GREATER MEKONG SUBREGION
ECONOMIC COOPERATION PROGRAM

STATUS AND POTENTIAL FOR THE DEVELOPMENT OF

# BIOFUELS

AND RURAL RENEWABLE ENERGY

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# CAMBODIA

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Printed in the Philippines.

ISBN 978-971-561-832-8
Publication Stock No. RPT090356

Cataloging-In-Publication Data

Asian Development Bank.
Status and potential for the development of biofuels and rural renewable energy: Cambodia.
Mandaluyong City, Philippines: Asian Development Bank, 2009.

1. Biofuels. 2. Renewable energy. 3. Cambodia. I. Asian Development Bank.



**In this report, "$" refers to US dollars.**

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# Abbreviations

| | | |
|---|---|---|
| ADB | – | Asian Development Bank |
| AKR | – | Angkor Kasekam Roonroeung |
| ASEAN | – | Association of Southeast Asian Nations |
| DATe | – | Development and Appropriate Technology |
| EDC | – | Electricité du Cambodge (Electricity of Cambodia) |
| GHG | – | greenhouse gas |
| GWh | – | gigawatt-hour |
| GMS | – | Greater Mekong Subregion |
| ITC | – | Institut de Technologie du Cambodge (Institute of Technology of Cambodia) |
| KR | – | riel |
| l | – | liter |
| Lao PDR | – | Lao People’s Democratic Republic |
| LPG | – | liquefied petroleum gas |
| MAFF | – | Ministry of Agriculture, Forestry and Fisheries |
| MIME | – | Ministry of Industry, Mines and Energy |
| MRD | – | Ministry of Rural Development |
| mt | – | million ton |
| NGO | – | nongovernment organization |
| REE | – | rural electricity enterprise |
| t | – | ton |
| WGA | – | working group on agriculture |

# Acknowledgment

The study "Strategy for Integrating Biofuel and Rural Renewable Energy Production in Agriculture for Poverty Reduction in the Greater Mekong Subregion" is a successful result of the close collaborative work among affiliates and friends of the Greater Mekong Subregion Economic Development Initiative. The study was made possible by funding from the Asian Development Bank (ADB) and the International Fund for Agricultural Development (IFAD). Special thanks are also due to the Food Agriculture Organization of the United Nations (FAO); and to its Regional Office for Asia and the Pacific (FAO RAP) in Bangkok for its assistance in organizing and hosting a number of workshops and meetings that brought together collaborators and partners to discuss the emerging issues confronting the development of the Greater Mekong Subregion (GMS).

The study was led and coordinated by Mercedita A. Sombilla of the Southeast Asian Center for Graduate Study and Research in Agriculture (SEARCA) and could not have been completed without the strong support of the governments of the GMS countries, particularly the national biofuel assessment teams composed of the following eminent experts and technical personnel:

Luyna Ung, Hay Sovuthea, and Sophiak Siek of the Supreme National Economic Council; and Sar Chetra of the Ministry of Agriculture, Forestry and Fisheries for the assessment study "Status and Potential for the Development of Biofuels and Rural Renewable Energy: Cambodia";

Jikun Huang, Huanguang Qiu, and Jun Yang of the Center for Chinese Agricultural Policy, Chinese Academy of Sciences; Yuhua Zhang and Yanli Zhang of the Institute of Rural Energy and Environmental Protection, Chinese Academy of Agricultural Engineering; and Yahui Zhang of the Center of International Cooperative Service, Ministry of Agriculture for the assessment study "Status and Potential for the Development of Biofuels and Rural Renewable Energy: the People's Republic of China";

Kham Sanatem of the Forestry and Agriculture Promotion Center, Ministry of Agriculture and Forestry; Bouathep Malaykham of the Electric Power Management Division, Department of Electricity, Ministry of Energy and Mines; Phouvong Phommabouth, Department of Trade Promotion, Ministry of Industry and Commerce; Sounthone Ketphanh, National Agriculture and Forestry Research Institute, Ministry of Agriculture and Forestry; and Keophayvan Insixiengmai, Technology Research Institute, Science and Technology Agency for the assessment study "Status and Potential for the Development of Biofuels and Rural Renewable Energy: the Lao People's Democratic Republic";

U Hla Kyaw of the Department of Agriculture and Planning, Ministry of Agriculture and Irrigation; Thandar Kyi of Yezin Agricultural University; San Thein, Myanma Industrial Crop Development Enterprise, Ministry of Agriculture and Irrigation; U Aung Hlaing, Department of Agricultural Planning; and U Tin Maung Shwe, Myanmar Academy of Agriculture, Forestry, Livestock and Fishery Sciences for the assessment study "Status and Potential for the Development of Biofuels and Rural Renewable Energy: Myanmar";

Suthiporn Chirapanda, independent consultant; Sudarat Techasriprasert, Office of Agricultural Economics; Somjate Pratummin, Ministry of Agriculture and Cooperatives; Samai Jain, Ministry of Science and Technology; and Prapon Wongtarua, Ministry of Energy, for the assessment study "Status and Potential for the Development of Biofuels and Rural Renewable Energy: Thailand";

Nguyen Do Anh Tuan, Nguyen Anh Phong, Nguyen Nghia Lan, and Ta Thi Khanh Van of the Institute of Policy and Strategic Agricultural and Rural

Development, Ministry of Agriculture and Rural Development (MARD); Tran The Tuong of the Department of Crop Production, MARD; Phan Dang Hung, Department of Forestry, MARD; Vi Viet Hoang, Department of Cooperation and Rural Development, MARD; and Ha Van Chuc, Department of Livestock Production, MARD, for the assessment study "Status and Potential for the Development of Biofuels and Rural Renewable Energy: Viet Nam"; and

Jikun Huang, Jun Yang and Huanguang Qiu of the Center for Chinese Agricultural Policy, Chinese Academy of Sciences; Scott Rozelle of Stanford University; and Mercedita A. Sombilla of SEARCA, for the projection study "Global and Regional Development and Impact of Biofuels: A Focus on the Greater Mekong Subregion".

The country reports were consolidated in the report entitled "Integrating Biofuel and Rural Renewable Energy Production in Agriculture for Poverty Reduction in the Greater Mekong Subregion: An Overview and Strategic Framework for Biofuel Development" by Mercedita A. Sombilla of SEARCA; and Urooj S. Malik, A. K. Mahfuz Ahmed, and Sarah L. Cueno of the Southeast Asia Department, ADB.

During the course of this study, the team received valuable advice and guidance from many individuals and agencies. Special thanks are due to Urooj Malik, Director, Christopher Wensley, Officer-in-Charge, and Mahfuz Ahmed, Senior Agricultural Economist of the Agriculture, Environment, and Natural Resources Division, Southeast Asia Department, ADB; Thomas Elhaut, Director, Asia and the Pacific Region, IFAD; Hiroyuki Konuma of FAO RAP, Bangkok, Thailand; and the members of the GMS Working Group on Agriculture: San Vanty, Under Secretary of State, Ministry of Agriculture, Forestry and Fisheries, Cambodia; Tang Shengyao, Director of Asia and Africa Division, Department of International Cooperation, Ministry of Agriculture, the People's Republic of China; Phouangpharisak Pravongviengkham, Director General, Department of Planning, Ministry of Agriculture and Forestry, the Lao People's Democratic Republic; U Than Thay, Deputy Director, Department of Agricultural Planning, Ministry of Agriculture and Irrigation, Myanmar; Dounghatai Danvivathana, Director, Foreign Relations Division, Office of the Permanent Secretary, Ministry of Agriculture and Cooperatives, Thailand; and Le Van Minh, Director General, International Cooperation Department, MARD, Viet Nam.

Technical and logistical support was provided by the GMS Working Group on Agriculture Secretariat based at ADB headquarters, composed of Marilou Drilon, Sununtar Setboonsarng, and Sarah Cueno. Thanks go also to the ADB Resident Offices for facilitating the workshops and team meetings in the GMS countries.

The initial editing of the reports was done by Mercedita A. Sombilla. The manuscript editor was Caroline Ahmad, and the copy editors were Corazon Desuasido and Toby Miller. The final review of the studies was done by Urooj Malik.

Financial management and accounting support was provided by Oscar Badiola. Imelda Batangantang and SEARCA's accounting unit monitored the project's financial flow.

Finally, many thanks are due to the numerous other colleagues, partners, and stakeholders who provided valuable comments and information which added to the richness of the documents.

# Introduction

Energy is the main contributor to development, especially in emerging markets. To sustain the development process, the supply of energy must be augmented. Cambodia's economic performance has been strong in 2000–2008 and the demand for energy is expected to increase. The country is a net oil importer, so growth in oil imports is projected to be rapid. Consequently, the current volatility of fossil fuel prices threatens development. For this reason, in both developed and developing countries, the search for alternative energy, including biofuels, is being pursued aggressively. However, expansion of the biofuel industry can conflict with food security, and this may have serious consequences, especially in countries where resources are not abundant. In Cambodia, land is available to produce energy crops; however, resource allocation for biofuels will affect the price of food and other agricultural products. Given the current pressure to seriously consider biofuel as an energy source, Cambodia should develop an integrated policy to simultaneously address food security, poverty reduction, and energy security.

The Asian Development Bank (ADB) conducted a scoping study on biofuels as part of the activities of the Greater Mekong Subregion (GMS) Working Group on Agriculture (WGA).[1] The Asian Development Bank Institute is undertaking similar analytical work on biofuels and other crops involved in contract farming. In addition, a number of centers of the Consultative Group on International Agricultural Research are working on productivity and agroecological issues relating to biofuels within the GMS.

Following a series of dialogues with GMS government representatives, the private sector, the Consultative Group on International Agricultural Research, the International Fund for Agricultural Research and the Food and Agriculture Organization of the United Nations, the delegates of the fourth meeting of the WGA (WGA-4 in Siem Reap, December 2006) discussed the issues, priorities, and needs for cooperation on biofuel. They endorsed an initiative to support national and regional assessments and feasibility studies, including country-level investment. Under this initiative, the GMS countries will develop a common framework for biofuel development to address issues present in all countries, such as linking small farmers to regional markets, policy and investment cooperation in contract farming, cross-border trade, technology transfer, information and communication, and sustainable development.

The GMS WGA conducted a study entitled "Country Assessment Study: Strategies and Options for Integrating Biofuel and Rural Renewable Energy Production into Rural Agriculture for Poverty Reduction in the GMS Countries". This qualitative study provides a preliminary assessment of the long-run commercial viability of a biofuel program in the GMS. It was conducted from October 2007 to June 2008 and involved country workshops as well as the compilation, review, and synthesis of literature, secondary data, case studies, information from interviews with key personnel, and focus group discussions related to bioenergy development and cooperation in and for the GMS. A core country assessment team was identified in Cambodia, comprising three representatives from the Supreme National Economic Council and two from the Ministry of Agriculture, Forestry and Fisheries (MAFF).

The study focused on (i) market outlook (trends in energy supply and use in each country were analyzed), (ii) characterization (the country's resource base and its potential for biofuel production

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[1] ADB. 2007. *Bioenergy Development for the Rural Poor in the Greater Mekong Subregion: Issues, Challenges, and Opportunities.* Consultant's report. Manila.

was described and technologies that could help promote more efficient production of biofuel were identified), (iii) prioritization (the potential of priority biofuel crops was assessed), (iv) biofuel business options (agribusiness modalities were identified that sufficiently integrate small farmers in the biofuel market chain, promote national and cross-border trade and investments, and strengthen public–private partnership), and (v) policy, regulatory, and institutional support (policy gaps in the areas of agriculture planning and legislation for biofuel development were identified; and the policy levers and the regulatory and institutional environment to implement integrated strategies, market-enabling measures, and institutional frameworks were identified).

The objectives of the country assessment study are to (i) identify promising areas for investment in biofuel development; (ii) assess the implications for crop diversification, land use patterns, farm restructuring, and cross-border contract farming; (iii) determine the appropriate public–private partnerships that would help foster market-driven business ventures in biofuel crops; and (iv) review current country policies on bioenergy and provide policy recommendations for the development of a new national strategy.

The results of the study will be used to develop a national biofuel program in the GMS countries or to strengthen current programs to institute biofuel systems that would promote greater energy security without endangering food security.

# Energy Market Outlook

In 1998, Cambodia regained peace and stability after decades of civil war, and the rebuilding of the nation soon followed. Infrastructure, especially roads, began to be improved and business activities were reestablished and continue to expand. The tourism industry is booming and tourist arrivals average around 2 million a year. Urban areas are slowly expanding and economic growth registered double digits from 2004 to 2007. Phnom Penh, which was home to a few hundred people in 1979, hosted nearly 1.4 million in 2008.

A steady increase in energy consumption has accompanied this rapid economic growth and lifestyle change. Energy consumption grew at an average annual rate of 7.7% from 2000 to 2004. Cambodia faces the great challenge of addressing the high cost of energy, especially fuel and electricity, as it has both the highest price and lowest consumption of energy in Southeast Asia.

Cambodia's rising demand for energy has not resulted in hardship for much of the population as the country's favorable climate means that domestic energy demand is mainly for cooking and lighting. The inhabitants of Phnom Penh constitute the majority of the users of electronic appliances such as electric fans and air conditioning units.

As the road network has expanded and improved, energy demand from motorized transport has experienced rapid growth. Industry has developed slowly, particularly garments and footwear. Tourism and other economic activities have proliferated, inducing greater energy consumption. Energy demand is projected to grow at an annual rate of 15% to 2015.

The supply of energy is limited by the current production capacity and a lack of investment. Wood and biomass are the dominant household cooking fuels, especially in rural areas. In urban areas, gas and electricity are used for cooking and lighting. Access to electricity is very limited and costly because it is generated using diesel. Even though Cambodia has hydropower potential, it is insufficient to ensure the future supply of electricity because of the huge costs associated with the development, transmission, and distribution of power from this source.

## Energy Consumption

Energy consumption can be categorized by purpose, source, and sector. In households, energy is used for cooking, lighting, traveling, and improving living conditions. In industry, energy is used to run machinery and transport facilities. Services need energy for their operations. Cambodia's energy consumption is limited by availability and high cost; therefore the commercial use of energy is very small.

### Households

The share of total energy consumption by households has fallen from 80.6% in 1994 to 70% in 2000. Energy is used primarily for cooking and lighting. Fuelwood, including firewood and charcoal, is the main source of energy available to the general population, and it plays an even greater role for the rural population and the poor. Data from the 2004 population census show that 94.4% of rural households used firewood for cooking (Table 1). Overall, 84.8% of Cambodian households used firewood and 6.2% used charcoal for cooking in 2004. Liquefied petroleum gas (LPG) is becoming a popular alternative, especially in Phnom Penh, where it is used by almost half of the population.

The use of kerosene lamps for lighting declined from 89% in 1989 to 55% in 2004 (Table 2). Batteries were also common for lighting, and less than 20% of households used electricity for lighting. Although 96% of households in Phnom Penh had access to electricity from private or public sources, the figure declines to

**Table 1: Main Sources of Energy for Cooking, 2004**
(%)

| Type of Fuel | Cambodia | Phnom Penh | Other Urban | Rural |
|---|---|---|---|---|
| Firewood only | 84.8 | 13.8 | 63.1 | 94.4 |
| Charcoal only | 6.2 | 24.4 | 20.0 | 2.6 |
| Firewood and charcoal, combined | 2.1 | 7.4 | 5.4 | 1.1 |
| Liquefied petroleum gas | 5.2 | 48.1 | 7.7 | 0.7 |
| Kerosene | 0.1 | 0.4 | 0.0 | 0.1 |
| Publicly provided electricity | 0.1 | 0.9 | 0.3 | 0.1 |
| Gas and electricity | 0.6 | 4.6 | 1.1 | 0.1 |
| Privately provided electricity | 0.0 | 0.0 | 0.1 | 0.0 |
| None/don't cook | 0.0 | 0.0 | 0.0 | 0.1 |
| Other forms of energy | 0.9 | 0.4 | 2.3 | 0.8 |
| **Total** | **100.0** | **100.0** | **100.0** | **100.0** |

Source: National Institute of Statistics. *2004 Cambodian Statistical Yearbook*. Ministry of Planning, Phnom Penh. Cambodia.

**Table 2: Main Sources of Lighting, 2004**
(%)

| Sources | Cambodia | Phnom Penh | Other Urban | Rural |
|---|---|---|---|---|
| Publicly provided electricity | 12.8 | 84.1 | 40.0 | 2.5 |
| Privately generated electricity | 6.5 | 11.7 | 10.8 | 5.4 |
| Battery | 24.3 | 1.6 | 10.7 | 28.3 |
| Kerosene lamp | 55.2 | 1.8 | 37.5 | 62.7 |
| None | 0.0 | 0.1 | 0.1 | 0.0 |
| Others | 1.1 | 0.8 | 1.0 | 1.2 |
| **Total** | **100.0** | **100.0** | **100.0** | **100.0** |

Source: National Institute of Statistics. 2004.

51% of households in other urban areas, and 8% of households in rural areas.

Data obtained by the Ministry of Industry, Mines and Energy show that electricity represents only 0.87% of total household energy consumption. In 2005, only 11% of almost 2.3 million households were connected to an electricity supply. The number of customers connected was 208,471 in 2004, an increase of 12.7% from 2003.

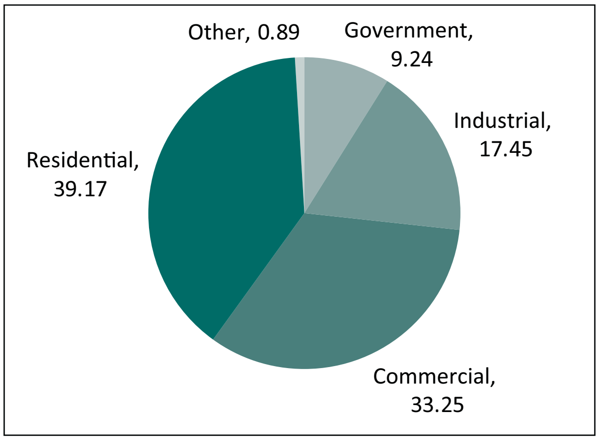
Almost three-quarters of the customers of Electricité du Cambodge (Electricity of Cambodia) (EDC) are in the Phnom Penh region (Figure 1). They account for more than 86% of consumption of the electricity generated by the EDC. Residential customers consume an average of 1,560 kilowatt-hours (kWh) per year (around 4.3 kWh/day). Electricity is used mainly for lighting and running household electric appliances and air conditioners. Only a few households use it for cooking. Users in Phnom Penh have the highest average of 1,836 kWh/year (around 5 kWh/day) while those in Prey Veng register the lowest consumption rate of 159 kWh/year (less than 0.5 kWh/day). This suggests that electricity is used mainly for lighting in the provincial areas.

Analysis of energy use by income quintile shows that poorer people rely more on fuelwood.[2] Time spent to collect wood involves a major trade-off with the opportunity to earn income that would reduce both time and physical workload of families. Moreover, fuelwood resources are decreasing rapidly, as locally accessible forests decline, and increasing the number of households need to buy wood. Food represents the highest monthly cost for rural families, but the cost of fuelwood directly affects family income and food security.

