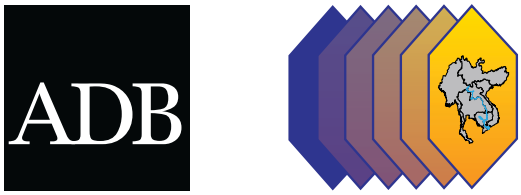
GREATER MEKONG SUBREGION
ECONOMIC COOPERATION PROGRAM

STATUS AND POTENTIAL FOR THE DEVELOPMENT OF

BIOFUELS

AND RURAL RENEWABLE ENERGY

THE LAO PEOPLE'S DEMOCRATIC REPUBLIC



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Kham Sanatem
Forestry and Agriculture Promotion Center, Ministry of Agriculture and Forestry
Bouathep Malaykham
Electric Power Management Division, Department of Electricity, Ministry of Energy and Mines
Phouvong Phommabouth
Department of Trade Promotion, Ministry of Industry and Commerce
Southone Ketphanh
National Agriculture and Forestry Research Institute, Ministry of Agriculture and Forestry
Keophayvan Insixiengmai
Technology Research Institute, Science and Technology Agency

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Asian Development Bank
6 ADB Avenue, Mandaluyong City
1550 Metro Manila, Philippines
Tel +63 2 632 4444
Fax +63 2 636 2444
www.adb.org

For orders, contact
Department of External Relations
Fax +63 2 636 2648
adbpub@adb.org

Contents

Abbreviations

ADB	–	Asian Development Bank
ktoe	–	thousand tons of oil equivalent
kWh	–	kilowatt-hour
Lao PDR	–	the Lao People's Democratic Republic
LIRE	–	Lao Institute for Renewable Energy
MOU	–	memorandum of understanding
mt	–	million ton
OSU	–	One-Stop-Service Unit
VDG	–	village development group
WWF	–	World Wide Fund for Nature

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Introduction

Background to the Study

The worldwide scarcity of raw mineral resources is well known. Estimates by the International Energy Agency suggest that underground petroleum reserves are sufficient for another 50–60 years, natural gas for about 150 years, and coal for about 200 years. Exponential growth in international demand for fossil fuels and accelerating consumption have led to oil price hikes. In addition, the excessive use of fossil fuels is leading to global climate change. Hence, it is becoming more critical to explore and develop measures to help reduce their use. Among the measures now being considered by many countries is the development of alternative energy resources from renewable sources.

Biofuels, such as biodiesel and bioethanol, are among the alternative renewable sources of energy receiving considerable interest. They are most applicable for transport, where they can help to decrease reliance on limited, and mostly imported, fossil fuels—chiefly gasoline. Biofuels and other alternative energy sources offer the threefold advantages of reduced dependence on imported oil, which saves foreign exchange; promotion of environmental protection; and the creation of new job opportunities and, hence, new sources of income.

These advantages are more pronounced in countries where domestic demand for transport fuels has been expanding rapidly, as is the case in the Lao People's Democratic Republic (Lao PDR).

The rapid economic and social developments that the Lao PDR is experiencing will continue to be accompanied by substantial increases in energy consumption. The rise in average per capita income introduces new needs and associated expenses, notably in the form of motorized transport, such as cars and motorbikes. In this context, the Government of the Lao PDR intends to develop a national policy to reduce its fossil fuel consumption through improved fuel efficiency, and to promote the production and use of biofuels as alternative energy sources. This will help keep fossil fuel imports and inflation rates at lower levels, and will help sustain economic growth. It will also help reduce poverty and so keep the country on track with its general objective of graduating from the United Nations' list of least developed countries by 2020.

In summary, the Lao PDR is facing the challenge of developing its renewable alternative sources of energy to help power the country's economic growth and promote energy security in a manner that will not endanger food security. The country has a great opportunity to capitalize on its advantageous climate and plentiful land and labor to initiate a national strategy for renewable energy. However, the emerging energy supply scarcity, continuing energy market instability, and a lack of investment in technology development are stumbling blocks that must be overcome. This study aims to provide insights on how to overcome such challenges through the development of an effective and sustainable strategic policy framework for renewable energy.

Scope and Objectives

The objective of the study is to formulate a strategic policy framework to promote and develop renewable energy resources, including biofuels, to improve rural living conditions and reduce poverty without endangering food security.

The study aims to

(i) assess the economic and market potential of biofuels to identify promising areas for investment in rural development;

(ii) assess the adequacy of current technologies for the development of biofuels;

(iii) identify needs for research and development, training, and investment in human capacity; and

(iv) review current policies that promote biofuel development and identify the most effective policy levers to strengthen public–private partnerships, encourage investment, and promote cross-border trade.

Energy Market Outlook

Development of Energy Resources

Overview

The Lao People's Democratic Republic (Lao PDR) is a landlocked, mountainous country with a population of about 5.6 million, more than 80% of which live in rural areas. The people are engaged in rice-based agriculture and the harvesting of forest products. The country's narrowly based economy is one of the least developed in Asia, with an approximate per capita gross national product of $500 per year. Continued economic growth is needed to reduce poverty and accomplish social development goals; however, policy options for achieving these goals are restricted by the small size of the domestic economy and the limited opportunities for trade. At its present stage of development, the country has few industries that enjoy a comparative advantage within the region. The most important of these is electricity generation based on the country's large, almost untapped energy reserves—principally hydropower. Its central location in the region makes the Lao PDR easily accessible and connectible to neighboring countries in the Greater Mekong Subregion.

Energy Resources

The Lao PDR is endowed with significant indigenous energy resources for electricity generation (Table 1). The main energy resources of the country are wood fuel, coal, and hydropower. Forest areas covering more than 41% of the total land area are a substantial source of traditional energy supplies, but hydropower constitutes the most abundant and cost-effective energy resource.

Hydropower

The hydropower potential of the Lao PDR is about 23,000 megawatts (MW) (Figure 1). By the end of 2007, hydropower development had gained popularity in the country. Memorandums of understanding (MOU) have been signed for more than 70 projects, while 5 projects are under construction (Appendix 1). The Nam Theun 2 Project is among the largest (with a capacity 1,088 MW) and is scheduled for completion by the end of 2009. There are promising locations for hydropower development on the major tributaries of the Mekong River.

The development of hydropower is time consuming and requires a large initial investment, but the returns are substantial because of its low operating and maintenance costs. In the next decade, income from the export of hydroelectricity will become the main source of revenue for the Lao PDR. Besides being a renewable source of energy, hydropower is considered a clean form of energy.

Coal

Indigenous reserves of fossil fuels, such as coal, are exploited for use in local industries and for export. The country's coal industry is still very young and is not yet widely used for energy generation. Coal reserves—mostly of lignite—are found mainly in the northern parts of the Lao PDR and are estimated at nearly 600 million tons (mt).

The Viengphoukha lignite coal deposit in Luang Namtha Province is being mined for export to Thailand at the rate of 300,000 tons per year (t/year). Hongsa lignite in Xaiyabuly Province has been earmarked to feed a thermal power plant with a capacity of 1,878 MW. Construction of the Hongsa thermal power plant is scheduled to begin in 2009 and is targeted for completion in 2013. Anthracite coal is exploited at the Bochan deposit in Vientiane Province, where it is used in local cement factories. Deposits were also found in Xieng Khouang and other provinces.

Table 1: Primary Energy Resources of the Lao People's Democratic Republic

Resource	Reserves	Potential for Use in Power Generation
Biomass (waste)	Biomass resources dispersed throughout the country.	Current share of biomass (mainly wood fuel) in total energy consumption is about 88%.
Coal (bituminous and anthracite)	Reserves, mainly anthracite, dispersed in various fields throughout Lao PDR. Exploration ongoing. Total proven reserve to date is about 100 mt. Energy content: 23–35 MJ/kg	Current annual production is 130,000 tons, used for local factories or export. Possible longer-term option for about 500 MW installed capacity, depending on results of exploration.
Coal (lignite)	Major resource located at Hongsa in northwest Lao PDR. Has some 810 mt proven reserve, of which more than 530 mt are deemed economically recoverable. Energy content: 8–10 MJ/kg, relatively low sulfur content of 0.7%–1.1%.	Sufficient reserves for about 2,000 MW installed capacity.
Geothermal	No significant known reserves.	Limited potential for power generation.
Hydropower	Average annual precipitation of about 2,000 mm. Total runoff about 240,000 million m^3, with theoretical hydropower potential of 26,000 MW (excluding mainstream Mekong).	Exploitable hydropower potential, including share of mainstream Mekong is about 23,000 MW.
Oil and gas	Three exploration concessions in central and southern Lao PDR. Mapping and geophysical investigations carried out, including one deep drill hole (2,560 m). Results not yet evaluated.	Possibly in the longer term (10–15 years), if sufficient reserves are found.
Solar	Annual solar radiation received in Lao PDR is about 1,800 kWh/m^2; possibly less in mountainous areas. Corresponds to conditions in southern Europe (Italy and Spain).	Photovoltaic modules already used for small-scale (e.g., 100 W) remote applications. Current costs of large-scale solar thermal (up to $1.10/kWh) or photovoltaic power (about $0.50/kWh) make the use of solar energy a little infeasible.
Wind	Mean wind speeds at Luang Prabang and Vientiane about 1 m/s; in mountainous areas likely to be somewhat higher.	Costs in areas of less than 4 m/s likely to be in upper end of range $0.05–$0.25/kWh, hence potential is limited.

kWh = kilowatt-hour, Lao PDR = Lao People's Democratic Republic, m^3 = cubic meter, m^2 = square meter, m = meter, m/s = meters per second, MJ/kg = megajoules per kilogram, mm = millimeter, mt = million ton, MW = megawatt, W = watt.

