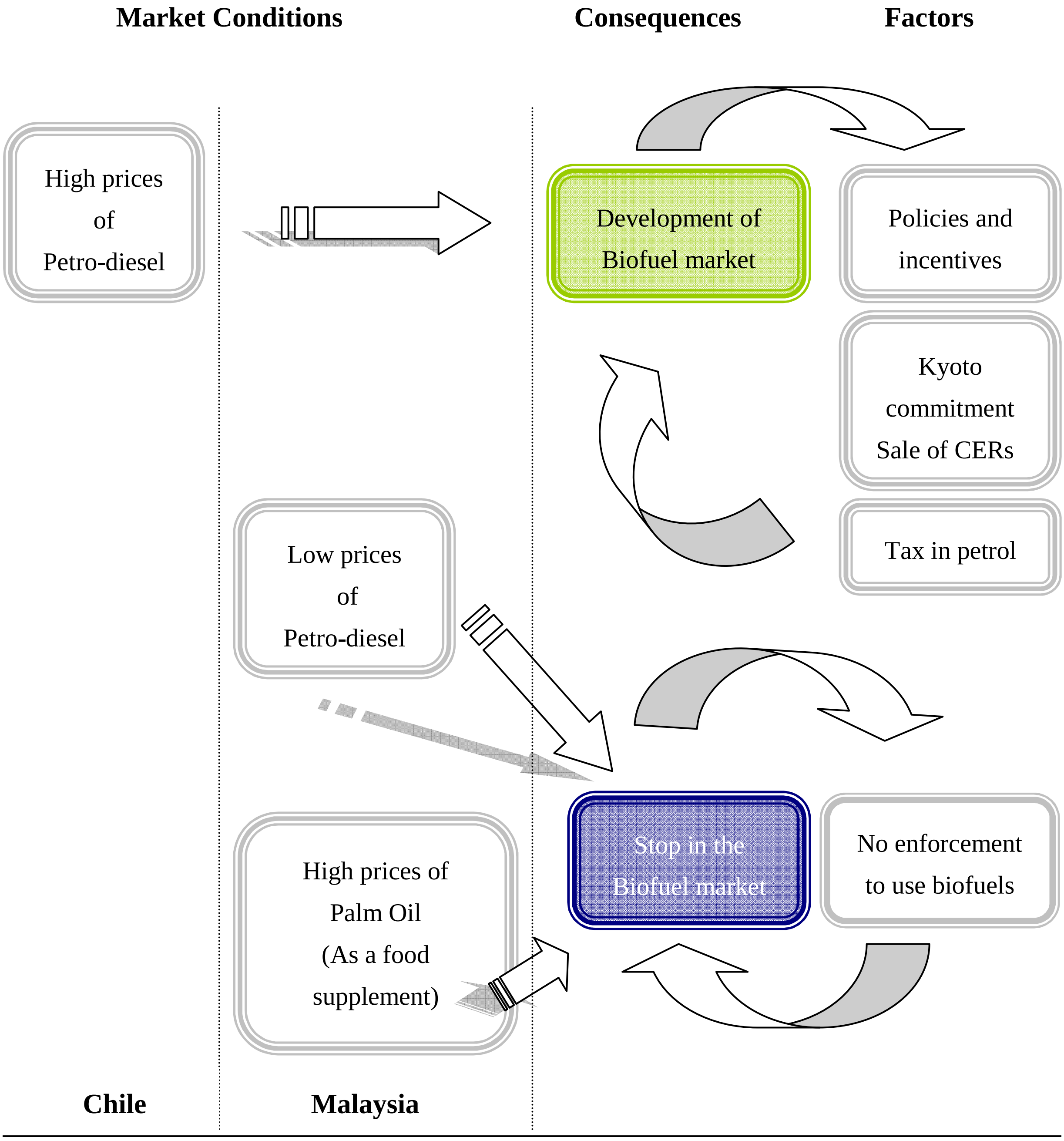
From Figure 4.3 it can be seen that there is a big gap between the prices and the final price that the consumer will pay in Malaysia and Chile.

An ideal price for producing biodiesel would be below the price of petroleum diesel, however some environmental and social costs associated with fossil fuels (environmental externalities) are not fully accounted for in their pricing in Malaysia and Chile, and as a consequence, the price of biodiesel can appear high relative to the price of diesel.

When a country does not have fossil fuel reserves of its own, such as Chile, the production and use of jatropha biofuel would create less dependence on imported fossil fuels. In the case of Malaysia, the promotion and use of jatropha, will create a sustainable option for Malaysia's source of energy.

Figure 4.4 shows the market conditions and how they may affect the development of the biofuel market.

Figure 4.4: Factors that affect biodiesel development in Chilean and Malaysian markets.



As Figure 4.4 shows, when the price of the petrol is high, then biofuel appears to be an economically attractive option. Kyle (2008) claimed that if oil prices decline, renewable projects will not be competitive and the companies working with green energy can easily break down. Even a temporary decrease in petroleum prices would undermine the long-term development of the alternative projects.

The low price of Malaysian diesel makes any biofuel product unprofitable that may be used as a replacement for petrol. As the Malaysian Government sets retail fuel prices below the market price and compensates retailers through subsidies, the possible realistic and credible alternative to the project activity is the continuation of the current practice of petroleum diesel consumption with no investment in bio-diesel production capacity.

In conclusion, the price of petrol in the host countries plus the cost of producing jatropha biofuel create conditions that together with other factors such as law, policies, and taxes make the developing of biofuel without an economic incentive from the Government, or without the economic benefit of the selling of carbon credits, unprofitable.

CER revenues may contribute significantly to the attractiveness of the biofuel project. In general, financial support either from the Government, or CERs sale, or the voluntary market will be required to make production and utilization of biofuels financially attractive.

Cultural barriers:

There are cultural barriers associated with traditional uses of jatropha; on the consumers' side, there is a concern about what would happen to their vehicular efficiency and to the engine performance if they switch to such fuel. Some vehicle manufacturers' representatives do not offer a warranty for cars that use biofuel, hence the consumers do not want to take the risk of using biofuel in their vehicle in case it damages the engine.

There are also some psychological obstacles emanating from known poisonous qualities of the crop, so workers can refuse to process the plant because of the toxic condition of jatropha.

Land and supplier availability barriers:

The second barrier to the introduction of biodiesel on a large scale is its present availability. The number of hectares in the project will largely depend on the availability of marginal land and farmers. Both Malaysia and Chile have lands that match the requirement for jatropha plantations, but on a commercial scale, it can be difficult to find the quantity of available land.

The barriers in Chile and Malaysia against this agricultural regime may include structural, infrastructural and logistical problems as probably the available land will be in remote areas. Technical skill and knowledge gaps may be also barriers.

4.3.1.3 Common practice analysis

There is no company selling the carbon credit from the jatropha project. Many other CDM activities have been proposed under IPCC, but only a few regarding biofuel from jatropha and none of them has completed the CDM process. The project activity will be one of the first of its kind in the host country in terms of magnitude and commercial production. Nevertheless there are projects in Chile and Malaysia that are exploring jatropha plantation.

The Malaysian company Sime Darby is interested in research on biofuel from jatropha fruit, exploring the possibility of *jatropha curcas* oil as the solution to the ongoing debate about converting food sources into biofuel. The company has planted 40 ha of jatropha which are ready for harvest. Going forward, the company will have its own jatropha extraction plant. However, to get carbon credit from the jatropha project, the company needs to use/produce a large amount of biofuel. Currently, the company is focusing more on composting and biogas projects in the palm oil process which are given more carbon credit values.

Platinum Energy Sdn Bhd and Nandan Biomatrix Limited are other Malaysian companies that have demonstrated interest within the biofuels' industry, specifically in the sustainable cultivation of jatropha as a commercial energy crop.

In the case of Chile, the University of Chile has been doing some research in jatropha plantation in order to evaluate the best conditions for the crop to grow and provide the highest yield.

If the proposed project activity is undertaken in any of the studied countries, it should lead to multilateral benefits, both tangible and intangible including a reduction in anthropogenic greenhouse gas emission from the manufacture of biodiesel and its use in transport, replacing fossil fuel. Further benefits are discussed in the next chapter on the sustainability of the project.

4.3.2 Sustainability of the Project

In addition to GHG reduction, projects contribute significantly to sustainable development. It may result in other benefits including fewer greenhouse effects, less local air pollution, less contamination of water and soil, fewer health risks, reduction of air pollutants, enhanced energy security of supply by reducing dependency on fossil fuels, promotion of employment, and transfer of new technologies.

The emissions of engines, lamps and stoves that use biodiesel are much less harmful to public health than emissions from petroleum-based fossil fuels. Both indoor air pollution in rural houses and outdoor air pollution in big cities could be greatly reduced as the studies carried out by Asselbergs et al. (2006) and Bakker (2006).

One of the strongest argument in favour of jatropha biodiesel is the opportunity to utilise land, which otherwise would be set aside as an unexploited resource. The use of a renewable energy and the fact that jatropha does not compete with food crops are also arguments to use this biodiesel.

Jatropha can grow on nearly any kind of land; it can be cultivated on land that is now useless. It can play a major role in the prevention of runoff and erosion, restoration of degraded soils; decrease evaporation, and increase infiltration. There are numerous cases of study in the literature where jatropha is used for control of erosion and to improve degraded lands as follows:

Asselbergs et al. (2006) cited the "Tempate" project, which refers to a program in Nicaragua financed by the Austrian government, where *jatropha curcas* was to be grown by farmers mostly on degraded lands. Wood (2005) mentioned two projects, the first in the Philippines, where the planting of jatropha to reclaim land degraded by mine workings was investigated. The second project was located in Saudi Arabia and expects to reclaim desert land by cultivating jatropha irrigated with waste water that, for religious reasons, can not be recycled for human use or for the irrigation of food crops. Heller (1996) mentioned two projects, the first is a project of reforestation for erosion control in Cape Verde and second project is in Mali which is to control erosion with hedges and oil production on 10,000 ha in marginal areas of India.

In terms of socio-economic benefits, the production of biodiesel will create new jobs in the developing country and will work against rural poverty. The workers can make vegetable oil and soap from *jatropha curcas* which can be carried out by most people without the need for long-term training. Furthermore, these products can provide the people in a rural area with a higher income. If the biodiesel is sold internationally it can place a country in a stronger economic position

One of the common judgments against biofuels is that large plantations destroy ecosystems by the planting of crops used for agrofuels. Examples given by NGOs such as Biofuelwatch et al. (2007) include sugarcane and soya in Argentina, Paraguay, Bolivia and Brazil. At the same time there are detractors of biofuel projects in countries such as Indonesia, Malaysia, Cameroon, Colombia and Ecuador because they are experiencing accelerating biodiversity loss due to oil palm plantations, often preceded by logging.

However, the case study of the jatropha project in this work does not need productive land to grow jatropha, therefore it does not compete with food crops as it is expected to use unused land.

The biodiesel company studied is not expecting either conflict over the use of land or disagreements with NGOs or international organizations about forest destruction, or lost of biodiversity. Furthermore, the local provincial government from the developing country is working closely with the company on this project to prevent any social and environmental inconsistency.

In terms of social benefits, the biodiesel company is planning to sign a contract with farmers and create many jobs within this activity. With this contract, the company can demonstrate that the suppliers will provide the raw material to produce biofuel, ensuring that the activity will run for a long term, and therefore the reduction of GHG will be long term too.

4.3.3 Ownership of Claimed Emission Reductions

The ownership of the carbon credits is a very important matter that must be considered in order to avoid double counting of emissions, and also in order to claim the income earned from the selling of carbon credits.

In terms of claiming credits for the substitution of fossil fuel, jatropha planting can be carried out either in a developed country (New Zealand) or in a developing country (Malaysia or Chile); even the production of biofuel can be carried out in any of those countries. What is important is where the biofuel is used and where the jatropha biofuel will replace fossil fuel consumption.