### Industry and Services

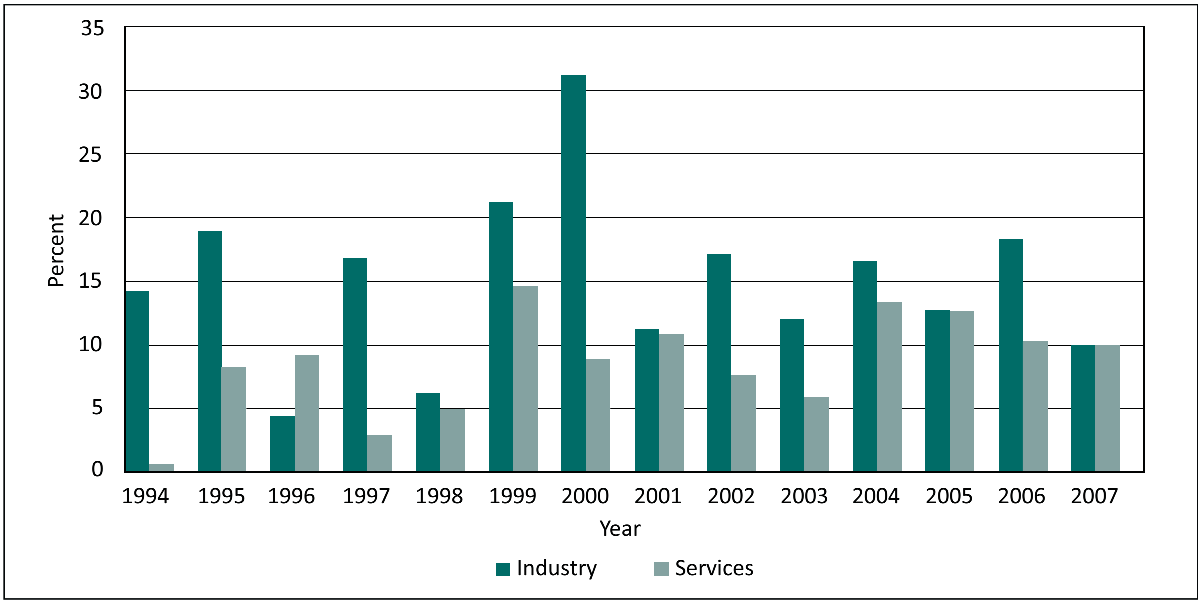
In 1994–2007, industry expanded at an average rate of 15% per year and services grew at an average annual rate of 8% (Figure 2). The two sectors contribute significantly to the rise in gross domestic product and absorb the young labor force, especially women. Garments and tourism have grown rapidly and electricity consumption has increased correspondingly. Electricity use by industry and commerce accounts for more than 50% of total electricity consumption. In 2006, of a total electricity consumption of 674.6 gigawatt-hours (GWh), 33% was used by the commercial sector and 17% by industry (Figure 1). As these two sectors expanded, electricity consumption increased at a similar pace. Due to the lack of input–output data, the elasticity of sector growth to electricity consumption could not be estimated.

**Figure 1: Energy Consumption in Phnom Penh, 2006**
**(%)**




Source: Electricity of Cambodia. 2007.

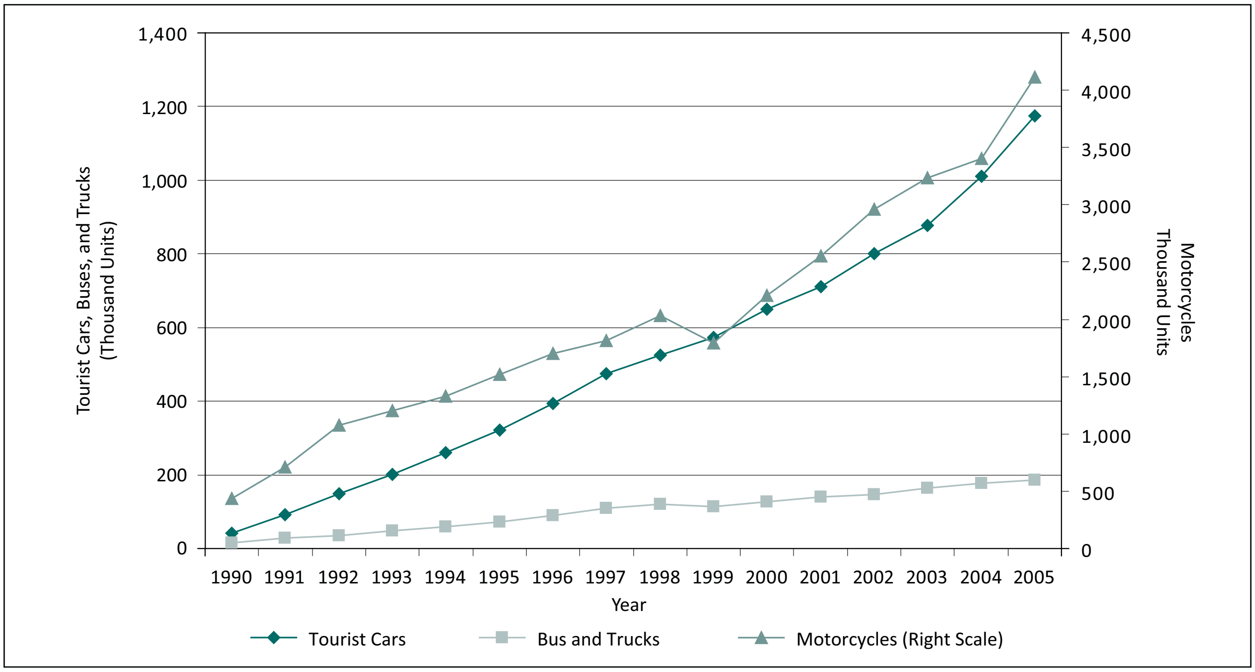
**Figure 2: Real Growth Rates of the Industry and Service Sector, 1994-2007**
**(%)**




Source: National Institute of Statistics of Cambodia. 2008.

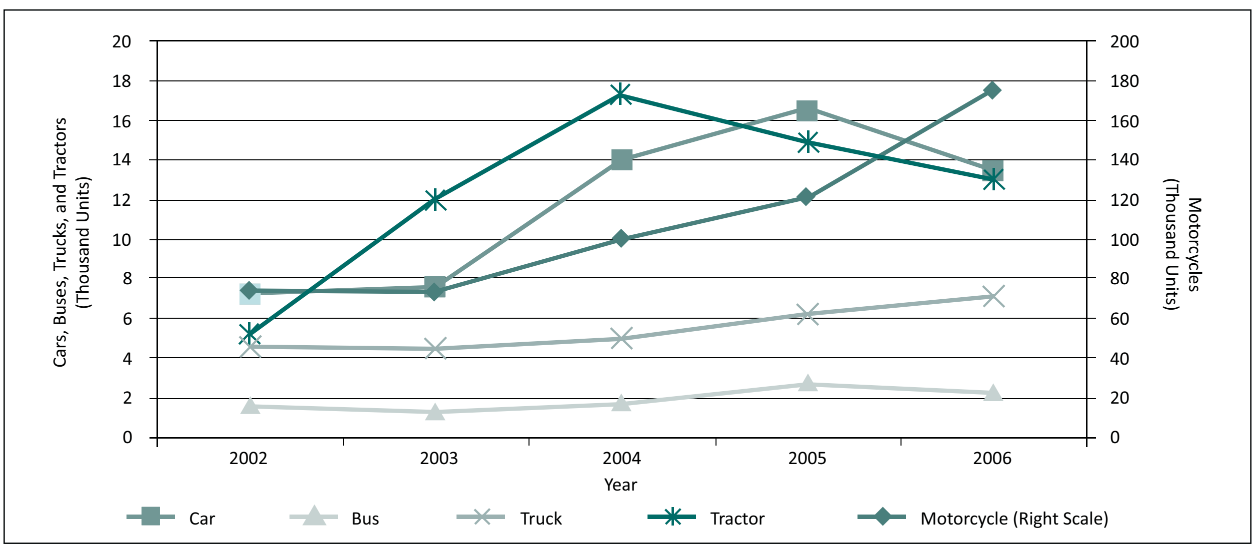
[2] Van Mansvelt, E.R., M.C. Le Quan, S. Im, E. Bu Buysman, R.K. Anaya De La Rosa, and A. Guidal. 2006. *Wood Energy Baseline Study for the Clean Development Mechanism in Cambodia: Household Woodfuel Use and Supply in Phnom Penh.*

**Figure 3: Number of Vehicles Registered**




Source: Ministry of Public Works and Transport.

**Figure 4: Number of Imported Vehicles**




Source: Ministry of Economy and Finance. 2008

### Transport

With the improvement of rural roads and market infrastructure since 2002, rural people now enjoy better and less costly access to main roads and markets. At the same time, the number of vehicles has risen substantially every year. The number of registered motorcycles increased rapidly in the last few years (Figure 3), causing a similar rise in the consumption of transport fuels.

Cars, trucks, and buses have been imported as the economy has expanded and as the road system has improved, adding to the stock of vehicles (Figure 4). Each household now has at least two motorbikes. Rising tractor imports signal the mechanization of agriculture.

Diesel and gasoline are the main transport fuels; but as the price of fossil fuels has increased, some vehicles have been converted to use LPG. No data is available on this substitution. The transport sector has been and will continue to be a major energy consumer.

### Projected Energy Demand

A long-term projection of the distribution of energy consumption in Cambodia in 2030 (Table 3) indicates a reduced share for households (48%) and increased shares for transport (42%) and the combined service and industry sectors (10%).

The projected electricity demand for Phnom Penh (Table 4) in the 2006 Energy Master Plan Study is based on the increase in the number of households and density of various household electrical equipment and changes in electricity demand patterns. The baseline average electricity consumption and demand patterns are summarized in Table 5. The total number of households is projected to increase to almost 3 million in 2010 and to 3.26 million in 2015. Most of these increases are for rural households in the provinces.

Residential electricity demand is forecast to triple between 2000 and 2010 and more than quadruple

**Table 3: National Energy Consumption by Sector**
(terajoules)

| User | 1994 | | 2000 | | 2010 | | 2020 | | 2030 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | TJ | % | TJ | % | TJ | % | TJ | % | TJ | % |
| Households | 79.47 | 86.4 | 90.11 | 80.6 | 113.98 | 71.7 | 142.12 | 61.4 | 166.29 | 48.0 |
| Industry | 0.52 | 0.6 | 0.87 | 0.8 | 2.25 | 1.4 | 4.87 | 2.1 | 14.71 | 4.3 |
| Service | 0.91 | 1.0 | 1.42 | 1.3 | 3.18 | 2.1 | 7.82 | 3.4 | 20.06 | 5.8 |
| Transport | 11.07 | 12.0 | 19.34 | 17.3 | 39.45 | 24.8 | 76.69 | 33.1 | 145.29 | 41.9 |
| **Total** | **91.99** | **100.0** | **111.73** | **100.0** | **158.87** | **100.0** | **231.49** | **100.0** | **346.34** | **100.0** |

TJ = terajoules.

Source: Adapted from the World Bank and HECEC Australia, 1998; and Electricité du Cambodge, 1999, by De Lopez, T.T., C. Praing, and S. Toch. 2003.

**Table 4: Electricity Consumption Forecast for Phnom Penh**

| | 2009 | 2010 | 2015 | 2020 |
|---|---|---|---|---|
| Power (megawatts) | 808 | 1,015 | 1,915 | 3,867 |
| Energy (gigawatt-hours) | 1,550 | 1,895 | 3,500 | 8,300 |

Source: Electricité du Cambodge. 2006.

### Table 5: Current and Projected Rural Energy Demand

| Demand | 2007 | 2010 | 2012 | 2015 | 2017 | 2020 | 2022 | 2025 | 2027 | 2030 |
|---|---|---|---|---|---|---|---|---|---|---|
| Electricity (GWh) | 750 | 932 | 1,098 | 1,217 | 1,296 | 1,472 | 1,613 | 1,887 | 2,026 | 2,222 |
| Total charcoal (000 t) | 321 | 424 | 535 | 801 | 807 | 770 | 756 | 729 | 719 | 724 |
| Total firewood (000 t) | 4,696 | 4,013 | 3,400 | 2,236 | 2,099 | 1,993 | 1,880 | 1,508 | 1,286 | 973 |
| Total Liquefied petroleum gas (000 t) | 61 | 77 | 83 | 96 | 110 | 147 | 180 | 232 | 255 | 283 |
| Total kerosene (000 t) | 329 | 336 | 351 | 388 | 417 | 451 | 457 | 501 | 535 | 589 |
| Total candles (t) | 626 | 688 | 740 | 822 | 885 | 987 | 1,067 | 1,186 | 1,276 | 1,410 |
| Total animal dung (000 t) | 25 | 28 | 28 | 27 | 28 | 29 | 29 | 30 | 31 | 32 |

GWh = gigawatt-hour; t = ton.

Note: The forecast excluded energy use for transportation.

Source: United Nations Development Programme. 2007.

between 2000 and 2015, and is expected to reach 950 GWh in 2010 and 1,427 GWh in 2015. The Phnom Penh region and other urban areas in the country are projected to experience the greatest increase in electricity demand.

Table 5 gives the projected rural energy demand by type based on two provincial case studies for cooking and lighting. Firewood is projected to remain in use until 2030, but its demand will decline and will be replaced by more efficient sources of energy. In 2007, households in rural areas relied primarily on firewood for cooking and kerosene for lighting. In 2030, these main sources of energy will be replaced by electricity and LPG, the demand of which is estimated to grow at around 6% per annum.

Combining both rural and urban projections, electricity demand is set to grow by around 18% per annum. This figure reflects the 83% share of energy consumption of Phnom Penh. The demand for LPG is also high due to the move away from fuelwood. The demand for fossil fuel for transport could increase by as much as 35% per annum.

## Energy Supply

Most energy used in Cambodia comes from wood in the form of fuelwood and charcoal, which is traditionally used for cooking. Other potential uses of biomass and waste for energy production have not been fully explored. Nongovernment organizations (NGOs) have conducted experimental projects to test technologies based on other biomass and waste products, but their use remains limited. It is estimated that biomass and waste could supply around 73% (Table 6) of the country's total energy needs.

### Table 6: Sources of Energy Supply, 2005 (%)

| Source of Energy Supply | % |
|---|---|
| Coal | 0.0 |
| Oil | 26.6 |
| Gas | 0.0 |
| Hydro, solar, wind, and geothermal power | 0.1 |
| Biomass and waste | 73.2 |
| Nuclear | 0.0 |

Source: International Energy Agency. 2005.

The second-largest source of energy is imported fossil fuels such as gasoline, diesel, heavy oil, fuel oil, and kerosene. Fossil fuel is used for transport and electricity generation. More than 90% of the electricity supply comes from generators. Even the batteries that rural households use for lighting are charged at diesel-powered charging stations.

Despite their potential, other sources of energy, such as coal, hydropower, solar, wind, natural gas, geothermal, and nuclear power contribute only a small share. From the 1990s onwards, gas consumption has slowly risen as people have begun to replace wood with gas for cooking. Moreover, as the price of gasoline increased, some cars were converted to use LPG, which is also imported.

Countrywide, the power supply is inadequate except in Kompong Cham, Phnom Penh, Siem Reap, and Sihanoukville. Supply is projected to increase on average by 12.1% per year. The peak load is projected to increase to around 1,000 megawatts (MW) in 2020 (649 MW for Phnom Penh and 342 MW for other areas). According to EDC, in 2006, the total generation was around 1,106 GWh, of which 5% was produced from hydroelectricity, 4% was imported and the rest was produced by fuel generators.

### Fuelwood and Biomass Resources

Natural forests are the main source of fuelwood in Cambodia. This resource has been severely degraded over the past 20 years due to widespread logging and conversion of forestland for various purposes.[3] Biomass energy resources also include residues from plantation forests (rubber wood), agricultural crops (rice husk), livestock (cattle manure), municipal waste, and sewage.

Forest cover has declined from over 75% in the 1970s to barely 59% in 2005. Rampant logging is more to blame for this decline than wood collection by rural folk. Nonetheless, wood is still widely used for energy, especially for cooking. Charcoal production is also on the rise because charcoal is a substitute for fuelwood; and since charcoal is made from wood, it too contributes to forest destruction, albeit on a smaller scale. In the absence of a reforestation program, natural forests will continue to decline.

### Electricity Production

Electricity is the major source of energy in Cambodia. Cambodia's power sector has made good progress since the early 1990s and has undergone considerable restructuring, but overall, the sector is still underdeveloped. Currently, Cambodia has no national grid, and the power supply is generated by 24 unconnected, isolated grids in 24 provinces. The Ministry of Industry, Mines and Energy (MIME) has responsibility for 10 provinces and EDC runs operations in 14 provinces, including Phnom Penh. Generation relies mostly on imported diesel and 2 mini-hydro plants with an installed capacity of 13 MW.

At present, the electricity provided by the state-owned EDC is generated using diesel oil. EDC has the most extensive supply network in the country, supplying slightly more than 50% of the installed generating capacity. Independent power producers contribute the remainder.

The 24 isolated grids serve major cities, provinces, and small towns, with the exception of the electricity supply system of Kampong Speu, which has been connected to the Phnom Penh system through a 115-kilovolt single-circuit transmission line since 2002. Electricity service providers in small towns and communes near the borders of Thailand and Viet Nam also source some power from electricity suppliers from these countries.

The domestic customers of EDC comprise 270,000 households, while licensed suppliers serve around 48,700 customers. In addition, small and locally owned rural electricity enterprises (REEs) consisting of a diesel engine and generator with low-voltage distribution lines serving 30–2,000 local households and businesses have been set up. Around 600 such enterprises supply electricity to almost 12,000 households, so in total there are around 330,700 households with access to grid or mini-grid electricity.

Electricity rates in Cambodia range from $0.09/kWh to $0.53/kWh for government services, but can be much higher for small private services or battery charging services.[4] Cambodia has the most expensive electricity in Southeast Asia. The average tariff charged by REEs is estimated at $0.53/kWh.[5] Around 8,000 battery-charging businesses serve households

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[3] ADB. 2000. *Cambodia Forest Concession Review.* Manila; Global Witness. 2002. *Deforestation Without Limits: How the Cambodian Government Failed to Tackle the Untouchables.* London.

[4] De Lopez, T.T., C. Praing, and S. Toch. 2003. Technical Potential and Institutional Features for Renewable Energy, Energy Efficiency, and Greenhouse Gas Abatement. Prepared for the Asian Development Bank. (unpublished).

[5] Hundley, C. 2003. *Renewable Electricity Action Plan (REAP).* World Bank. Washington, DC.

and businesses, and their effective tariff is often over $1.00/kWh.[6]

Per capita consumption is among the lowest in the region at about 55 kWh per annum. Less than 17% of households have access to electricity (54% in Phnom Penh and 13% in rural areas), compared with almost 100% in Singapore and Thailand.