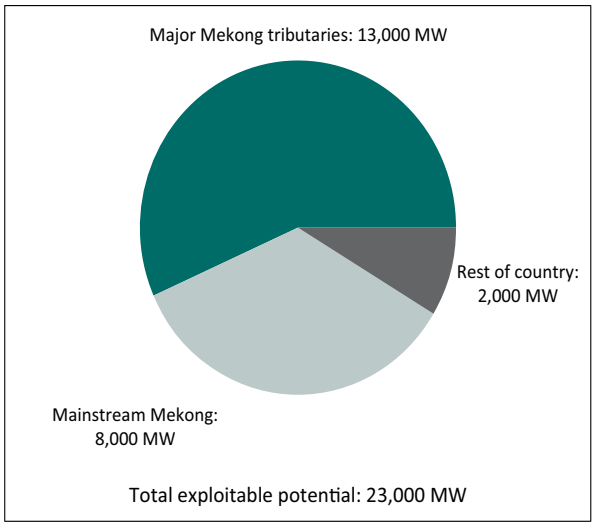
Source: Power Sector Policy Statement, Ministry of Industry and Handicraft, Department of Electricity. 2001.

Biomass

The Food and Agriculture Organization of the United Nations estimated that wood fuel consumption (consisting of fuelwood and charcoal) in 1993–1994 was more than 2.3 mt and accounted for nearly 80% of the total energy consumption of the country. It is estimated that 92% of households use wood for cooking. Besides wood, an estimated 0.3 mt of agricultural wastes (e.g., crop residues and sawdust) were also available for use as fuel in 1993–1994.

Wood fuel is widely used in agribusinesses, such as in pottery-making and tobacco-drying in kilns. Wood fuel is also directly traded as fuelwood or as charcoal for urban consumption. Rice husks and sawdust are also used as fuel to partially meet the energy demands of certain businesses.

Figure 1: Exploitable Hydropower Potential in the Lao People's Democratic Republic
(megawatts)



MW = megawatt.

Source: Department of Electricity, Ministry of Industry and Handicrafts. 2001.

New and renewable energy technologies are being promoted throughout the world largely as a consequence of the surge of oil prices in mid-2008 and their continuing volatility that has caused apprehension in both the developed and developing countries. One type of renewable energy that has generated interest is biomass, which includes biogas, bioethanol, and biodiesel.

Energy generation from biomass requires the necessary raw materials and technology to be available. Investment costs are generally low because the feedstock is typically a widely available waste product. In that sense, biomass is a renewable energy source that can provide environment-friendly, clean energy.

Biogas. Biogas produced from livestock manure can be a substitute for traditional sources of energy both for cooking and lighting, but not for space heating. Although biogas has a long history in the Lao PDR and has many benefits, almost all of the digesters, with the exception of 30 units installed in early 2005, are no longer operational. This is mainly due to incorrect sizing and a lack of understanding of how to manage and maintain the units.

Biogas can substitute for other sources of energy and saves time in cooking and cleaning cooking utensils. It also reduces the financial burden of buying fuelwood and/or time and effort expended collecting it. Cooking with biogas instead of fuelwood significantly reduces particulate emissions, which affect the health of people close to the fire. Thus, biogas has a beneficial effect on health, particularly of women and children.

The Lao Biogas Pilot Program is an ongoing project supported by SNV Netherlands Development Organization. It aims to improve the quality of life and livelihood opportunities of rural families, and reduce biomass resource depletion in the Lao PDR by exploiting the market and nonmarket benefits of domestic biogas digesters. It will set up a series of biogas pilot activities to form the basis of a future larger biogas program that will establish a commercially viable domestic biogas sector. The pilot program will explore the biogas market in a specific area of the country and test the most suitable approach for wide-scale biogas dissemination.

The pilot program began in 2007 and the tentative cumulative production targets and number of beneficiaries up to 2010 are shown in Table 2. Project implementation has been relatively slow because of the significant rise in the cost of labor and materials. By March 2008, 100 digesters had been constructed for 100 households, and the program will continue to spread out to other provinces as intended.

Biofuels. Energy crops are crops grown mainly to generate feedstock for biofuels. The main feedstock derived from these plants is either oil, which is used for biodiesel production; or molasses and starch, which are used for ethanol production. A major concern regarding the use of crops for biofuel production is their possible competition with food crop production, which can threaten food security. Special care must be exercised when formulating a biofuel development strategy to ensure that other national goals, such as ensuring food security, are not compromised.

Research on energy crops suitable for biofuel production is in its infancy in the Lao PDR. Biofuel processing plants are nonexistent in the country, so there are no data to assess the feasibility and sustainability of biofuel production. In addition, the possible environmental impacts will also be hard

Table 2: Digesters and Beneficiaries of the Lao Biogas Pilot Program, 2007–2010

	2007	2008	2009	2010
Cumulative number of biogas digesters	100	1,200	3,400	6,600
Cumulative number of beneficiaries	600	7,200	20,400	39,600

Source: The Lao Biogas Pilot Project Annual Plan and Budget. 2008.

to ascertain. Nevertheless, private companies have shown interest in establishing biodiesel plants. Kolao Bio-Energy is the biggest private company to invest in the production of biodiesel from jatropha in the Lao PDR.

Gas and Oil

The Lao PDR imports all the oil and gas it consumes. The oil and gas potential of the country has yet to be determined. International oil firms conducted oil and gas explorations in 1993–1998 and 2006–2007. Two companies from Viet Nam and the United Kingdom recently carried out surveys for fuel oil and gas but the results have not been published at the time of writing.

Solar Energy

The Lao PDR's annual solar radiation is about 1,800 kilowatt-hours per square meter, and may be less in mountainous areas. Solar energy is clean, renewable, and environment-friendly. Solar technology systems are also easy to install and their maintenance costs are low. Photovoltaic solar technology is being used for water pumps, water purification, and communications; however the initial investment cost of these ventures is high.

Solar energy was first introduced to rural communities in 1997 as part of a rural electrification program. The pilot scheme, implemented by the government, involved five districts. The Japan International Cooperation Agency provided a grant to the government for the Master Plan Study on Rural Electrification Projects by Renewable Energy in Lao PDR conducted during 1998–2001. This project was piloted in Vientiane and Bolikhamxay provinces through solar home systems and battery-charging stations. It was demonstrated in 12 villages with 440 households connected to solar home systems and 2 villages supplied with charging stations, providing a total capacity of about 37 kilowatts (kW).

During the same period, the Southern Province Rural Electrification Project added an off-grid component on a pilot hire purchase arrangement that aimed to develop a management system to supply electricity to isolated areas or villages where connection to the national grid will not take place within 5–10 years. This pilot hire purchase system was expanded to the national level in December 2006. By 2008, it provided electricity to about 10,000 customers.

A new renewable energy technology was introduced and implemented in 2005 with funding from the New Energy and Industrial Technology Development Organization of Japan, in cooperation with the Ministry of Energy and Mines. The new technology is a combination of 100 kW photovoltaic solar, 60 kW water pumps, and 100 kW micro-hydropower installations. It could supply electricity for 10 villages with 1,034 households.

A second new form of technology combines 40 kW photovoltaic solar, 110 kW micro-hydropower, and 40 kW capacitor installations. Construction began in February 2009 and will be completed in May 2010. Approximately 700 households in 10 villages are expected to be supplied with electricity.

Wind and Geothermal

The potential for wind power systems in the Lao PDR is limited due to unreliable winds, low average wind speeds, and the high investment costs of the equipment. The country's natural hot springs are known for their important role in tourism; however, to date, no significant geothermal areas have been identified for possible power generation. Known sources are too small to be tapped.

Energy Production and Supply

The main source of energy supply in the rural and isolated areas is wood (predominantly for cooking and heating); however, about 99% of the electricity supply comes from hydropower, and diesel generators and photovoltaic solar systems provide the remainder. Of an estimated potential of 23,000 MW, current total installed capacity for hydropower is almost 671 MW

(Table 3). The main hydropower plants are Nam Ngum (155 MW), Theun Hinboun (210 MW), Houy Ho (152 MW), Xeset (45 MW), and Nam Leuk (60 MW). The other hydropower plants have much lower production capacity. The Theun Hinboun and Houay Ho projects were built and are operated by private joint-venture companies in partnership with Electricité du Laos, principally to export power to Thailand.

Most of the country's population lives in rural communities beyond the reach of these large-scale energy projects. Therefore, decentralized solutions will be an essential component of the total electricity supply for the Lao PDR. More than 20 micro-hydropower plants are currently in operation, mostly in the northern regions of the country, and several thousand small photovoltaic solar installations are also in use. Together, these provide around 1 MW of energy. Other sources of energy, which may be more appropriate in some communities, are currently being studied.