According to IPCC (2006a) in the “Guidance on double-counting in CDM project activities using blended biofuel for energy use”, there are two possible project activities that seek to claim certified emissions from the substitution of fossil fuels by biofuels:

1. The producers of biofuels claim CERs for the biofuel production provided. In this case, the consumers, to whom the biofuel is sold, are included in the project boundary.
2. The consumers (end-users) of biofuels claim CERs from replacing fossil fuel consumption with biofuel. An example is a transport company that expects to replace fossil fuel with biofuel.

On top of that, the owner of the land would be a third claimant to the ownership of the carbon credits. In the case study, the project is a contract farming project and hence the company will provide the farmers with a buy-back guarantee on an agreed pricing mechanism that will be related to the crude oil price, but with a capped minimum price to ensure a reasonable income for the farmers.

Therefore, in this case, the NZ Company does not own the land where jatropha will be planted, so the owners of the jatropha plantation can claim the carbon credits either for sink, or for the fact that the oil produced will replace fossil fuels in the end. However, it is difficult to prove straightaway that these projects are reducing greenhouses gases from the substitution of fossil fuels and it is quite complicated to avoid double counting.

An easy way to recognize a direct replacement of fossil fuels and a clear activity that avoids greenhouse gases is through the production and consumption of biodiesel. In this case, the company studied has two options:

a) The biodiesel is used as a replacement for fossil fuels in New Zealand: The reduction will be part of the commitment to reduction in the country and it will not qualify as a CDM project.
b) The biodiesel is used in Chilean or Malaysian companies: The reduction will generate CERs and can be traded in the carbon market.

The second option is the most suitable to follow because in that way CERs are generated. However as it is necessary to include consumers in the biodiesel methodologies based on the IPCC, the project must define and include the consumer in the project boundary. The company shall define clearly the conditions and provisions that would prevent the end users from claiming the credits.

4.3.4 Monitoring

In all the cases mentioned above, the project holders must have a monitoring methodology in order to claim the carbon credits. Most of the comments on the rejected projects in biofuel under CDM are about double counting and the complexity in monitoring parameters.

In the years that the project generates emission reductions, the variables that determine the emission reduction have to be monitored accurately, in order to ensure real climate benefits. The company should define a clear methodology of how the actual quantity of biodiesel consumed by the fleet owners or independent consumers would be used and tracked/monitored. Verification by a Designated Operational Entity increases transparency and provides robust evidence of real benefits.

The emission reductions from the use of biofuel should be estimated based on monitored consumption by the consumers included within the project activity. It can be carried out if the party who wants to claim the carbon credits arranges contracts with suppliers and customers and ensures that the emission will not be double counted.

As the case study uses raw material from a developing country for biodiesel production in New Zealand, the company should supply the biofuel to:

a) Consumers (end-users) that are under the same company placed in a developing country (tracks, fleet or process activities), or

b) External consumers that actually are using fossil fuel and can provide consistent parameters for the monitoring. In this case, the consumer and the producer of the biodiesel are bound by a contract that allows the producer to monitor the consumption of biodiesel and states that the consumer shall not claim CERs resulting from its consumption.

4.3.5 Detractors of Biofuel Plantations

Some authors and NGOs such as Biofuelwatch et al. (2007) and Asselbergs et al. (2006) claim there are potentially negative aspects connected to increased cultivation of *jatropha curcas* and large-scale production of biodiesel.

Most of these negative aspects are related to risks of increased socio-economic inequality, pressure on natural lands with a high scale of production, and dependence on unstable world market prices for income. Other negative aspects are associated with intensified agricultural practices and mono cultures. They may cause increased pressure on the environment and an increased vulnerability to plagues and pests.

There are some organizations that assert that agro-energy monocultures are linked to accelerated climate change, deforestation, the impoverishment and dispossession of local communities, bio-diversity losses, human rights abuses, water and soil degradation, loss of food sovereignty and food security.

4.3.5.1 Ecosystem Destruction

Recently, environmental groups accused Air New Zealand of using a source of energy not sustainable, causing deforestation and abuse of Third World countries such as Africa. Other NGOs are warned that promotion of jatropha for biodiesel is likely to lead to the destruction of primary and secondary forests in India, with serious consequences for biodiversity.

Biofuelwatch et al. (2007) shows some evidence of emission savings from reduced fossil fuel combustion being cancelled out by greater emissions from deforestation, peat drainage and burning, other land use change, soil carbon losses and nitrous oxide emissions when the jatropha plantation is not carried out from a sustainable approach.

4.3.5.2 Fertilizer, Water and Soil Requirements

Another concern is that the production of agrofuels requires large inputs of fossil fuels in fertilizer production, refineries and agricultural machinery and for transport, something which is rarely considered in calculating emissions savings.

Jatropha is widely promoted as a crop that can grow in dry regions; however some research in different climate conditions shows that regular and sufficient rainfall is needed to sustain high yields. Most of the jatropha projects are developed with the aim of obtaining a highest yield, and therefore water may be required to achieve it, causing depletion of ground water and water sources that supply food crops.

In arid and semi-arid areas, fertilisers and irrigation may be needed for the first three years as most of the practical research shows. Jatropha can grow in any soil, but because it is an industrial process, the better the soil condition, the higher the seed yield. Although it can survive or grow on low nutrient or low moisture soils, the fruit yield will be very low and there will be very few or no seeds to harvest.

If the goal is to produce seed on a commercial scale, input application has to match the crop requirements. This is supported by studies carried out by Daniel (2008) who declared that such requirements are usually much higher for trees grown for the purpose of production than those serving the function of live fencing

4.3.5.3 Threat to Food Supplies

The Trade and Agricultural Directorate for the Organization for Economic Cooperation and Development (OECD) has stated that conventional biofuels such as rapeseed oil and ethanol are ecologically problematic and threaten food supplies. First generation biofuels "don't hold as much potential environmental benefit as people thought when they embarked on these policies".

Some of the jatropha projects have taken place in lands that are suitable for food crops. This condition can threaten the future of agriculture over large areas and increase the bad perception of the biofuels.

4.3.5.4 Land use

There are also questions as to whether the unused wastelands targeted for cultivation of jatropha crops are really unused. In many developing countries, even degraded wastelands that can no longer be cultivated for mainstream agriculture are often inhabited and used by small livestock keepers, marginal farmers or landless people.

A concern of some groups is that the cultivation of biofuel crops on such lands can therefore lead to displacement of people who currently still depend on them. As with other intensive crops, biofuel production can displace other activities to new areas, whether they are small scale agriculture or large-scale cattle ranching.

4.3.5.5 Conclusion of Detractors of Biofuel Plantations

The belief that jatropha grows with little or no input applies mainly to areas that are not producing it on a large scale and is generally for local production. In order to produce biodiesel or to grow it on low potential lands, fertilisers and/or irrigation systems will probably have to be used and accounted for in the estimation of GHG.

In conclusion, jatropha is a plant that certainly can grow in conditions where no other plant could, however in order to produce an acceptable fruit yield for commercial cultivation, *jatropha curcas* needs sufficient light, water, fertilizer and good soil conditions. Since jatropha is drought resistant it can potentially be used to produce oil from marginal semi-arid lands, without competing with food production.

4.3.6 Detractors of CDM projects

One of the principles of CDM is to help developing countries to set environmental projects that reduce GHG emissions. From this, developed countries can buy carbon credits and comply with their Kyoto commitments.

This simple action can be seen from different viewpoints:

a) The industrialized country can pay for someone else to reduce their carbon emissions without any real effort to cut their own carbon emissions or;

b) The industrialized country use this “help” as Social Responsibility marketing and get free publicity and promotion.

c) The industrialized country is transferring a new technology to a country that is still in a developing stage and it does not matter where the reduction occurs, as climate change is an international issue.

There are many detractors of carbon markets that create doubts about the reliability of the off-sets or reduction generated by CDM projects. Companies have the chance to offset their emissions by purchasing carbon credits from projects developed in other countries. However, some authors and NGOs, believe that some of the projects do not have environmentally sustainable practices, or do not comply with the additionality criteria, and accuse them of Greenwashing.

4.3.6.1 Greenwashing

Some NGOs believe some of the companies are carrying out "greenwash" business. This term is used to describe the practice of companies that untruthfully spin their products and policies as environmentally friendly, such as by presenting cost cuts as reductions in the use of resources.

An example of this is a UK Airport being declared "Carbon neutral" after offsetting its GHG emissions by investing in renewable energy projects in developing countries. The scheme has been accused of "greenwashing" the airport's rapid expansion after it was revealed that the emissions from take-offs and landings were not included in the carbon count.

On the other hand, some companies are proud to demonstrate their commitments to climate change adopting practices beneficial to the environment or offsetting their carbon emissions. Most of the companies use this as a marketing strategy in order to be seen as a "green company", "carbon neutral company", "carbon zero" or many other marketing names which are not considered serious and effective for the reduction of GHG, because they focus more on offsetting the emissions rather than in the reduction.

4.3.6.2 Conclusion of Detractors of CDM projects.

In the case of replacing fossil fuel with biodiesel, there is a direct reduction in GHG with the replacement of fossil fuel. This condition makes the biodiesel offsets more reliable in the carbon market than other CDM projects.

CHAPTER 5

5 RESULTS AND DISCUSSION FOR QUANTITATIVE FINDINGS

The calculations of emission reduction described in 5.2 were carried out taking two scenarios into account. Scenario 1 considered a conservative yield of 2.5 tonnes/ha/year of biodiesel and Scenario 2 considered an optimistic yield of 5 tonnes/ha/year. A period of 10 years was allowed.

5.1 CO_2 Captured for Jatropha forest

The methodology for verifying the capturing of emissions has not yet been approved for other sink projects with jatropha by the IPCC. However, in the bibliography there are methodologies to estimate the amount of CO_2 captured by forest. According to IPCC values, the CO_2 captured by exotic species differs according to the years.

An estimation of CO_2 captured (tonnes) was carried out according to the New Zealand methodology given by the Ministry of Agriculture & Forestry (Table 5.1) that relates the amount of sink with the type of trees and their ages.

This approach is in terms of carbon stock values which include all carbon in all components of a forest: that is, in the stems, branches, leaves and roots, and in the coarse woody debris and fine litter on the forest floor. The look-up tables also allow for the decay over time of the coarse woody debris, stumps, roots and other woody residues that remain after thinning or harvest.

Table 5.1 shows the carbon stock per hectare for 4 different species along 20 years.

Table 5.1 : Carbon stock per hectare for Douglas-fir, exotic softwoods, exotic hardwoods and indigenous forest (expressed as tonnes of carbon dioxide per hectare)

Age (yrs)	Douglas-Fir	Exotic softwoods	Exotic hardwoods	Indigenous forest
1	0.1	0.2	0.1	3
2	0.1	1	3	6
3	0.4	3	13	9
4	1	12	34	12
5	2	26	63	15
6	4	45	98	18
7	7	63	137	21
8	20	77	176	24
9	33	87	214	27
10	50	95	251	30
11	69	106	286	33
12	90	118	320	36
13	113	132	351	39
14	138	147	381	42
15	165	163	409	45
16	193	180	435	48
17	222	197	459	51
18	253	214	483	54
19	268	232	505	57
20	286	249	526	60

Source: (MAF, 2009)

Jatropha is considered to be a poor quality fuel wood since the soft wood burns too rapidly; hence it was considered under the carbon stock estimation for exotic soft woods given by the Table 5.1. The calculation was carried out multiplying a factor of carbon stock by the number of hectares of the jatropha project.