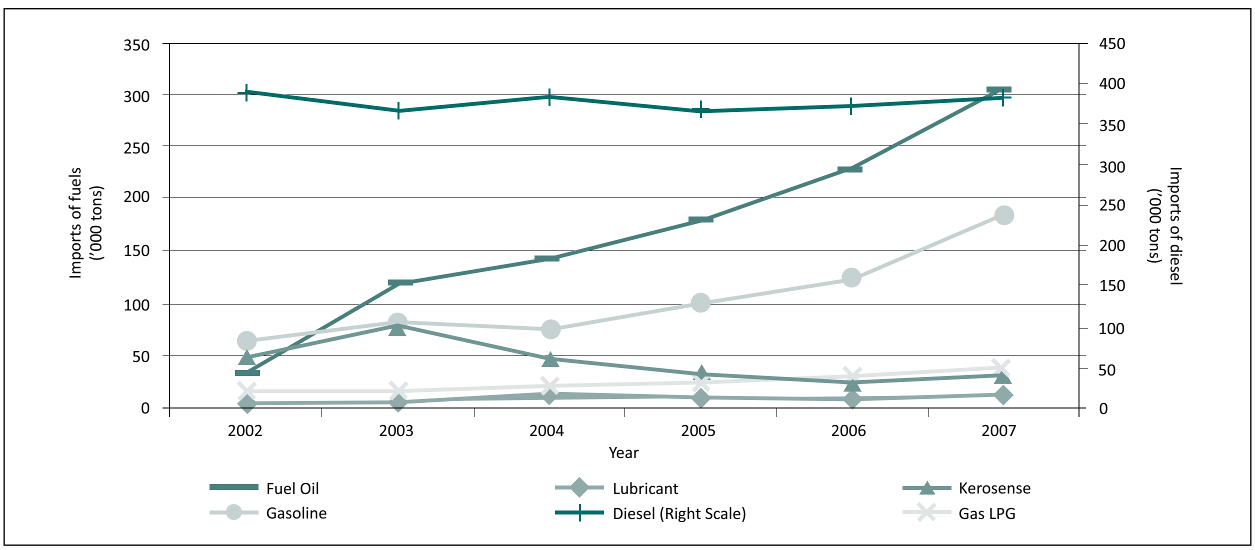
### Oil and Gas Imports

All commercial fuels in Cambodia are imported. Annual imports of petroleum products averaged an estimated 900,000 tons (t) in 1998–2000, an increase of about 700,000 t from 1985. However, official figure for imports recorded only 600,000 t. The mismatch in the figures is likely to be due to smuggling. In 2002–2007, fuel oil and gasoline imports increased sharply while diesel import remained virtually stable during the same period (Figure 5).

Cambodia possesses oil and gas resources; however, in-depth comprehensive geological survey data are not available to assess the extent of these fossil fuel deposits. Offshore surveys of oil and natural gas in the past 10 years met with varying success. Test drills have revealed the potential existence of presumably large, but yet undetermined, offshore natural gas deposits. These are now being commercially explored and there is a high probability that Cambodia will be able to exploit its fossil fuel reserves. Commercially viable offshore gas extraction will probably not be achieved for at least another 5 years, however, and substantial investment in infrastructure would be needed.

At present, Thailand is the largest supplier of gas to Cambodia. Cambodia does not have gas pipeline, because of low demand for natural gas and the high construction costs of a pipeline. The volume of gas reserves in Cambodia influences investment decisions for gas electricity plants. If the reserve is not big enough, another option is to obtain natural gas from Viet Nam to fuel a power station in the Mekong delta, which in turn could secure and improve the supply of energy to industry. Cambodia needs to be connected to the trans-ASEAN gas pipeline—a regional initiative to build interconnected gas pipelines within the Association of Southeast Asian Nations (ASEAN) area to link natural gas production centers to the regional markets—to lower the price and ensure economically efficient supply of natural gas.

**Figure 5: Oil and Gas Imports** ('000 tons)




Source: Ministry of Economy and Finance. 2008.

[6] Maritec. 2001. *Final Report on Renewable Energy Strategy and Program for the Rural Electrification Strategy and Implementation Program for the World Bank.* Phnom Penh.

### Coal Production

Coal deposits are thought to exist in the provinces of Stung Treng, Preah Vihear, and Kampong Thom, and there are also offshore deposits of bituminous coal south of Kompot and Koh Kong province. However, there has not been a comprehensive national survey of these reserves nor has there been any exploration.[7] There is a plan to establish a coal-fired power plant, which would run on imported coal. Local coal could be used In the future if the deposits are found to be commercially viable.

## Potential Alternative Sources of Energy

The government also recognizes the important role renewable energy could play in improving access to electricity, particularly in rural areas. Under the 2003 Renewable Energy Action Plan, the government aims to (i) supply 5% of new electricity generation—about 6 MW—through renewable energy technologies, (ii) supply 100,000 households with electricity from renewable energy sources on a competitive basis, (iii) provide 10,000 households with electricity through the use of solar photovoltaic systems, and (iv) establish a sustainable market for renewable energy systems.

Cambodia has substantial energy resources, but very little of this potential has been exploited and converted into usable power. Consequently, electricity generation in Cambodia relies heavily on imported oil and diesel. The discovery of oil and gas in the coastal areas could mean a substantial potential resource for the future development of the energy subsector and the economy as a whole. Renewable energy resources such as biomass, solar, wind, and hydropower are also available and the potential and current installed capacity of these sources is listed in Table 7.

### Hydropower

The technical potential of hydropower resources in Cambodia in terms of installed capacity is estimated at 5,000–8,600 MW. Around 50% of these resources are located in the Mekong River Basin, 40% on tributaries of the Mekong River, and the remaining 10% in the southwestern coastal areas. Current use of hydropower resources is, however, relatively limited. At present, only two projects are operating with an installed capacity of 13 MW, while four projects are being developed. Williamson et al[8] identified 42 potential hydropower projects with a total installed capacity of 1,825 MW and capable of generating around 9,000 GWh/year of electricity.

### Solar Power

The current utilization of solar power in the country is low. Total installed capacity between 1997 and

**Table 7: Potential of Renewable Energy Generation in Cambodia**

| **Energy Sources** | **Potential** (GWh/year) | **Current Installed Capacity** (GWh/year) | **Remaining** (GWh/year) | **Potential Annual GHG Abatement** (kton $CO_2$ equivalent) |
|---|---|---|---|---|
| Hydropower | 37,668 | 55 | 37,613 | 26,228 |
| Biomass | 18,852 | 0 | 18,852 | 13,146 |
| Solar | 65 | 1 | 64 | 44 |
| Wind | 3,665 | 0 | 3,665 | 2,556 |

CO2 = carbon dioxide, GHG = greenhouse gas, GWh/year = gigawatt-hour per year, kton = kiloton.

Source: Seng. 2007.

7 New Energy and Industrial Technology Development Organization. 2002. *Assistance Project for the Establishment of an Energy Master Plan for the Kingdom of Cambodia.* Tokyo.

8 A. Williamson et al. 2004. *Sustainable Energy in Cambodia: Status and Assessment of the Potential for Clean Development Mechanism Projects.* The Cambodian Research Centre for Development. Phnom Penh.

### Table 8: Capacity of Solar Photovoltaic Systems Installed between 1997 and 2002

| **Item** | **Use Capacity** (Wp) | **Share of Total** (%) |
|---|---|---|
| Mobitel Telecoms Company | 127,000 | 62.0 |
| Samart Telecoms Company | 38,000 | 18.6 |
| Battery charge stations | 2,196 | 1.1 |
| Training centers | 19,691 | 9.6 |
| Bridges | 7,280 | 3.6 |
| Nongovernment organizations | 3,825 | 1.9 |
| Schools | 3,279 | 1.6 |
| Households and pagodas | 1,720 | 0.8 |
| Health centers | 1,595 | 0.8 |
| **Total** | **205,036** | **100** |

Wp = watt-peak

Source: The Ministry of Industry, Mines and Energy. 2002.

2002 reached 205 kW and increased to over 300 kW by the beginning of 2004 (footnote 8). Surface solar irradiation in the country has not been comprehensively assessed; therefore, most estimates of solar energy potential in Cambodia use data generated by the National Aeronautics and Space Administration's Global Solar Radiation Model. The New Energy and Industrial Technology Development Organization used a 10-year annual average solar irradiation of 5.0 kilowatt-hours per square meter per day (kWh/m$^2$/day), based on readings of 4.7 kWh/m$^2$/day average in the lowest area and 5.3 kWh/m$^2$/day in the highest area (footnote 8). It is estimated that the theoretical maximum potential surface solar irradiation could reach as much as 21 GWh/day (13 times the power generated by the EDC in 2002).

### Solar Photovoltaic Systems

Solar photovoltaic systems in Cambodia currently produce 200–250 kilowatt peak.[9] Telephone repeater stations account for more than 80% of the installed systems (Table 8).

### Wind Energy

The Wind Energy Resources Atlas Report in Southeast Asia that covers Cambodia, the Lao People's Democratic Republic (Lao PDR), Thailand, and Viet Nam shows that the theoretical wind energy resource potential in the country amounts to 1,380 MW. The report indicates good sites for the future development of wind energy, but the potential values must be taken cautiously since the simulations were based on global winds and were not supported by ground measurements.

In preparing the Energy Master Plan study in 2002, NEDO analyzed wind flow and speed, taking into account wind measurements available in the country. NEDO's wind map identified three promising areas for development: the southern coastal region, the southern coast of the Tonle Sap Lake, and the southern mountain region. Four small wind turbines were installed, but are currently not operational due to various technical failures (footnote 9).

### Other Forms of Renewable Energy

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. The workshop was organized by a local NGO, Small and Medium Enterprise Cambodia, which subsequently facilitated the establishment of

[9] A measure of the peak output of a photovoltaic system

a new REE that uses biomass gasification technology from India.[10] 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 and other local farmers.

### Biofuel Options

Cambodia's potential for hydropower, if realized, could reduce the high cost of electricity; however, fuels used for mechanized transport will remain costly as they will continue to be entirely imported until the country begins to exploit any domestic oil and gas reserves it may possess. Furthermore, the demand for transport fuels is rising at the same time as the awareness of their environmental cost is growing and causing increasing concern. Given the land area available, biofuel presents an attractive opportunity in Cambodia. The blending of biofuel with conventional fuels not only can lower the financial cost, but may also reduce the environmental cost associated with mechanized transport.

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10 Small and Medium Enterprise Cambodia. 2001. *Cambodia REE Association Building Initiative.* Small and Medium Enterprise Cambodia. Phnom Penh. Cambodia.

# Biofuel Characterization and Priorities

## Types of Biofuel

Biofuel refers to liquid or gaseous fuels that are produced from biological sources. Liquid biofuel commonly refers to specific types of biofuel 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, biodiesel, and bioethanol. Straight vegetable oils, such as oil from peanuts, olives, or sesame seeds are possibly the simplest form of biofuel. These pure vegetable oils have the energy content and some physical characteristics similar to diesel fuel.[11] Biodiesel is a biofuel made by the process of transesterification of suitable biological oils, and should conform to a commercial standard such as ASTM D675. Biodiesel is very similar to fossil-based diesel fuel and has a long shelf life. It can be used in almost any type of diesel engine without modifying the engine. The third common type of biofuel, bioethanol, can be produced from a wide range of biomass. Generally, ethanol is mixed with gasoline in varying concentrations. Flexible fuel cars which can run on pure ethanol are now available in some countries.

## Biofuel Use

Liquid biofuel derived from biomass can be used as transport fuel. It is a direct substitute for gasoline and diesel in transport fuel and can be used in automotive vehicles either as blend or in its pure form. In the current world situation of fluctuating and high oil prices and climate change concerns, both developing and developed countries are keen to develop and use liquid biofuels, bioethanol, and biodiesel.

Biofuel can be used in older engines that use the direct injection system of fuel mixing and delivery. These engines are very common in rural Cambodia and are found in many stationary (i.e., non-transport) applications such as electricity generation, power generation, and water pumping. Examples of engines used for electricity generation are the mini-grids operated by REEs, battery-charging businesses, and many other businesses that have their own on-site generator because grid power is unavailable, unreliable, or unaffordable. Examples of engines used for power generation are found in rice mills, ice-making factories, woodworking businesses, and other small manufacturing operations. Pumps are commonly used to draw water for irrigation and drinking.

Many smaller businesses that provide these services in rural areas of Cambodia use previously used diesel engines and generators. These engines usually have a direct-injection fuel delivery system and are tolerant of a range of fuel quality. Consequently, it is assumed that use of straight vegetable oil biofuel without engine modification should not cause any problems. Due to their age, these engines require relatively frequent maintenance. Thus, possible longer term effects such as buildup of impurities may not be a significant problem.

## Potential Risks, Benefits, and Impact on Climate Change of Biofuels Development

### Potential Risks

Potential risks can be divided into those associated with land use changes, those pertaining to fuel quality and sustainability, and those relating to the government's tax revenues.

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[11] Williamson, A. 2006. *Biofuel: A Sustainable Solution for Cambodia?* Cambodia Research Center for Development. Phnom Penh. Cambodia.

Changes in existing land uses can create conflict and economic hardship if not managed properly because property title regulation and enforcement in Cambodia are still being developed, so it is common for poor communities not to have a legal title to their property. Inappropriate land use change can also attract conflict and criticism and can also cause long-term environmental damage; for example, an area of existing forest of ecological or cultural significance could be cleared to make way for energy crop cultivation. This is not a problem for farmer landowners who decide to shift existing land use; however, there is a risk that the initial benefit from oil crops may tempt these farmers to plant oil crops on land where food crops are growing, thus competing with food crops.

If fuel quality is not maintained there could be a net cost to the country from the introduction of biofuel due to engine damage by low-quality fuel. If this were to occur, the sustainability of the industry and the livelihoods of farmers and businessmen involved would be threatened. Therefore, it is important that appropriate fuel standards and testing are established and enforced.

Diesel fuel and gasoline are currently subject to tariff rates of around 100% in Cambodia. If biofuel is introduced successfully, the government's tax revenue could be reduced as biofuel would replace taxable fossil fuel. However, this scenario is unlikely because (i) the total energy demand, including 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; (ii) a significant proportion of diesel fuel consumed in Cambodia is smuggled across the borders, and therefore does not contribute to the government's tax revenue; and (iii) 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.

### Potential Benefits

Notwithstanding the risks outlined, there are a number of potential benefits to the development and use of biofuels which warrant more detailed study and the formulation of appropriate national policies. These include:

**Economic development.** Local production of biofuels could improve Cambodia's balance of trade through reduced imports of fossil fuels. It could also reduce pressure on foreign currency reserves. Biofuel production would directly create new employment and business opportunities, and could attract foreign and local investment. If biodiesel can be supplied at a lower price than fossil diesel, the economy will be further boosted as other businesses become viable due to the lower energy costs.

**Rural development.** The production of biofuels could improve rural livelihoods by providing new income opportunities for families and communities that cultivate oil crops, or who may also be directly employed by private biofuel processing companies. Biofuel will benefit women in rural areas who can grow oil crops on the family property or on other available land, and harvest and sell the seeds to add to the household income. This requires minimal investment costs and training.

**Poverty reduction.** The cultivation of biofuel crops may help reduce poverty by offering income opportunities for rural families with minimal investment costs and training, and insulating the rural poor from external energy price fluctuations.

**Potential for community energy cooperatives.** Local biofuel production introduces the possibility of community energy services that do not require cash transactions (i.e., a community-owned energy cooperative could provide energy services to households in exchange for their supply of oil crop seeds or labor input.) A variation on this concept is found in the Battambang region of Cambodia where a community cooperative operates a biomass gasifier and members are required to grow wood to supply it.

**Energy security.** The cost and availability of biofuel in Cambodia are independent of the world oil market and will therefore improve the long-term resilience of Cambodia's economic and political situation by reducing reliance on its regional neighbors and oil-producing nations.

**Health and safety.** Unlike diesel, biofuel can be handled and transported safely as it is not explosive or corrosive.

**Renewable energy.** In switching from fossil fuel to biofuel, a rural entrepreneur will need no capital investment to convert an old diesel engine into a renewable energy generator and thereby become a clean power producer. This will be attractive if the government or other organizations introduce incentives to encourage the use of renewable energy.

**Environmental benefits and the clean development mechanism.** The use of biofuel can reduce both net greenhouse gas (GHG) emissions and air pollution. The cultivation of energy crops can also impact biodiversity, and soil and water resources. Although the positive effects of biofuel use are consistently greater than the negative, the environmental impact of a biofuel project must be carefully assessed.

### Impact on Climate Change

The principal environmental benefit of biofuels over fossil fuels is the reduction in GHG emissions through the recycling of carbon dioxide that occurs as biofuels are grown and consumed. While efforts have been successful in reducing GHG emissions from industry, electric power generation, agriculture, and construction, the growth in emissions from road transport is uncontrolled even in developed countries. As a developing country, Cambodia can expect to see GHG emissions increase as the economy grows.

Life-cycle analysis consistently shows that, compared with fossil fuel, the use of biofuel results in net reduction of carbon emissions. However, biofuels are not carbon neutral, since their production leads to GHG emissions, particularly from the cultivation of crops, the manufacture of fertilizers, and the processing and distribution of the fuel. The extent of carbon reduction and environmental effects varies widely depending on project execution and the choice of feedstock. Jatropha is considered one of the most favorable feedstock crops for biodiesel production in terms of reducing GHG emissions.

### Impact of Feedstock Cultivation on the Environment

To analyze the environmental impact of energy crop cultivation, the life cycle approach needs to be complemented by a farming systems approach to take account of possible changes in cropping patterns and input use at the level of the whole farm, as well as of the effects of these changes on the overall ability of farms to continue to provide environmental services.

Increased use of inputs per hectare (ha), such as fertilizers and pesticides, and changes in land use could have negative effects on the environment. However, the cultivation of energy crops may benefit the environment when the fertilizer input is reduced to improve the starch content of cereals, or when crop rotation systems are improved.

The main environmental impacts of energy crop cultivation for biofuel production relate to (i) areas brought into production, (ii) change in crops cultivated for biofuel, (iii) changes in the use of chemical inputs and (iv) prevention of the abandonment of agricultural land.

### Environmental Impact of Biofuel Use

The environmental effects of biofuel use will require monitoring. Cambodia has low vehicle emission standards, so biofuel use will be very beneficial for air quality. Biofuel is by nature very clean because it contains few impurities and, due to its oxygen content, it should lead to more complete combustion and lower emission of pollutants.

## Production of Biofuel

### Biofuel Crops and their Characteristics

Bioethanol—the principal fuel used as a substitute for gasoline for road transport vehicles—is produced by the sugar fermentation of cellulose (starch), derived mostly from maize and sugarcane. Biodiesel, on the other hand, is produced from oil crops such as rapeseed, oil palm, and soybean (Table 9).

Most of these crops are grown in Cambodia. Figure 6 shows the relative contribution of various crops to the gross valued-added of agriculture in 2006. Paddy rice contributed the highest at 54%, followed by other cash crops at 9%, vegetables at 8%, other crops at 8% each; maize, cassava, and rubber at 5% each; and soybean and tobacco at 3% each.