Fossil Fuel Supply and Use in the Lao People's Democratic Republic

The majority of the imported fuel is used in mechanized transport. Most of the fuel is imported from Thailand and a portion comes from Viet Nam, which obtains most of its oil supply from a refinery in Singapore.[1] Imports amounted to 450 million liters (l) in 2006 and 485 million l in 2007.[2] It is estimated that fuel oil consumption will continue to increase at an annual rate of 10%. At this rate, fuel use in 2010 is estimated to reach 561 million l, increasing further to 716 million l in 2015 and 914 million l in 2020. It is calculated that diesel will make up 55%; gasoline, 40%; and other fuels, 5% of the total fuel consumption.

Table 3: Electricity Generation from Hydropower Plants

Project	Installed Capacity (MW)	Year Completed	Average Annual Production (GWh)	Owner	Province	Remark
Nam Ngum 1	155.0	1970	1,025	EDL	Vientiane	Main grid
Nam Dong	1.0	1970	5	EDL	Luang Prabang	Main grid
Selabam	5.0	1969	34	EDL	Champasak	Main grid
Xeset	45.0	1994	181	EDL	Salavan	Main grid
Nam Ko	1.5	1996	8	Provincial	Oudomxai	Main grid
Theun Hinboun	210.0	1998	1,620	IPP	Khammouane	Export
Houy Ho	152.1	1999	617	IPP	Attapeu	Export
Nam Leuk	60.0	2000	245	EDL	Vientiane	Main grid
Nam Mang	40.0	2005	147	EDL	VTE Capital	Main grid
Nam Ngai	1.2	2002	7	EDL	Phongsaly	Isolated
Total	**670.8**		**3,889**			

EDL = Electricité du Laos, GWh = gigawatt-hour, IPP = independent power producer, MW = megawatt, VTE = Vientiane.

Source: Department of Electricity, Ministry of Energy and Mines. 2006.

1 Interviews with Mr. Phougom, Head of Renewable Energy Division, Lao State Fuel Company; and Mr. Lamphoune Phimphavong, Director, Societé Shell du Laos, conducted in 2007.

2 Figures were obtained from the Department of Domestic Trade Department, Ministry of Industry and Commerce.

These figures are predicated on the expected rapid rise of fossil fuel demand, especially for transport. The calculation comes from the observed dramatic rise of vehicles, including cars, buses, trucks and pickups, and tricycles—from 51,000 units in 2000 to 557,000 units in 2004.

Energy Consumption

Total Electricity Consumption in the Lao People's Democratic Republic

Household electrification can help the Government of the Lao PDR achieve its social and economic development objectives. The expanded availability and reliability of low-cost electricity in the country helps create livelihood opportunities that can increase household income. In addition, foreign exchange earnings from the sale of electricity to other countries in the region provide additional funds for investment in socioeconomic development.

In 2006, about 900 gigawatt-hours (GWh) of electricity were consumed by the 54% of Laotian households that have access to power (Table 4). By 2010, estimated domestic demand for electricity is expected to almost triple to 2,684 GWh. Electricity generation using diesel is not common in the Lao PDR, and is used in only a few locations.

Overall power demand is projected to increase by 8%–10% per year. In 2006, energy generated from hydropower was 3,595 GWh per year, of which 1,173 GWh was for domestic use, and 2,487 GWh was exported to Thailand (Table 5). The Lao PDR also imported 340 GWh of power from neighboring countries for use in its border communities.

Among energy user groups, the residential group accounts for about 51% of all power consumed (Table 6). This is followed by industry (23.1%) and commerce (12.4%).

Energy Consumption by Transport, Agriculture, and Industry

A survey conducted by the Department of Alternative Energy Development and Efficiency of the Ministry of Energy, Thailand, indicated that the diesel and gasoline consumed in 2004 by the Lao PDR's transport sector was 162.3 thousand tons of oil equivalent (ktoe), industry consumed 1.56 ktoe, agriculture consumed 33.6 ktoe, and industry accounted for 8.8 ktoe.

The provinces with the highest energy consumption for transport were Vientiane, with a total energy consumption of 110.0 ktoe (of which 28.3 ktoe was gasoline and 81.8 ktoe was diesel); followed by Savannakhet, with 37.3 ktoe; and Champasak with 30.8 ktoe. Motorcycles accounted for 133.7 ktoe of gasoline consumption, or 82.3% of the total gasoline consumption by all types of vehicles. Buses accounted for the largest share of diesel consumption, with 56.7 ktoe; pickup trucks consumed 56.7 ktoe; and trucks used 36.9 ktoe.

Estimation of Future Fossil Fuel Consumption in the Lao People's Democratic Republic

Lao PDR consumed a total of 450 million l fossil fuel in 2006, and increased to 485 million l in 2007. It is estimated that fossil fuel consumption in the country will increase by 8%–10% per year. The projected consumption is shown in Table 7.

Domestic Energy Consumption

According to statistics from the Department of Electricity, wood fuel use in 2005 was about 0.75 m^3 per capita, or approximately a total of 2.4 mt. Wood

Table 4: Electrification Ratio in the Lao People's Democratic Republic, 2006
(%)

Number of Districts	% of Districts	Number of Villages	% of Villages	Number of Households	% of Households
132	94.3	5,294	50	510,529	54

Source: Department of Electricity, Ministry of Energy and Mines. 2006.

Table 5: Energy Generation and Consumption, 2006

Total Electricity Generated (GWh)	For Domestic Use (GWh)	Exported Electricity (GWh)	Imported Electricity (GWh)	Imported Fuel Oil ('000 liters)	Natural Gas (tons)
3,595	1,173	2,487	340	450	58

GWh = gigawatt-hour.

Sources: Department of Electricity, Ministry of Energy and Mines; and Ministry of Industry and Commerce.

Table 6: Energy Consumption Share by User Group, 2006

User Group	Energy Consumption (GWh)	Percentage
Residential	567.2	50.9
Industry	257.7	23.1
Commerce	138.2	12.4
Government offices	96.6	8.7
Agriculture	39.7	3.6
Embassies	8.2	0.7
Entertainment	6.7	0.6
Total	**1,114.3**	**100.0**

GWh = gigawatt-hour.

Source: Ministry of Energy and Mines, Department of Energy. 2006.

fuel, in the form of fuelwood and charcoal, is mainly used for cooking and heating. In rural areas, it accounted for 69% of average energy use.[3]

In 2002, the total primary energy supply[4] amounted to 1,811 ktoe. It was estimated that fuelwood represented 56% of the total energy consumption; petroleum, 17%; electricity and charcoal combined, 12%; coal, 3%; and city gas, 0.08%.

Table 7: Projected Fossil Fuel Consumption

Fuel	Projected Consumption (million liters)		
	2010	2015	2020
Diesel	300	440	640
Gasoline	220	320	470
Total	**520**	**760**	**1,110**

Source: Department of Domestic Trade, Ministry of Industry and Commerce.

Power Sector Policy and Targets for 2020

Government policy gives priority to power sector development as a means of achieving the country's macroeconomic, microeconomic, and social development aspirations. A number of laws and regulations of the Lao PDR directly or indirectly influence energy use efficiency, fuel savings, and the promotion and development of renewable energy, including biofuels. The overall policy aim, according to the electricity and agriculture laws, is to increase the household electrification ratio from approximately 45% in 2005, to 70% in 2010, and 90% in 2020; and to reduce the use of imported fuels for electricity generation and other uses through increased use of indigenous energy resources, principally hydropower, as well as solar, coal, and biomass energy. The laws also provide for the development of capital and promotion funds to promote new forms of agricultural production.

[3] ADB. 2006. Promotion of Renewable Energy, Energy Efficiency and Greenhouse Gas Abatement (PREGA). Lao PDR, Country and Policy Report. Draft Final Report. Vientiane.

[4] Primary energy supply includes fuelwood, hydropower, electricity, natural gas, and petroleum oil.

The four priorities of the government's power sector policy are to

(i) maintain and expand an affordable, reliable, and sustainable electricity supply in the Lao PDR to promote economic and social development;

(ii) promote power generation for export to provide revenues to meet the government's development objectives;

(iii) develop and enhance the legal and regulatory framework to effectively direct and facilitate power sector development; and

(iv) reform institutions and institutional structures to clarify responsibilities, strengthen commercial functions, and streamline administration.

Energy Development Plan

To achieve the government's policy and targets, 5 hydropower projects with a total capacity of 2,121 MW are under construction (Appendix 1, Table 1). Memorandums of understanding have been signed for 47 hydropower projects. Power development agreements have been signed for 18 projects with a capacity of about 15,000 MW and 1 thermal power plant with a capacity of 1,878 MW (Appendix 1, Table 2).

The Government of the Lao PDR has signed an MOU with the Government of Thailand for the provision of 7,000 MW of power to Thailand by 2020. The government also has signed an MOU with the Government of Viet Nam for the supply of 5,000 MW by 2020. There are plans for the construction of high-, medium-, and low-voltage transmission lines from the north to the south of the Lao PDR.

