Biofuel: A Sustainable Solution for Cambodia?

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Cambodia's energy sector has a crucial role to play in the country's continued development. However the current situation in Cambodia with respect to energy costs, service provision, sustainability and security may prove to be a barrier to development.

Cambodia has no proven fossil fuel reserves, and is almost completely dependent on fully-imported diesel fuel for electricity production and other power applications. The demand for fossil fuel imports in Cambodia grew by an average 33% per year from 1997 to 2000 and there is no sign of the trend slowing (MIME, 2004). Meanwhile the international price of oil has risen to record levels over $55 per barrel which is a 57% rise for the year to March 2005 (*The Economist*, 2005b).

This situation has serious implications for a country like Cambodia with limited reserves of foreign currencies and no reserve stocks of fossil fuels to insulate domestic consumers from price shocks. Consequently Cambodians face some of the highest energy prices in the world, and an insecure supply. The impacts of this are widespread and appear to hinder development in terms of economic growth and poverty reduction.

Biofuels may offer a solution to some of these issues by providing a substitute for diesel fuel that can be manufactured locally for a lower price, and independent of the international oil price. The local production and use of biofuel also offers other benefits such as improved energy security, rural development opportunities and environmental benefits.

The Jatropha Curcas species appears to be a particularly suitable source of biofuel as it already grows commonly in Cambodia and has no other commercial value. One study suggests that the biofuel could be produced in Cambodia from Jatropha on a commercial basis for around US$0.53 per litre. This compares favourably with the current price of fossil fuel diesel at US$0.64 per litre. And the production cost of the biofuel is not likely to follow the rising trend of the international oil price.

A range of business models can be considered for the commercialisation of the biofuel production. A plantation model that encourages private farmers to produce the Jatropha seed on their own properties offers good benefits with respect to minimising initial risk and maximising community involvement and sustainable benefits. In this model the processing plant would be operated by investors who buy the Jatropha seeds from the farmers. The investors may also wish to directly purchase some land to establish a plant nursery that would help ensure consistent supply and quality of the Jatropha.

This paper concludes that local production of biofuel in Cambodia, based on the Jatropha Curcas species or other sources, offers good potential benefits for the investors, the economy, rural communities and the environment. A series of recommendations are made for further analysis that is needed to ensure that biofuel can indeed become a sustainable solution for Cambodia.

Foreword

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1. Background on Cambodia's Energy Situation

This section provides an introduction to the energy resources, demand and supply in Cambodia, and then discusses some apparent issues that are emerging as possible barriers to Cambodia's development. In following sections the paper will discuss to what extent Biofuel may provide solutions to these issues.

1.1 Energy Resources

Cambodia has few conventional energy sources available within the country, and even fewer currently exploitable. Wood accounts for more than 80% of total national energy consumption (MIME, 1996). Fuelwood is by far the main source of energy available to the general population, but plays an even greater role for the poor and rural people. Yet, the main source of fuelwood in Cambodia, that is, natural forests, have been severely degraded due to widespread logging and forest land conversion for various purposes over the past twenty years (ADB, 2000; Global Witness, 2000).

The country relies almost entirely on imported fossil fuels, mainly diesel and heavy oil, for electricity production. There is no in-depth comprehensive geological survey data available to assess the extent of Cambodia's fossil fuel deposits. Offshore surveys of oil and natural gas have been conducted for the past ten years with various successes and failures. Test drills have revealed the potential existence of presumably large, but yet undetermined, offshore natural gas fields in Cambodia's portion of the Gulf of Thailand. Since neighbouring Thailand has confirmed gas deposits, and has been commercially exploiting them, the probability is high that Cambodia will be able in the longer term to undertake similar development. This would, however, require substantial investments in infrastructures. Commercially viable offshore gas extraction will probably not be achievable for at least another five years. Two US and one Japanese oil companies have signed concessionary agreements with the Royal Government of Cambodia (RGC) and were scheduled to begin extensive exploration in early 2003 (Carmichael, 2003).

Coal deposits are thought to exist in Stung Treng, Preah Vihear and Kampong Thom provinces. As well as some off-shore deposits of bituminous coal south of Kampot and Koh Kong. However there has not been a comprehensive national survey of either (NEDO, 2002).

1.2 Electricity supply

Electricity was introduced into Cambodia at the beginning of last century under the French colonial administration. Today electricity is provided by a number of different organisations using many different systems, standards and levels of quality. The various types of electricity suppliers in Cambodia can be summarised as follows:

Table 1: Electricity suppliers in Cambodia

Supplier	**Areas Supplied**
Electricity du Cambodge (EDC)	6 Major towns, including Phnom Penh (MIME, 2002).
Independent Power Producers (IPP) selling to EDC	Phnom Penh and Kompong Cham (MIME, 2002)
Provincial Electricity Operators (provincial offices of MIME)	10 Provincial towns

Rural Electricity Enterprises (REE) operating mini-grids	4 Provincial towns and hundreds of smaller towns and villages (estimated 600 REEs)
Battery Charging Services (REEs which do not also operate a mini-grid)	1500 battery charging services (REEs) in hundreds of towns (Hundley, 2003)
Imported Power from Thailand and Vietnam (22kV lines)	7 Border towns (Hundley, 2003)
Private stand-by diesel generation (large scale only)	All areas, but mainly Phnom Penh and Siem Reap (Hundley, 2003)

Electricity costs in Cambodia range from US$0.09/kWh to US$0.53/kWh for government services, and can be much higher for small private services or battery charging services (De Lopez, Praing & Toch, 2003; Hundley, 2003). Cambodia has the highest electricity costs of any ASEAN country, as shown here in Table 2. Note that the tariff ranges quoted here for Cambodia must be for government serviced urban areas because they are much lower than the figures reported elsewhere for rural areas.