Among the agricultural products grown in Cambodia, soybean, peanut, sesame, sugarcane, maize, cassava, jatropha, and oil palm can be used as feedstocks

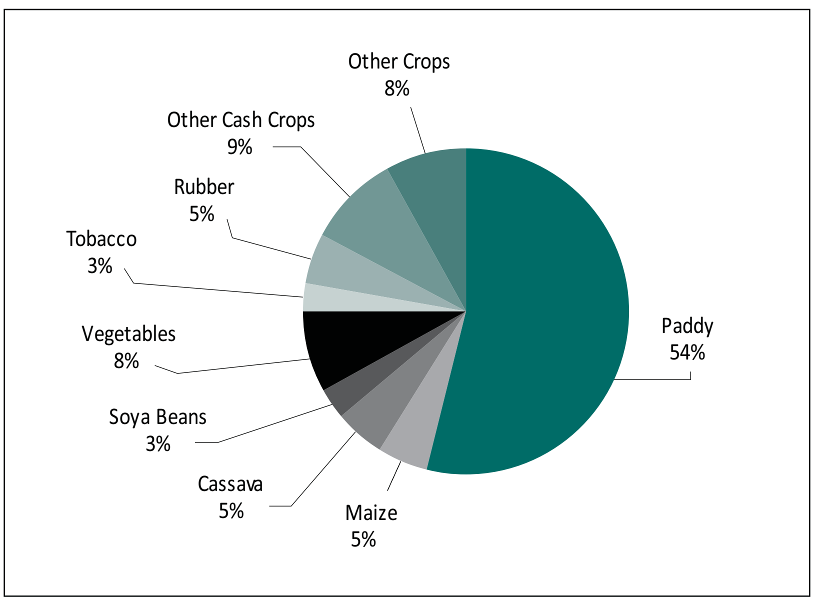
## Table 9: Main Energy Crops Worldwide

| Country | Bioethanol | Biodiesel |
|---|---|---|
| Australia | Cereals, sugarcane | Sunflower seed |
| Brazil | Sugarcane | — |
| Canada | Cereals | — |
| PRC | Sweet sorghum | — |
| Czech Republic | — | Rapeseed |
| Denmark | — | Rapeseed, sunflower seed |
| France | Sugar beet | Rapeseed, sunflower seed |
| Germany | Sugar beet | Rapeseed, sunflower seed |
| Italy | — | Rapeseed, sunflower seed |
| Spain | Sugar beet | — |
| Thailand | Cassava | Oil palm |
| United States | Maize | Soybean |

— = not available, PRC = People's Republic of China.

Source: United States Department of Agriculture, United States Department of Energy, and the European Commission.

## Figure 6: Crop Production in 2006
(%)




Source: Ministry of Agriculture, Forestry and Fisheries. 2007. *Annual Report on Agriculture, Forestry and Fisheries 2006–2007*. Phnom Penh.

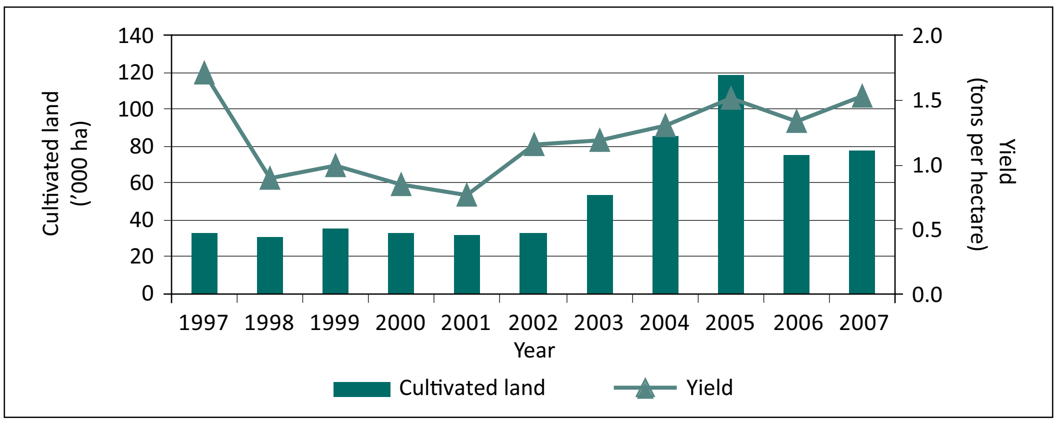
for biofuel production. The crops are further characterized below:

**Soybean.** The area planted to soybean in Cambodia in 2006 was about 75,053 ha (Figure 7). Yield was around 1.4 tons per ha (t/ha) in 2003–2008 and raw seed production was 114,000 tons per year (t/year). Generally, the oil content of soybean is about 20% by weight. In 2005, Cambodia exported 54,000 t of soybeans in the form of raw grain, amounting to 30% of total production and equivalent to 10,800 t of soybean crude oil.[12]

**Peanut.** Peanuts are grown widely in Cambodia. In 2006, about 12,990 ha were planted to peanuts. Production was 18,221 t, and this increased to around 30,000 t in 2007 (Figure 8). The oil content of peanuts is 30% by weight; therefore, the peanut crop can yield around 9,000 t of peanut oil if the cultivated area and yield can be maintained at the 2007 level. However, the majority of peanut production is used in local cooking, and a small portion is exported to Viet Nam.

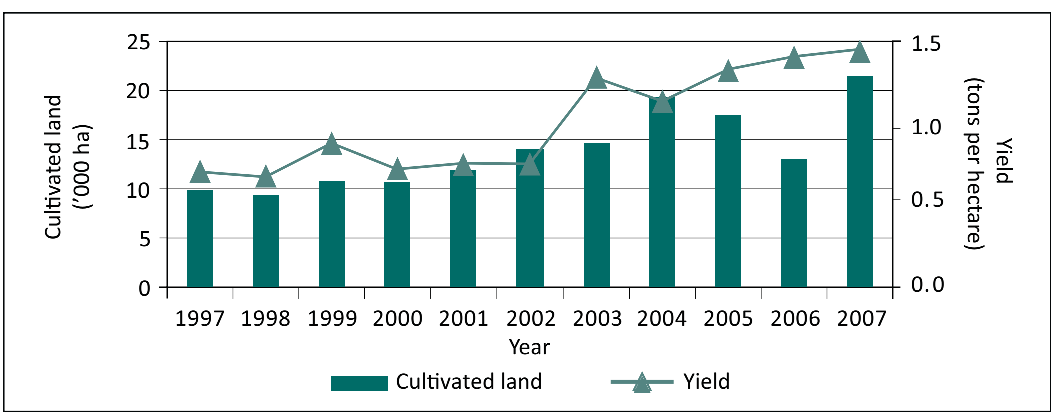
**Sesame.** Sesame is grown mostly in Pailin town, Banteay Meanchey, Battambang, Kompongcham, Kompong Thom, Kratie, Preah Vihear, and Prey Veng provinces. The area under sesame in 2006 was about 56,000 ha and production was 25,000 t (Figure 9). The oil content of sesame is about 24% by weight. Therefore, an annual production of 25,000 t could yield around 6,000 t of sesame oil. However, sesame produced in the country is used for local consumption

## Figure 7: Soybean Area and Yield Trend




Source: Ministry of Agriculture, Forestry and Fisheries. 2007.

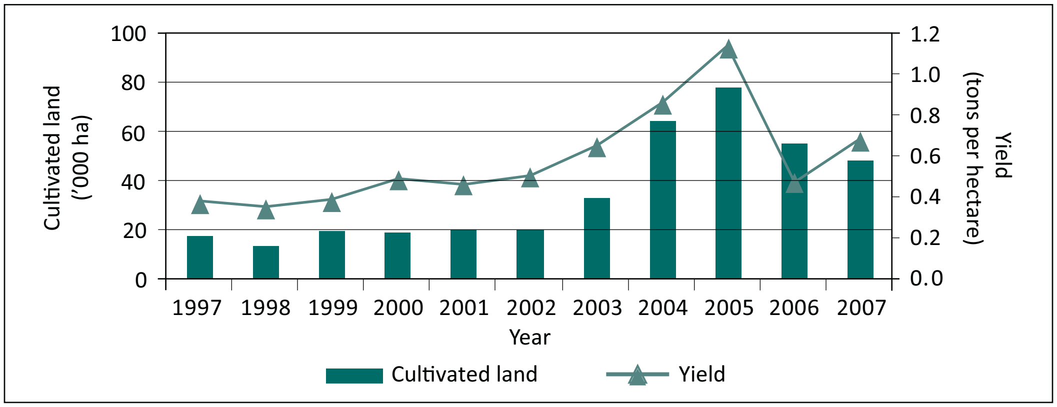
## Figure 8: Peanut Area and Yield Trend




Source: Ministry of Agriculture, Forestry and Fisheries. 2007.

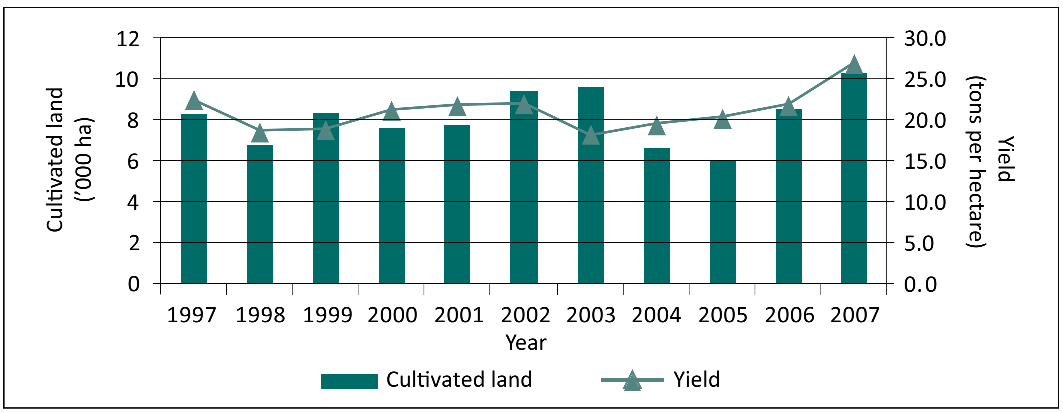
[12] Ministry of Agriculture, Forests, and Fisheries; and the Food and Agriculture Organization of the United Nations. 2007. *Final Report on Bio-Fuel Energy Feasibility Study for Food Security and Income Generation of the Rural Poor in Cambodia.* Phnom Penh. Cambodia.

**Figure 9: Sesame Area and Yield Trend**




Source: Ministry of Agriculture, Forestry and Fisheries. 2007.

**Figure 10: Sugarcane Area and Yield Trend**




Source: Ministry of Agriculture, Forestry and Fisheries. 2007.

as well as for export. The data for 2007 shows that while the land area planted to sesame declined, yield improved from 0.44 t/ha in 2006 to 0.67 t/ha in 2007.

**Sugarcane.** Sugarcane is mostly grown in areas where irrigation is available. In 2006, the area in sugarcane was about 8,358 ha (Figure 10). Total production was 176,740 t in 2006 and this increased by 62% to 286,811 t in 2007. Both the area planted and yield increased.

**Maize.** The most important non-rice crop is maize. Maize is often cultivated in the more fertile soils, including riverbanks. Planting takes place early in the wet season, and the crop is harvested in August or September just before the floods. Cultivated areas of maize are concentrated in Battambang Province, which produces some of the highest yields averaging 5.4 t/ha. Battambang Province and Pailin town combined produced 278,079 t of maize in 2006, accounting for around 76% of national production. In 2006, the total area for maize cultivation was 109,000 ha and production was 377,000 t (Figure 11). The increase in the area planted to maize reflects increased demand during last few years. Most of the maize crop is exported to Thailand.

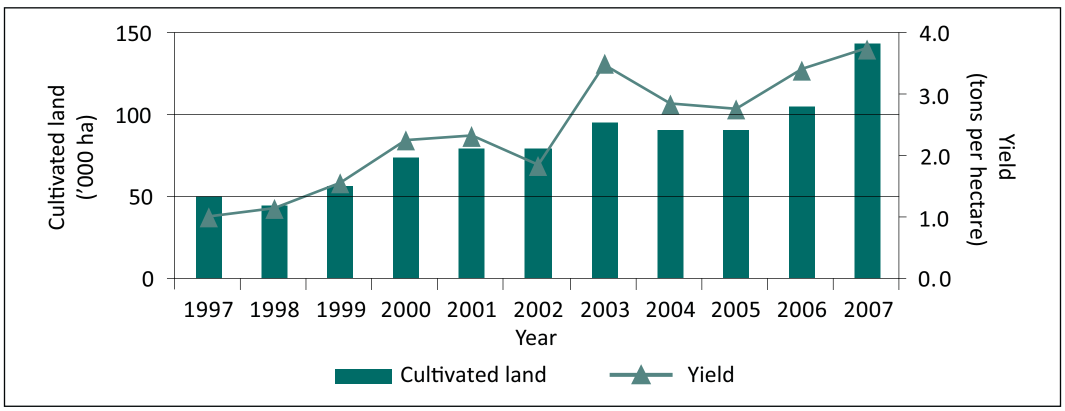
Maize is a cash crop, rather than a subsistence crop, and has the potential to improve the rural economy. For example, the concentration of maize in Battambang Province is largely a response to the demand for feed for the Thai livestock market. There is great potential for further expansion in production and income generation from maize.

**Cassava.** Cassava is one of the world's top calorie producers for human consumption. It is easy to cultivate and is generally grown without fertilizer on soils with poor fertility where other crops would fail.[13] Cassava is a valuable dual-purpose crop, producing human food and animal feed. It is also known as manioc, tapioca, and yucca in different parts of the tropics, and is an important subsistence crop for resource-poor farmers due to its capacity to produce reasonable yields for home consumption, animal feed, and income.

The area of cassava in Cambodia was 99,000 ha and production was 2.18 million tons (mt) in 2006, representing over a twofold increase in planting area and a threefold increase in production compared with 2005. In 2007, cassava production increased slightly to 2.22 mt.

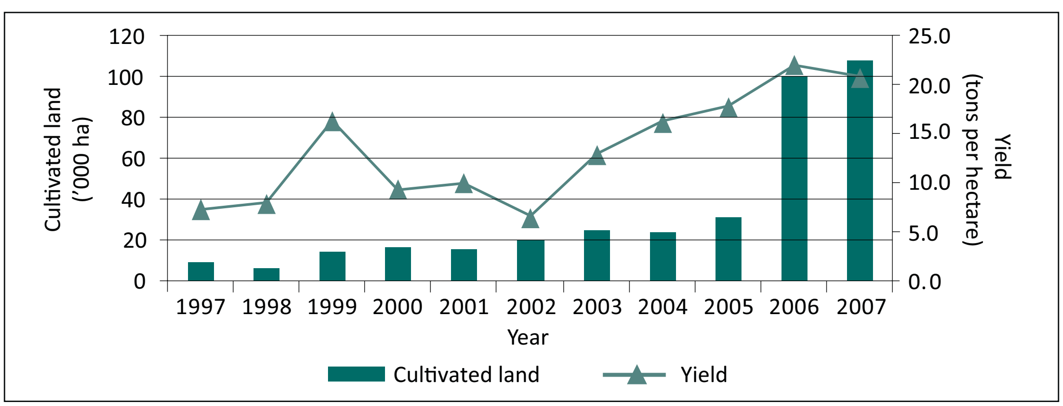
Yields averaged 20.5 t/ha in 2007 (Figure 12), which is comparable with yields in Thailand of 20.3 t/ha in 2004–2005. It is believed that Cambodian yields can be raised substantially. Thailand started with lower yields of around 14 t/ha in the late 1980s, but achieved a large increase by adopting new high-yielding and high-starch varieties. Yields in the Mekong Region are much higher than the world average of about 11 t/ha.[14]

## Figure 11: Maize Area and Yield Trend




Source: Ministry of Agriculture, Forestry and Fisheries. 2007.

## Figure 12: Cassava Area and Yield Trend




Source: Ministry of Agriculture, Forestry and Fisheries. 2007.

[13] Howler, R. H., and L. F. Cadavid. 1990. Short and Long Term Fertility Trials in Colombia to Determine the Nutrient Requirements of Cassava. *Fertilizer Research*. 26. pp 61–80.

[14] Markandya, A., and S. Setboonsarng. 2008. *Organic Crops or Energy Crops? Options for Rural Development in Cambodia and the Lao People's Democratic Republic.* Asian Development Bank Institute. Tokyo.

**Jatropha.** *Jatropha curcas*, or the physic nut plant, is common in Cambodia where it is known as Lhong Kwong.[15] Jatropha, as it is commonly known, is generally grown as bio-fencing to protect farmland and houses from soil erosion due to wind and water, and is used as a natural fence or hedge because animals do not eat it. One critical observation is that it contains hydrocyanic acid, a toxic substance. It is a drought-resistant perennial that grows on marginal soil and has a life span of up to 50 years. A close relative of the castor oil plant, its seeds contain about 35% non-edible oil. Its productivity can be improved by using better seeds and applying inputs to maintain yields at a level that allows commercial use and gives sustained returns to farmers.

The energy content of jatropha oil is similar to that of diesel oil and jatropha oil can be substituted directly in most diesel engines. The oil can also be used as a lubricant and for making high-quality soap, and the seed cake residues from oil extraction can be used as a high-grade fertilizer. Farmers traditionally use jatropha oil for lighting. However, the recent interest in extracting the oil and marketing it on a commercial scale has attracted small-scale farmer entrepreneurs. Farmers report that 1 ha of jatropha yields about 2,500 kilograms (kg) of seeds with 25% oil content. Some empirical calculations indicate that a total of 68,000 t of jatropha seeds are produced every year in Cambodia, with an annual yield potential of 17,000 t of oil (footnote 11).

**Oil Palm.** In 2005, oil palm fields covered about 4,000 ha of southern Cambodia, such as Sihanoukville, producing about 60,000 t/year of palm seeds, with an oil content of about 20% by weight. This can produce about 12,000 t of crude palm oil. According to the MAFF's statistics, all crude palm oil is exported since Cambodia does not have an oil refinery.

### Technology and Processing

In Cambodia, the technology is available to extract oil from seeds and convert jatropha oil to biodiesel for use in diesel engines. The technology for producing bioethanol is not available, although it is well-developed in other Southeast Asian countries, such as Thailand.

Having observed the promotion of pilot biodiesel projects and commercialized energy technology, various nongovernment organizations (NGOs), academics, and private enterprises are now conducting studies to formulate the energy supply chain, and train and disseminate information for the planting of jatropha and the use of biodiesel. While project impact assessments have been conducted, the scale is still small and large-scale private enterprise is not yet fully motivated to implement biodiesel development projects.

The process to produce biofuel mainly from jatropha seeds is relatively simple and has been summarized by A. Williamson (footnote 11) as follows:

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

2. **Seed Drying** – the fruit is opened and the three or four seeds inside each are removed and sundried 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, moldy, 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.[16]

5. **Oil Filtering** – the extracted oil is passed through a press filter that removes all remaining seed

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[15] Williamson, A. 2006. *Biofuel: A Sustainable Solution for Cambodia?* Cambodian Research Center for Development. Phnom Penh.