To achieve electrification of the whole country, the government must, in addition, promote other sources of renewable energy, such as bioenergy, including biomass, biogas, and the liquid biofuels—biodiesel and bioethanol.

Biofuels Resource Base and Feedstock Prioritization

Analysis of Potential Energy Crops

The government recognizes the potential of biofuels to help meet the country's energy demand. The potential capacity for biofuels development is being studied by several institutions and will be outlined in the following sections. Owing to the relative dearth of information on biofuels in the country, this subsection borrows from the report of the Lao Institute for Renewable Energy (LIRE).[5] The report details the findings of a survey on the range of feedstock crops available to identify suitable options for the production of biofuels in the country. A further, more detailed study will be needed to collect more data to understand the current use pattern, to explore issues such as the opportunity cost of diverting crops or residues to energy use, and to gain a better understanding of the technological issues.

Crops for Biodiesel Production

Promising oil-producing energy crops available in the Lao People's Democratic Republic (Lao PDR) include jatropha, coconut, oil palm, and the castor oil plant. The agronomic and oil production capacity of these crops differ greatly. Exploitation of these crops for oil production on a large scale has not yet been attempted in the country. For biodiesel production, the most valuable crops are those that require low inputs and have high oil content. Suitable crops for the production of plant oils for transesterification[6] into biodiesel are listed and the strengths, weaknesses, opportunities, and threats of each crop are described in Appendix 2, Table 2.1.

Jatropha

Biodiesel from jatropha (*Jatropha curcas*) has the potential to become one of the major energy sources of the Lao PDR. Jatropha is widely grown as a hedge plant, especially in rural areas of the country. Many areas are suitable for growing this plant since it can grow in nearly every type of soil and can thrive on poor quality and degraded land. Jatropha's ability to thrive in areas that are least cultivated for food crops makes it particularly appealing as a feedstock. The plant does not need much water and can survive the dry season in the Lao PDR without adverse effect on its growth.

Jatropha has a life span of more than 50 years. The oil content of the seeds ranges between 28% and 42%.[7] With an estimated seed yield of 3 tons per hectare (t/ha), it would be possible to produce about 0.8 t/ha of jatropha oil.[8] The oil can be used in modified plant-oil-fueled engines and can also be transformed into biodiesel for the normal diesel engine.[9] (See Table 2.2, Appendix 2 for oil yield data of major biodiesel feedstock crops.)

There are drawbacks, however. Jatropha seeds contain curcin, a poisonous substance that could endanger people who harvest the seeds, and children that

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5 LIRE. (date unavailable). *Suggestion Policy Document on Biofuel Promotion and Development in Lao PDR*. www.tech.nedo.go.jp/PDF/100011693.pdf

6 Esterification and transesterification are processes involved in biodiesel production where vegetable oils or animal fats are made to react with alcohol (methanol) in the presence of a catalyst (sodium or potassium hydroxide) to produce glycerine or methyl ester or biodiesel.

7 From a personal interview with a Ministry of Agriculture official.

8 Heller, J. 1996. *Physic Nut. Jatropha curcas L. Promoting the Conservation and Use of Underutilized and Neglected Crops.* Institute of Plant Genetics and Crop Plant Research, Gatersleben and International Plant Genetic Resources Institute, Rome. www.ipgri.cgiar.org/publications/pdf/161.pdf

9 Kaltschmitt, M. and H. Hartmann, eds. 2001. *Energie aus Biomasse–Grundlagen, Techniken und Verfahren*. Springer Verlag. Berlin. Germany.

may play with them. Jatropha oil cannot be used for human or animal consumption and the plant is toxic to livestock. Harvesting of jatropha is labor intensive because the seeds do not mature at the same time.

Seed yield depends on factors such as the quality of the planting stock, climate, rainfall, and soil fertility. As with any other crop, there is a risk of total loss of production, and thus loss of investment. Jatropha seeds need special storage bins with good air ventilation for proper drying.[10]

Castor Oil Plant

The castor oil plant (*Ricinus communis)* is widely grown in tropical regions, although it is not widely cultivated in the Lao PDR. It is a fast-growing, perennial shrub that can reach a height of 20 meters. The plant thrives during the dry season and can be cultivated without irrigation. Moreover, it does not have many soil quality requirements, hence it can be planted on wastelands. It is also an annual plant that can be used in crop rotations.

Like jatropha, castor oil seeds do not mature at the same time, making harvesting time-consuming and laborious. Harvesting of ripe seeds takes place 5 times a year. A mechanical harvesting and processing system exists but this is quite costly. The seeds of the castor oil plant contain a high proportion of oil (up to 60%).[11] The oil has a substantially higher viscosity than other plant oils; therefore its use in engines could cause fuel injection problems. Besides its potential use as biofuel, castor oil can be used for medicinal and chemical purposes. Castor oil seeds are also very toxic to humans and other animals.

Soybean

This annual plant is also grown in the Lao PDR and currently covers a total area of 8,920 ha, with an average yield of 1.34 t/ha.[12] Soybean (*Glycine max*) can grow in altitudes of up to 3,000 meters and, hence, is suitable for mountainous regions such as the north of the country. It can have a positive effect on the soil because, like many other bean plants, it has the ability to fix nitrogen. Soybean is rich in protein and oil. Soybean oil is used for human consumption while soybean waste is used as animal fodder.

The beans can have a maximum oil content of approximately 20%, or 0.17–0.67 t/ha.[13] The oil can be extracted using solvent extraction or a normal expeller. Manual harvesting would require a huge amount of labor, though harvesting machines are available.

Oil Palm

Oil palm (*Elaeis guineensis*) is a perennial plant with a production life of up to 30 years. Seed production starts in the third year of its establishment, and at peak production the annual oil yield can reach about 7 t/ha. Oil palm is the highest yielding oil-bearing plant in tropical areas (Appendix 2, Table 2).

Oil palm cultivation entails relatively high investment costs because establishing the crop is labor intensive, and fertilizer applications and good planting materials are required. Oil palm trees grow well in areas close to the sea, which have a humid environment, a relatively high temperature, and air that contains salt. Since the Lao PDR is a landlocked country, it has very limited potential for growing oil palms.

Crops for Ethanol Production

Ethanol can be used as a substitute for gasoline. Crops for ethanol production are the saccharose- (sugar) and starch-producing crops such as sugarcane, cassava, and maize.

Sugarcane

Sugarcane (*Saccharum officinarum*) is one of the most efficient plants at transforming the sun's energy into carbohydrates. It can produce up to 110 t/ha of stalks

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[10] Kuratorium für Technik und Bauwesen in der Landwirtschaft e.v. 2005. Dezentrale Ölsaatenverarbeitung. Lokay. Germany.

[11] Roth, L. and K. Korman, eds. 2005. *Atlas of Oil Plants and Vegetable Oils.* AgriMedia. Germany.

[12] Data from the Ministry of Agriculture and Forestry, 2007.

[13] Gunther, F. 1989. *Nutzpflanzen der Tropen und Subtropen*. S. Hirzel Verlag. Leipzig. Germany.

annually. In the Lao PDR, sugarcane covers an area of 6,000 ha, producing an average annual yield of 36 t/ha.[14] The main output of this plant is saccharose and biomass. The saccharose can be transformed into ethanol. Approximately 15 kilograms of sugarcane are needed to produce 1 l of ethanol.[15] For the production of bioethanol as a substitute for gasoline, large-scale facilities are necessary to fully extract the water content. Simple distillation is not enough to do this.

Sugarcane demands nutrients and needs frequent applications of fertilizer. The plant prefers sunny and warm conditions but needs rainfall of 1,000–2,000 millimeters for proper growth. The crop is also sensitive to pests and diseases. In Asia, up to 60% of the harvest can be lost to diseases. Sugarcane harvesting is very labor intensive.

Cassava

Cassava (*Manihot esculenta*) is an easily cultivated, woody shrub that is grown widely in the Lao PDR. Cassava is an important food source because of its calcium (50 milligrams per 100 grams), phosphorus (40 milligrams per 100 grams), and vitamin C (25 milligrams per 100 grams) content. It is also used in traditional medicine to treat diarrhea, malaria, headache, and pain. Moreover, cassava can be used for other starch-based products besides the production of ethanol for energy. Ethanol production using cassava is profitable and has a positive energy balance due to the plant's high photosynthetic efficiency. The plant's roots and biomass can both be used: the root can be used for food and energy, and the biomass in the wood can be converted to energy through biomass gasification.

Under normal conditions, the cassava usually requires at least 8 months to mature. In extreme climatic conditions, however, such as cold temperatures and drought, which are commonly experienced in parts of the Lao PDR, cassava can take 18 months or more to mature. The yield of roots can reach 90 t/ha, compared to a worldwide average of about 100 t/ha. Harvesting of the roots is labor intensive. They also require large amounts of storage space or storage bins. Cassava cultivation, harvesting, and processing require a significant amount of investment.

One drawback of the cassava plant is its toxicity (especially the roots and leaves), and the consequent threat to humans and animals. Cassava remains a possible crop for perennial planting and can be integrated into a rotation system with other crops.