Table 2: Official electricity tariffs in ASEAN countries in US cents per kWh (Source: ACE, 2004)

Country	Residential	Commercial	Industrial
Brunei Darussalam	2.88-14.42	2.88-11.54	2.88-11.54
Cambodia	9.17-17.03	15.72-17.03	12.58-15.72
Indonesia	1.69-4.60	2.77-5.65	1.71-4.38
Lao PDR	0.55-3.8	4.18-5.22	3.51
Malaysia	5.53-8.94	2.63-10.52	2.63-10.52
Myanmar	8.14	8.14	8.14
Philippines	3.15-10.71	3.68-9.85	3.35-10.84
Singapore	9.23	4.42-7.18	4.16-6.69
Thailand	3.41-7.47	2.94-7.47	2.94-7.13
Vietnam	2.92-8.17	4.24-13.96	2.83-13.96

1.3 Rural Electricity Enterprises

An estimated 600 Rural Electricity Enterprises (REE) operate small diesel-powered mini-grids to sell power to an estimated 60,000 customers (Meritec Ltd, 2001b). The REEs are usually small locally-owned businesses which consist of a diesel engine and generator with low voltage distribution lines which service anywhere from 30 to 2000 local households and businesses. The average tariff charged by REEs is estimated at US$0.53/kWh (Hundley, 2003). An estimated 8000 battery charging businesses provide services to households and businesses, and the effective tariff is often over US$1.00/kWh (Meritec Ltd, 2001b).

Some REEs have expressed interest in using renewable energy technologies in their businesses. A large group of REEs, mainly from provinces in the northwest of the country, attended a workshop in April 2004 to discuss the potential for biomass gasification technologies in Cambodia. This workshop was organised by a local non-government organisation, SME Cambodia, which has subsequently facilitated the establishment of a new REE that uses biomass gasifier technology from India. The new REE is a community-owned cooperative and operates the gasifier using wood supplied from dedicated energy crops grown by members of the cooperative plus other local farmers.[1]

The government's plans for rural electrification promote an important role for REEs, which echoes the World Bank's mantra of greater private sector participation. However in practice there has been friction between public and private industry in some areas where the government's electricity utility, EDC, have allegedly established operations in the business area of existing REEs, thus threatening the REEs' business viability. REEs are currently seeking longer licence periods from the Electricity Authority of Cambodia (EAC) to allow them to plan further in advance and achieve investment returns over a longer period. They claim this would allow them to reduce their electricity tariffs (SME, 2001).

The World Bank and Asian Development Bank as funded an extensive Rural Electrification and Transmission project for Cambodia that involves building transmission lines and other infrastructure for importing power from Vietnam, plus upgrading existing network and management systems. One part of this project aims to support improved rural electricity services by offering subsidies to private entrepreneurs to expand existing REEs or establish new ones. This subsidy program, called the Rural Electrification Fund (REF), will seek to encourage some use of renewable energy technologies but is limited in the first year to solar home systems and micro-hydro systems.[2]

1.4 Current Issues for Cambodia's Energy Sector

The previous sections briefly outline the current status of Cambodia's energy sector with respect to the sources and costs of energy, and with particular emphasis on electricity. Some of the adverse effects of the Cambodia's current energy situation are:

a) <u>Poverty Reduction:</u> high energy prices, including the opportunity cost of people's time for collecting non-commercial energy sources such as fuelwood, can affect poverty levels by requiring a larger proportion of household income to be spent on essential basic energy services such as cooking fuel and lighting. This situation can also reduce the available household spending on health, nutrition and education and result in further issues developing.

b) <u>Economic Growth:</u> the high price of energy services, especially electricity and fossil fuels, affects Cambodia's economy by reducing the viability of commercial activities that would otherwise attract foreign investment, create employment, and general economic activity.

c) <u>Energy Security:</u> the lack of any national reserves of fossil fuels means that energy consumers in Cambodia are fully exposed to short-term fluctuations in international oil prices and supply.

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[1] See www.smecambodia.org for further information.

[2] See www.recambodia.org for further information on the REF.

This lack of energy security has the effect of raising the costs of operating some types of businesses. This can have particularly adverse effects for small businesses and low income groups that do not have their own financial reserves to absorb short term price rises. And finance is extremely expensive and difficult to obtain in Cambodia. Consequently a relatively small jump in the international oil price may thrust a small business or a family into a situation of debt and hardship that can be difficult to break.

d) Inflation: the reliance on imported fossil fuels for transport and power generation means that reserves of foreign currencies, mainly US dollars, are constantly being depleted. This can have a long term inflationary effect on the economy, especially in the case of Cambodia that has minimal export earnings.

e) Natural Environment: it appears inherently unsustainable that most of Cambodia's households currently rely on dwindling natural forests for their fuelwood. As this source of energy is consumed it is inevitable that households will be faced with rising energy costs and the environment will be further degraded.