[16] Estimate based on technical specifications for a 12-horsepower diesel engine driving a TinyTech Oil Mill manufactured by Tinytech, India.

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, airtight 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.

A key to the economic feasibility and sustainability of biodiesel projects and businesses is to have a constant supply of the raw material. Thus it is essential that this is considered carefully early in the planning phase of any biodiesel project.

### Early Initiatives in Biofuel Production

In 1994, the Mong Reththy Group and its South Korean venture partner, Borim Universal, launched a large-scale project to plant oil palms on 11,000 ha near Sihanoukville. The project is the first commercially motivated attempt to develop a vegetable oil plantation in Cambodia.

The commercial planting of jatropha to produce biodiesel has also attracted attention more recently, and the area planted has expanded to about 500 ha. These projects provide precedents in relation to land ownership and investment incentives for jatropha plantation which can be useful in evaluating future large-scale oil crop plantation projects.

The Biofuel for Rural Electrification in Cambodia project, in cooperation with Groupe Energies Renouvelables, Environnement et Solidarités Cambodia, a French NGO involved in energy, environment, and poverty reduction, and the Institute of Technology of Cambodia (ITC)—a national academic institute located in Phnom Penh—conducted a test of a small diesel engine with crude vegetable oil. The overall objective was to evaluate the performance of a small diesel engine run on crude vegetable oil, and to assess its durability at 100% load for a specific period of time.

Some Cambodian entrepreneurs and businesses have already invested in small-scale pilot jatropha plantations and have successfully extracted crude jatropha oil from seeds. However, initial trials on 100% replacement of diesel fuel with crude jatropha oil in electricity generation were not satisfactory due to engine failures after a short period of operation. The cause of engine failure has not been identified or evaluated due to limited knowledge and institutional capacity.

Mr. Tham Bun Hak of Botrang village, Batrang commune, Mong Kul Bory District, Banteay Meanchey Province is a showcase for the application of jatropha oil in rural electricity enterprises. He produces biofuel from jatropha and kapok, and uses it in his diesel engines to provide electricity to 83 households. After several trials, he successfully produced biofuel from jatropha seed oil for the first time in 2005; however, he acknowledges that the biodiesel is still low quality because it is sticky. The technology will be developed further to improve the quality of the fuel.

As for biodiesel production, Maharishi Vedic University located in Prey Veng Province has completed a biodiesel refinery that can produce 200 liters per day (l/day). Development and Appropriate Technology (DATe), a local NGO, has also established a new rural business model that will produce biodiesel and seed cake fertilizer from jatropha. DATe has also conducted a training program for local farmers to teach them how to plant, harvest seeds, and process them to produce biodiesel in their communities.

Biodiesel Cambodia is piloting a project to produce biodiesel in de-mined areas in Banteay Meanchey on a 10 ha trial plantation of jatropha in cooperation with local NGOs. The NGOs will identify participating farmers, train them, and give other support. Biodiesel Cambodia is to source the capital to run the project for 2 years until the project is sustainable, and provide a guaranteed market for the farmers' crops. It also has the technology to extract the oil from the seeds and process the oil into biodiesel for use in diesel engines. Biodiesel Cambodia owns a small pilot refinery that can produce 500 l/day and a biodiesel machine that it uses to convert old cooking oil and jatropha plant oil into international-standard biodiesel.

Jatropha yields vary depending on farming techniques. Under optimum growing conditions, including proper pruning and irrigation, each shrub can produce as much as 9 kg of seeds per year once it reaches maturity in its fifth year. In Thailand, yields can reach

20 kg per tree. The yield differences may be due to the species used and farming techniques. To increase the yield of jatropha in Cambodia, new species with optimum yield and high adaptability will be needed, as well as improved farming techniques.

### Research and Development into Biofuel Technology

Research and development and demonstration of biofuel production in Cambodia remain at their infancy. The only institute to conduct research on the production of vegetable oils and ethanol is the ICT.

The ITC conducted research on the technology for small-scale biodiesel production. Vegetable oil was extracted from jatropha, and subjected to etherification to obtain methyl-ester and glycerin. But the final cleaning step for biodiesel has not been developed due to the high cost of investment for quality management. Before biodiesel can be used, technology will need to be developed to reduce or remove the phosphorus content of biodiesel, and to improve storage conditions to reduce acidity and ensure quality.[17] The ITC has not yet developed these technologies.

The technology for processing cassava to extract 95% ethanol has been applied on a small scale at the ITC. The further process of dehydrating the 95% ethanol to produce 99% ethanol needs to be developed to produce purified ethanol for blending with gasoline.

The Royal University of Agriculture and the ITC could collaborate fruitfully on research to develop feedstock and sustainable management practices that reduce pressure on farmland and food security, and to develop technologies for harvesting, processing, transporting, and storing feedstock and fuel. In the future, research and development should aim at appropriate sizing of the technology according to the required application, cost reduction, and the improvement of overall efficiency.

Before releasing biofuel onto the market, the Cambodian government should strongly support the development of technology to produce good quality biofuel. In addition, the government should promote biofuel blends of 5%, 10%, or 20%. Technology to remove the stickiness of jatropha-based biodiesel is also needed to enable diesel generators to run well on biodiesel alone, without mixing it with fossil diesel.

## Available Resources for Biofuel Production

### Land

Careful land management is critical to socioeconomic development as 85% of the population relies on agriculture, fisheries, and forest products for their livelihoods. Cambodia's total land area of 181,035 km² comprises 61% forests, 5% agriculture, 8% scrub land, and 16% other uses such as urban areas and fishing concessions (Figure 13). Cambodian agriculture is predominantly organized on the basis of small farming communities. The plight of these communities in relation to access to natural resources and land ownership is possibly one of the most significant factors related to land-use issues today. In this regard, the Statement of the Royal Government on Land Policy, issued in 2001, aims to (i) strengthen land tenure, security, and land markets, and prevent or resolve land disputes; (ii) manage land and natural resources in an equitable, sustainable, and efficient manner; and (iii) promote land distribution in an equitable manner.

Since the 1990s, the main change in land use has been the establishment of industrial concessions in forestry, fisheries, and, more recently, agriculture. The unsustainable use of many of these concessions, combined with their inability to increase economic activity at the local level, has led the government to seek alternative management practices that will support its goal of poverty reduction and will maintain or improve the environment.

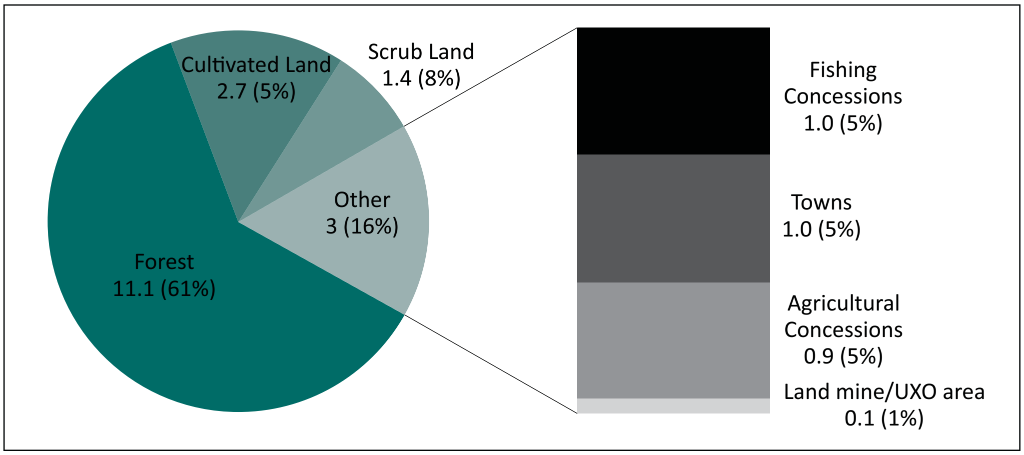
Fertile land is mostly used for rice production. Fields not used for rice are planted to maize, mung bean, soybean, cassava, and sugarcane. Rubber is also an important crop in eastern Cambodia. Cultivated agricultural land is estimated at around 3.5 million ha out of a total agricultural area of about 4.1 million ha.

More land, including previously forested land, is being converted to arable use, and between 2002 and 2006, about 0.4 million ha of forest was cleared.[18] Forest

[17] Personal communication with the ITC researchers.

[18] Danish International Development Agency. 2006.

**Figure 13: Land Use**
(million hectares)




UXO = unexploded ordinance.

Note: figures in parentheses show the percentage of the total land area.

Source: Danish International Development Agency. 2006.

resources in the form of firewood, charcoal, and timber are an important income source, especially for the rural population. As a result, forest degradation and clearance in areas with low agricultural potential is increasing. It may be assumed that land scarcity caused by rapid population growth exaggerates this trend. Most industrial land and cleared forest areas are suited to biofuel crop production. The total land area available for biofuel crop production from this source is over 1.5 million ha.

### Rainfall

Rainfall of at least 600 millimeters (mm) per year is needed in areas where jatropha and cassava are planted. Cambodia's average annual rainfall is 1,604 mm, ranging from 1,200 mm in Battambang Province to more than 3,500 mm in the coastal zone and highlands. The dry period (less than 40 mm rain per month) ranges from 1 month (Bokor Mountain) to 5 months in Siem Reap Province.

The erratic rainfall over most of Cambodia may create difficulties for crop emergence. Intense rainfall coupled with low soil structural stability causes loss of surface soils, making them prone to form hard crusts as they dry. Crusting impedes seedling emergence, so a well-maintained nursery is necessary for the propagation of fuel crops such as jatropha. Good drainage is also needed as waterlogging is harmful to jatropha, especially if prolonged.

### Labor Supply

Total employment in 1993 was estimated at 3.9 million, increasing to 7.5 million by 2004. Between 1993 and 2004 employment in agriculture declined from 81% to 60.3%, industry's share of employment increased from 3% to 12.5%, and services increased from 16% to 27.2%.

**Labor force participation, employment and unemployment rates.** According to the 2004 Cambodia Socio-Economic Survey, the labor force participation rate for females was 70.7% and that for males was 78.9%.[19] The employment rate for females was 99.1%, and the female unemployment rate was 0.8%, while the rates for men were the same as for the total labor force. Labor force participation rate in Phnom Penh at 60.8% and in other urban areas 69.5%, compared with 77.0% in the rural areas.

The employment rate in Phnom Penh for females was 96.2%, and that for males was 97.3%. In other

[19] National Institute of Statistics. 2006. *Cambodia Statistical Yearbook, 2006*. Ministry of Planning, Royal Government of Cambodia. Phnom Penh.

urban areas the employment rate for females was 98.6%, and that for males was 98.8%. By contrast, the employment rate was slightly higher in rural areas for females (99.5%) than for males (99.4%). The unemployment rates for females were higher in Phnom Penh (3.8% for females, 2.7% for males) and other urban areas (1.4% for females, 1.2% for males) but lower in rural areas (0.5% for females, 0.6% for males).

**Primary industry and employment sector.** About 68.1% of employed persons in rural areas worked in agriculture, compared with 2.6% in Phnom Penh and 40.3% in other urban areas. The main sources of employment were crop production (41.6%), retail trade (13.4%), livestock farming (11.7%), and fishing (4.8%).

The main sources of employment in urban areas excluding Phnom Penh were crop production (25.8%), retail trade (23.3%), livestock farming (7.2%), and fishing (6.5%). In rural areas, the main sources of employment were crop production (47.2%), livestock farming (13.6%), retail trade (10.3%), and the manufacture of textiles, garments, and footwear (3.7%).

**Primary occupation and employment status.** The primary occupation of 42.3% of Cambodian workers was crop, fruit, and vegetable growing; 12.0% were dairy, livestock, and poultry producers or workers; 15.2% were models, salespersons, and demonstrators; and 4.8% were fishery producers or workers.

About 34.4% of employed persons were own-account workers[20] and a further 43.3% were unpaid family workers. Only around 20.0% were paid employees. Employers accounted for 0.1% and others accounted for 0.5% of total employed persons. The employment status of 1.5% of employed persons was not specified.

**Average hours worked.** In 2004, Cambodians worked an average of 43 hours a week. Paid employees worked longer, averaging 51 hours a week, compared with 45 hours for employers, 46 hours for own-account workers, and 37 hours for unpaid family workers. On average, workers in urban areas worked longer hours (46 hours) than rural workers (42 hours).

**Earnings and wages.** The average monthly cash wage for paid employees in November 2001 was around KR125,000, compared with average monthly earnings in cash or in kind for employers and own-account workers of approximately KR100,000.

### Sources of Finance

**Commercial banks.** Cambodia's commercial banking subsector is vibrant, competitive, and innovative, and is expanding rapidly to fulfill its role in the high-growth economy. There are 15 fully licensed banks and 6 licensed specialized banks. Most banks have established additional branches in other urban centers and plan to continue to expand their activities. On average, each bank branch provides full banking services to 460,000 customers. Acleda Bank is the leading commercial bank with about 219 branches covering all provinces and cities in Cambodia.

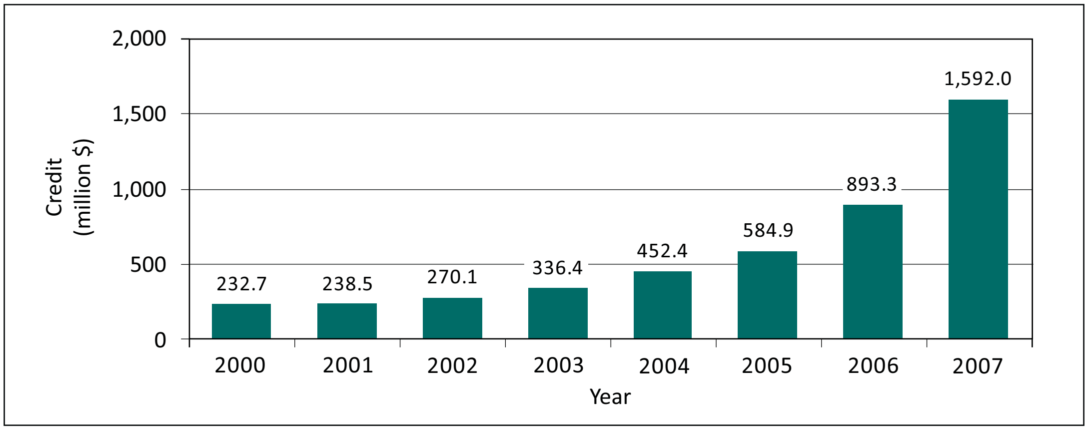
Commercial banking is growing rapidly, with the more aggressive and progressive banks attaining annual growth rates of 40%–100% in deposits. Similarly, loans to the private sector increased rapidly from $233 million in 2000 to more than $1.6 billion in 2007 (Figure 14).

Small and medium-sized enterprises receive 90% of commercial bank lending. These organizations generally do not maintain written financial records and cannot provide clear explanations of the financial aspects of the proposal. To manage risk, loans are secured by collateral, usually in the form of land certificates. Banks now encourage customers, including small and medium-sized enterprises seeking working capital, to compile and maintain financial records. High interest rates of around 16%–20% per annum are charged.

**Microfinance institutions.** Only a minority of the rural population has access to credit for consumption or production. There are 17 licensed microfinance institutions and 86 NGO-type microfinance operators,

[20] According to the Organisation of Economic Cooperation and Development (OECD) glossary of statistical terms, own-account workers are those workers who, working on their own account or with one or more partners, hold the type of job defined as a self-employed job, and have not engaged on a continuous basis any employees to work for them during the reference period. It should be noted that during the reference period the members of this group may have engaged employees, provided that this is on a noncontinuous basis. The partners may or may not be members of the same family or household.

**Figure 14: Amount of Credit to the Private Sector**
(millions $)




Source: National Bank of Cambodia. 2008.

26 of which were registered with the National Bank of Cambodia in 2008. Rural credit is used to cushion weather shocks or unanticipated cash shortfalls in the production cycle. It is also used for capital investment and working capital, including the purchase of agricultural tools, seeds, fertilizers, pesticides, and payments for labor. In 1994–1995, 704,000 families accessed rural credit to the value of $120 million. According to the National Bank of Cambodia, in 2003–2004 the number of families obtaining rural credit rose to 940,000, and the sum borrowed also increased sharply to about $200 million. Borrowing from formal institutions (banks and NGOs or microfinance institutions) comprised about 10% of total borrowing by families in 1994–1995.[21] This share increased to 20% in 2003–2004. The market share of moneylenders also increased from 15% to 25% during the same period, while the share of traders and merchants remained unchanged. As a consequence, informal borrowing from family members was cut by almost half from 52.6%.

Statistics gathered by the National Bank of Cambodia show that in 2007, microfinance institutions loaned $158 million to 624,089 customers and collected deposits of $6 million from 148,000 customers. That represents an increase of 71% in loans, 32% in borrowers, 103% in deposits, and 30% in depositors over 2006 figures.

The 9% average monthly interest rate from moneylenders was high compared with the 5%–6% offered by the formal institutions. The average size of a loan from a bank was $400, while the average size of loans from NGOs and moneylenders was about a half that amount. The interest rate of NGOs was only half that of the moneylenders. The limited outreach of formal credit was due to both demand and supply constraints.

Loans to agriculture have increased significantly over the last 3 years from $37 million in 2004 to a little over $144 million in 2007. This reflects the better returns to agriculture. Microfinance institutions have played a significant role in providing loans for agricultural investment, especially small and medium-sized enterprises. The share of all loans provided by microfinance institutions increased to almost a half, helped by their accessibility to the local population.

[21] Microfinance institutions in Cambodia established by both the government and national and international NGOs have been operating since the 1990s. Microfinance operations performed by NGOs in the 1990s were neither regulated nor supervised. The Law on Banking and Financial Institutions promulgated in late 1999 has prescribed the regulatory and supervisory framework for microfinance institutions, which has helped the microfinance sector to grow modestly. The National Bank of Cambodia provides the overall regulatory and supervisory oversight of this sector with the objective of ensuring financial sustainability and preventing financial mismanagement of the regulated institutions.

Although commercial banking is well established in Cambodia, it is not fully mature. As in all growing industries, the lack of experienced personnel in commercial banking at all levels has restricted planned growth and caused an increase in compensation due to the scarcity and high demand for suitably qualified and experienced staff. Capacity building in banking and other finance sector activities is therefore crucial to sustain the recent high growth rates.

Conditions to ensure the sustainability of the banking system must be firmly embedded in the regulatory and supervisory mechanisms. Strengthening the legal infrastructure, electronic automation of National Bank of Cambodia's processes, establishment of an interbank and capital (stock exchange) market, and further capacity building will all help sustain the development of the banking system.

Cambodia's banking system is well capitalized and highly liquid. Its profitability has doubled. However, the concentration of the banking sector has accelerated during the last few years, with 71% of all loans granted by the five largest banks.

Microfinance institutions in Cambodia are highly liquid. The liquidity ratio was 3.6% in 2005, 4.1% in 2006, and 2.6% in 2007. This is because its assets were mostly short term and do not collect deposits. The National Bank of Cambodia has a cautious role to play in advancing rural credit to maintain a balance between management capacity and the growth of microfinance institutions. The license provided to these institutions limits them to certain activities in which deposit is mostly not allowed. The level of nonperforming loans was only around 0.2% in 2007.