Maize

Maize (*Zea mays*) can grow in the dry season and is therefore a potential biofuel crop for unused lands that are not suitable for other crops. Due to its relatively short maturation time (90–100 days), other crops can also be grown before or after the corn-growing season. Average annual yields are usually in the range of 1.5–2.0 t/ha. Besides the production of ethanol, maize is used for food and feed production in the Lao PDR.

Demand for Further Research

Jatropha has been the focus of intensive research by the LIRE. LIRE's jatropha study is therefore described to illustrate the amount of research effort required to implement new energy crops in an existing farming system. LIRE conducted research on jatropha because of the attention the plant was receiving due to its great potential as biofuel feedstock. The study shed light on some misconceptions that require further research before any implementation plan can be recommended.

Case Study of Jatropha

The jatropha research program conducted by LIRE provided information to better understand its potential, particularly the technological options for possible implementation in the Lao PDR (for an overview, see Appendix 3). LIRE found that there was great demand for research, especially on the provision of suitable seed material and information on proper plantation management. If the seed material is of poor quality, the seed yield of the plantation will be below

[14] Data from the Ministry of Agriculture and Forestry, 2007.

[15] Gunther, F. 1989. *Nutzpflanzen der Tropen und Subtropen*. S. Hirzel Verlag. Leipzig, Germany.

potential. To illustrate this point, consider the example of wheat production in Europe, where wheat yields are 6 times their 1950s level as a result of selecting the best-performing plants and creating a huge seed bank.

Research on the agronomic aspects of biofuel crop production is tremendously important not only for jatropha but also for other biofuel crops in the Lao PDR. Similar research studies are also needed for coconut and sweet sorghum. An evaluation of their use as biofuel feedstock is a critical prerequisite to the formulation of development plans.

Vision for Agriculture and Natural Resource Management

The government's strategic thinking on future upland development is articulated in a series of vision documents.

Agriculture

The major elements of the government's strategic vision for agricultural development have been incorporated into all plans and programs, including the National Poverty Eradication Plan.

The two key elements are (i) the identification of two agro-geographical zones: the Mekong corridor flatlands, where agricultural transformation has begun; and the sloping lands, where subsistence agriculture resource degradation results in poverty and negative downstream impacts; and (ii) the identification of generic types of farming systems with different development strategies for each agro-geographical zone.

General Strategies for Flatland and Sloping Land Development

The Ministry of Agriculture and Forestry estimates that there are some 3 million ha available for further crop cultivation, the majority of which is located in the northern part of the country. This is mostly the result of shifting cultivation, which is practiced for rice production. The policy of the government is to stabilize land use in this area. Strategies for the development of flat and sloping lands are summarized in Table 8.

Small Farmer Integration in Biofuel Agribusiness

People living in poor districts have a long tradition of working hard and collectively using their own traditional methods of production. These areas still have abundant forest, land, and water. Plentiful natural resources and a suitable climate are very favorable for crop production, livestock and fish raising, industrial tree plantations, and the collection of non-timber forest products.

The Government of the Lao PDR has gained experience in village cluster development, or *Kum ban phattana*, to facilitate large-scale crop production for industrial use. This model has been set up for different types of crop production, such as sugarcane, cassava, and maize. It is also used to provide access to water for irrigation—similar to irrigation associations in other countries—and in the collection and marketing of non-timber forest products. However, an individual farmer can also engage in production on his own and sell his products to the cluster.

Table 8: Strategies for Developing Flat and Sloping Lands

Emphasis for Flatlands		Emphasis for Sloping Lands	
(i)	Intensify cash crop, livestock, and fisheries production through farmer demand-driven extension	(i)	Land-use zoning based on physical and socioeconomic features
(ii)	Expand value-added commodity processing for domestic consumption and exports	(ii)	Farming system diversification and agroforestry development through on-farm research, trials, and demonstrations
(iii)	Commodity market research and information delivery	(iii)	Community management of natural resources
(iv)	Agricultural product grades and standards development and regional marketing link promotion	(iv)	Intensive small-scale community-managed irrigation systems
(v)	Strengthen and expand competitive credit facilities	(v)	Farmer demand-driven research and extension
(vi)	Strengthen agribusiness lending by banks	(vi)	Soil erosion control, afforestation, and conservation
(vii)	Rehabilitate and expand dry season irrigation system and commodity management transfer	(vii)	Savings mobilization and microcredit, interest subsidy to poor
		(viii)	Strengthen capacity and legal framework of banks
		(ix)	Market access through road and market information delivery

Source: Ministry of Agriculture and Forestry.

Stakeholders in the Biofuels Arena and Proposed Agricultural Models for Biofuel Production

Main Actors and Key Partners in the Biofuel Subsector

Several potential biofuel investors are showing a growing interest in acquiring land and starting plantations with a view to producing fuel from energy crops in the Lao People's Democratic Republic (Lao PDR). Some initiatives aim to contribute to the promotion and development of fuel crops as feedstocks for biodiesel and ethanol production; however most remain at the conceptualization stage and there has been little, if any, implementation. All players interviewed identified the same problems: lack of knowledge about the processes, a shortage of staff with specialized engineering skills, lack of available technology, and a shortage of funding.

Current and potential players in the biofuels arena fall into four categories: (i) government authorities, (ii) nonprofit associations and research institutes, (iii) private companies, and (iv) international nongovernment organizations.

Government Authorities

The Department of Electricity, in the Ministry of Energy and Mines, was the first to become involved in biofuels, and is currently taking the lead in national policy development on biofuels. The Prime Minister's Office, the Water Resources and Environment Agency, and other agencies are also supporting biofuel development initiatives in the country, especially those focused on jatropha plantations. The National Agriculture and Forestry Research Institute under the Ministry of Agriculture and Forestry has already begun research work on jatropha.

Nonprofit Associations and Research Institutes

A number of public institutes and associations, such as the Lao Institute for Renewable Energy, are affiliated with the Lao Union of Science and Engineering Association, the National Science Council, the Prime Minister's Office, the Technology Research Institute, and the Renewable Energy for Sustainable Development Association. These institutions and associations are involved in research on promising feedstock crops, notably jatropha for biodiesel production and cassava for bioethanol production.

Other organizations involved in the promotion and development of biofuels are the National University of Laos, Department of Vocational and Higher Education, Dongkhamxang Agriculture Technical School; the Lao Promotion Organic Product Association [sic]; the nonprofit organization, Lao ABC; the Association of Agriculture and Handicraft Promotion; and the Tree Plantation and Livestock Promotion Association.

Private Companies

The private sector has a pioneering role in biofuel development. Table 9 lists the companies that have shown interest in biofuel production in the Lao PDR.

International Nongovernment Organizations

The international nongovernment organizations involved in biofuel development so far include SNV Netherlands Development Organization, the World Wide Fund for Nature (WWF), Vredeseilanden (VECO), Triangle Génération Humanitaire, and International Cooperation for Development and Solidarity (CIDSE).

Table 9: Companies Planning or Involved in Biofuel Production in the Lao People's Democratic Republic

Company Name and Location	Scope of Activities
Kolao Bio-Energy, Vientiane Capital	Biofuel production using jatropha as feedstock from large-scale plantations
Sunlabob Renewable Energy, Vientiane Capital	Sunlabob has shown interest in investing in the jatropha plant, in partnership with the Association for Organic Products in Khammouane; and in investing in existing plants in Xieng Khouang. The company emphasizes biofuel development in decentralized plantations in rural areas
Phetdalah Agricultural, Saravan (Ta Oy District)	Large-scale jatropha plantations; intends to become a seed provider.
Taisei, Vientiane Capital	Small-scale jatropha plantation for the National Agriculture and Forestry Research Institute.
Mitr Lao Sugar, Savannakhet	Large-scale sugarcane production for export.
Savannakhet Sugar, Savannakhet	Sugarcane and ethanol factory planned.
Tenghui Trade, Savannakhet	Large-scale cassava production for export to the People's Republic of China
Bio and Alternative Energy Lao, Vientiane Capital	Jatropha plantation
Southeast Agriculture Promotion, Vientiane Capital	Cassava and soybean plantation

Source: Authors' research findings.

Existing Biofuel Business Model

An investor wishing to set up a biofuels-related business in the Lao PDR must (i) follow the applicable regulations and laws, (ii) study the Law on Foreign Investment Promotion, (iii) prepare a feasibility study of the project one plans to invest in, and (iv) submit the application forms to authorities, such as the Committee for Promotion and Management of Investment at the ministerial or provincial levels at the One-Stop-Service-Unit (OSU). After receiving an Investment License from the OSU, the investor registers the invested capital in the commercial section and then notifies the tax collection section about his or her business plan. In some cases, the three state-run services will approve and endorse these documents simultaneously in the OSU.

An investor may select one of three investment forms: (i) business cooperation by contract, (ii) joint venture between foreign and domestic investors, or (iii) 100% foreign enterprise.

The investor must use the investment form that corresponds to the specific project, which may be demonstrated under the Contract Farming formula (1) + (4), or formula (2) + (3). The existing biofuel business model and project implementation in the Lao PDR have, so far, followed the same general models.