No hectares * Factor (Carbon Stock) **Equation 1**

Source: (MAF, 2009),

The project activity studied involves 20,000 hectares in a period of 10 years. Each year the plantation area increases by 2,000 until reaching the total area planned, as is shown in Table 5.2. The planting schedule mentioned (increasing the plantation area every year) is achievable as other jatropha plantation projects have used the same plan of gradually increasing the land involved in the project. In the Project Design Document of *jatropha curcas* cultivation in the Democratic Republic of Congo (Carbon2green, 2008) it is mentioned that during the four years of the plan, the total areas to be planted are: 1,200 ha (year 1), 4,655 ha (year 2), 4,655 (Year 3) and 3,490 ha (year 4). This means an average of 3,500 hectares per year. Table 5.2 shows an estimation of the CO_2 captured along the period of 10 years using Equation (1)

Table 5.2: Carbon stock per year CO_2 (Tonnes)

Year	**No hectares**	**Carbon stock per hectare CO_2 (Tonnes)** *****Source: (MAF, 2009)	**Carbon stock per Year CO_2 (Tonnes)**
1	2,000	0.1	200
2	4,000	0.1	400
3	6,000	0.4	2,400
4	8,000	1	8,000
5	10,000	2	20,000
6	12,000	4	48,000
7	14,000	7	98,000
8	16,000	20	320,000
9	18,000	33	594,000
10	20,000	50	1,000,000
Total			**2,091,000**

From Table 5.2 it can be concluded that in a period of 10 years, the maximum carbon stock from the plantation will be 2,901,000 tonnes of CO_2.

Other studies carried out by Gropower (2007) estimated that the jatropha tree stores 0.002983 tons of carbon per year. If it is assumed that 1 ha has around 2,000 trees, therefore the amount of carbon captured per ha/year would be around 6 tonnes of CO_2. In a 10 year period it will be 2,102,738 tonnes of CO_2.

According to Henning (undated) 1 ha of jatropha has, after 7 years about 200 kg of biomass, including roots with a dry matter content of about 25 %. This gives a biomass of 80 tons of dry matter per ha. About half that weight is carbon dioxide, i.e. 40 tons. Hence, assuming the same number of trees (2000), the amount of carbon captured in 10 years will be 5,500,000 tonnes of CO_2.

The net sequestration of greenhouse gases by sinks associated with the implementation of the CDM afforestation project of “Jatropha curcas Cultivation in the Democratic Republic of Congo” estimates 3,219,899 tonnes of CO_2 equivalent over a credit period of 30 years in 14,000 hectares, considering 2500 trees per hectare (Carbon2green, 2008). This means 1,533,285 tonnes of CO_2 equivalent over a credit period of 10 years in 20,000 hectares.

Comparing the sources of different methodologies to estimate carbon sink such as the methodology done by Gropower (2007), the methodology proposed by MAF (2009) and the methodology of jatropha in Congo (Carbon2green, 2008) have similar results, which are around 2 millions of CO_2 tonnes.

However the results obtained by using Henning's (undated) data are almost 40% higher in comparison with the previous estimations. Given the fact that jatropha is a very light wood, with a density ranging from 0.33 to 0.37, this figure given by Henning (undated) seems extremely high.

Having high amounts of CO_2 in a forest includes a large potential storage volume in the jatropha plant and significant quantities of organic matter in the soil and peat. The environmental advantages of having large plantations of jatropha in degraded soils are among others (CO_2 storage, increasing biodiversity, soil stability, and improved watershed structures). Jatropha transfers CO_2 from the atmosphere to new biomass, therefore CO_2 is captured in the trunk and leaves of the trees.

In terms of economic perspective, the value of carbon sequestration is being traded in international markets; support from the government and carbon sink credits are the economic incentives used to encourage forest management in order to stabilize the CO_2 emissions.

5.2 Estimation of the Amount of Reduction Emissions or Certified Emission Reduction (CERs)

The biofuel company studied expects to plant 2,000 hectares of jatropha in the first year and increase this gradually to 20,000 hectares in a period of 10 years. The seeds that the company will use are expected to produce about 2-2.5 tonnes of oil per hectare per year. However, there is much literature containing estimates of jatropha yield which are considerably more optimistic.

Amoah (2006) suggests that the yield of crude jatropha oil per hectare per annum is about 3.5 tonnes. Enthusiastic promoters of jatropha often claim that the yield can be as high as 8.0-10 tons per ha per year when the trees mature in 3-4 years. BioFuelsRevolution (2009) claims that 2500 plants (1 hectare) will produce around 10 tons of seeds which at 35% yield will produce up to 3.5 tonnes of biodiesel. The state-owned Philippine National Oil Company Alternative Fuels Corporation PNOC-AFC (2007) believes that a hectare of jatropha plantation can yield a minimum of 15 tonnes per year in the fifth year with a modified jatropha technology, crop improvement and scientific crop management.

These are highly optimistic projections and the variation in the yields can be explained by the difference between regions and different cultivation methods.

In order to calculate the estimation of reduction emission two scenarios are considered; the first is a conservative scenario in which the New Zealand company studied is expecting to get 2.5 tonnes of oil ha/year; the second one is an optimistic scenario of 5 tonnes of oil per ha/year which is an average of the yield cited by the literature.

5.2.1 Estimate of Jatropha's Biofuel Production

The typical management of a jatropha plantation is as Table 5.3 shows:

Table 5.3: Management of Jatropha

Years	Planting
1st year	Planting and cutting back, no seed production expected
2nd year	Maintenance, protection % pruning, no seed production expected
3rd year	Period allowed for establishment and growth of plants, no seed production expected
4th year	Plants expected to be ready to produce seed, but because the priority for the first three to four years of establishment of a commercial plantation is to develop the tree structure no harvesting of seeds is expected as the study of Daniel (2008).
5th year	The seed production starts increasing and stabilizes from the 7th year

onwards	onwards as is supported by Foundation (2006).

The biofuel company expects to start the plantation by 2010. According to the management of jatropha, in the fifth year, it is estimated there will be enough yield to produce biofuel. Hence the estimation was carried out using 2015 as year number one, when the jatropha plantation will be able to produce a yield. Table 5.4 shows the estimation of biofuel production in 10 years.

Table 5.4: Jatropha oil expected to be produced/year

Year	**No hectares**	**Tonnes/Year (2.5 tonnes/ha/year) Scenario 1**	**Tonnes/Year (5 tonnes/ha/year) Scenario 2**
1	2,000	5,000	10,000
2	4,000	10,000	20,000
3	6,000	15,000	30,000
4	8,000	20,000	40,000
5	10,000	25,000	50,000
6	12,000	30,000	60,000
7	14,000	35,000	70,000
8	16,000	40,000	80,000
9	18,000	45,000	90,000
10	20,000	50,000	100,000
Total		**275,000**	**550,000**

Figure 5.1 shows the jatropha oil estimation of both scenarios during the period studied.

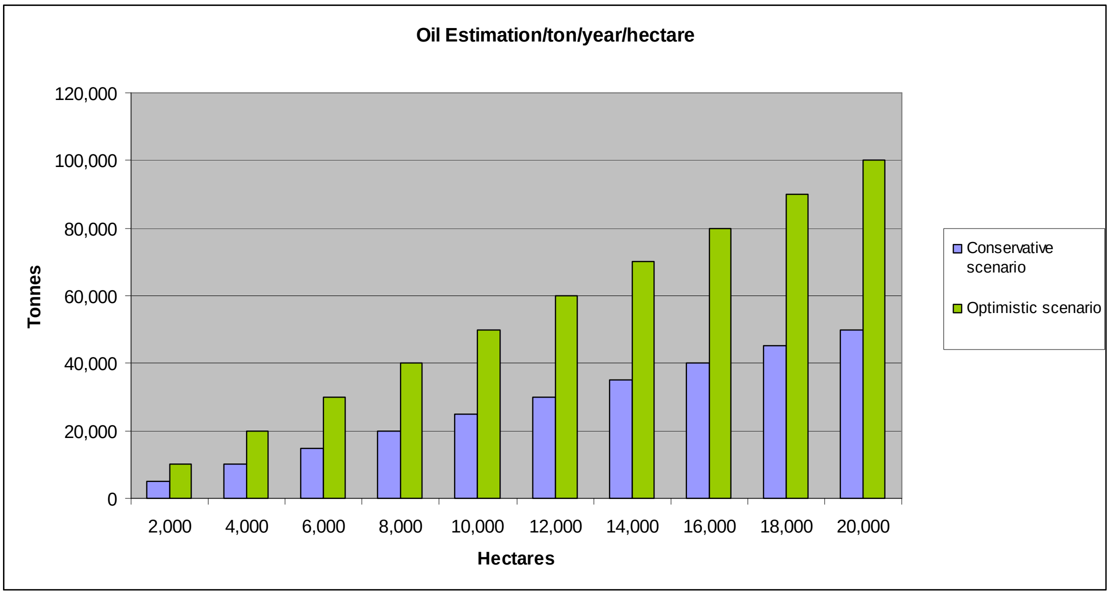


Figure 5.1: Jatropha oil (tonnes/year/hectare)

Considering the data provided by the company, as Table 5.4 and Figure 5.1 show, in the conservative scenario, 1 hectare of jatropha will produce 2.5 tonnes of fuel per year. Therefore 20,000 hectares will produce 50,000 tonnes of fuel. In the second very optimistic scenario, that 1 hectare of jatropha produces 5 tonnes of fuel per year, the result will be 100,000 tonnes of fuel in the same number of hectares (20,000). As mentioned before, the life of the jatropha is between 40 and 50 years, so the period that the company will claim the reductions (10 years) will be during 20% of the whole life of the plantation. The remaining years will not be counted as part of this project, given the uncertainties in the future regulations and laws regarding biofuels and the additionality criteria. This approach gives a conservative margin of error for the calculations of reduction and sequestration of greenhouse gases.

The jatropha oil obtained will require further down stream processing for degumming the oil and filtration of sediments before the oil is ready to be converted to biodiesel. Some studies by Kumar Tiwari et al. (2007) and Amoah (2006) claimed that the conversion of raw jatropha oil into biodiesel is in the proportion of 1:1 if the correct process is used. Hence, the amount of raw jatropha oil per hectare will be considered to be of same quantity as the jatropha biodiesel.

5.2.2 Estimation of the Baseline Emissions

The baseline for a CDM project activity is the scenario that reasonably represents the anthropogenic emissions by sources of GHG that would occur in the absence of the proposed project activity. A baseline shall cover emissions from all gases (baseline emissions), sectors and source categories listed in Annex A of the Kyoto Protocol within the project boundary (UNFCC, 2008).

The baseline scenario considered was the consumption of the fossil fuel (biodiesel) that would have been used in the absence of the project activity times an emission coefficient for the fossil fuel displaced

The calculation of baseline emissions was carried out taking petrodiesel fuel, as the fuel to be replaced, into consideration. Baseline emissions from displaced fossil fuel were determined using Equation (2) and the oil/year fossil fuel consumption provided by the company.

$$\mathbf{BEy = EF_{CO2,FD} * (FC_{BF,y} * NCV_{BF}) * \eta_{BF/FF}} \qquad \textbf{Equation 2}$$

Source: (UNFCC, 2007).

BEy : Baseline emissions in year y (t CO_2e)

$EF_{CO2, FD}$: Emission factor of fossil fuel substituted (petrodiesel) (t CO_2e/TJ)

$FC_{BF,y}$: Fuel consumption of biofuel for substitution of fossil fuel (petrodiesel) in year y (t)

NCV_{BF} : Net calorific value of biofuel (TJ/t)

$\eta_{BF/FF}$: Engine efficiency ratio biofuel/fossil fuel

In determining the carbon dioxide emission factor from petrodiesel ($EF_{CO2, FD}$) in this methodology, guidance from the IPCC (2006b) has been followed. The value is 74.1 (tCO_2/TJ).

The amount of fossil fuel displaced by the amount of biofuel consumed was calculated on an energy (net-calorific-value) basis. In determining the net calorific value of jatropha biofuel (NCV_{BF}) in this methodology, the average of the value established by the results of Achten et al. (2008) which is 0.03963 TJ/tonne has been used.