2. Introduction to Biofuel

2.1 Biofuel Description

Biofuel is a generic term that is used to refer to liquid or gaseous fuels that are produced from a biological source.[3] The term 'liquid biofuel' is more commonly used to refer to specific types of biofuels used as fossil fuel substitutes. These are further defined by the particular type of biomass from which they are made, and the degree to which they are refined before use. The most common types of liquid biofuel are:

- **Straight Vegetable Oils** (SVO) - possibly the simplest form of biofuel is pure vegetable oil, such as the oil from peanuts, olives or sesame seeds. This oil has similar energy content and some similar physical characteristics to diesel fuel. In fact the inventor of the diesel engine, Mr Rudolph Diesel, originally designed his engine to be run on peanut oil.
- **Biodiesel** – this is a product that is made through the 'trans-esterification of suitable biological oils, and strictly speaking should confirm to a commercial standard such as ASTM D 675. This product is very similar to fossil-based diesel fuel and can be used in almost any type of diesel engine without modification, and has a long shelf life.
- **Ethanol** – this can be produced from a wide range of biomass (plant) material using a relatively complex chemical process. Generally the ethanol is mixed with gasoline, in varying concentrations, although cars are now produced for sale in some countries that can run on pure ethanol ("flex-fuel cars").

2.2 Biofuels for Cambodia

Each of the types of liquid biofuel described above has similar characteristics with respect to their applications and benefits for a developing country like Cambodia. However they are not identical and some important differences must be noted.

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[3] One possible definition for biofuel is found in the Oregon Senate (USA) House Bill 3481 (see http://www.greencarcongress.com/2005/07/oregon_senate_p.html).

For example SVO biofuel can be produced with a very simple mechanical extraction process, but requires small engine modifications for it to be used in modern diesel engines. The production process for biodiesel is relatively simple but does require additional inputs of hazardous chemicals such as pure methanol and lye, and requires careful quality control. The extra benefits of Biodiesel over SVO are the greater flexibility of uses of the fuel, and also a by-product of its production is glycerine that can be sold for soap production.

The remainder of this paper will focus on one type of liquid biofuel in order to allow a more useful discussion and analysis. This type is SVO biofuel made from seeds of the Jatropha Curcas plant. The reasons for focussing on this one particular type of biofuel for this study are:

a) The simplicity and low cost of producing SVO is appropriate for adoption by rural entrepreneurs in Cambodia;
b) Straight SVO appears to be appropriate for many stationary applications in Cambodia such as power generation by REEs, water pumping, rice milling etc;
c) The Jatropha Curcas species already grows commonly throughout Cambodia and many rural people are familiar with the plant, and it is well suited to growing on degraded land with minimal rain;
d) The Jatropha Curcas has no other commercial value in Cambodia, which is an important factor in its economic viability; and
e) The Jatropha Curcas has been cultivated commercially for biofuel production in other countries, such as India and parts of Africa, and trials have started in Cambodia.

While this paper will now focus on biofuel from Jatropha Curcas, many aspects of the commercialisation and potential benefits will also apply to other types of biofuels.

2.3 The Jatropha Curcas Species

The *Jatropha Curcas*, or Physic Nut plant grows commonly in Cambodia where it is called the "Lhong Kwong". It is a drought-resistant perennial which grows in marginal soils and lives for up to 50 years. It is a close relative of the Castor plant, and its seeds contain about 35% non-edible oil. This oil has similar energy content to diesel oil and can be substituted directly in most types of diesel engine. The oil can also be used for a range of other applications such as lubrication and making high quality soap. The seed cake residue, left after expelling oil from the seeds, can be used as a high grade fertilizer. The plant helps prevent soil erosion from wind and water, and is used as a natural fence or hedge because animals do not eat it (World Bank, 2002).

2.4 Physical Properties of Jatropha Oil

Jatropha Oil is a vegetable oil, and thus is similar to more common household oils such as olive, peanut or sesame oil. It is also has some similar physical and chemical properties to diesel fuel, which is why it is possible to run diesel engines on this fuel (Knotte et al, 2002).

Table 3: Comparison of the Properties of Diesel Fuel and Jatropha Oil (*Source: website www.jatropha.de)*

Parameter	Diesel Fuel	Jatropha Oil
Energy content (MJ/kg)	42.6 - 45.0	39.6 - 41.8
Spec. weight (15/40 °C)	0.84 - 0.85	0.91 - 0.92
Solidifying point (°C)	-14.0	2.0

Flash point (°C)	80	110 - 240
Cetane value	47.8	51.0
Sulphur (%)	1.0 - 1.2	0.13

The most significant differences in the properties of Diesel Fuel and Jatropha Oil are the calorific content and viscosity of the two substances, which have the following implications:

- The **lower calorific content** of Jatropha Oil means that for a given quantity of Jatropha Oil there is about 7% less energy available than for diesel fuel. So an engine will consume slightly more Jatropha Oil than it would if it were running on diesel. However this does not indicate any difference in *efficiency*, because the same total amount of energy will be consumed in both cases.

- The **higher viscosity** of Jatropha Oil, compared to fossil-based diesel, at lower temperatures can cause problems for certain types of diesel engines and particularly during start-up when the engine and fuel are relatively cold. This puts more stress on the fuel pump, filter and injectors. This is a significant problem in cold climates, such as in Western Europe, and is solved by installing heating coils around the fuel lines. Trials in Cambodia and other tropical countries indicate that there is no problem in starting 'cold' with pure Jatropha Oil.