In the (1) + (4) formula, (1) refers to the farmer who may be hired to work in the concession plantation area of the investor, and (4) refers to the investor who is totally responsible for the invested capital, including working capital, seeds, techniques, technology, and marketing of the agricultural produce.

The formula (2) + (3) will be explained in the section on contract farming.

Economic Land Concession Model

Under current law, the government may concede a parcel of land to an investor to develop the project according to the project feasibility study

approved by the OSU. The land leasing (concession) agreement allows a rental period of up to 30 years, which can be extended on a case-by-case basis subject to government approval and based on the characteristics, size, and conditions of the operation and project. Leasing of a land area that exceeds 10,000 ha requires approval from the National Assembly. The agreement stipulates the obligations of each contracting party, and specifies issues such as compensation for losses. This land concession model is applied to general foreign investments, including biofuel crop plantations.

Contract Farming

The majority of agribusiness contract farming involving farm producers and agricultural buyers has followed the formula (2) + (3). The (2) in the formula means the land does not change its previous status or remains under ownership of the contracting farmer, who uses her or his land area for commercial production and has an obligation to sell the output produced to the buyer stipulated in the contract. The quantity and minimum procurement price are also specified in the contract. If during the harvest season the market price for the crop is higher than the contract price, the two contracting parties will once again review past expenditure, and the buying party may opt to pay the farmer the difference.

The (3) in the formula relates to the responsibility of the buyer contracting party. As indicated in the contract, the buying party must provide in advance the seeds, pesticides, technical assistance, and production technology to the contracting farmer. The contracting buyer is also responsible for marketing the produce offered by the producer party. There have been cases of contract distortion caused by some brokers when the buying price is high and when there are seasonal risks. In some cases, the application of the law is ineffective and various problems occur during product handover.

Community-Based Business Model

Establishing a producer group at the village level can help small farmers supply feedstock on the scale required for biofuel production. Many producer and buyer groups exist at the village, district, and provincial levels in the Lao PDR. Most of the producer groups in the rural areas have been set up with the aim of contributing to the implementation of the government's National Poverty Reduction Programme.

Village development groups (VDG) are set up in communities to advocate integrated development in agriculture, fisheries, and livestock as a means of advancing social goals. The VDGs' activities are managed by a board consisting of committee members elected by the membership. Under the proposed biofuels business model, the VDG should be divided into three sections—production, marketing, and microfinance. The production section is responsible for ensuring the quality of the agricultural products; the marketing section is responsible for gathering and warehousing the products prior to their sale to the buyer; and the microfinance section has a scheme in place to provide immediate loans to producers, thereby reducing farmers' exposure to illegal black market lenders.

This is regarded as an appropriate and effective model, which can help increase the bargaining power of the group members, provide assurances to the buyer in terms of quality and supply, and obtain a higher wholesale price for the products.

Small Household Financing Model

The majority of local farmers have small seasonal incomes, which are ploughed back into their agricultural activities. Besides spending their earnings on inputs for the production of foodstuffs, small producers may also finance plantations of biofuel crops, such as jatropha, cassava, maize, and sugarcane. In addition to their own income, farmers can tap other sources of household financing, such as their relatives, the contract farming formula, and loans from the banks and the microfinance operations of the VDGs.

Microfinance at the grassroots level is established with the unanimous approval of all village members, and aims to reduce farmers' dependence on illegal moneylenders who may charge monthly interest rates as high as 20%–30%. A member can borrow money at a monthly interest rate of 4% (reduced to 2% in case of illness or emergency). A number of village microfinance funds now exist around the country. The lending process is very simple and effective because villagers are neighbors who know each other well. Village funds are managed by the Lao Women's

Union. According to the funds' regulations, the men can make deposits but cannot borrow from the fund. The minimum monthly deposit is KN57,000 ($6). The deposit amount is not fixed and has no limit.

Although microfinance is functioning well at the grassroots level, the funds are very small compared to the villagers' funding needs. The government does not make contributions to these funds to help lower the interest rate. It has been observed that the financial management by the Lao Women's Union members is better than other village or district banks, so the government may decide to transform these villagers' funds into villagers' banks and allow them to expand their lending activities to cover small agribusiness or retail activities.

A Suitable Business Model for the Biofuel Industry

Based on existing registered business ventures, a capital investment of $10 million is required to establish a biofuel distillation plant with its own crop plantation. This large sum is not easy to acquire in a country at the level of development of the Lao PDR. Small-scale distillation plants are therefore being promoted and these are also better suited to the scale of raw materials supplied by small farmers. The (2) + (3) contract farming formula could work best in the villages that would use the distilled diesel themselves. This will make these villages less dependent on fossil fuel and more energy secure.

To evaluate the efficacy of the contract farming model, a local cassava powder factory owned and operated by Lao Indochina Trading was examined. The government did not grant a land concession to this company, and instead recommended the contract farming model. The investor planned to grow cassava on 8,000 ha in Bolikhamxay, Vientiane Capital, and Vientiane Province. The factory dispatched a team of technical officers to work with district village authorities and growers groups, to organize workshops, and to demonstrate and share ideas and experiences relating to cassava cultivation and marketing. Growers who were interested to join the project submitted a proposal through the cassava plantation group at the village level. The head of the group signed the contract. The company provided cassava seeds in advance, and bought back the seeds according to the quality, quantity, and wholesale price stipulated in the contract.

This model provides mutual benefits for both farmers and the factory owner. The planted area still belongs to farmers and the factory owner does not have to invest much in cassava production.

Suggested Policy Goals and Strategies to Support Biofuel Promotion and Development

This section presents a preliminary political framework for biofuel promotion and development. The political framework will ensure that biofuel development maximizes the benefits to the country without negative impacts on its population and environment, while reducing fossil fuel imports.

Issue, Goal, and Principles

The cultivation of energy crops is mainly motivated by fossil fuel substitution. In the Lao People's Democratic Republic (Lao PDR), fossil fuels are entirely imported. Producing biofuels from crops that are already cultivated locally would be positive for the national economy. Energy crop cultivation will give rise to more income-generating opportunities and employment in agriculture. This will contribute to the reduction of poverty in the country, in line with the United Nations Millennium Development Goals. Furthermore, there is huge potential in the country to plant energy crops in areas of degraded or underused land. A combined approach is needed, which emphasizes the efficient use of fossil fuels nationwide, and the development, production, and promotion of biofuels.

The development of such policy must respect the following proposed general principles:

(i) Reduce the Lao PDR's dependence on imported fossil fuels to reduce foreign exchange expenditure, improve the import–export balance and maintain inflation at a manageable level. Foreign exchange savings can then be channeled for other development activities to further enhance economic growth. The development of biofuels also contributes to reducing fossil fuel dependence.

(ii) Develop biofuels as a new economic subsector that creates a new source of revenue and jobs for the local population, especially in rural areas, thus contributing to poverty reduction.

(iii) Promote biofuels production and appropriate technologies suitable for identified land areas. This should not compromise the development of land for food production, or the collection of non-timber forest products important to the local population. It should also avoid areas with cultural or religious sites.

(iv) Promote biofuels production while avoiding damage to livelihoods, and helping preserve the cultural assets and natural environments of the Lao people, especially in plantation areas.

(v) Favor and support local producers' organizations and investors in the villages, where possible, to maximize the potential benefits for the Lao people.

(vi) Ensure that legal and financial conditions are adequate, both for potential investors and farmers who would participate as contracted parties.

(vii) Promote new technology for the production of biodiesel and bioethanol.

(viii) Promote research for new technologies for the biofuel industry.

Strategies and Targets

The Ministry of Energy and Mines has proposed several government policies, which will form the basis for implementing national policies on the promotion of fuel efficiency, consumption, and the development and use of biofuels in the Lao PDR.

The proposed policies are to

(i) promote energy-saving strategies and more efficient energy consumption practices, starting in all government organizations;

(ii) promote the cultivation of oil crops for processing into biodiesel and bioethanol, which could initially fuel low-speed engines and could subsequently fuel high-speed engines;

(iii) promote and disseminate fossil-fuel-saving technologies, including those that would enhance biofuel production, for use throughout the country;

(iv) promote foreign investment and facilitate the importation of appropriate technologies by providing government incentives, such as tax exemptions and tax holidays; and

(v) promote private sector participation in research, promotion, development, and investment in biofuels.

The success of the policies can be judged by how effectively they meet explicit targets. The two targets currently proposed are to reduce fossil fuel use by 5% each year from 2009 onward, and to reach a 5% share of biofuel use in the total fuel consumption by 2015.

Targets for Biodiesel and Bioethanol Production

Biodiesel production can be divided into community-based biodiesel production, and commercial production. Community-based biodiesel production should be promoted widely in the rural areas because it requires simple technology. However, the equipment should be provided to the communities. Biodiesel produced from jatropha could fully replace fossil fuel needed to power low-speed agricultural machinery. Commercial production and consumption of biodiesel made from jatropha and oil palm will enable the blending of diesel with biodiesel on a phased schedule.

The level of technology and investment cost required for bioethanol production is high. At the time of writing, there are only three sugar factories in the country: the small-scale, aging Pak Sap Sugar Factory; the new, medium-scale Lao Mithphone Sugar Factory in Savannakhet Province, which plans to produce ethanol; and the Ban Pong Group sugar factory, which is under construction in Savannakhet Province.