The total baseline emissions during the year (E_{BLy}) were estimated in both conservative and optimistic scenarios. The results are in Table 5.5 and Table 5.6:

Table 5.5: Baseline Emissions Scenario 1 (conservative scenario)

Year	**No ha**	**Oil/Year (2.5 tonnes/ha/year)**	**E_{BLy}**
1	2,000	5,000	14,683
2	4,000	10,000	29,366
3	6,000	15,000	44,049
4	8,000	20,000	58,732
5	10,000	25,000	73,415
6	12,000	30,000	88,097
7	14,000	35,000	102,780
8	16,000	40,000	117,463
9	18,000	45,000	132,146
10	20,000	50,000	146,829
Total		**275,000**	**807,560**

Table 5.6: Baseline Emissions Scenario 2 (optimistic scenario)

Year	**No ha**	**Oil/Year (5 tonnes/ha/year)**	**E_{BLy}**
1	2,000	10,000	29,366
2	4,000	20,000	58,732
3	6,000	30,000	88,097
4	8,000	40,000	117,463
5	10,000	50,000	146,829
6	12,000	60,000	176,195
7	14,000	70,000	205,561
8	16,000	80,000	234,927
9	18,000	90,000	264,292
10	20,000	100,000	293,658
Total		**550,000**	**1,615,121**

The methodology selected comprises project activities that substitute fossil fuel (petrodiesel) in internal combustion engines (mainly transport) with biodiesel. Jatropha can be included in that selection. The methodology also includes the restriction that the biomass feedstock should be produced on degraded land to avoid environmental problems such as forest destruction, lost of habitats or competition for food land among others.

5.2.3 Jatropha's Biodiesel Process Emissions

In the context of a Clean Development Mechanism, and according to the Marrakech Accords UNFCC (2002) all the anthropogenic GHG emissions that are under the control of the project's proponent are under the scope of the project. They are significant and they can be added to the activity of the CDM project.

Jatropha biofuel is considered to be carbon neutral; this means that the CO_2 balance remains equal. When these fuels are burned, the atmosphere is not polluted by carbon dioxide, since this has already been assimilated during the growth of these crops. Biofuels are produced from biomass and exactly the same amount of carbon dioxide (CO_2) that is absorbed from the atmosphere by the plants is set free through combustion, unlike fossil fuels, which contain carbon stored for millennia underground. This theory has been supported by Heller (1996) and Institute (2007).

According to Bakker (2006), the GHG sources that should be considered in a biofuel production are shown in the next table:

Table 5.7: GHG sources in well-to-wheel analysis

Source	GHG	Explanation
Biomass cultivation	CO_2 CH_4 N_2O	May be positive Anaerobic digestion From fertiliser production
Biomass transportation	CO_2	From plantation to plant
Fuel	CO_2	Biofuel processing plant
Power	CO_2	Biofuel processing plant
Biofuel transportation	CO_2	From plant to distribution station

Different sustainability evaluation tools and environmental impact assessment tools are available to investigate the environmental impacts of jatropha production. Life-cycle assessment (LCA) is such an instrument and has already shown its usefulness in evaluating the environmental balance of biofuel from other vegetable oils. Institute (2007) highlighted that in the life cycle analysis of a biofuel, the following emissions from the processes mentioned in the Figure 5.2 must be considered:

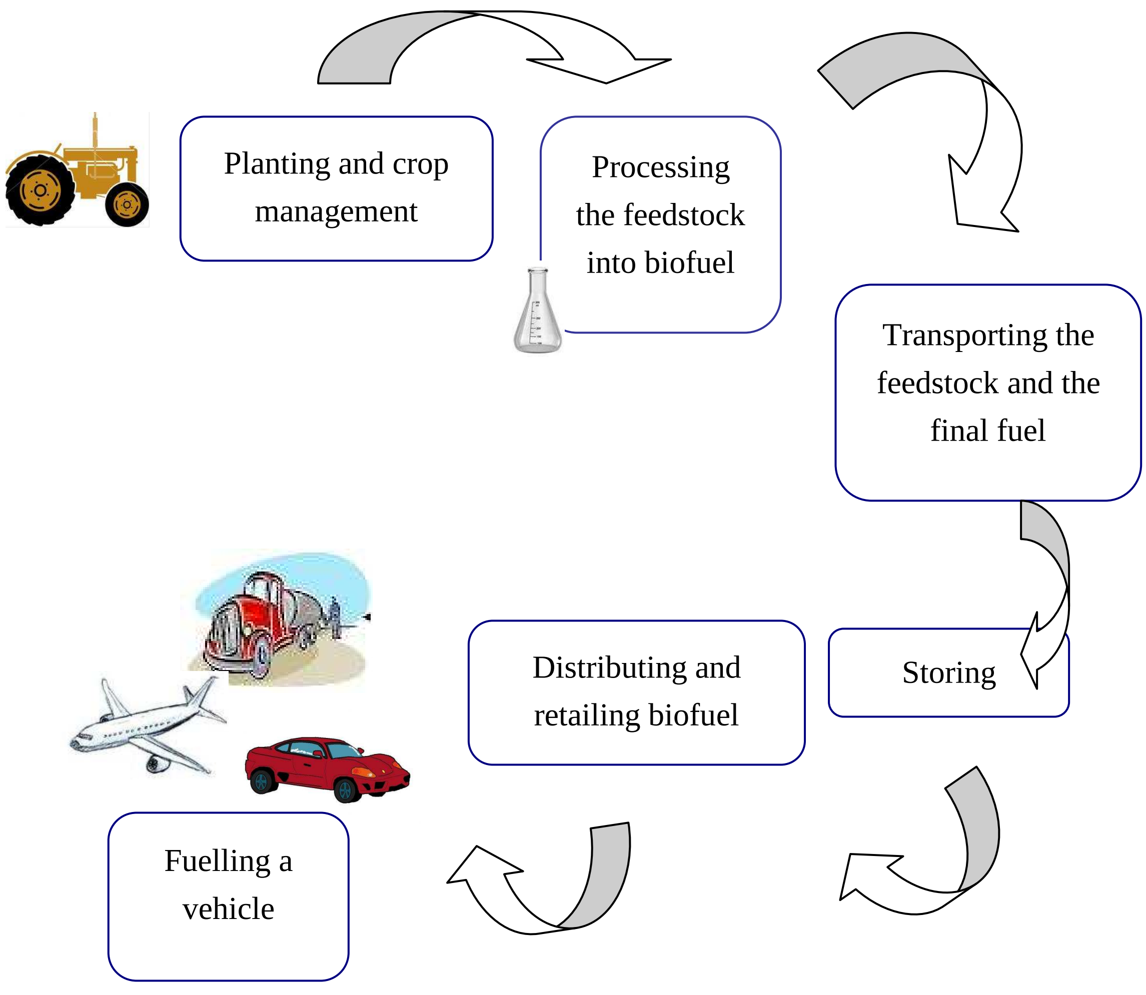


Figure 5.2: Life Cycle of Biofuel Production

Figure 5.2 shows different processes of production of biodiesel. In each process there are GHG emissions that must be considered in order to calculate the life cycle assessment of the biodiesel.

In order to estimate GHG emissions for jatropha biodiesel production, emissions beyond the boundaries of the CDM project were not considered. The following are different GHG taken into account as part of the project activity.

5.2.3.1 Planting and Crop Management

The GHG emissions considered in planting and crop management of jatropha were classified as below:

a. Land conversion
b. Consumption of fossil fuel for land management practices
c. Use of fertilizers

The electricity emissions in this step were not taken into account, because the emissions are expected to be smaller than 10% of emissions reduction.

The GHG impact depends upon what the jatropha plantation is replacing; if jatropha crops replace natural grass or forest, GHG emission will probably increase. If, on the other hand, jatropha crops are planted in place of annual crops, or on unproductive or arid land where conventional crops cannot grow, they have the potential to significantly reduce associated emissions.

Jatropha has the capacity to restore soil carbon contents over time and could help to improve the quality of degraded lands. Furthermore, organic matter in soils contains more than twice the carbon in atmospheric CO_2 and additional carbon is stored in biomass. Therefore, for the case studied, it is assumed that jatropha will grow on marginal soils with low nutrient content. Hence, there was no consideration of possible changes in carbon stocks.

The other GHG considered comes from land management practices which are among others: irrigation and treatment of the soil, soil cultivation, plantation management, harvest and agricultural post harvest processing.

For all these previous practices, GHG emissions are likely to occur as in this project studied fossil fuel consumption from the farm machinery was assumed. One bulldozer/tractor for land clearing and motorcycles for transporting the harvested fruits/seeds to the factory were considered.

Project emissions related to consumption of fossil fuel for land management practices were calculated with the formula below. Data supplied for the company was fossil fuel consumption of the machinery and vehicles used by the activity:

$$\mathbf{PE_{FF,I,y} = FC_{i,y} * NCV_i * EF_{CO_2 e,i}} \qquad \textbf{Equation 3}$$

Source: (UNFCC, 2007).

Where:

$FC_{i,y}$: Fossil fuel consumption of type i within the project boundary in year y

NCV_i : Net calorific value of fuel type i

$EF_{CO_2 e,i}$: Carbon dioxide equivalent emission factor of fuel type i, IPCC default values will be used according to fuel type

The net calorific value of petrodiesel (NCV_{fuel}) was estimated at 0.04333 TJ/tonne considering IPCC default values.

In determining the carbon dioxide emission factor from petrodiesel (EF $_{CO_2, FF}$) in this methodology, guidance from the IPCC (2006b) has been followed. The value is 74.1 (tCO_2/TJ). The total fossil fuel consumption in the harvesting process is shown in Tables 5.8 and 5.9.

In order to estimate the GHG emission for the project studied of land management practices, it was assumed:

- One motorcycle will be required per 5 hectares for transporting harvested fruits/seeds.
- The frequency of harvesting was assumed to be 3 times per year
- Fuel consumption per motorcycle is 0.3 tons per each harvesting event in scenario 1 and 0.6 tons in scenario 2 per each harvesting event.
- One bulldozer per 2,000 hectares with a fossil fuel consumption of 6 tonnes/year in both scenarios, as the number of hectares is the same.
- Fuel consumption for thermopac 0.005 tonnes per litre of biodiesel which is used to generate heat using thermal fluids.

In order to estimate the fossil fuel consumption of the farm machinery, an average age of the equipment was used. This assumption is also related to the engine efficiency and therefore the fuel consumed. Tables 5.8 and 5.9 show the projected emissions in the 10 year period.

Table 5.8: Project emissions for fossil fuel consumption (Scenario 1)

Year	Tonnes of fossil fuel used by motorcycle (Ton/year)	Tonnes of fossil fuel used by bulldozer (Tonnes/year)	Tonnes of fossil fuel used in Thermopac (Tonnes/year)	Project emissions related to consumption of fossil fuel
1	360	6.0	25	1,255
2	720	6.0	50	2,492
3	1,080	6.0	75	3,728
4	1,440	6.0	100	4,964
5	1,800	6.0	125	6,200
6	2,160	6.0	150	7,436
7	2,520	6.0	175	8,672
8	2,880	6.0	200	9,908
9	3,240	6.0	225	11,145
10	3,600	6.0	250	12,381
Total	**19,800**	**60**	**1,375**	**68,180**

Table 5.9: GHG Project Emissions for Fossil Fuel Consumption (Scenario 2)

Year	**Tonnes of fossil fuel used by motorcycle (ton/year)**	**Tonnes of fossil fuel used by bulldozer (tonnes/year)**	**Tonnes of fossil fuel used in Thermopac (tonnes/year)**	**Project emissions related to consumption of fossil fuel**
1	720	6.0	50	2,492
2	1,440	6.0	100	4,964
3	2,160	6.0	150	7,436
4	2,880	6.0	200	9,908
5	3,600	6.0	250	12,381
6	4,320	6.0	300	14,853
7	5,040	6.0	350	17,325
8	5,760	6.0	400	19,798
9	6,480	6.0	450	22,270
10	7,200	6.0	500	24,742
Total	**39,600**	**60**	**2,750**	**136,168**

Emissions can be neglected in cases where fuel or power is from renewable energy sources, therefore, if the company can replace the fossil fuels used in the farm machinery with the biofuel produced, these emissions would not be considered.