Jatropha Oil is also inedible to humans and this is an important factor in its suitability for biofuel. This is because there are no other commercial applications for Jatropha Oil, so therefore the supply and demand for the Biofuel product is not affected by other commodity markets. In contrast the price of high quality edible seed oils, such as almond and walnut oils, can be over US$10 per litre.[4] These oils would also work well in a diesel engine, but obviously they are far too expensive due to their high value in other markets.

[4] Author's survey of prices for imported almond oil and walnut oil found in supermarkets in Phnom Penh in May 2005.

2.5 Biofuel Applications

Jatropha Oil biofuel can be used for older diesel engines that use "direct injection" system of fuel mixing and delivery. These types of engines are very common in rural Cambodia and can be found in many *stationary* (ie: non-transport) applications such as:

a) **Electricity generation –** Rural Electricity Entrepreneurs (REEs) that operate mini-grids, battery charging businesses, and a high proportion of other types of businesses that have their own on-site generator because grid power is not available, not reliable or not affordable.

b) **Power generation** – rice mills, ice making factories, wood working businesses and other small manufacturing operations.

c) **Water pumping –** for irrigation and drinking.

Most of the smaller businesses that provide these services in rural areas of Cambodia use old pre-used diesel engines and generators. These engines usually use a 'direct-injection' fuel delivery system and are tolerant to a range of fuel quality. Consequently it is assumed that the use of SVO biofuel without engine modifications should not cause any problems. Due to their age these engines require relatively frequent maintenance, so possible longer term effects such as build-up of impurities may not be a significant problem. The current Jatropha biofuel project described later in this paper reports satisfactory operation of a small diesel generator set with SVO biofuel.

Some businesses with greater power demand may use old pre-used car and truck engines. Most of these engines are diesel, and some of the newer ones may use in-direct injection. These engines are less tolerant to varying fuel quality and the higher viscosity of SVO biofuel. Therefore in some cases small engine modifications may be needed, or else a procedure of starting the engine on regular diesel until the engine reaches operating temperature, then switching to the biofuel.

2.6 By-product: Fertilizer

The residue that remains when oil is extracted from Jatropha seeds is high in carbohydrates, nutrients and energy as shown in the table below. It has been used successfully in other countries as a natural fertilizer, and the chemical analysis suggest it would be beneficial for a range of crops and conditions, such as mushroom cultivation. It also may be useful as an ingredient in stock feeds.

Table 4: Analysis Results for Jatropha Seed Cake (*Source: ITC 2005*)

Parameter	Value	Method
Humidity	10%	Drying
Acidity	1.55 mgKOH/g	Titration
Residual oil	8.3%	Extraction
Protein (N * 6.26)	8.27 %	Kjeldahl
Total carbohydrate: - α-chain (starch) - β-chain (cellulose)	 24.4 % (g/g) 31 % (g/g)	 Titration Extraction
Phosphorous content	1.03 % (g/g)	Spectroph.

Potassium (K^+)	0.66 % (g/g)	Atom. Abs.

Cambodian farmers generally use a large quantity of fertilizer on their crops despite the high cost of imported chemicals, and poor knowledge of side effects. Imports of fertilizer increased from 10,000-20,000 tons per year in 1990-1992, to 80,000-90,000 tons per year in 1993-1995 (MAFF, 1996). Jatropha seed cake could offer a safe, natural, and locally-made alternative to imported chemical fertilizers.

2.7 Biofuel Production Process

The process to produce biofuel from Jatropha seeds is relatively simple and can be summarised in the following main steps:

1. **Seed Harvesting** – the whole fruits are collected once they are ripe order to maximise oil content. This is performed by hand as trees are kept pruned to a height that allows easy harvesting, and to maximise the yield.

2. **Seed Drying –** the fruit is opened and the 3 or 4 seeds inside each are removed and sun-dried by spreading on a large flat dry surface such as a concrete slab.

3. **Seed Cleaning** – the seeds are checked for basic quality parameters (not old, mouldy, damaged etc) and then filtered to remove any foreign material that may damage the oil extraction machine such as stones or sticks.

4. **Oil Extraction** - a specially designed oil seed extraction machine is used that typically crushes the seeds in a screw press arrangement and separates oil from the 'seed cake' residue. The machine is driven by either an electric motor or diesel engine. The engine can be run on biofuel which will consume somewhere in the order of 5% of the oil output from the machine.[5]

5. **Oil Filtering** – the extracted oil is passed through a press-filter that removes all remaining seed sediment and impurities from the oil. This step is critical to the quality and performance of the end product. Other chemical and physical qualities of the oil are important and must be monitored and treated within certain parameters if necessary.

6. **Packaging** – the final product is bottled in standard clean, air-tight plastic containers or pumped directly into containers of suppliers at the factory. Special fuel-quality chemical resistant plastic is not required for these containers. The seed cake is packaged into bags or sacks for the fertilizer market.

[5] Estimate based on technical specifications for a 12HP diesel engine driving a TinyTech Oil Mill manufactured by Tinytech Plants, India (see www.tinytechindia.com).

3. Potential Benefits and Costs for Cambodia

The local production and use of Jatropha oil biofuel as a substitute for fossil-based diesel fuel offers a long list of attractive benefits for Cambodia, and some potential costs to the economy. The list of benefits and costs that are briefly described below could form the basis of a more detailed study of the costs and benefits of biofuel in order to guide appropriate national policies on the subject.