It is projected that gasoline with a 10% mix of bioethanol (E 10) will be available in the country in 2015 and 20% bioethanol (E 20) will be added to gasoline by 2020.

Recommendations for Advancing Biofuel Development in the Lao People's Democratic Republic

Five recommendations are put forward to provide inputs into the formulation a policy framework to support local and national authorities and the general public in the sustainable development of biofuels.

(i) A needs assessment should be conducted to provide updated information for the development of the biofuel subsector master plan. This plan would include detailed strategies and a regulatory framework to guide biofuel production and use. At its current stage of development, the biofuel subsector lacks a clear plan for the production and use of biofuels. Areas that need to be mapped out include feedstock development, the choice of processing technology to pursue and adopt, the appropriate business model to promote, research and development and human resource capacity enhancement needs, and the investments that need to put in place to ensure the sustainable development of the subsector so that it can be used as an instrument of economic growth and poverty reduction.

(ii) Careful delineation of land for the cultivation of food crops and energy crops is needed, and

production plans should be developed to match, as closely as possible, the input requirements of processing businesses and markets. This would entail close coordination and collaboration among several government offices and organizations.

(iii) Formulate clear and feasible policies on technical support. This will encompass the development of human resource skills and capacities, and the identification and adoption of appropriate and sustainable technologies. Sufficient investment support will have to be made available for these activities.

(iv) Formalize cross-border contract farming production and trade arrangements, and develop and adopt harmonized sanitary and phytosanitary standards that are of mutual interest to countries on both sides of the borders.

(v) Clarify the roles and contributions of development partners, such as ADB, the International Fund for Agricultural Development, and the Food and Agriculture Organization of the United Nations, in undertaking studies, setting up information networks, and in addressing problems that vary from country to country.

Appendix 1: Actual and Planned Hydropower Plants in the Lao People's Democratic Republic

Table 1.1: Hydropower Projects under Construction in 2007

Name	Basin	Province	Capacity (megawatts)	Progress
Nam Theun 2	Nam Theun	Khammaoun	1,080	Under construction
Nam Ngum 2	Nam Ngum	Vientiane	615	Under construction
Nam Lik1/2	Nam Ngum	Vientiane	100	Under construction
Xeset2	Sedon	Salavan	76	Under construction
Xekaman3	Sekong	Attapeu	250	Under construction

Table 1.2: Hydropower Projects in Lao People's Democratic Republic with Memorandum of Understanding, December 2007

Name	Basin	Province	Capacity (megawatts)	Progress
Nam Pha	Nam Pha	Louangnamtha	150.0	MOU
Nam Long	Nam Ma	Louangnamtha	5.0	MOU
Nam Ngone	Nam Ngone	Bokeo	2.4	PPA, CA
Nam Tha1	Nam Tha	Bokeo	168.0	PDA
Nam Beng	Nam Beng	Oudomxay	30.0	MOU
Phathung (Nam Ou 1)	Nam Ou	Louangprabang	180.0	PDA
Huai Kan (NamOu 2)	Nam Ou	Louangprabang	90.0	PDA
Ngoy Nua (Nam Ou 3)	Nam Ou	Louangprabang	240.0	PDA
Muang Khua (Nam Ou 4)	Nam Ou	Phongsaly	60.0	PDA
Hat Koven (Nam Ou 5)	Nam Ou	Phongsaly	99.0	PDA
Phongsaly (Nam Ou 6)	Nam Ou	Phongsaly	180.0	PDA

continued on next page

Table 1.2: continued

Name	Basin	Province	Capacity (megawatts)	Progress
Hat Hin (Nam Ou 7)	Nam Ou	Phongsaly	180.0	PDA
Nam Nga	Nam Ou	Louangprabang	120.0	MOU
Nam Souang 1	Nam Souang	Louangprabang	32.0	MOU
Nam Souang 2	Nam Souang	Louangprabang	135.0	MOU
Nam Khan 2	Nam Khan	Louangprabang	145.0	MOU
Nam Khan 3	Nam Khan	Louangprabang	60.0	MOU
Nam Ham	Nam Heung	Xayabuly	5.0	CA
Nam Feung	Nam Feung	Vientiane	60.0	MOU
Nam Lik 1	Nam Ngum	Vientiane	60.0	MOU
Nam Ngum Downstream	Nam Ngum	Vientiane	100.0	MOU
Nam Ngum 3	Nam Ngum	Vientiane	460.0	PPA
Nam Ngum 4A	Nam Ngum	Vientiane	54.0	MOU
Nam Ngum 4B	Nam Ngum	Vientiane	56.0	MOU
Nam Ngum 5	Nam Ngum	Vientiane	120.0	CA
Nam Bak 1	Nam Ngum	Vientiane	80.0	MOU
Nam Bak 2	Nam Ngum	Vientiane	68.0	MOU
Nam Mang 1	Nam Mang	Vientiane	50.0	MOU
Nam Ngiep Downstream	Nam Ngiep	Bolikhamxay	20.0	PDA
Nam Ngiep 1	Nam Ngiep	Bolikhamxay	260.0	PDA
Nam Pot (Nam Ngiep 2)	Nam Ngiep	Xiengkhouang	20.0	MOU
Nam Ngiew (Nam Ngeip 2)	Nam Ngiep	Xiengkhouang	30.0	MOU
Nam Chain (Nam Ngiep 2)	Nam Ngiep	Xiengkhouang	62.0	MOU
Nam Sen (Nam Ngiep 2)	Nam Ngiep	Bolikhamxay	60.0	MOU
Nam San 3	Nam San	Xiengkhouang	60.0	MOU
Nam Theun1	Nam Theun	Bolikhamxay	523.0	PDA
Xebangfai 2 (Xenua)	Xebangfai	Khammouan	40.0	MOU
Sebang Hieng 3 (Xepon 3)	Sebanghieng	Savannakhet	70.0	MOU
Sebang Hieng 3 Downstream	Sebanghieng	Savannakhet	30.0	MOU
Tadsalen	Sebanghieng	Savannakhet	3.2	PDA
Xelanong 1	Sebanghieng	Salavan	60.0	MOU

Table 1.2: continued

Name	Basin	Province	Capacity (megawatts)	Progress
Xelanong 2	Sebanghieng	Salavan	30.0	MOU
Xebangnouan 1	Sebangnouan	Salavan	30.0	MOU
Houaykatam	Houybanglieng	Champasak	33.0	MOU
Nam Phak	Houybanglieng	Champasak	40.0	MOU
Xekatam	Sekong	Champasak	68.0	PDA
Xepian Xenamnoy	Sekong	Champasak	390.0	MOU
Xekong 3 (downstream)	Sekong	Sekong	96.0	MOU
Xekong 3 (upstream)	Sekong	Sekong	152.0	MOU
Xekong 4	Sekong	Sekong	600.0	MOU
Xekong 5	Sekong	Sekong	400.0	MOU
Dak E Muen	Sekong	Sekong	126.0	MOU
Xekaman Sanxai	Sekong	Attapeu	32.0	MOU
Xekaman 1	Sekong	Attapeu	290.0	MOU
Xekaman 2A	Sekong	Attapeu	64.0	MOU
Xekaman 2B	Sekong	Attapeu	100.0	MOU
Xekaman 4A	Sekong	Attapeu	96.0	MOU
Xekaman 4B	Sekong	Attapeu	74.0	MOU
Nam Kong 1	Sekong	Attapeu	150.0	MOU
Nam Kong 3	Sekong	Attapeu	30.0	MOU
Nam Xam 1	Nam Xam	Houaphan	40.0	MOU
Nam Xam 2	Nam Xam	Houaphan	90.0	MOU
Nam Xam 3	Nam Xam	Houaphan	150.0	MOU
Nam Xam 4	Nam Xam	Houaphan	450.0	MOU
Nam Sim	Nam Ma	Houaphan	8.0	PDA
Mekong-Pakbeng	Main Stream	Oudomxay	1,320.0	MOU
Mekong-Laungprabang	Main Stream	Louangprabang	1,410.0	MOU
Mekong-Xayabouly	Main Stream	Xayabuly	1,260.0	MOU
Mekong-Paklai	Main Stream	Xayabuly	1,320.0	MOU
Mekong-Sanakham	Main Stream	Vientiane	1,000.0	MOU
Donsahong	Main Stream	Champasak	360.0	MOU
Ban Khoum	Main Stream	Champasak	2,330.0	MOU
Lat Suea	Main Stream	Champasak	800.0	MOU

CA = concession agreement, MOU = memorandum of understanding, PDA = project development agreement, PPA = power purchase agreement.

Source: Department of Energy Promotion and Development, Ministry of Energy and Mines.