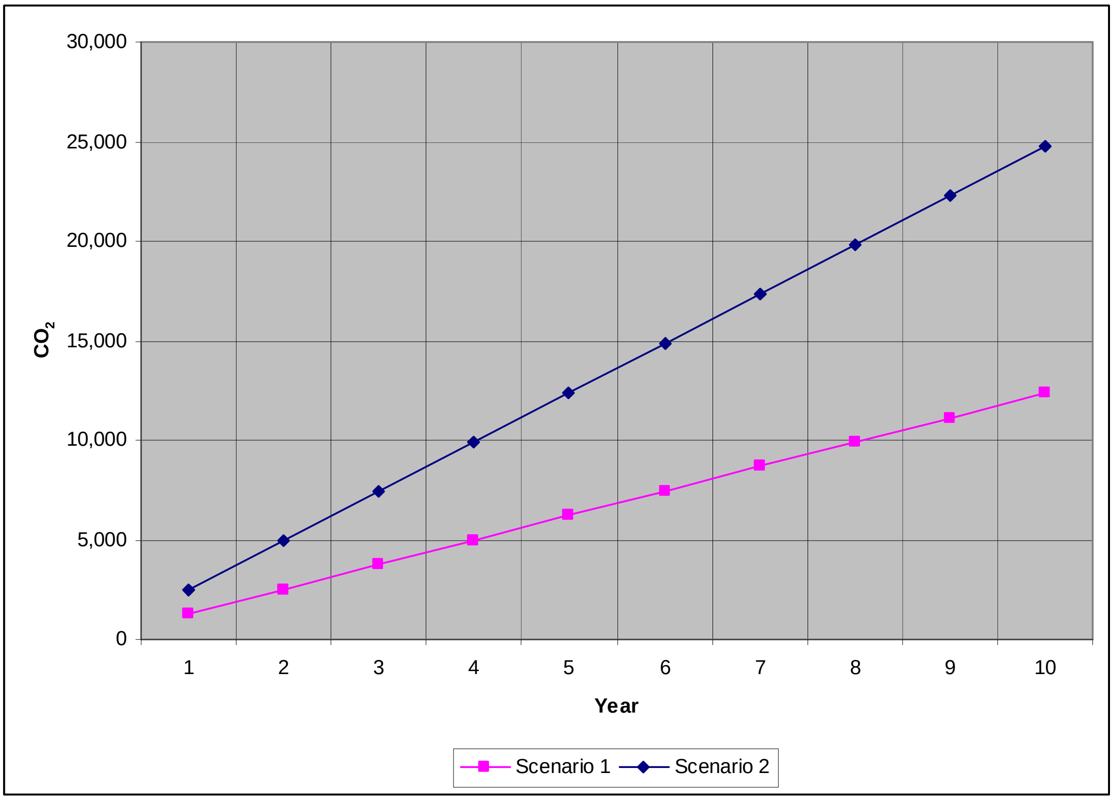


Figure 5.3: Project emissions related to consumption of fossil fuel (tonnes CO_2)

The residual biomass of jatropha oil or "press-cake" can be used to produce energy and generate electricity or steam, reducing or eliminating the need for external energy inputs coming from fossil fuels. If the company can verifiably demonstrate that carbon input is derived from a renewable source (e.g. methanol from biogas from the press cake digestion) that does not claim CERs for substituting for fossil sources, no emissions have to be considered.

In the plantations, usually there are emissions associated with the energy required for the production and use of fertilizers and pesticides. Institute (2007) declares that the most significant factor in terms of climate impact is chemical fertilizers, which require large amounts of fossil energy input. Typically, fertilizers and pesticides are manufactured using a natural gas as an input, and nitrogen (N) fertilizer, in particular, can require vast amounts of natural gas to produce. Some of the nitrogen fertilizer used on fields is eventually emitted as nitrous oxide (N_2O), which is released directly from the soil or through run-off water. Pesticides are generally fossil fuel based, increasing energy inputs and, therefore associated GHG emissions.

In the project activity studied the amount of synthetic and organic fertilizers estimated is 0.1 tonne/ha per year. It is assumed that every year 0.1 tonne/ha per year will be added for the new hectares and the same amount for the previous land.

The N_2O emissions were estimated according to IPCC guidelines according to the formula below and the amount of fertilizer supplied by the company:

$$\mathbf{PE_{NF,i,y} = NF\ i,\ j,\ * (EF_{N_2O\_direct,\ I} * (44/28))\ GWP_{N_2O}} \qquad \textbf{Equation 4}$$

Source: (UNFCC, 2007).

Where:

$PE_{NF\ i,\ j,}$: Amount of nitrogen in fertilizer type i applied in year y

$EF_{N_2O\_direct,\ I}$: Emission factor for N_2O-N from nitrogen fertilizer type i

GWP_{N_2O} :: Global warming potential of N_2O

The emission factor for N_2O-N from the nitrogen fertilizer type was assumed in 0.01 (t N_2O-N/t N) (IPCC, 2006c). The GWP of N_2O is 310 (t CO_2e/t N_2O).

The projected emissions resulting from the application of nitrogen fertilizer including crop residues, type i, in year y are shown in Table 5.10:

Table 5.10: Projected emissions resulting from the application of nitrogen fertilizer

Year	No ha	Tonnes CO_2
1	2,000	974
2	4,000	1,949
3	6,000	2,923
4	8,000	3,897
5	10,000	4,871
6	12,000	5,846
7	14,000	6,820
8	16,000	7,794
9	18,000	8,769
10	20,000	9,743
Total		**53,586**

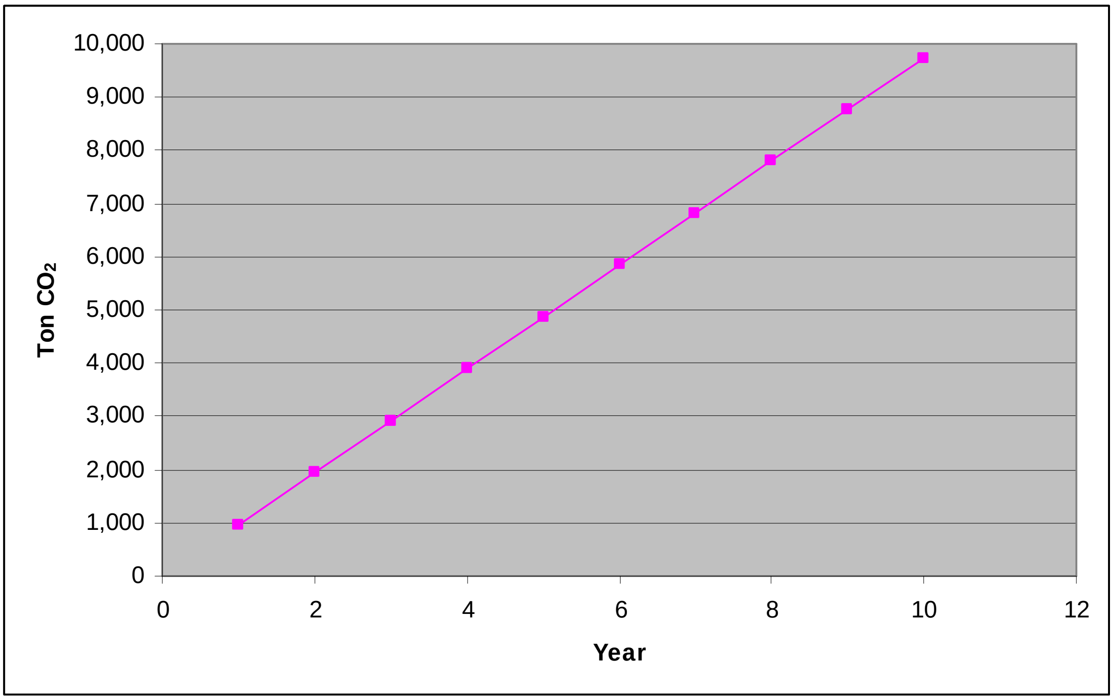


Figure 5.4: Projected emissions resulting from the application of nitrogen fertilizer

The 20,000 ha of jatropha will produce 65,000 tonnes of biomass from the seedcake or press cake. This estimation is supported by studies carried out by BiofuelsRevolution (2009), where it found out that 10 tonnes of seeds will produce 6,500 kg biomass from oiled seedcake.

If the crops utilize the biomass of press cake as a fertilizer, the amount of GHG emissions from nitrogen fertilizer can be avoided. The seedcake should be given back to the farmers for use as fertiliser and it would also mean a reduction in greenhouse emissions. In this work, the emissions from fertilizers were taken into account in the project activity's emissions.

5.2.3.2 Processing the Feedstock into Biofuel

The GHG emissions considered in processing biofuel were classified as below:

a. Electricity consumption: Significant amounts of energy, in the form of process heat, mechanical energy and electricity are needed for the refining process.
b. Emissions related to the fossil carbon content of methanol input to biodiesel production

To calculate the electricity consumption emissions, it was assumed that:

- Significant emissions from the consumption of electricity are only caused by machinery in the oil press and transesterification unit.
- The production of biofuel will be carried out in New Zealand and the supplier of electricity will be Meridian Energy.

In the case studied, the electricity estimated to be consumed is 8kW per tonne of biodiesel produced. As the supplier of electricity in the South Island of New Zealand provides electricity from renewable wind and hydro resources, no GHG were considered in this case. Meridian Energy is one of the largest electricity suppliers in the South Island and the electricity is sourced from hydro and wind farm projects.

To calculate the emissions related to CO_2 from the combustion of fossil carbon contained in methanol that is chemically bound in the biodiesel during the esterification process and released upon combustion it was assumed that:

- The project utilizes 90 kilos of methanol to produce 1 tonne of biodiesel.
- The weight fraction of fossil carbon in methanol is 0.375 (IPCC, 2006c)

The project emissions related to the fossil carbon content of methanol input to biodiesel production in a year have been calculated with the equation below considering the data supplied by the company which is the amount of methanol used to biodiesel production. The results are shown in the Figure 5.5

$$PE_{CC, MeOH,y} = MI_{MeOH, y} * w_{ciCarbon, MeOH} \times (44/12) \qquad \textbf{Equation 5}$$

Source: (UNFCC, 2007).