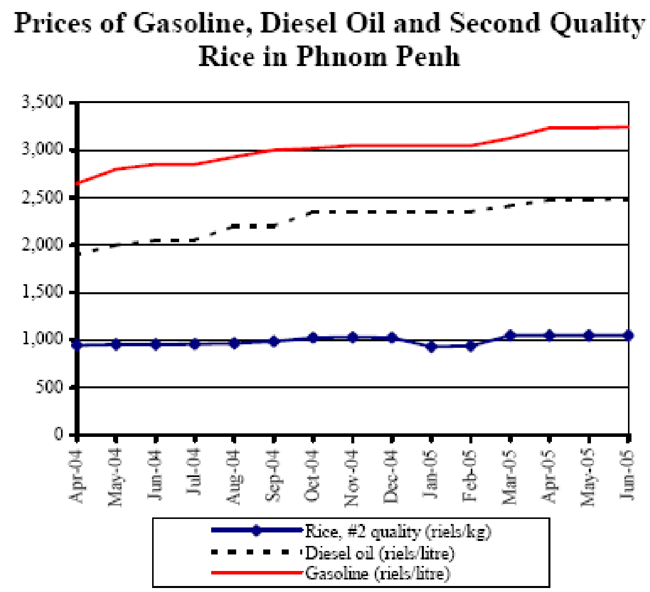
3.1 Potential Benefits

a) **Economic Development** – local production of biofuel would benefit Cambodia's balance of trade through reduced imports of fossil fuels, and would also reduce pressure on reserves of foreign currency. Production activities would directly create new employment and business opportunities, and likely attract foreign and local investment. If the biofuel can be supplied at a lower price than diesel then the economy will be further boosted by other businesses that become viable because of the lower energy costs.

b) **Rural Development** – the production of biofuel can improve rural livelihoods by providing new income opportunities through families and communities cultivating their own Jatropha Curcas crops, and also through direct employment by the company. This type of development is well-suited to Cambodia's rural communities that have basic agricultural skills but minimal access to finance. These opportunities are also well-suited to women in rural areas who can grow Jatropha around the family property or other available land, and harvest and sell the seeds to add to household income. This activity requires minimal investment cost or training.

c) **Poverty Reduction -** The introduction of biofuel may help reduce poverty in two ways. Firstly its production can provide income opportunities for rural families with minimal investment cost or training. And secondly by insulating the rural poor from energy price fluctuations, as indicated by the chart here that shows the rise in diesel fuel prices in the year to March 2005, while the price of rice remains stable (CDRI, 2005). This suggests that an alternative, cheaper fuel could ease this financial pressure on rural communities that would otherwise face increasing energy costs without increased revenue from rice production to cover these costs.

Table 5: Price of Gasoline, Diesel and Rice Quality in Phnom Penh (Source: CDRI, 2005)



Sources: CDRI and National Institute of Statistics

d) **Community Energy Cooperatives -** local biofuel production introduces the possibility of community energy services that do not require cash transactions. In other words it is conceivable that a community-owned energy cooperative could provide energy services to households in exchange for their supply of Jatropha Seeds or labour input. This could help families that are cash-poor access essential energy services. A slight variation on this concept is currently working in the Battambang region of Cambodia where a community cooperative operates a biomass gasifier and members are required to grow wood to supply the gasifier.[6]

e) **Energy Security** – the cost and availability of biofuel in Cambodia is independent of the world oil market and therefore improves the long term resilience of Cambodia's economic and political situation by reducing reliance and risk related to relationships with regional neighbours and oil-producing nations.

f) **Health and Safety** - there are no dangerous handling or transport issues with biofuel, as there are with diesel, as it is not explosive or corrosive.

g) **Environmental** – the biofuel is biodegradable so any spillage will quickly break-down and be absorbed with no lasting effect on soil or water sources. The production of Jatropha Oil biofuel has no adverse effect on the environment. The cultivation of Jatropha Curcas can have positive impacts in degraded areas, such as control of soil erosion, wind break and shading.

h) **Renewable Energy** – by simply switching from using fossil fuel to biofuel, with no capital investment, a rural entrepreneur can make their old diesel engine into a renewable energy generator, and become a clean power producer. This will become relevant if the government or other organisations introduce incentives to encourage the use of renewable energy. The Rural Electrification Fund (REF) will do just this and is currently being prepared by the

[6] Project implemented at Anlong Tmey village in Battambang province by SME Cambodia (see www.smecambodia.org for more details).

Ministry of Industry Mines and Energy and the World Bank, although biofuels will not be eligible for the initial 12 month pilot period.[7]

i) **Global Warming -** biofuel is considered 'carbon neutral' which means its use does not add to the problem of global climate change, whereas every litre of diesel fuel used in a diesel engine adds additional greenhouse gases to the atmosphere.

j) **Carbon Trading –** International markets are now established to purchase rights to equivalent savings in greenhouse gas emissions, with current prices in the range of US$5 to US$10 per tonne of certified greenhouse gas emissions. The market is still immature and small individual projects are usually not feasible, however the opportunity exists for groups of large biofuel consumers to sell their 'carbon credits'. Cambodia has already ratified the Kyoto Protocol and has an active Climate Change Office within the Ministry of Environment that facilitates such carbon trading projects under the Clean Development Mechanism (CDM).

k) **Productive Use of Degraded Land –** the Jatropha Curcas grows well in poor soils and is drought resistant. In fact it does not grow well in saturated soils. Consequently the cultivation of these energy crops offers a new opportunity for developing productive uses from areas of Cambodia that are not currently productive due to poor soil conditions, low rainfall etc.