## Potential Oil Crops for Biofuel Production

### Production of Biodiesel from Jatropha

Considering the characteristics and requirements of oil crops, it appears that only oil palm and jatropha are suitable for biodiesel production in Cambodia. There is limited land suitable for oil palm trees, which require a tropical forest climate with an annual rainfall of over 3,000 mm. Within this range, only Sihanoukville Province, with an estimated 2,937 mm, and Koh Kong Province, with 3,512 mm, qualify. Jatropha is being grown in Kompong Speu, Battambang, Banteay Meanchey, Prey Veng, Siem Reap, Kompot, Kep (Kampot) and probably also in other provinces that are not yet aware of it. The trees are not difficult to grow and their rainfall requirements are 300 mm to 1,500 mm per year. In Cambodia, the normal range is between 1,000 mm and 3,512 mm per year. Being an inedible plant that has no other commercial value, its use for biodiesel production does not affect food security directly and adds economic value.

The current trend of expanding agriculture onto unused land or cleared forested areas is widespread throughout rural areas. Previously forested lands under cultivation are not of medium to low fertility. Jatropha is an attractive crop because it is productive in relatively poor soils and is a drought-resistant perennial. It can therefore be planted on cleared forest land to combat deforestation and prevent land degradation, which leads to landslides, soil erosion, and soil nutrient outflow during heavy rainfall. It can be used as a natural fence or hedge because animals do not eat it. These characteristics make jatropha a priority raw material for biodiesel production in Cambodia (footnote 11).

Currently, jatropha occupies a very small portion of the 3.8 million ha of land currently used for agriculture in Cambodia.[22] Eighty percent of the nation's farmers grow rice, maize, corn, cassava, soybeans, and other vegetables. Soaring food prices have been blamed, at least in part, on the conversion of land to grow crops for biofuel. However jatropha plantations avoid conflicts with existing food crops because they require completely different types of soil from rice and cannot be grown on the same land. Rice requires low-lying land with extensive surface water, whereas jatropha requires well-drained soil and cannot survive when the soil is continuously saturated.

For every hectare planted with jatropha, one farm job is created, and farmers can generate income from selling jatropha seeds at KR500/kg. to supplement and diversify farm income. When biodiesel refineries are established, low-priced fuel will become available for agriculture, industry, and transport.

[22] David. 2008. Biofuel Boom? *Economics Today*. 2 (14). 1–15 May.

A significant benefit of planting jatropha is the increased income and improved livelihood it can provide for the rural poor by making land productive and by diversifying crops. In addition, the residue that remains when oil is extracted from jatropha seeds is high in carbohydrates, nutrients, and energy and has been used successfully in other countries as a natural fertilizer. Chemical analysis suggests it would be beneficial for a range of crops and conditions, such as mushroom cultivation, and it may also be useful as an ingredient in stock feed (Table 10).

A small pilot project on jatropha-based biofuel for sustainable development and poverty reduction in rural Cambodia, implemented at Kompong Chhnang Province and run by Development and Appropriate Technology (DATe), showed that the project directly helped reduce poverty by introducing a viable, replicable new rural enterprise with two levels of income and job creation—nut collection and biofuel production. The purchase of seeds from villagers can be done in a barter exchange system, in which shopkeepers provide their customers goods to the value of their seed, calculated at the fixed rate offered by oil producers. This greatly benefits poor families with insufficient cash flow at some times of the year, particularly given that the peak of these income-generating activities coincides with the "food gap" at the end of the rice-planting period. This is typically the hardest time of year for poor rice farmers because most of their cash has been invested in planting rice and they must wait until the rice is harvested before they realize income. Families often go into debt at this time, or start other temporary income-generating activities such as charcoal production. In the long run, the project will also indirectly help reduce poverty by providing a cheaper and more secure source of fuel, and will reduce the proportion of household income spent on energy. A cheaper source of energy will also remove one of the barriers that entrepreneurs face in developing economic activities in rural areas.

Another pilot program conducted in four villages in Kampong Province with support from the Canada Fund and a private donor achieved similar results. The government should therefore look to expand production on a significant scale by supporting the growing of jatropha among smallholders and by allowing concessions of jatropha on government-owned land. The cultivation of the crop by smallholders is more likely to benefit the poor and raise rural incomes, whereas allowing concessions on government-owned land is more profitable and would have the benefit of increasing the domestic production of a diesel substitute. Underemployment in rural areas and the presence of microfinance institutions could help make this a reality.

The long-term sustainability of the production of jatropha biodiesel is contingent on the following conditions being met:

Ecological: The rate of soil nutrient extraction (including not only nitrogen, phosphorus, and potassium, but also other important secondary and macronutrients) should not exceed natural replacement rates, or extracted nutrients should be replaced artificially; irrigation should be sustainable; and the planting of jatropha should not

**Table 10: Analysis of Jatropha Seed Cake**

| Parameter | Value | Method |
|---|---|---|
| Humidity | 10% | Drying |
| Acidity | 1.55 mg Potassium Hydroxyde (g) | Titration |
| Residual oil | 8.3% | Extraction |
| Protein (N X 6.26) | 8.27 % | Kjeldahl |
| Total carbohydrate:<br>- α-chain (starch)<br>- β-chain (cellulose) | 24.4 % (g/g)<br>31 % (g/g) | Titration<br>Extraction |
| Phosphorus content | 1.03 % (g/g) | Spectrophotometer |
| Potassium (K+) | 0.66 % (g/g) | Atomic Absorption |

Source: Institute of Technology of Cambodia. 2005.

increase erosion and other forms of mechanical soil degradation.

Socioeconomic: The production of jatropha seeds and biofuel should not lead to a net decrease in income in the mid- to long term for those involved; production should not lead to a significant increase in financial risks (e.g., because of loans needed for investments or because of increased dependence on volatile market prices for income); production should not increase financial inequality (e.g., by favoring large landowners or companies, and further marginalizing the rural poor due to factors such as increasing land prices); production should not increase gender inequality (e.g., by further marginalizing the role of women in communities or families); and cultivation of public wasteland should not displace landless people without offering them a viable alternative.

Land Issues: Land in its natural (uncultivated) state should not be converted to agricultural land for biodiesel production or to maintain the production of other crops; existing land should be used, and degraded lands should be restored where possible.

Jatropha biodiesel production may improve food security if one or more of the following conditions are met: (i) soil erosion decreases, and soil infiltration and water-retaining capacity increases; (ii) soil nutrient levels are restored; (iii) firewood is partially or fully replaced as a rural fuel source for cooking, heating, and lighting; (iv) diesel is partially or fully replaced, thus reducing expenses for and dependence on fossil fuels; (v) extra income is generated by marginal groups; (vi) gender equality improves, e.g., by allowing women to generate their own income; and (vii) agricultural diversity increases, thus reducing problems related to monoculture and spreading the risk of market or crop failure over multiple crops.

### Production of Bioethanol from Cassava and Sugarcane

Cambodia does not have a clear policy framework for agricultural production. Land allocation is based more on market signals than on coordination among farmers. Thus, the country has not targeted any crops for biofuel development. Cambodia should consider following Thailand's lead, given its similar climatic conditions and land structure. In Thailand, sugar and cassava are the main raw materials for producing bioethanol.

Cassava can be grown without irrigation under rain-fed conditions and in areas of low soil fertility, and is grown mostly on soils that have already been degraded and eroded.[23] Cambodia's rainfall (1,000–3,512 mm/year) is favorable for cassava, which requires annual rainfall of 500–2,500 mm. Sugarcane, on the other hand, normally requires irrigation; therefore, growing areas will be limited to areas where irrigation systems are available or can be developed. Under the current trend of expanding agriculture into unused land, cassava has good prospects when grown on cleared forestland with soil of low to medium fertility, as it can combat deforestation and prevent land degradation (Table 11). Provinces such as Battambang and Pailin, and Kompong Cham are already growing cassava for Thai, Vietnamese, and Chinese buyers.

**Table 11: Comparison of Cassava and Sugarcane for Biofuel Production**

| **Raw Material** | **Rainfall** (mm) | **Yield** (tons/ha) | **Cost** ($/ton) | **Biofuel Production Cost** ($/ liter) | **Impact on Food Security** |
|---|---|---|---|---|---|
| Cassava | 500–2,500 | 20 (fresh)<br>13.3 (dry) | 73 (fresh)<br>170 (dry) | 0.18 | positive |
| Sugarcane | Irrigation needed | 20–40 | 120 | 0.14 | positive |

ha = hectare, mm = millimeter.

Source: Authors.

23 Ung, L. 2006. Cambodian Agriculture Development Institute. Ministry of Agriculture, Forestry and Fisheries. Phnom Penh.

The experience of Thailand suggests that Cambodian yields could be raised substantially. Thailand started with yields of around 14 t/ha in the late 1980s, but achieved large increases by adopting new high-yielding and high-starch varieties. Yields in the Mekong Region are much higher than the world average of about 11 t/ha.

In Cambodia, a private sector initiative is currently seeking to produce ethanol from cassava, partly by leasing land to grow the crop and partly through concessions granted to the company. The Korean company, MH Bio-Energy Group, set up a facility 15 km from Phnom Penh with a production capacity of 40 million l/year from 85,000 t of tapioca chips (a dried cassava product). It aims to procure 300,000 t of chips by 2010.

A program is also in progress to increase cassava production in the country from about 2.2 mt of fresh root in 2006 to about 5.0 mt by 2011. The additional production will be processed to ethanol and some by-products, notably carbon dioxide. Production of the additional cassava will be undertaken partly by smallholders and partly by concessions given to the companies that will produce the ethanol. One such concession has already been granted to MH Bio-Energy Group, which will procure from the army as well as other government land 175,000 t of feedstock, yielding 80,000 t of cassava chips. Production by smallholders is more likely to benefit the poor and raise rural incomes.

In Cambodia, cassava is grown as a feed crop, and small quantities are exported. In Thailand, the estimated cost of producing cassava is $341.7/ha for the average farmer. If the yield is 20.3 t/ha and the root price is $21.6/t, the farmer can expect to get a gross income of $438.48/ha and net return of $96.78/ha. This is above the average for crops in Cambodia ($46.3/ha) and is comparable with that of rice (around $100/ha). Consequently, farmers would have an incentive to grow cassava on cleared forestland and unused land that is not suited to rice and other higher-value crops. The planting of cassava can complement other income-generating activities.

To expand the planting of cassava for bioethanol production, the government should send a clear message backed by a bioenergy plan and legislation, as many other countries have done. This should include (i) the rationale; (ii) details of the bioethanol plan; (iii) construction of a pilot bioethanol plant and experiments with E5 (a 5% mix of bioethanol with gasoline); and (iv) implementation nationwide of E5, 10, and 20 (5%, 10%, and 20% blends of bioethanol with gasoline).

# Agribusiness Models in Practice

In rural areas, smallholders are at a disadvantage because farms are fragmented and have a wide geographic spread. The few buyers commonly have a higher bargaining power. Lack of storage facilities and periodic urgent cash needs further weaken the position of smallholder farmers. As a result, they tend to farm for subsistence rather than for commerce, and thus limit the supply chain of agricultural produce. In agriculture, the market often fails to transfer a fair value-added to the mass sellers, and this results in an uncertain supply chain.

To secure the supply chain, an economic land concession system operated by large firms with a hired labor force has been introduced. The system involves substantial investment, better infrastructure, and high-level technology. Because the wage or salary is fixed due to excess labor supply, wages are generally low, and this has an impact on labor efficiency.

Experience now shows that win–win outcomes are possible, a commercially viable business model that either establishes a reliable supply chain or increases the value-added that accrues to small farmers. As Cambodia has great potential for biofuel crops, this opportunity should be captured for the benefit of the majority of smallholders, 68% of whom have less than 1 ha of agricultural land. This section gives an overview of lessons learned about business models for small farmers in modernizing markets and agro-industries.

## Existing Biofuel Business Model

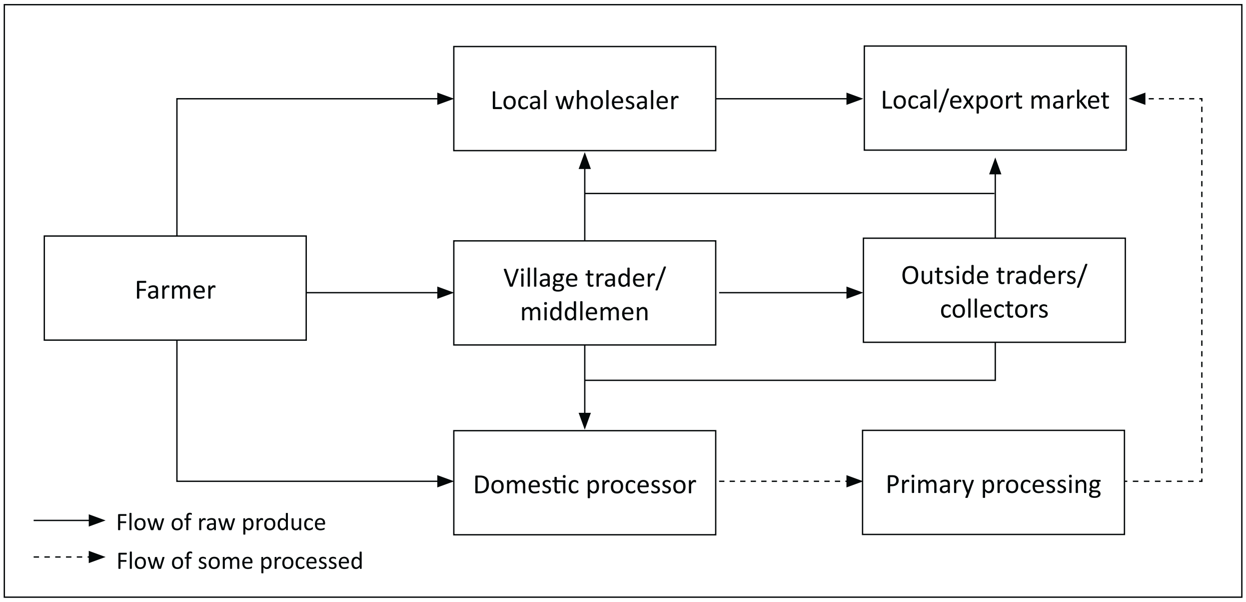
At present, biofuel production in Cambodia is in its infancy. Soybean, cassava, maize, sugarcane, and jatropha are the biofuel crops planted. Soybean is grown mainly in Battambang in the Tonle Sap region and in Kampong Cham in the plains region, but most of it is exported. Cassava cultivation has increased significantly, and is mainly grown in Kampong Cham Province. Maize is grown in Battambang, Tonle Sap, and Pailin in the mountain region. Sugarcane is grown in Kampong Cham and Kampong Thom provinces. The bulk of the agricultural produce is exported to Viet Nam and Thailand.

In the existing business model, the farmers' produce reaches the export market via a hierarchical structure of village traders or middlemen, local wholesalers, and outside collectors (Figure 10). A small proportion of the products is processed locally, and the export market absorbs almost 95% of all cash crop production, including cashew nut, cassava, maize, and soybean. Under this model, the estimated farm gate price is around 70%–75% of the border price, which is similar to the percentage for rice export.

The lower farm gate price is due not to the market structure alone but also to high transport costs and the add-on unofficial fee that serves as an informal export tax. Rural roads have improved, but the fuel cost remains relatively high. The margin that traders earn is not unreasonable because they are highly competitive. Advanced buying from farmers is also common, especially when farmers are in urgent need of money at the end of a cropping season. In exchange for credit, village traders set an advanced price which is usually 30% lower than the expected price. Farmers' expenses cannot wait until after harvest, and the formal credit system does not accept produce in the field as collateral for small amounts of credit.

Under MH Bio-Energy's model, farmers are offered a guaranteed demand at a reasonable price. The company also secures its input by investing in 1,000 ha of cassava plantations. The company offers technical services, free seed, and a buying guarantee to small farmers. The ethanol is produced for export. This model enables farmers to sell directly to the factory, which raises the farm gate price. The factory

## Figure 15: Marketing Chain of Cash Crops




Source: Hach et al. 2001; and Field Study. 2006.

competes with collectors and processors for the farmers' produce. Expanding the choice to farmers could considerably increase the farm gate price and maintain farmers' interest in cultivating the crop.

A similar project based on jatropha is being piloted in Kampong Chhnang Province and the local NGO, Development and Appropriate Technology (DATe), is contracted to operate it with financial support from a Singapore-based company. The project is being piloted on a 100 ha plantation and employs 30 workers. A jatropha oil refinery will be constructed and inputs will be secured from the plantation and from farmers who will be engaged through contract farming or a buying guarantee at the market price. Around 10 projects have been piloted in a similar way to assess the adaptability of jatropha to the soil and weather conditions. Under such a model, firms will plant some jatropha to secure their input supply and the contract farming system will be used to supplement the supply of feedstock to the oil refinery. Most of the investors expect to export the jatropha oil rather than use it domestically.

An experiment used jatropha oil for a small-scale electricity generator. This project focused on private rural electricity enterprise, which used jatropha oil exclusively for electricity generation. The pilot project is partly funded by German development cooperation through the German Agency for Technical Cooperation to promote biofuel awareness and development in Cambodia. It provided the project generator and the oil expeller equipment with a capacity of 200 l/hour. The generator runs on the seed yield from 6 ha of jatropha, or about 5 t of seed per year. The project is in its second year. Currently, the seed yield is not adequate, but it is expected to increase when the trees become more mature. The production cost is much lower than the current diesel price in Cambodia, and is estimated to be KR3,200/l. Moreover, jatropha seed cake can be sold for KR200/kg. The generator's maintenance cost is slowly rising. This model can be adapted by mobilizing broad participation from farmers for community electricity supply. Farmers could plant jatropha and sell the seeds for biodiesel production and electricity generation. The farmers could then pay to have access to the electricity produced.

A similar model in Battambang uses a different input and is managed by the community. The unconventional generator produces electricity using biomass from the *Leucaena* tree which is planted by the community. The tree can also be sold as fuelwood or used to make charcoal. Good management has ensured the model's success. Under the project, 1,500 households have access to electricity for 6 hours every day. It is financially sustainable, but it excludes the maintenance, start-up, and training costs. This purely community-based model is successful because members of the community own fairly large farms.

## Other Agriculture Business Models

### Contract Farming

Contract farming is practiced both formally and informally in rural Cambodia. It is uncommon in rice cultivation, but common with vegetables, soybean, cashew nut, fruit trees, and other secondary crops. The informal contracts are loosely enforced and are based on mutual trust and relationship. Most contracts are entered into during harvest time, and farmers are rarely engaged in a contract from the beginning of planting. Advance payment is common so that farmers can use the money to buy inputs. The full risk of crop failure is usually shouldered by the farmers.