Where:

$w_{Carbon,MeOH}$: Weight fraction of fossil carbon in methanol

$MI_{MeOH, y}$: Amount of methanol input to biodiesel production, year y

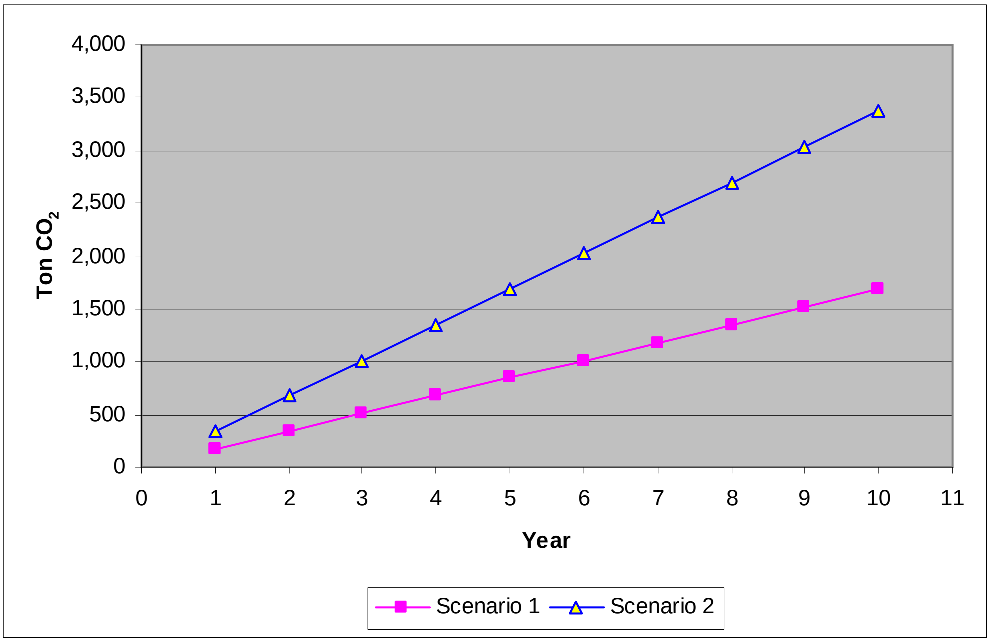


Figure 5.5: Project emissions related to fossil carbon content of methanol input to biodiesel production

As Figure 5.5 shows, both scenarios increase the amount of emissions as the number of hectares increases. Table 5.11 and Table 5.12 show in detail the emissions in the period studied.

Table 5.11: Project emissions related to fossil carbon content of methanol input to biodiesel production (Scenario 1).

Year	**No ha**	**Biofuel Production**	**Project Emissions (Tonnes CO_2/year)**
1	2,000	5,000	169
2	4,000	10,000	338
3	6,000	15,000	506
4	8,000	20,000	675
5	10,000	25,000	844
6	12,000	30,000	1,013
7	14,000	35,000	1,181
8	16,000	40,000	1,350
9	18,000	45,000	1,519
10	20,000	50,000	1,688
Total		**275,000**	**9,281**

Table 5.12: Project emissions related to fossil carbon content of methanol input to biodiesel production each year (Scenario 2).

Year	No ha	Biofuel Production	Project Emissions (Tonnes CO_2/year)
1	2,000	10,000	338
2	4,000	20,000	675
3	6,000	30,000	1,013
4	8,000	40,000	1,350
5	10,000	50,000	1,688
6	12,000	60,000	2,025
7	14,000	70,000	2,363
8	16,000	80,000	2,700
9	18,000	90,000	3,038
10	20,000	100,000	3,375
Total		**550,000**	**18,563**

5.2.3.3 Transporting the Feedstock and the Final Fuel

Emissions from fossil fuel consumption in the transportation of raw materials and biomass between plantation and technological installations are likely to be smaller than 10% of emissions reduction, while transport and distribution of biofuel to the consumer may cause significant emissions depending on the transport distance.

In the case studied, the biofuel will be exported to New Zealand as feedstock for the production of biodiesel. The transport used in this case will be a ship that will travel from Malaysia/Chile to New Zealand.

To calculate the emissions related to the transport by ship the following factors were considered:

- CO_2 factors for marine freight transport.
- That the distance of the voyage is 8,078 kilometres or 5020 miles approximately, between Malaysia (Port Klang) and New Zealand (Auckland) Portworld (2009).
- That the distance of the voyage is 8,502 kilometres or 5,283 miles between Chile (Port Valparaiso) and New Zealand (Auckland) Portworld (2009).
- One large container vessel and just one trip from one port to another port.
- The value of 0.000013 tonne of CO_2 per tonne km was obtained from DEFRA (2008).

The results for both scenarios are shown in Figure 5.6. The emissions in the period of time are considered in Tables 5.13 and 5.14:

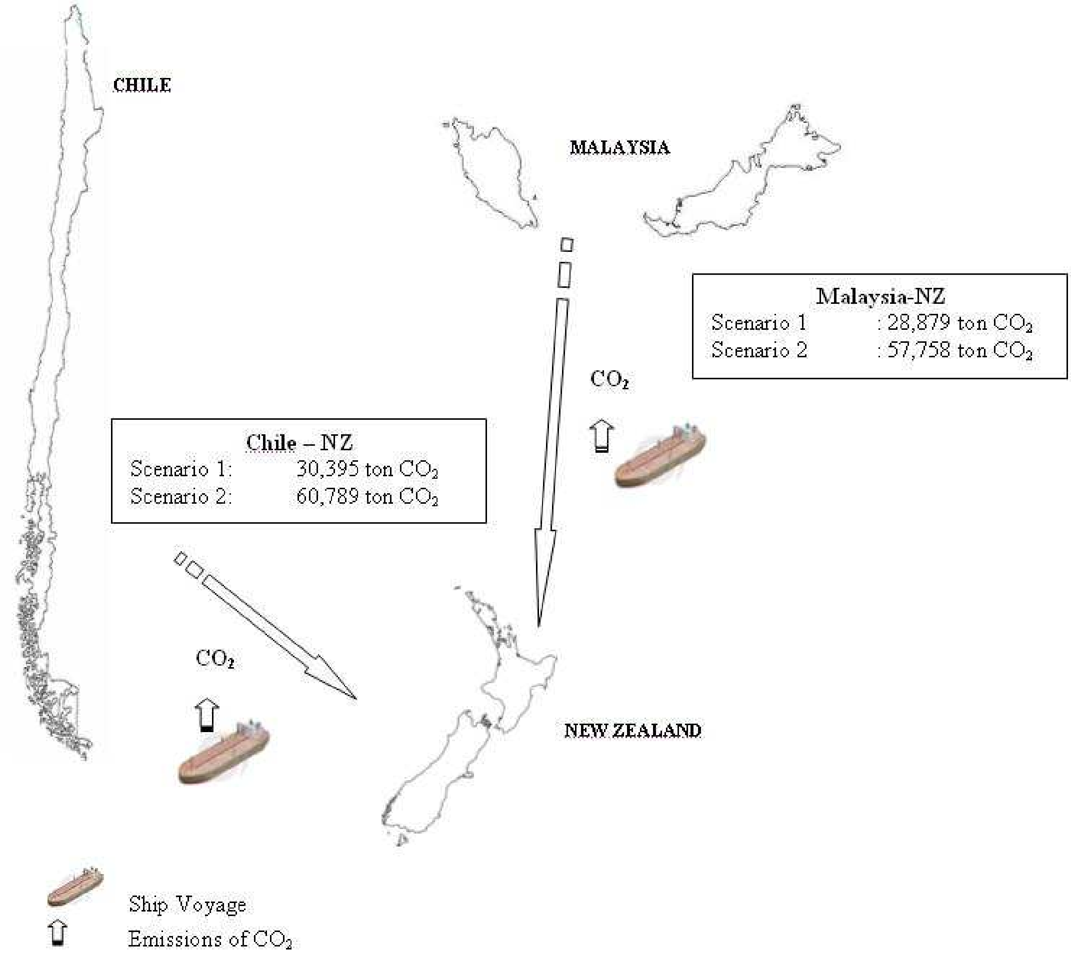


Figure 5.6: Project emissions resulting from transportation (fuel consumption).

Table 5.13: Project emissions resulting from transportation (fuel consumption) Scenario 1.

Year	**Oil/Year Weight (metric tonnes) (Scenario 1)**	**tCO_2-e Malaysia-NZ**	**tCO_2-e Chile-NZ**
1	5,000	525.07	552.63
2	10,000	1050.14	1105.26
3	15,000	1575.21	1657.89
4	20,000	2100.28	2210.52
5	25,000	2625.35	2763.15
6	30,000	3150.42	3315.78
7	35,000	3675.49	3868.41
8	40,000	4200.56	4421.04
9	45,000	4725.63	4973.67
10	50,000	5250.70	5526.30
Total	**275,000**	**28,879**	**30,395**

The total amount of emissions in Scenario 1 are around 30,000 (CO_2-e) taking both countries (Malaysia and Chile) as suppliers of the raw material to produce jatropha biofuel.

Table 5.14: Project emissions resulting from transportation (fuel consumption) Scenario 2.

Year	Oil/Year Weight (metric tonnes) (Scenario 2)	tCO_2-e Malaysia-NZ	tCO_2-e Chile-NZ
1	10,000	1050.14	1105.26
2	20,000	2100.28	2210.52
3	30,000	3150.42	3315.78
4	40,000	4200.56	4421.04
5	50,000	5250.70	5526.30
6	60,000	6300.84	6631.56
7	70,000	7350.98	7736.82
8	80,000	8401.12	8842.08
9	90,000	9451.26	9947.34
10	100,000	10501.40	11052.60
Total	**550,000**	**57,758**	**60,789**

The value in Scenario 2 is nearly double 60,000 (CO_2-e) as the amount of biofuel to be produced is also double.

5.2.3.4 Other Emissions

The last steps that would produce GHG emissions are storing, distributing and retailing biofuel, and also fuelling a vehicle and the evaporative and exhaust emissions resulting from combustion. These steps were not considered in the calculation as they are beyond the boundaries of the CDM project.

5.2.3.5 Total Emissions from the Project Activity

Each of these steps in the process to produce jatropha biofuel is a source of GHG emission. To calculate the emissions from the project activity, the following equation was used

$$\mathbf{PE_y = (PE_{FF,I,y} + PE_{BDP,y} + PE_{NF,i,y} + PE_{CC,MeOH,y} + PE_{MY\text{-}NZ,MY\text{-}CH})} \qquad \textbf{Equation 6}$$

Source: (UNFCC, 2007).

Where,

$PE_{FF,I,y}$ = Emissions from project emissions related to consumption of fossil fuel

$PE_{BDP,y}$ = Emissions from electricity consumption activity

$PE_{NF,i,y}$ = Emissions resulting from the application of nitrogen fertilizer

$PE_{CC,MeOH,y}$ = Emissions related to the fossil carbon content of methanol input to biodiesel production in a year

$PE_{MY\text{-}NZ,MY\text{-}CH}$ = Emissions from the ship voyages

The electricity consumption is 0, as the plantation and management crop was considered not significant and at the Biofuel Plant, the supplier of electricity is considered to be carbon neutral owing to the use of renewable sources in New Zealand.

In the case of the ship voyage, the emissions from Malaysia to New Zealand were considered, as the values were close to the distance between Chile and New Zealand.

Table 5.15: Project Activity Emissions (Scenario 1)

Year	Project Activity Emissions				
	Fossil fuel	**Nitrogen Fertilizer**	**Methanol**	**Ship Voyage**	**Total**
1	1,255	974	338	525	863
2	2,492	1,949	675	1,050	1,725
3	3,728	2,923	1,013	1,575	2,588
4	4,964	3,897	1,350	2,100	3,450
5	6,200	4,871	1,688	2,625	4,313
6	7,436	5,846	2,025	3,150	5,175
7	8,672	6,820	2,363	3,675	6,038
8	9,908	7,794	2,700	4,201	6,901
9	11,145	8,769	3,038	4,726	7,763
10	12,381	9,743	3,375	5,251	8,626
Total	**68,180**	**53,586**	**18,563**	**28,879**	**47,441**

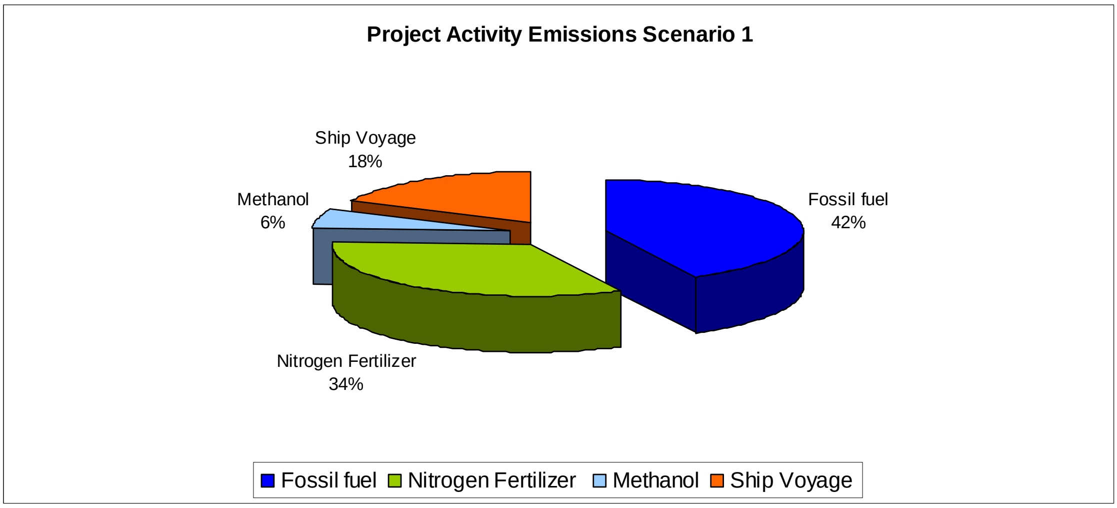


Figure 5.7: Classification of project activity emissions during the period studied (Scenario 1)

In Scenario 1 the largest sector of GHG emissions is the fossil fuel consumption, followed by the nitrogen fertilizer application to the land. The smallest emission is the one related to the methanol used to produce biofuel.