3.2 Potential Costs

a) **Tax Revenue –** diesel fuel and gasoline are currently subject to tariff rates of around 100% in Cambodia. Therefore if biofuel is introduced successfully then it is conceivable that the Government's tax revenue would be reduced as taxable fossil fuel consumption is substituted by biofuel consumption. However this scenario is unlikely because of three main reasons: firstly the total energy demand, including for fossil fuels, is projected to grow strongly in the medium term and this would likely more than compensate for any small reduction in fossil fuel consumption. Secondly: a significant proportion of diesel fuel consumed in Cambodia is smuggled across the borders, and therefore does not contribute to Government tax revenue. And thirdly: any potential reduction in direct tax revenue from reduced fossil fuel sales should be compensated by increased tax revenue from other parts of the economy that would be stimulated by the new income generated from the biofuel industry.

b) **Land Use Issues –** changes in existing land uses can often create conflict and economic hardship, if not managed properly. This is because property title regulation and enforcement in Cambodia is still being developed and so it is common for poor communities not to have legal title to their property. Inappropriate land use change can also attract conflict and cause long term environmental damage. An example would be if an area of existing forest with ecological or cultural significance was cleared to make way for crop cultivation.

c) **Quality and Sustainability –** it is conceivable that there could be a net cost to the country from the introduction of biofuel if a large number of consumer's engines were damaged due to low quality fuel. If this happened it would threaten the sustainability of the industry and all the farmers and businessmen involved in it. Therefore it is important that appropriate fuel standards and testing would be established and enforced.

[7] See www.recambodia.org for further information on the Rural Electrification Fund.

4. Biofuel Experiences in Cambodia

Some older Cambodians provide unverified accounts that a range of different biofuels were sometimes used during Cambodia's turbulent recent history at times when supplies of fossil fuels were limited. They suggest that biofuels such as animal fats and also producer gas made from charcoal were used to drive engines for vehicles, electricity production and other power applications.

4.1 Current Projects

Good progress is being made on a pilot project for village-scale biofuel production in Kompong Chhnang province, central Cambodia, which started in November 2004 and is due to be completed in mid 2006. This pilot is based on domestic Jatropha crops and small oil expellers, rather than commercial energy crops and central oil production. The details of the project are described below.

Project Title	Biofuel for Sustainable Development and Poverty Alleviation in Rural Cambodia
Project Objective	To trial a business model based on Jatropha oil production in a small rural village setting.
Project Location	4 villages of Ponley District, Kampong Chhnang Province, CAMBODIA
Project Duration	17 months (start Nov 2004 to end March 2006)
Project Funding	The Canada Fund plus Private Donor
Lead Organization	Development and Appropriate Technology (DATe) *(Locally registered Cambodian NGO)* *Contact:* Mr San You, san_you@online.com.kh
Partner Organization	GERES Cambodia *(Locally registered French NGO – www.geres.free.fr)*
Activity Progress	

December 2004: One small "Komet" oil expeller was imported from Germany for initial trials

January 2005: Basic chemical analysis conducted on samples of 1 litre of Jatropha Oil and 1 litre of Kapok Seed Oil

March 2005: A Jatropha nursery was established in the Buddhist Pagoda at the first project village of Ponley with around 400 trees.

April 2005: A small diesel engine was fitted to the Komet expeller in order to raise output and test oil performance, and it is now running well on local supply of Kapok Seed oil

May 2005: A larger Chinese oil expeller was bought locally with 1.5 tonne per day seed capacity, and a small diesel engine was fitted to it.

June 2005: Village meetings were held to introduce the project to the locals and invite them to participate in the trials by collecting seeds from around their properties and selling them to the project for 350 Riels per kg (approx US$0.09 per kg). Villagers were provided with free promotion t-shirts and collection sacks to improve awareness of the concept and the project.

5. Commercial Viability of Biofuel in Cambodia

Despite the numerous logical arguments to support its viability, the best way to ensure the effective introduction of biofuel production in Cambodia is to demonstrate the commercial viability of it. This is not a simple matter because it can be difficult to find reliable data in Cambodia regarding the costs of establishing and operating such businesses, the potential market demand and even the yield of particular crops in Cambodian conditions. This section discusses the general conditions for such a business in Cambodia, and compares the implications of two different business models.

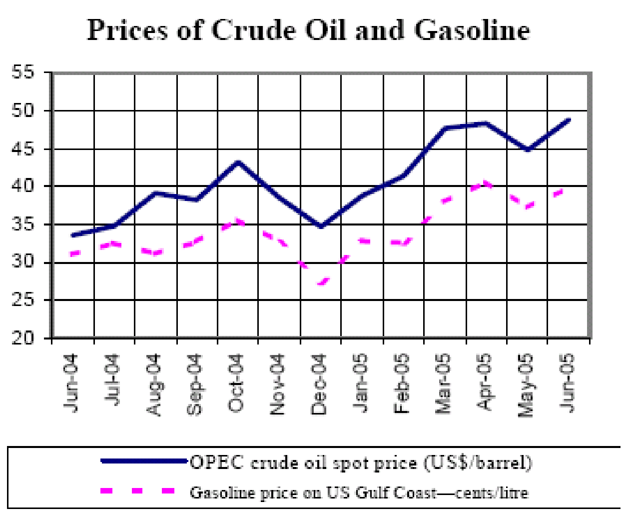
5.1 International Market Developments

A recent article in the usually conservative *The Economist* magazine reported that the world market for biofuels is well established and gave the following examples of strong growth (*The Economist,* 2005a):

- Germany is raising output of biodiesel by 50% per year;
- America is boosting ethanol production by 30% per year;
- France aims to triple output of biodiesel and ethanol by 2007;
- China has just built the largest ethanol plant in the world; and
- Brazil is producing around 4 billion litres of ethanol per year, and hopes to export 8 billion litres per year by 2010.