Appendix 2: Analysis of Alternative Biofuel Crops

Table 2.1: Analysis of the Strengths, Weaknesses, Opportunities, and Threats of Selected Biofuel Crops

Strengths	Weaknesses	Opportunities	Threats
Castor Oil Plant			
Annual plant	Toxic to human and animals	Used as medicine by the chemical industry	Can poison humans and animals
Grows on poor soil	High viscosity	Machines for harvesting available	Requires labor-intensive harvesting
High oil content	Hydroscopic oil		
High yield	Maturation of seeds not at the same time		
Can resist dry periods			
Soybean			
Annual plant	Not a perennial plant	Suitable for crop rotation	Requires high investment because of annual planting
Suitable for growing in areas up to 3,000 m altitude	Requires high temperatures	Suitable for mountainous regions	Requires high investment for oil extraction
Used for food and fodder production	Low oil content		
Nitrogen-fixing, hence improves soil quality	Labor-intensive cultivation (e.g., cutting) involving too much manual work		
Oil Palm			
High yield (7 tons of oil per ha per year; up to 10 tons is possible)	No yield until 3 years after planting	Long-term plantation possible (up to 30 years)	Not adapted to most areas of the Lao PDR
High photosynthesis productivity	High investment cost (planting material, fertilizer, labor)	Good feedstock for vegetable or biodiesel plants	Risk of disinvestment
	Can grow in special environments (humidity, proximity to sea)		Limited experience with oil palm in the Lao PDR
Cassava			
Abundant source of human food and other starch-based products	Has toxins in root	Also useful for biomass gasification	Can poison humans and animals
High biomass production	Susceptible to pests (up to 50% yield losses)	Efficient for ethanol production	Requires a storage room
High photosynthetic efficiency	Requires high work input	Used for the production of ethanol	

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Table 2.1: continued

Strengths	Weaknesses	Opportunities	Threats
Medical uses	Large roots		
Sugarcane			
Edible	Negative effects on soil	Used also for biomass gasification	Can induce erosion that degrades land
High biomass production	Not resistant to low temperatures	Multiple uses (sugar, alcohol, fertilizer, bioplastic, fuel)	Requires high investment costs
Can be used in crop rotations	Susceptible to water accumulation	Efficient for ethanol production	Requires laborious fieldwork
High photosynthesis productivity	High soil requirements	Used for the production of ethanol	
	Needs significant amount of sunlight		
	High input of water and fertilizer		
	High yield losses (up to 65%)		
	Not suitable for cold and misty areas		
Maize			
Can grow during dry season	Not acceptable to local farmers	Can be grown in unused land during dry season	Needs high investment cost because of annual planting
Short maturation period (90–100 days)	Requires high cultivation effort	Used for ethanol and food production (e.g., bread)	Labor intensive and no machines available for planting and harvesting
	Machines necessary for planting are not available in the Lao PDR		
	Not a perennial plant		
Jatropha			
Can improve soil quality	Little research undertaken	Can create agricultural jobs	Poses health risk due to poisoning
Production of biomass and energy	Unsure market	Can strengthen the economy	Uneconomical
High photosynthesis productivity	Requires high investment	Can serve as replacement for fossil fuels	
Erosion control	High processing costs	Used in intercropping	
		Can grow on degraded land	

ha = hectare, Lao PDR = Lao People's Democratic Republic, m = meter.

Source: Study by the Lao Institute for Renewable Energy. www.tech.nedo.go.jp/PDF/100011693.pdf

Table 2.2: Oil Yield of Various Biofuel Crops

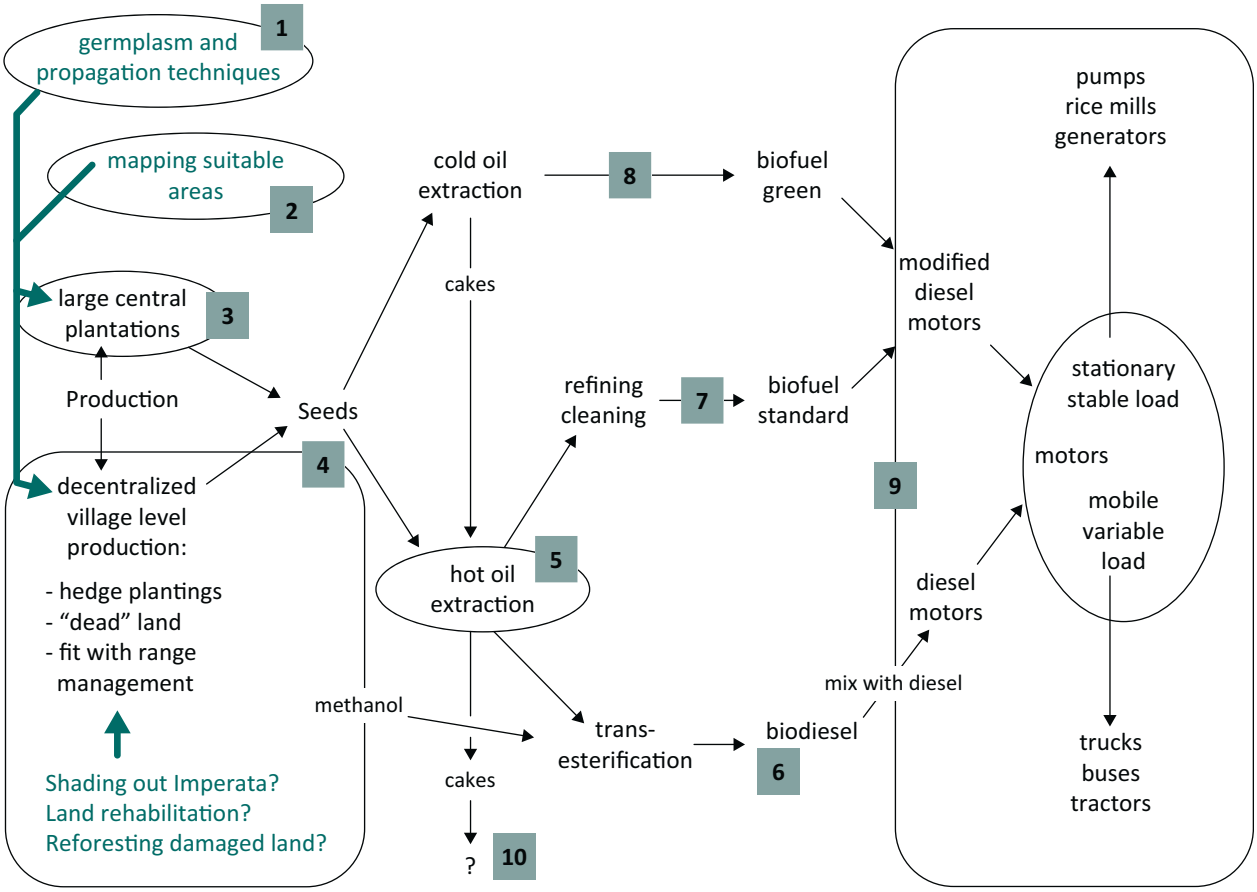
Crop	Oil Yield (kg/ha)	Oil Yield (liters/ha)
Jatropha	1,590	1,892
Coconut	2,260	2,689
Maize	145	172
Cotton	273	325
Soybean	375	446
Oil palm	5,000	5,960

ha = hectares, kg = kilograms.

Source: Eco Sustainable Village.

Appendix 3: Jatropha Program at the Lao Institute for Renewable Energy

Overview of Jatropha Pathways



Note: Numbers indicate research topics.

Source: Lao Institute for Renewable Energy.

Proposed research topics include the following:

1. **Germplasms and propagation techniques for various purposes.**
   Which varieties grow best under what conditions? What are the efficient propagation techniques suitable on the spot?

2. **Mapping suitable areas for planting and logistics for various operational approaches.**
   What are the ecological, social, and economic criteria for mapping the suitability of land types and locations for growing jatropha? Produce maps accordingly.

3. **Operating large plantations (similar to tea estates)**.
   What are the most efficient ways to operate large-scale plantations?

4. **Decentralized village-level production.**
   How will jatropha production fit into the village farming systems which include hedges, wasteland, degraded land, erosion control, interactions in grazing and fencing?

5. **Hot oil extraction.**
   Explore and demonstrate viability of hot oil extraction in the Lao PDR.

6. **Transesterification and producing biodiesel for normal diesel motors.**
   Explore and demonstrate viability of producing biodiesel in the Lao PDR.

7. **Refinement and producing standard biofuel for modified diesel motors.**
   Explore and demonstrate production of standard biofuel under the conditions found in the Lao PDR.

8. **Cold oil extraction and producing green biofuel for modified diesel motors.**
   Explore and demonstrate cold-pressed oil for use as biofuel in modified motors.

9. **Motor technology for various applications.**
   Which types of motor can run on jatropha biodiesel in the Lao PDR and for what kinds of application?

10. **Profitable use of press cakes.**
    How can press cakes be most profitably used to offset the costs of processing the fuel?

Status and Potential for the Development of Biofuels and Rural Renewable Energy: The Lao People's Democratic Republic

This report contains a detailed assessment of the status and potential for the development of biofuels in the Lao People's Democratic Republic and presents a country strategy for biofuels development consistent with the Greater Mekong Subregion Regional Strategic Framework for Biofuel Development. The findings of the report were endorsed at the Fifth Meeting of the Greater Mekong Subregion Working Group on Agriculture on 22-24 September 2008 in Vientiane, the Lao People's Democratic Republic.

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