Table 5.16: Project Activity Emissions (Scenario 2)

Year	Project Activity Emissions				
	Fossil fuel	**Nitrogen Fertilizer**	**Methanol**	**Ship Voyage**	**Total**
1	2,492	974	338	1,050	1,388
2	4,964	1,949	675	2,100	2,775
3	7,436	2,923	1,013	3,150	4,163
4	9,908	3,897	1,350	4,201	5,551
5	12,381	4,871	1,688	5,251	6,938
6	14,853	5,846	2,025	6,301	8,326
7	17,325	6,820	2,363	7,351	9,713
8	19,798	7,794	2,700	8,401	11,101
9	22,270	8,769	3,038	9,451	12,489
10	24,742	9,743	3,375	10,501	13,876
Total	**136,168**	**53,586**	**18,563**	**57,758**	**76,320**

In Scenario 2 the fossil fuel consumption accounts for the largest sector of GHG emission and the emissions produced by the ship's voyage are larger because the amount of biofuel is double

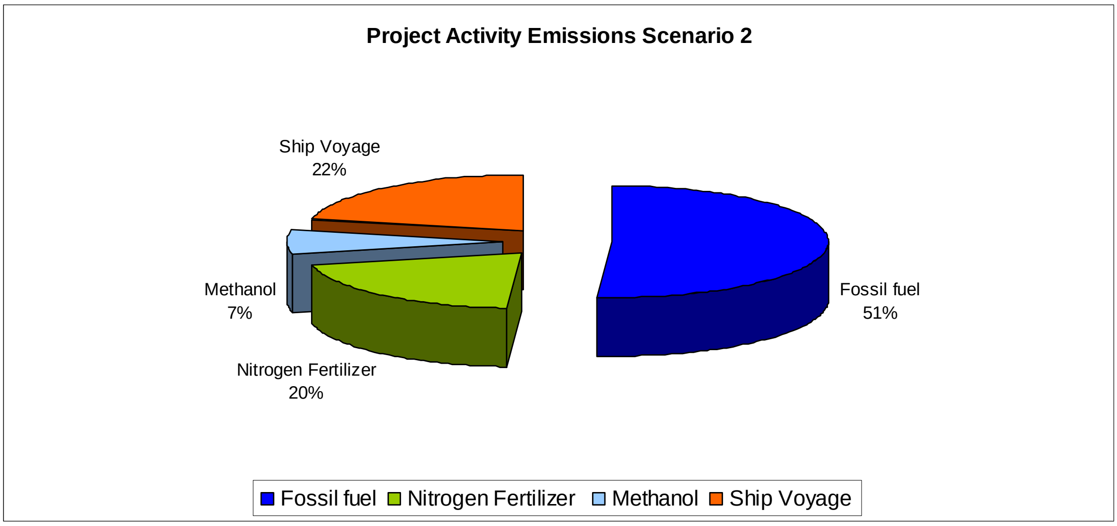


Figure 5.8: Classification of project activity emissions during the period studied (Scenario 2)

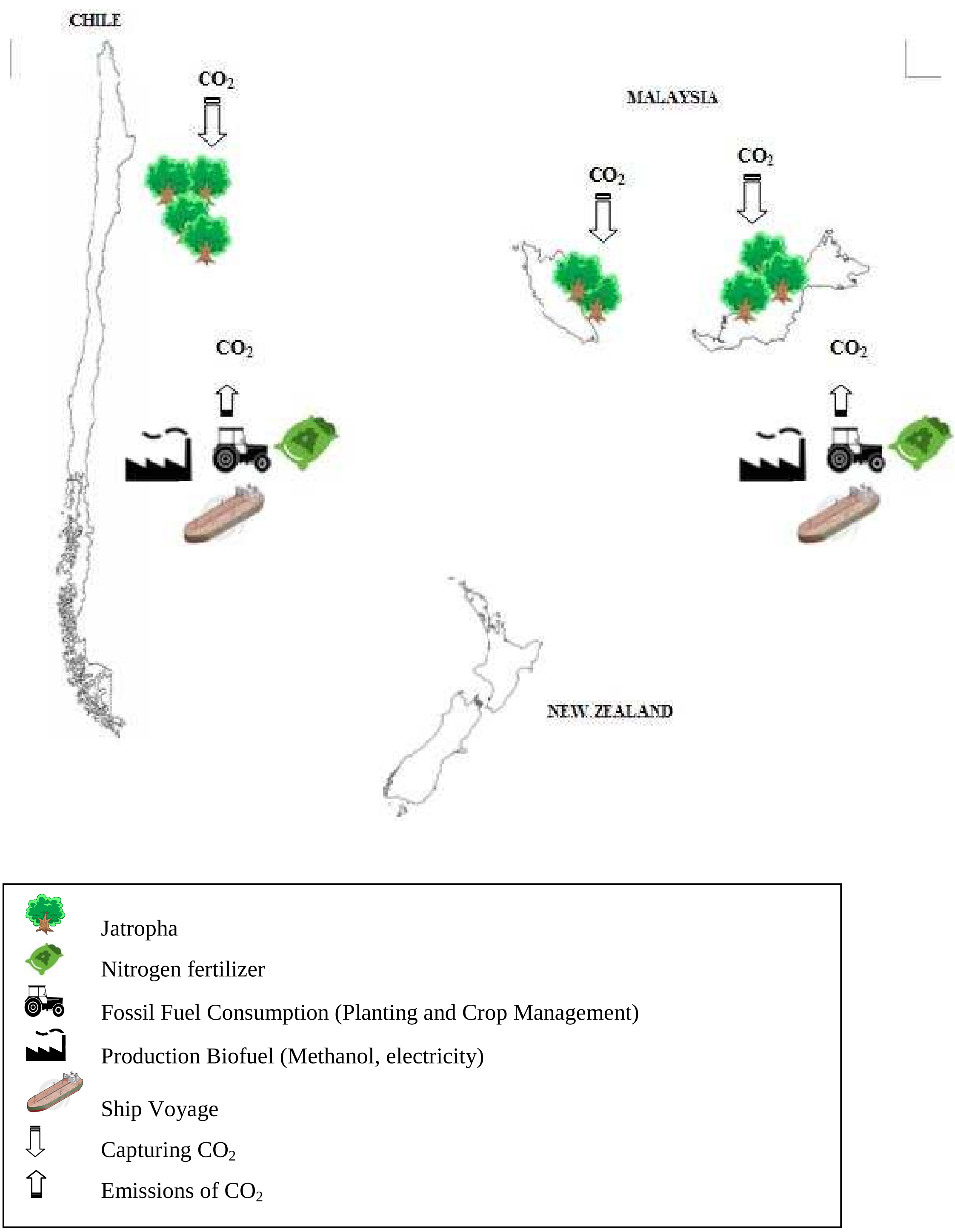


Figure 5.9: Capture and emissions of CO_2 of jatropha.

Figure 5.9 summarize the different activities that produce emissions of CO_2 such as Nitrogen fertilizer, Fossil fuel consumption, Production of biofuel and Ship Voyage. These emissions will be produced either in Chile or Malaysia depending which one will host the project. Capturing emissions of CO_2 are also represented in the diagram.

5.2.4 Estimation of Emission Reductions

The emission reductions of the project activity were calculated with the difference between the estimated emissions from sources of GHG of the baseline and the project activity emissions.

Table 5.17: Emissions Reduction- Scenario 1 (CO_2-e)

Year	Estimated emissions by sources of GHG of the baseline	Project Activity Emissions	Emissions Reduction (Tonnes CO_{2-e}/year)
1	14,683	863	13,820
2	29,366	1,725	27,641
3	44,049	2,588	41,461
4	58,732	3,450	55,282
5	73,415	4,313	69,102
6	88,097	5,175	82,922
7	102,780	6,038	96,742
8	117,463	6,901	110,562
9	132,146	7,763	124,383
10	146,829	8,626	138,203
Total	**807,560**	**47,441**	**760,119**

The total emissions reductions are 760,000 CO_{2}-e in Scenario 1. Because Scenario 2 considered a double amount of biofuel produced, the emission reductions are nearly double as can be seen in the next Table:

Table 5.18: Emissions Reduction- Scenario 2 (CO_2-e)

Year	Estimated emissions by sources of GHG of the baseline	Project Activity Emissions	Emissions Reduction (Tonnes CO_{2-e}/year)
1	29,366	1,388	27,978
2	58,732	2,775	55,956
3	88,097	4,163	83,935
4	117,463	5,551	111,913
5	146,829	6,938	139,891
6	176,195	8,326	167,869
7	205,561	9,713	195,847
8	234,927	11,101	223,826
9	264,292	12,489	251,804
10	293,658	13,876	279,782
Total	**1,615,121**	**76,320**	**1,538,800**

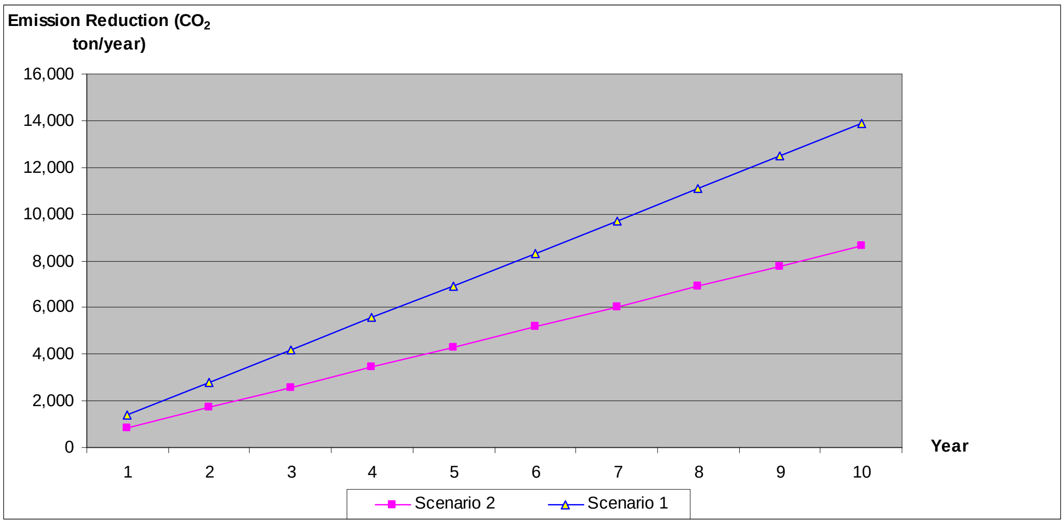


Figure 5.10: Comparison between the emission reductions in both scenarios.