Biofuel production using Jatropha Curcas is currently in varying stages of commercialisation throughout India, and the African and South American sub-continents (Heller, 1996). These markets are being driven, in part by the rising price of crude oil as illustrated in the chart below (CDRI, 2005).

Figure 1: Prices of Crude Oil and Gasoline in Cambodia (Source: CDRI, 2005)

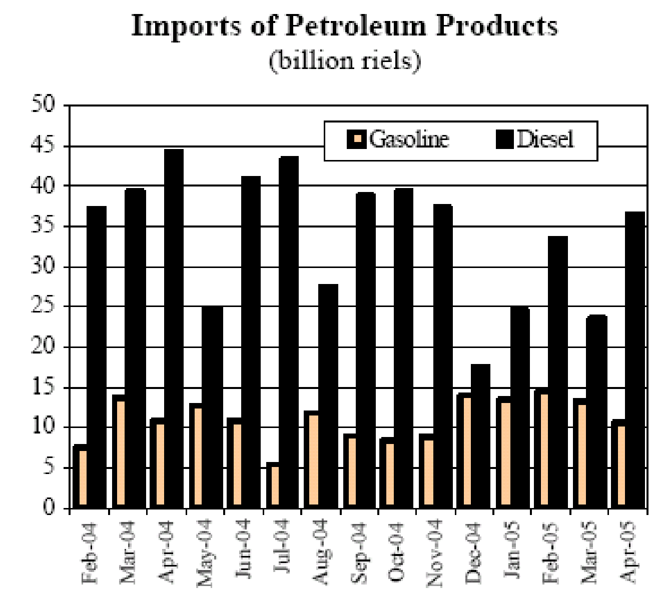


Note: Data are up to 26 May 2005.
Source: US Energy Information Administration

5.2 Diesel Fuel Market in Cambodia

There is no accurate data available for the consumption of diesel fuel by sector in Cambodia. One of the main reasons is that a significant proportion of the fuel is smuggled into the country and therefore does not appear in national statistics.

Figure 2: Imports of Petroleum Products into Cambodia (Source: CDRI, 2005)
Note: 1 billion Cambodian Riels is approximately US$250,000



Note: Latest data available are for April 2005.
(Excluding public sector imports.)
Source: Customs and Excise Department

The official statistics in this chart show that the value of imported diesel fuel was a total of about 460 billion Riels for the year to January 2005, or about US$115 million. Assuming an average wholesale price to the importer of 2000 Riels per litre, then this represents about 130 million litres for the year. This figure clearly understates the total quantity of imports because in 1995 the total consumption of diesel fuel in Cambodia was estimated at about 149 million litres (see description of Energy Balance below), and the economy has seen significant growth since then.

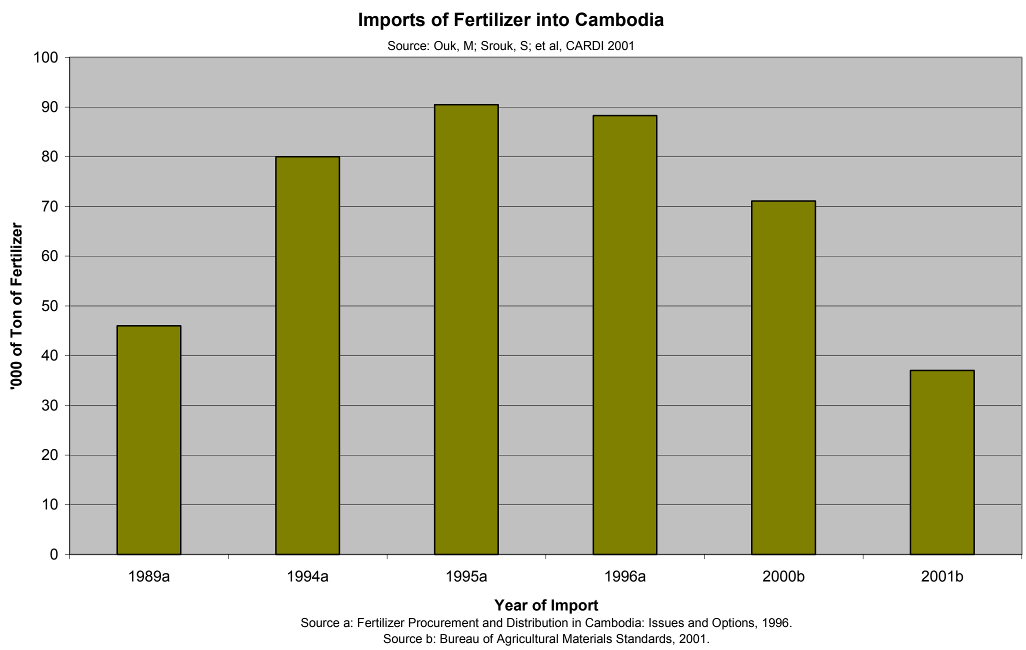
An Energy Balance for the Cambodian economy was performed in 1995 and provides a good, but outdated, perspective of diesel fuel consumption across various broad sectors. The Japanese International Cooperation Authority (JICA) are currently performing a new Energy Balance in order to update the 1995 data. The primary data for this exercise is being collected now (June 2005) and the results expected to be available at the end of 2005.[8]

In the meantime the 1995 Energy Balance provides an initial indication of the relative quantities of diesel use by sector. This study estimated that a total of approximately 149 million litres was consumed throughout the economy, and that 7.8 million litres was used for non-transport applications. Unfortunately the study failed to account for agricultural uses, which would include common stationary applications of diesel fuel such as rice milling.