Angkor Kasekam Roonroeung (AKR), a Cambodian investment company established in 1999, specializes in rice processing and export. It is the only rice exporter that targets the organic market in the developed world and supplies *neang malis*, a Cambodian aromatic rice variety famous for its fragrance and distinctive taste. AKR invested some $8 million for a rice mill with a processing capacity of 10 t/hour. The company can process up to 30,000 t of rice each year. The rice is processed at the mill, packaged, and then exported to markets such as Australia, the European Union, and Hong Kong, China.

The company has engaged some 80,000 local farming households in the contract growing of rice. Each household operates at 1 ha of rice-growing land. The company provides the seeds on credit and offers extension services covering production, harvesting, farm management, and quality control. AKR's technicians show farmers how to use organic fertilizers and pest control practices. Rice yields vary from 1.8 t/ha to 2.5 t/ha. After harvest, the farmers repay the seed credit and transport the harvested rice to the company's rice mill.

AKR has monopolized the marketing process and is able to provide a higher price to the farmer. The company's approach involves engagement not only in the market, but also in production. Under this arrangement, farmers receive information on minimum price and expected transport costs in advance to help them make production decisions. Farmers are thus able to allocate their resources, both labor and nonlabor, to maximize profit and produce at the most efficient level. Contract farming offers a better market participation deal: it eliminates most middlemen and brings farmers to the end user in the domestic or export market. Farmers report receiving higher farm gate prices than those of noncontract farmers. Given the huge potential of the export market and the high potential for increased production, AKR plans to build another rice mill to expand its processing capacity.

This is the best model for connecting farmers to the global rice supply chain. It could potentially do the same for other crops, including fuel crops. Investment in a vegetable oil refinery could similarly pave the way for contract farming. The AKR model is based entirely on smallholders, and a better relationship between AKR and farmers during difficult times ensures it is successfully implemented (for example, AKR delayed debt repayment until the following year during the 2003 drought). Another key to the success of AKR is better coordination between farmers and the company through the use of an existing institution—the commune council—as the coordinator.

The major problem, however, is that some farmers do not respect contracts and tend to sell to anyone that offers a better deal. However, the firm is committed to buy at a price agreed in advance. Law enforcement must work to cement the relationship between the company and the farmers. Experience shows that distrusting farmers at the start could ruin such a relationship and it would be very difficult to get farmers to enter into a contract again. A committed firm should find no difficulty in enforcing repeat contracts.

The success of AKR is also based on centralized quality assurance. The price paid depends on quality and farmers are encouraged to improve quality to obtain a higher price. The company retains the right to determine quality based on a scientific method, and farmers are required to accept the findings. In the end, the firm's objectives and the farmers' objectives converge; yields and quality increase, and the price and supply are secured.

With the commitment of both buyer and sellers, contract farming is suitable for connecting small farmers to the global value chain. For fuel crops, it is an appropriate model for both jatropha and cassava. Small farmers are willing to supply the crop in exchange for a good advance price. They can also access capital and technical assistance from the company. This arrangement is more efficient from the point of view of the firm, as a foreign investor can easily invest without buying land that they cannot legally own, and they need not get involved in day-to-day operations of the farm.

### Economic Land Concession Model

According to the Sub-Decree on Economic Land Concessions, an investment project involving an economic land concession must be approved by the MAFF, while the provincial governor exercises the right to approve land concessions of up to 1,000 ha. The Council for the Development of Cambodia has jurisdiction over investment incentives related to such projects. As a condition for its approval, the proposed project for economic land concessions needs to exceed a total investment value of KR10 million (about $2,400) for a total land concession area of 1,000 ha. The economic land concession proposal must comply with the required environmental and social impact assessment, and must not be involved in a resettlement issue. Land ownership is granted exclusively to Cambodians, and its use is limited to a lease period of up to 70 years, renewable upon request.

Industrial plantation agriculture is an important means of supplying large volumes of agricultural crops of consistent quantity. Plantation agriculture contributes significantly to the national economy and provides much employment. It has long been practiced and 46 private companies have run most of the industrial and agricultural crop plantations under economic land concession arrangements. Economic land concessions have been offered for crops such as rubber, palm oil, sugarcane, cashew, coffee, and forest plantations. Most concessions involve trees that take at least 3 years to give returns, and require a large investment cost.

Some of the economic land concessions that were granted have not been used for agricultural purposes, but have been kept inactive for speculation, and were subsequently cancelled by the government. Most economic land concessions are in nonflooded areas and degraded forests. Among the crops planted, the most successful are rubber and cashew, due to their high world prices. The palm oil plantations occupying thousands of hectares in the coastal zone have had limited success. The initial plan to set up a cooking oil refinery was not realized, and instead seeds were collected and exported to Malaysia, and Cambodia imported tax-exempt cooking oil. Few workers were employed because wages are low and there is a lack of living infrastructure. This example underlines the importance of commitment from investment companies, and high global prices to ensure success.

The case of a smallholder rubber plantation developed by a private company in Ratanakiri Province illustrates how a project can have both positive and negative impacts on the household. The community has benefited from new roads, a new school, a pagoda, and gifts for the local farmers, but has lost out due to the taking of land by the rubber company, the cutting of rubber trees, loss of livelihoods, and environmental impacts. The cost–benefit analysis undertaken by the NGO Forum estimated that converting cleared forest to rubber plantations leads to a loss of around $1 million, not counting the environmental cost. The analysis, however, assumed that the cost of upland cultivation and tapping of rubber trees is almost zero, and the estimate excluded both social benefits from improved infrastructure and schools as well as the environmental cost.

Given the similarity of jatropha's return period to crops such as rubber, cashew, and fruit trees, the economic land concession model has great potential. Cassava could also be included to provide a portion of the input if the refinery is finally established. Large plantations could be helpful to start up the pilot project before opening it to small farmers who are less willing or able to take risks. Options for short-term concessions that can be used and transferred when the concession becomes operational can also be considered.

Foreign investors could invest in joint ventures with Cambodian firms, as has been the case in bioethanol production. Such joint ventures combine the foreign investor's modern techniques and refinery technology, and the local entity's rights to obtain economic land concessions, good relations with farmers, and familiarity with local institutions. Economic land concessions could open opportunities for new crops, and attract farmers' participation.

Dishonest partners and a lack of commitment to invest constitute the major risks of economic land concessions. Past experience of land speculation under the concession necessitate strict enforcement of rules and a commitment to invest in fuel crops. Since much agricultural land in Cambodia is inactive, there is room for the development of fuel crops, especially if the price of oil remains high.

Another concern is deforestation. Economic land concessions should be encouraged only in degraded forest areas, especially where the demarcation and responsibility are clear cut. Because some land concessions are subjected to land grabbing and deforestation, a monitoring system should be in place before any new concessions are granted.

As the cases illustrated show, serious investment, commitment, and cooperation from both government and the local people are prerequisites for the success of the economic land concession model.

### Small Households in Rubber Plantations

This model is different from contract farming and economic land concession in the sense that there is no contract and farmers are offered a social land concession. Moreover, farmers are welcome to join in this scheme if they own some land. Farmers receive credit and technical assistance for farm management. When the trees are tapped, the farmers make payments with interest at a concessional rate.

Projet Hévéaculture Familiale, a project involving rubber smallholdings, was launched in 1999 as a pilot project in Kampong Cham Province, with funding by Agence Française de Développement (the French Development Agency). The project aimed to integrate small households into a rubber plantation and create a sustainable development model in the monoculture environment. The target of the project was to plant 500 ha each year.

The project gives permanent land title, credit, and technical support to participating households. The households must apply to the Land Titles Department for the delivery of titles for land not exceeding 5 ha, at a cost of $10 per title. In addition, the households receive up to 20 years' credit at only 9% interest per annum, with an 8–year grace period. They can borrow up to $890/ha using land as collateral. To ensure progress, the project provides good quality polybagged plants, grafted with certified budwood, as well as technical advice on monitoring and maintenance. The project also gives information on crop diversification.

The project started with 25 ha in 1999 compared with the target of 500 ha. The low participation was due to doubts about the project and the low price of rubber. By 2006, the total household rubber plantation had increased to 3,000 ha as the price of rubber had begun to rise in 2002. The increase in the rubber price encouraged more people to plant rubber, regardless of financial and technical support from the project. Available data indicate that autonomous growers in Kampong Cham account for more than 7,000 ha of rubber plantations.

The first tapping of a rubber tree can yield nearly 700 kg/ha. The target is to increase it to 1,500 kg/ha/year within 3 years. If the price of rubber is stable at around $0.8/kg, a farmer can earn the first revenue stream of $560 after 3 years and $1,200 from the eighth year. The investment cost is about $450 in the first year and about $100 after the second year. It is an attractive scheme if people can manage to maximize their farm gate price. The net present value is estimated to be $200/ha.

Because of the increase in the price of rubber, small household rubber plantations have been successful and more households are willing to join the program. The program is attractive because farmers obtain both credit and technical assistance from the same source.

This model is highly recommended for the fuel crops jatropha and cassava if market absorption and price are assured. Recently, cassava planting has increased because of good market prospects brought about by the establishment of a bioethanol factory, and the huge demand created by the mandate for blending in many countries. There appears to be a stable environment for a fuel crops market, but the possible conflict with food supply calls into question its long-term stability.

### Community-Based Business Model

The community-based business model leaves everything from inputs to marketing in the hands of the farmer. The model is common for the production of handicrafts such as silk, mats, and silverware. Villagers are self-reliant in obtaining inputs, acquiring technological knowledge, and selling their products. Farmers usually receive little support from financial institutions and technical extension services. In the community-based business model, farmers usually work independently for a collective market.

A rural enterprise could be set up under the community-based model to extract and market oil from individual farmers' crops. In this model, the biofuel crop is planted by farmers on their own fields in consideration of an early fixed price. The rural enterprise can arrange seed collection for oil extraction and marketing. It must also ensure that the seed quality and price are maximized for the consumer and the welfare of the community. In this regard, the community plays a role in determining food security and oil consumption.

In Cambodia, community organization is weak and coordination is never beyond politics. As the commune council takes shape,[24] the role of the community is upgraded and enhanced by being transformed from a political to an economic relationship. Therefore, the community-based business model needs a lot of support in terms of knowledge, technology, management, and finance to manage such business relationships. The community requires strong leadership, dedication, and patience to function well and succeed.

A community electricity enterprise could be implemented using this model. The community could run the generator using biofuel planted and extracted for their own consumption. This practical model could be set up in the community if farmers are trained in the use of biofuel for power generation. This would require investment for the generator and transmission line. The maintenance cost could be met by fees from consumers.

### Artisans D'Angkor Model: Silk Production

Artisans D'Angkor is very successful Cambodian company that produces silk and other craft products for an exclusive clientele. Production is kept to a modest scale so that the high quality of its products can be maintained. Nevertheless, it has been able to move away from resource and technical dependence to become self-sustaining. Its success is due partly to its management as public–private partnership, which boosts productivity, sustainability, and performance. The extent to which this organization benefits the local community has not been calculated; however, it has provided employment and income to over 100 staff. Most employees earn around $50–$120 per month, and the most highly skilled workers can earn up to $250 per month.

Under a project funded by the Government of France, the National Silk Center was established in Siem Reap with a contribution from the Royal Government of Cambodia. The center aims to revive the knowledge of silk production in Cambodia and transfer it to the younger generation. Artisans D'Angkor was subsequently developed as the NGO to sell the center's products. With help of French experts, silk designs were developed and branded. The quality is acknowledged to be superb and the handmade products sell at high prices both domestically and internationally.

The model allows people to work in their villages under technical guidelines and strict quality control to produce items bearing the Artisans D'Angkor brand name. Farmers are responsible for investing in production equipment and facilities. In effect, each household is the center of production, while the company is mainly responsible for quality control and design. Artisans D'Angkor has achieved success by connecting skills to markets and by developing small and medium-sized enterprises with government support.

This model could also be used in the biofuel industry if the technology is suitable and can be easily applied by small farmers. Technical steps like seed crushing and filtering are not difficult if the cost of the investment is not very high. The distillation technology to convert cassava to ethanol is also largely available to households. Improving the technology could contribute to efficient production. Using the Artisans D'Angkor model, the firm could upgrade the quality of the ethanol produced by the farmers. The household is likely to benefit more since the residual from crushing and distillation could be used as fertilizer and animal feed.

[24] There are 1,621 communes in the country, each represented by 5–11 members. Commune Councils are viewed as a step towards strengthening the democratic process in Cambodia.

This model has weaknesses that need to be anticipated. Without coordination between the firm and the farmers, a secure input supply may not be attained. The efficiency of household technology should be assessed and cost–benefit analysis conducted. Working with farmers requires patience and mutual understanding which usually takes time to establish.

## A Suitable Business Model for the Biofuel Industry

The plantation model is necessary for establishing the biofuel industry. It benefits farmers in terms of wages. Its advantages depend on the crop, level of technology, infrastructure, and stage of development. Large plantations are suitable for crops that require intensive new technology and a large investment at the start; and they benefit from economies of scale. The model is also suited to a new area where there is no infrastructure and requires no investment from the government. In the past, the model has not ensured maximum benefits to the poor. The plantation sometimes ended up idle after the land concession was received from the government and was kept for speculation. If the government can address this issue, the plantation can be an effective model with which to begin biofuel development. Jatropha is a suitable crop for large plantations since it is a new crop, needs large investments, and gives medium- to long-term returns. Small-scale plantings of jatropha are not economically viable.

For cassava, a large plantation is not needed, since farmers already know how to plant it and the market has been established countrywide. In this case, smallholders can be connected by contract farming that serves best the interest of farmers. To ensure success, technical assistance, credit, and mutual understanding are needed. A secure marketplace is necessary to encourage farmers to invest. Centralized cassava collection, drying, and chopping will further increase value-added for the farmer. The only problem is enforcing the contract because some farmers tend to sell to anyone that offers them a higher price. However, good management and strict enforcement of contracts can minimize the problem.

The model used in rubber plantations can be used for jatropha, since it requires a longer payback period. During the grace period of one year, farmers can depend on other sources to make a living. Because jatropha is a new crop and a nonfood crop, farmers need support, and both domestic and international markets need to be assured. This model should be based on contracts. In the case of cassava, farmers can diversify their crops to maximize their benefit.

A small-scale refinery could serve the farmer best if the technology is available for both ethanol and biodiesel. If quality control could be assured around a big refinery, it would maximize the value-added to farmers. Farmers could plant jatropha and cassava themselves and extract and distill it to obtain the primary output; this would then be supplied as the primary input to the large refinery with its sophisticated technology.

The community-based business model is unrealistic in the context of Cambodia. Limited capacity for field management and technical knowledge would be a hindrance. Many community models are run with financial support, so the sustainability of the project is unclear. However, the model is suitable for rural electricity enterprises. Jatropha has been found to work well in generators, and can therefore keep the price of electricity low when fossil fuel prices are high.

Current practices justify the agribusiness model for biofuel development. The contract farming and plantation models could be combined in the short run to get the biofuel industry started. The plantation model could secure the minimum input needed for the operation of a refinery, though this might not be as efficient as a small household plantation. To connect the smallholder to the supply chain, farmers should be engaged through contract farming. Experience shows some success in rice contract farming, so it is highly likely to be successful with biofuel crops. Small-scale extraction and distillation are also feasible to maximize the value-added to farmers at the cost of efficiency. The cost of foregone efficiency may not be too high compared with the welfare that accrues to farmers.

The government should take the lead in biofuel development, especially for electricity generation. By blending biodiesel for electricity generation and to run state-owned cars, it could create the market for biodiesel. The blending of biofuels for private and commercial activities will follow if oil prices remain high and fuel quality is assured.

# Energy Policy and Planning

The Royal Government of Cambodia formulated a national energy sector policy in October 1994. Its objectives are to (i) provide an adequate supply of energy throughout Cambodia at reasonable and affordable prices; (ii) ensure a reliable and secure electricity supply at prices that facilitate investment in Cambodia and development of the national economy; (iii) encourage exploration and environmentally and socially acceptable development of energy resources needed in all sectors of the Cambodian economy; and (iv) encourage efficient use of energy, and minimize detrimental environmental effects resulting from its use.

However, the action plan focuses mainly on electricity. The objectives of the action plan are to (i) enable consumers to receive a reliable and adequate supply of electric power services at reasonable cost, (ii) promote private ownership of the facilities providing electric power services, and (iii) encourage competition wherever feasible in the electric power sector. The Electricity Authority of Cambodia is assigned to oversee the above objectives, and all power service suppliers are required to obtain a license from the authority.

In pursuance of this national energy policy, the Royal Government of Cambodia recently developed the Rural Electrification by Renewable Energy policy as an integral part of the government's overall agenda for the energy sector. The Cabinet approved the policy in January 2007. The main objective of the policy is to create a comprehensive enabling framework for renewable energy technologies as a means to increase access to electricity in the rural areas. The policy acknowledges the Master Plan Study on Rural Electrification for Renewable Energy[25] as the guiding document for implementing projects and programs. Although the policy framework for rural electrification is comprehensive, there is a policy gap with respect to other types of energy that are essential for the rural population. For example, cooking energy that is supplied by biomass or fuels such as liquefied petroleum gas (LPG) and kerosene is not yet covered by a specific policy.

## National Strategic Development Plan 2006–2010

The National Strategic Development Plan 2006–2010 is a comprehensive policy to achieve the objectives stated in the Cambodia Millennium Development Goals, the National Poverty Reduction Strategy, and the Rectangular Strategy for Growth, Employment, Equity and Efficiency, using available resources in a cost-effective and results-oriented manner.

Agricultural development is the main responsibility of the Ministry of Agriculture, Forestry and Fisheries (MAFF), while other related institutions and ministries, NGOs, and civil society provide cooperation to ensure that agricultural development objectives are realized. These objectives consist of three pillars: i) agricultural production improvement, ii) poverty reduction, and iii) the conservation of natural resources.

To achieve the objectives, it is necessary to put the proper policies in place. Consequently, the government has established eight policy areas to contribute to its effort in agricultural development as follows:

### Food Security

In the government's policy, food security is the top priority. According to data gathered by the Ministry

[25] This plan was developed by the Japan International Cooperation Agency to help Cambodia identify potential energy sources and promote energy production without depending on any particular type of fuel.

of Economics and Finance, in 2008, more than 30% of the total population was living below the poverty line. Therefore, the policy is to allocate land for agricultural production to ensure an adequate domestic supply of food before land is allocated for other purposes, such as biofuel production.

### Improvement of Productivity

This policy area focuses mainly on rice production and other crops, plantations, livestock, and poultry. Agriculture is considered a key sector to provide income to rural households. The 2006 Agriculture and Water Resource Strategy embraces the following:

**Agricultural land management.** Smallholders, farm cooperatives, contract farming, and large-scale economic land concession need to be taken into account in formulating a national agriculture development policy, especially in the context of increasing productivity and diversification.

**High-yielding varieties.** More investment is needed for research and development of high-yielding varieties. The cooperation of NGOs and other countries in the region must be sought.

**Increased domestic production of imported vegetables and fruits.** These are commonly supplied by neighboring countries.

**Choice of crops to plant.** The choice of crops should take into consideration the limited water resources and risks associated with weather variations.