In conclusion, the total emission reductions of the jatropha project in a period of 10 years are 760,119 tonnes of CO_2 in Scenario 1. In Scenario 2 the emission reductions are 1,538,800 tonnes of CO_2 in the same period.

This amount is quite significant and it is assumed that the biodiesel generated from the project activity will replace fossil fuel that would otherwise be used as fuel in mobile combustion engines for road, rail or air transport as well as in stationary combustions. The project activity would avoid GHG emissions that would otherwise be generated from the burning of diesel. With the amount of emission reduction, the project activity will cut GHG emissions in the transport sector either in Malaysia or Chile, depending on which country hosts the project.

The amount reduced by tonne of jatropha biofuel produced is quite conservative. Studies by BioFuelsRevolution (2009) concluded that 1 hectare (2500 plants) will produce up to 3.5 tons of biodiesel which will result in 9.2 tons of CO_2 offset every year. According to Errázuriz (2008) approximately 0.44 tons of biodiesel used in a developing country are equivalent to 1 tonne of reduced CO_2.

5.2.5 Estimation of Carbon Credit Profit

According to the tendency, the price per tonne of CO_2e from a CDM project varies from NZ $30 to NZ $40. However, voluntary markets in the same project can have prices that fluctuate between NZ $10 and NZ $20 according to CarbonCatalog (2009). This difference is explained because CDM projects consider a verification and validation step which is quite costly and those credits have more credibility in terms of being used as an offsetting.

Estimates of the profits earned by selling carbon credits have been carried out with New Zealand, Malaysia and Chile currency conversions. An average amount of $NZ 15 was used. The results are in Table 5.19 and Table 5.20:

Table 5.19: Profit from the selling of CERs (Scenario 1)

Year	Millions NZ$ (Scenario 1)	Millions RM[1] (Scenario 1)	Millions Chilean Pesos[2] (Scenario 1)	Millions US$[3] (Scenario 1)
1	0.21	0.09	72.56	0.15
2	0.41	0.19	145.11	0.29
3	0.62	0.28	217.67	0.44
4	0.83	0.37	290.23	0.59
5	1.04	0.46	362.79	0.74
6	1.24	0.56	435.34	0.88
7	1.45	0.65	507.90	1.03
8	1.66	0.74	580.45	1.18
9	1.87	0.84	653.01	1.32
10	2.07	0.93	725.57	1.47
Total	**11.40**	**5.11**	**3,990.62**	**8.10**

[1] 1 NZ$: 2.23 RM

[2] 1 NZ$: $350 Chilean pesos

[3] 1 NZ$: 0.71 US$

Table 5.20: Profit from the selling of CERs (Scenario 2)

Year	Millions NZ$ (Scenario 2)	Millions RM[4] (Scenario 2)	Millions Chilean Pesos[5] (Scenario 2)	Millions US$[6] (Scenario 2)
1	0.42	0.19	146.89	0.30
2	0.84	0.38	293.77	0.60
3	1.26	0.56	440.66	0.89
4	1.68	0.75	587.54	1.19
5	2.10	0.94	734.43	1.49
6	2.52	1.13	881.31	1.79
7	2.94	1.32	1,028.20	2.09
8	3.36	1.51	1,175.08	2.38
9	3.78	1.69	1,321.97	2.68
10	4.20	1.88	1,468.85	2.98
Total	**23.08**	**0.19**	**8,078.70**	**16.39**

[4] 1 NZ$: 2.23 RM

[5] 1 NZ$: $350 Chilean pesos

[6] 1 NZ$: 0.71 US$

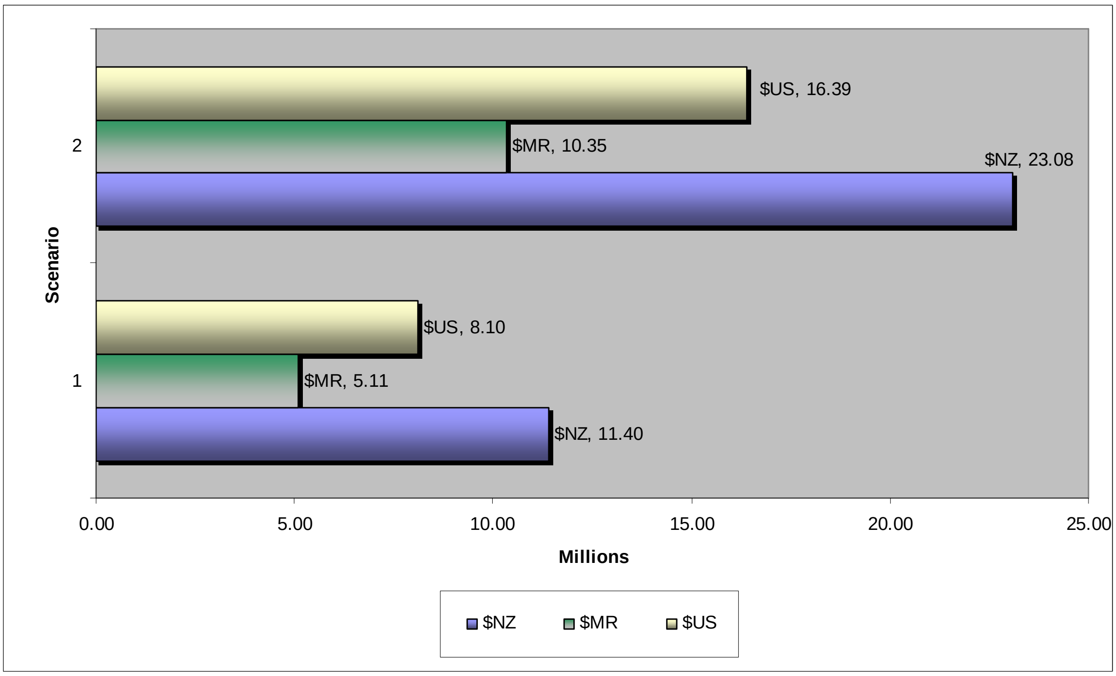


Figure 5.11: Profit from the selling of CERs. Both Scenarios.

5.2.6 Summary

Table 5.21 shows a summary of the calculations:

Table 5.21: Results Summary

Results	Scenario 1	Scenario 2
Yield (tonnes of biofuel/ha)	2.5	5
Yield (tonnes of biofuel/ 10years)	275,000	550,000
Carbon stock (CO_2 Tonnes)	2,091,000	
Baseline emissions (CO_2 Tonnes)	807,560	1,615,121
Emissions from Fossil Fuel Consumption (CO_2 Tonnes)	68,180	136,168
Emission from Transportation (CO_2 Tonnes)	28,879	57,758
Emission from Methanol input (CO_2 Tonnes)	9,281	18,563
Emission from Nitrogen fertilizer (CO_2 Tonnes)	53,586	
Total Project activity emissions (CO_2 Tonnes)	47,441	76,320
Emission Reduction (CO_2 Tonnes)	760,119	1,538,800
Economical benefits (millions RM)	5.11	10.35

6 CONCLUSIONS AND IMPLICATIONS

The aim of this study was achieved successfully as it was evaluated the potential of jatropha in the Clean Development Mechanism. Each specific objective was addressed in order to achieve the main objective of this study.

There were identified and evaluated potential activities that reduce GHG gases through jatropha plantation and the use of jatropha biofuel. It was found that biodiesel can be used in most diesel engines; therefore the fossil fuel used in diesel engines can be replaced by biodiesel thus avoiding GHG. The most common activity that currently uses fossil fuel in diesel engines is the transport sector, including airplanes and aquatic transport. This sector is the one most likely to use biodiesel and replace fossil fuel. Potential by-products of jatropha that may reduce greenhouse gases are press cake that can be used to produce methane through the bio-digestion process, or as a fertilizer avoiding the emissions from nitrogen fertilizers. If the methane produced is used to replace fossil fuel there is a reduction in GHG that can be discounted from the project's emissions.

The project activity studied complies with the requirements for a forestation or afforestation project by UNFCC as the land is an "eligible land" and meets the requirements of an "eligible project". The following findings achieve the second objective of this research: The definition of "forest" given by UNFCC accords with the characteristics of the jatropha tree, so it will be an eligible project. The project qualifies as an afforestation project as long as can be demonstrated that, for at least 50 years, vegetation on the land has been below the thresholds adopted by the host country for a definition of a forest (Chile or Malaysia); otherwise it will be classified as a reforestation project if the land was not forest before 31st December 1989.

Qualitative analysis on the suitability of CDM for jatropha biodiesel according to local laws, policy and regulation has been done. New Zealand as a developed country can transfer technology to Chile and Malaysia as a developing countries

For the rest of the specific objectives, it has been used a quantitative analysis, calculating the reduction/capture of GHG, quantifying in terms of CERs and estimating the economic benefits for the sale of those credits in the market. The capture of GHG through the planting of biofuel crops may create carbon sinks that can earn through the sale of sink carbon credits. If CDM credits do become available for planting trees, it could add a further inducement to plant jatropha to act as an energy-producing carbon sink.

As the calculations of emission reduction were carried out taking two scenarios into account, the findings are different in each scenario calculated. The scenario 1 considered a conservative yield of 2.5 tonnes/ha/year of biodiesel and Scenario 2 considered an optimistic yield of 5 tonnes/ha/year.

For each scenario the following calculations were done: Baseline emissions, jatropha's production emission (project emission), emission reduction and potential profit in CER's.

The emissions at the baseline in Scenario 1 were 807,560 tonnes CO_2, likewise in Scenario 2 the emissions at the baseline were double at 1,615, 121 tonnes CO_2 as the calculation considered the amount of biofuel produced.

The emissions from jatropha's biodiesel process were categorized according to fossil fuel consumption, use of nitrogen fertilizer, electricity consumption and methanol used in the process. Each of these categories was analyzed and calculated through the different steps of the jatropha's biodiesel process.

The total fossil fuel consumption in the harvesting process was 68,180 tonnes of CO_2 in Scenario 1, meanwhile in Scenario 2 the fossil fuel consumption was double, caused by the double yield in the harvesting process and therefore double consumption of fossil fuel by the machinery.

The project activity emissions resulting from the application of nitrogen fertilizer were estimated to be 53,586 tonnes of CO_2 during the period studied. As the scenarios do not vary in the number of hectares, this value was considered equal for both scenarios.

The project activity emissions related to the fossil carbon content of methanol input to biodiesel production were 9,281 of CO_2 in Scenario 1 and 18,563 in Scenario 2, during the period studied. This is because the methanol used in the process is directly proportional to the amount of biodiesel to be produced.

Project activity emissions resulting from the transportation of raw material from Chile or Malaysia to New Zealand were estimated at around 30,000 tonnes of CO_2 in Scenario 1 and double in Scenario 2, owing to the methodology used, considering an emission factor per tonne transported.

The total project activity emission is 47,441 of CO_2 in Scenario 1 and 76,320 in Scenario 2. In both scenarios the biggest percentage of emissions are produced by fossil fuel consumption, followed by the nitrogen used as a fertilizer.

The emission reductions in Scenario 1 are 760,119 tonnes of CO_2 which is an estimated profit of RM 5.11 million during the period of 10 years, considering an average price of NZ$ 15 per tonne of CO_2 reduced.

The emission reductions in Scenario 2 are 1,538,000 tonnes of CO_2 which is an estimated profit of RM 10.35 million during the period of 10 years.

The importance on the achievement of the objectives in this study leads the fight against Climate Change and studies the challenges of CDM projects. Jatropha biofuel made on degraded and abandoned land with environmentally sustainable practices will reduce GHG by displacing fossil fuels. Biofuels can offer immediate and sustained GHG advantages if the production is carried on in a sustainable way.