[8] JICA study status provided by staff of MIME Energy Planning Department, May 2005.

5.3 Market Potential for Seed Cake Fertilizer

The chart below shows some official figures for the quantities of chemical fertilizers imported into Cambodia between 1989 and 2001. This suggests that the total imports fell from a peak of about 90,000 tons in 1995. However the authors of the study suggest that these figures do not account for the significant and increasing quantity of fertilizers that are smuggled into Cambodia, and in that actually the quantity of fertilizer has increased directly with increased crop production over this time (CARDI, 2001).



5.4 Appropriate Business Models

A wide range of different business models could be used as the basis for a new business producing biofuel in Cambodia. The issues to be considered in choosing an appropriate model are similar to other businesses based on processing of agricultural products, and include:

a) The proportion of crop area owned and managed by the business, or contracted to private farmers, or purchased at a market;

b) The ownership and location of the processing plant;

c) Security of supply of the feed stock; and

d) Ownership and management of distribution chain.

Some additional issues need to be considered in the case of a biofuel business in order to capture some of the additional benefits described earlier in section 3. These additional issues include:

a) The degree of local community ownership and involvement;

b) Pricing strategies;

c) Growth strategies; and

d) Intellectual property strategy.

A simple business plan for a potential Cambodian biofuel business was prepared as part of the Global Village Energy Partnership program (GVEP, 2005). This exercise considered two different business models. In scenario A the business would own and manage 100 hectares of Jatropha crop, and private suppliers would have around 11 hectares. Scenario B has the business owning just 60 hectares and private farmers with 47 hectares.

The following table summarises the predicted outcomes for the two scenarios. The business plan concluded that the production cost of biofuel in scenario A would be approximately US$0.53 per litre, while for scenario B it would be approximately US$0.58 per litre. Both cost estimates compare favourable with the current diesel fuel price in Cambodia of approximately US$0.64 per litre.[9]

Table 6: Comparison of possible business models (Source: GVEP 2005)

	Scenario A	**Scenario B**
Jatropha Crop owned by Business (Ha)	100	60
Jatropha Supplier's Crop Area (Ha)	10.8	46.8
Jatropha Supply Cost (R/kg)	400	350

[9] Based on exchange rate of 3900 Cambodian Riels to 1 US Dollar, and average fuel price in Phnom Penh for June 2005 (CDRI 2005).

Cost of Seed Production	Initially this is cheapest option, as efficient commercial crops should produce for under 300R per kg.	Initial costs involved in farmers establishing new crops, changing land use, learning new techniques, managing risk etc. Thus market costs are estimated above 350R per kg.
Reliability of Seed Supply	High reliability with respect to market forces, due to control over own crops, however exposed to short term issues such as poor yield, crop failure or harvest problems.	Improved diversity of supply through community owning supplying from larger area, but after a point it becomes risky if another buyer enters the market so the businesses must compete for each harvest. These risks can be managed by negotiating appropriate contract terms with suppliers, but enforcing this is difficult.
Community Benefits	Some opportunities for local famers to supply seeds (approx 11 Ha), but long term benefits limited to the direct employment of a limited number of staff from local community, plus some 'trickle-down' of economic boost to an area, although these would not be significant	Potentially significant benefits as local community participates in crop cultivation, harvest and supply. Could potentially be increased through efficient management by a co-operative of growers who also have own a share of oil production facilities.
Capital Outlay	This option raises the initial business set-up costs by about 40% due mainly to the extra land cost, but also some extra preparation costs.	This option is clearly cheaper initially, although the local farmers would most likely require some assistance in order to establish the Jatropha, in the form of training, materials, cuttings and fertilizer.

Conclusions and Recommendations

The supply of basic energy services in Cambodia is expensive and dependent on imported fossil fuels. This situation is not sustainable, and may present a barrier to the country's economic development.

The local production and use of biofuels in Cambodia could help to provide solutions to this problem. This paper has discussed the potential benefits offered by a particular type of biofuel, based on the Jatropha Curcas species. However a sustainable energy strategy should be based on a diverse range of energy sources and technologies, and a range of alternative biomass sources exist in Cambodia.

This preliminary discussion has highlighted some important issues that require further attention:

a) The potential costs and benefits outlined here in section 3 should be investigated and quantified in order to ensure that the energy source is commercialised appropriately for Cambodia;
b) The outcomes of the analysis of costs and benefits should be used to assess current policy for any potential barriers or opportunities for appropriate policy support;
c) One particular area of government policy that should be considered with respect to biofuel is taxation with the aim of maximising the net benefits to the whole economy; and
d) Appropriate biofuel quality standards, awareness and enforcement should be developed as early as possible.

This paper has shown that there are significant potential benefits for Cambodia from the local production and use of biofuel. Private entrepreneurs will explore the commercial opportunities if they prove to be sufficiently attractive. Appropriate public policy and support should be developed in parallel to such private business activity in order to maximise the potential benefits for Cambodia's development.

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