Promoting productivity through rural infrastructure, and providing credit and technical training are all prioritized. Agriculture spending doubled from KR52.7 billion in 2001 to KR118.6 billion in 2007. The use of high-yielding seeds, improved practices for the control of pests and diseases, government initiatives to provide irrigation facilities for dry paddy farming, and the introduction of a system of rice intensification help improve rice productivity.

Rice productivity increased from 1.5 t/ha in 1993 to 2.5 t/ha in 2007. Programs to improve agricultural productivity include (i) strengthening natural disaster prevention systems; (ii) improving irrigation systems; (iii) improving farmland quality; (iv) developing new varieties and distributing certified rice seeds, developing high-quality and high-yielding seeds, and establishing a seed management office and seed banks; (v) applying adequate amounts of fertilizer; and (vi) improving labor productivity.

### Diversification

Since 1995, Cambodia has become a rice surplus country. Now, the government is encouraging crop diversification and investment in larger plantations, especially through economic land concession. The effect of this policy remains to be seen. Cassava, sugarcane, bean, rubber, and other agro-industrial crops are booming, especially in land at higher elevations. Diversification is important as reliance on a very narrow base of agricultural products makes farmers vulnerable to upsets in domestic and international markets.

### Agricultural Marketing Systems

In the past, domestic farmers suffered from a lack of formal marketing mechanisms, organization, and facilities. They showed no enthusiasm for forming associations that were perceived to provide no real benefits. The practice of contract farming was recently introduced to local farmers. Regional cooperation and membership of the Association of Southeast Asian Nations (ASEAN) and the World Trade Organization open a new window for the export of agricultural products. The export of rubber, cassava starch, bean, and rice increases every year. The local market also absorbs larger amounts of agricultural products, thanks to a dramatic increase in tourist arrivals and strong economic growth.

### Human Resource Development

The objective of human resource development in agriculture is to develop quality farming experts and farming companies to improve productivity and modernize agricultural practices. Agricultural technicians are being dispatched nationwide to help farmers deal with crop diseases and pests. Some NGOs (e.g., the Cambodia Agriculture Research and Development Institute, and the Cambodia Center for Study and Development in Agriculture) operate agricultural research and development institutes to give technical advice to farmers to improve the productivity and quality of their crops.

### Improvement of the Rural Areas

Improving rural life is the key to stimulating the rural economy. The government is channeling more resources for building rural infrastructure such as hospitals, schools, water supply systems, and village roads, to improve rural living standards and provide cheaper access to services. In the past, people had to travel to the provincial center or city for health care services. Today, most of these services are available at the district level, enabling people to save time and money.

### Land Reform and Mine Clearance

Only 20% of landowners in Cambodia have individual title to their land. One million parcels of land were registered to provide secure tenure to landowners in 2002–2007. The 2001 Land Law will continue to be implemented to ensure an equitable, proper, and efficient system of land management and distribution; land tenure security; eradication of illegal settlements and land grabbing; and the control of ownership for speculative purposes. The challenge is to curb further land concentration in the hands of a few. This includes reviewing already-granted large concessions that exceed the limits established under the 2001 law, and where land is still lying fallow and unproductive. Socal land concessions and economic land concessions have been implemented. This mechanism provides a good starting point for biofuel development in Cambodia, as land will be made available to investors who are genuinely interested in investing in the planting of biofuel crops.

Large areas of agricultural and forest land in Cambodia remain unoccupied because of land mines and other unexploded ordnance. Mine clearance is the first stage in reclaiming land for distribution within the framework of social land concessions. This also paves the way for rural development and improving the safety of people living in rural areas.

### Forestry Reform

The target is to maintain 60% forest cover and to continue reforestation efforts. Forest concessions have been suspended and the existing concessions are subject to stricter scrutiny to ensure that the Strategic Forest Management Plan is followed and environmental impact assessments undertaken. The national forest policy rests on three pillars: (i) a sustainable forest management policy to ensure the rational and strict monitoring of forest exploitation according to international best practices in forest management, to provide adequate forest reserves for domestic consumption, to protect against drought and floods, as well as to preserve wetlands that serve as fish sanctuaries; (ii) a protected area system to protect biodiversity and endangered species; and (iii) community forestry as a sound, transparent, and locally managed program.

To complement the policy pillars, the government has formulated the National Forestry Program, which prioritizes (i) strengthening forestry management and conservation; (ii) promoting man-made plantations by encouraging private investment and public participation; (iii) promoting forestry's contribution to social and economic development; (iv) promoting forestry's contribution to poverty reduction by strengthening community forestry initiatives and by involving local communities in forest exploitation plans; and (v) creating public awareness to add to, replant, and use community plantations for firewood and charcoal needs, and not destroy forests.

## Rural Development

The government has set up a rural development program that focuses on improving the livelihoods and living standards of the rural poor. The program includes activities such as constructing physical infrastructure in rural areas, providing a reliable supply of electricity, improving rural health care, supplying clean water, providing education and training services, initiating community development projects, facilitating access to fertilizer and credit, and supporting small and medium-sized enterprises.

The objectives of rural development strategies are to (i) decentralize financial planning and implementation of rural development projects; (ii) diversify rural development, focusing on key regions and sectors; (iii) facilitate involvement of all levels of administration, institutions, NGOs, and the community; and (iv) optimize the use of comparative advantage and channel domestic resources to boost rural development.

The government introduced the Second Socio-Economic Development Plan 2001–2005 (SEDP II) in 2000 to concentrate all efforts on rural development.

The ultimate goal of rural development is to achieve poverty reduction and improve the quality of life in the rural areas. The plan is designed specifically for development in rural areas and focuses on the following five parameters:

### Institutional Strengthening and Human Resource Development

It is vital to ensure the efficient management and implementation of integrated rural development work, particularly in the areas of infrastructure and poverty reduction. To make these tasks more attainable, two new departments were established in the Ministry of Rural Development (MRD): the Department of Rural Roads, and the Department of Ethnic Minority Development.

Capacity building is considered a priority to improve the competence of MRD staff and the efficiency of its development work. Acknowledging the fact that farmers make up nearly 80% of Cambodia's population, the MRD, together with development partners, has organized and facilitated many training programs across the country to enable farmers to improve productivity and learn how to market their products. Development partners have provided both financial and technical support for institutional and human resource development. The effort has been further boosted by the decentralization of rural development work, e.g., the establishment of village development committees, to speed up and increase the effectiveness of rural development.

### Development of Basic Services and Rural Infrastructure

Recognizing the importance of rural infrastructure in socioeconomic development programs, the government aims to improve transport services in all rural areas to enable farmers to maximize profits from the sale of agricultural products and enjoy a higher quality of life. Rural roads also enable better access to education, health care, and business opportunities. The MRD has initiated the use of a labor-based appropriate technology scheme, which is based on the optimal use of local resources such as labor, materials, and skills. The scheme is viable and cost-effective for rehabilitating rural infrastructure because it employs local people. Currently, the MRD is taking a more proactive approach by regularly maintaining rural roads rather than leaving them until they are severely damaged.

The Ministry of Health is in charge of providing effective and affordable health care. A user fees program was introduced in 1996 to eliminate unofficial payments and ensure adequate operational revenue for hospitals. The poorest of the poor do not have to pay fees for the health service as an equity fund has been established to meet their medical expenses. The fund was established between 1999 and 2000 and is managed by NGOs.

The Education for All National Plan 2003–2015 is the government's pragmatic approach to provide an education service to everyone. The plan takes into account the broader demographic, macroeconomic, and social development outlook for the next 10–15 years. Its objective is to improve the quality of formal and nonformal education and ensure that everyone will receive this service, by maintaining a high share of government spending on education, and allocating more experienced teaching staff to currently disadvantaged areas.

### Development of Irrigation Systems

Building an adequate irrigation system is a priority in Cambodia. The MRD is responsible for pinpointing smaller areas in need of an irrigation system, and rehabilitating and constructing small-scale irrigation systems; while the Ministry of Water Resources and Meteorology is tasked with the construction and rehabilitation of large irrigation systems. The local community is required to bear part of the cost, especially for operation and maintenance, through water user groups and associations.

### Rural Credit

Rural farmers need capital to expand their farming activities, invest in new agricultural equipment, or buy seed and fertilizer. Adequate rural credit will greatly improve agricultural productivity. Although the government is not directly involved in providing credit to rural people, it closely monitors progress in the rural credit subsector through the National Bank of Cambodia. Microfinance enterprises operate across the country, thanks to the government's full support. Currently, more than 10 credit providers are operating in rural areas.

### Rural Electricity

Less than 9% of the rural population has access to electricity supplied by a grid, while other rural areas have access to part-time mini-grids or battery-charging services. Investing in rural electricity is being highly encouraged. A rural electricity fund has been established to contribute some start-up capital to appropriate rural electricity investment plans. For the construction of mini grids, the extension of existing grids, or the construction of mini- or micro-hydropower systems, qualified proponents will be entitled to a grant equal to 25% of the start-up capital. This mechanism reduces the capital cost and thus the retail cost of rural electricity.

## The Energy Sector

The policy on energy security promotes not only energy sector growth and development, but also overall economic growth. The objectives of the energy sector development policy are to: (i) provide an adequate supply of energy throughout Cambodia at reasonable and affordable prices; (ii) ensure a reliable and secure electricity supply to facilitate investments and boost economic growth; (iii) encourage exploration, and environmentally and socially acceptable development of energy resources; and (iv) encourage efficient use of energy, and minimize detrimental environmental effects resulting from energy supply and use.

The energy strategy in Cambodia covers four main categories: electricity strategy, renewable energy, power sector strategy and wood energy strategy.

### Electricity Strategy

To meet the growing demand for electricity and achieve electricity access goals and targets, the government recognizes the need for a balanced development of centralized and decentralized electricity supply systems. In the power sector strategy, the government is calling for the extension of grid-based electricity supply to provincial and district towns, and the promotion of private investment in the development of mini-grids based on diesel and/or renewable energy systems in rural and isolated areas. Most of the activities under the Power Sector Development Plan, however, are focused on national grid development, and investments in large-scale power generation.

Similarly, the Generation Development Plan supports the development of centralized electric power systems. Small- to medium-scale diesel generating units are programmed to be commissioned in the short run, while mini- and large-scale hydropower units are planned to be introduced in the medium and long terms.

The government's plans for rural electrification give an important role to rural electricity enterprises (REEs), echoing the World Bank's emphasis on greater private sector participation. In practice, however, there has been friction between public and private industry in some areas where the government's electricity utility, Electricité du Cambodge (Electricity of Cambodia) (EDC), has allegedly established operations in the business area of existing REEs, thus threatening the REEs' business viability. REEs are currently seeking longer license periods from the Electricity Authority of Cambodia to allow them to plan in advance and achieve investment returns over a longer period which in turn would allow them to reduce their electricity tariffs.

The World Bank and ADB have funded an extensive rural electrification and transmission project for Cambodia that involves building transmission lines and other infrastructure for importing power from Viet Nam, and upgrading the 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 is called the Rural Electrification Fund. The fund will seek to encourage the use of renewable energy technologies, but is limited in the first year to solar home systems and micro-hydro systems.[26]

Because almost 90% of the households in the country do not have access to modern electricity services, the government has made rural electrification one of its key energy sector priorities. Under the

[26] Cambodia Research Center for Development. 2006. *Feasibility Study of Rural Renewable Energy Options for Rural Electrification in Cambodia*. www.recambodia.org/ref.htm

Power Sector Policy, the government's long-term targets are to increase the access rate to reliable and good quality electricity services to 70% of rural households by 2030, and provide 90% of villages with electricity by 2030. A village is considered "electrified" when most community facilities and more than 50% of households have electricity. In addition, the government has set the medium-term target of providing an electricity connection to 25% of households by 2010. The government plans to achieve this through (i) grid extensions; (ii) obtaining cross-border power supplies from neighboring countries; (iii) rehabilitating existing isolated grid systems in provincial towns; (iv) creating new isolated grid systems; (v) rural electrification using sources such as solar, micro- and mini-hydro, wind power, and biomass and biogas; and (vi) the provision of battery-based and stand-alone systems for dispersed remote customers.

### Renewable Energy

The dominant objective of the Renewable Energy Strategy is to start using local natural resources to provide power. The Renewable Energy Action Plan, which was formulated in 2003, acted as the framework for renewable energy development programs in the country. The four targets of the plan were to (i) increase electricity supply from renewable energy sources up to 6 MW; (ii) give 100,000 households access to renewable electricity; (iii) install 10,000 solar power systems; and (iv) create profitable, demand-driven renewable electricity markets.

The dominant objective in the renewable energy subsector is to provide access to an affordable and sustainable source of electricity. The 2004 Strategy for Rural Electrification by Renewable Energy policy also highlighted six objectives:

- Widely expand access to electricity services for the rural population by developing appropriate programs and action plans to promote renewable energy technologies;
- expand the supply base for renewable energy services by promoting the participation of private entrepreneurs so as to provide the rural population with efficient and cost-effective services at an affordable price;
- facilitate systematic market and institutional development in the renewable electricity subsector by creating a comprehensive legal and regulatory framework to enable effective participation of government, private, and community-based entities in providing electricity services to rural consumers;
- ensure wide and equitable access to electricity services for all sections of the rural population by developing appropriate tariff policies and instituting a rational tariff regime;
- promote environmentally sustainable renewable energy technologies in on-grid and off-grid mode to give rural consumers greater access to affordable electricity services; and
- contribute to the empowerment of the rural poor by creating economic opportunities and uplifting standards of living through electricity services, and by involving them in the planning, operation, maintenance, and management of programs providing those services.

### Power Sector Strategy

To meet expanding demand, Cambodia must develop an adequate and reliable source of electric power in the years to come. A comprehensive power sector strategy has been formulated that consists of investment in the power sector, interconnection with neighboring countries' and ASEAN power grids, priorities for power generation and transmission systems, establishment of the energy sector's regulatory framework, and provincial and rural electrification.

**Investment in the power sector and private sector participation.** The government encourages private participation in the energy sector, attested to by the initiative to contribute up to 25% of start-up capital, tax incentives, and investment facilitation. In 2004, private power supplies accounted for only 5% or 10 MW of the total electricity supply. Phnom Penh absorbs more than 70% of the total; thus, it hinders economic and industrial development in other provinces. The government clearly supports private investment in the energy sector through a licensing regime, technical assistance to small private electricity suppliers, and especially the introduction of the build–operate–transfer scheme. Private investors who have enough capital can sign an agreement with the EDC to build and operate generators or transmission systems for a specified period of time before transferring ownership to the government. This scheme has been implemented in many provinces.

**Interconnection with neighboring countries' power grids.** Member countries of ASEAN have agreed on an interconnection master plan for electricity and natural gas through the ASEAN power grids to achieve an efficient power supply market, to facilitate economic generation and transmission of electricity, enhance security of the power system, and provide opportunities for private investment in the energy sector among member countries. Most of Cambodia's power plants—both hydropower and thermal—that supply power for domestic supply and for export are located in the southwestern and northeastern parts and along the coastal areas of the country. These power plants will be connected to the national grid, interconnecting the systems of Cambodia, the Lao PDR, Thailand, and Viet Nam. In the near term, the power supply will be based on power imported from Viet Nam to Phnom Penh and from Thailand to northwestern Cambodia (Banteay Meanchey, Battambang, and Siem Reap provinces). The government is building a transmission grid from Viet Nam to Phnom Penh, funded by ADB and the Nordic Development Fund. The Ministry of Industry, Mines and Energy (MIME) has authorized a Chinese company to conduct a preliminary study of a project to construct a transmission grid from Phnom Penh to Battambang to interconnect Cambodia, Thailand, and Viet Nam.

**Power generation and transmission.** The government plans to build base load thermal generators in coastal areas to enable better access to imported oil, to cut down the cost of transporting oil from Sihanoukville, to reduce the amount of oil transported through the Mekong River, and to improve the efficiency of the Greater Mekong Subregion (GMS) transmission line connecting Phnom Penh and Sihanoukville. The government also plans to build peak load thermal generation in Phnom Penh, and small and medium-sized diesel units for base and peak load generation in the provincial towns and cities. Many hydropower plants are being constructed or studied. Currently, Sinohydro Corporation is building the Kamchay hydropower plant, which is expected to produce more than 190 MW. Smaller hydropower plants are also being built, and many hydropower projects are being studied, such as Sambo (467 MW), Sre Pork II (222 MW), Steung Atai (120 MW), and Steung Reusey Chrum Krom (125 MW).

As regards the development of a transmission system, Cambodia maintains its six strategic thrusts of reducing reliance on oil imported through the Mekong River for power generation in Phnom Penh; increasing the operational efficiency of the system and reducing environmental impact; encouraging cost-effective grid expansion and local private generation; increasing competitiveness in power generation by facilitating access to competitive sources of electricity from the Lao PDR, Thailand, and Viet Nam; maintaining the reliability of the power supply; and facilitating power trade in the region. The development of power generation and transmission is divided into three 5-year stages: stage one, 2004–2008; stage two, 2009–2013; and stage three, 2014–2018.

**Provincial and rural electrification.** Officers of the MIME, in collaboration with provincial authorities, oversee provincial power utilities. The government plans to restructure the provincial power sector, especially in the area of tariff and management, to improve efficiency and serve customers better. Six provincial power utilities have been integrated into the EDC and the rest are preparing for integration. Some parts of Kampong Cham, Kampot, Banteay Meanchey, Koh Kong, and Battambang provinces are being connected to cheap electricity from Thailand and Viet Nam.

### Wood Energy Strategy

Fuelwood is the main source of energy for rural households. It accounted for 96.3% of national fuel consumption in 1999.[27] Its consumption in Cambodia is closely correlated with deforestation as most wood is taken from natural forests. A strategy to improve the efficiency of fuelwood use and maintain supplies has been introduced. It aims to (i) Increase the efficiency of the transformation process; (ii) improve household cook stoves; (iii) Improve the efficiency of fuelwood use in traditional industries; (iv) encourage the use of biomass and agriculture residues in place of fuelwood; (v) identify a fuelwood distribution system such as market structure, price, volume, and source of supply; (vi) outline the social and economic aspects of using fuelwood; (vii) promote the incorporation of fuelwood analysis into policy-related initiatives; and (viii) strengthen human and institutional capacity for conducting wood energy research. To attain these

[27] National Institute of Statistics. 1999. *Cambodia Statistical Yearbook, 1999*. Ministry of Planning, Royal Government of Cambodia. Phnom Penh.

objectives, the Forestry Administration is committed to implementing the following measures:

**Sustainable forests as sources of wood energy supply.** A subdecree on the establishment of community forestry has been in operation since 2003. So far, 280 community forests covering 508 villages have been established in Cambodia. Community forestry is limited to non-timber forestry products and firewood. Currently, there are initiatives to associate community forestry with fuelwood supply in those communities by ensuring that the community forestry will be the sustainable source of fuelwood supply. The Forestry Administration and the Ministry of Environment are the coordinating agencies of this initiative.

Regarding the national forest as a whole, a national wood energy working group was established in 2006 to formulate a national policy to ensure the sustainable management, supply, and consumption of wood energy. The working group comprises representatives from the MIME, the MAFF, the Forestry Administration, NGOs, and the wider community. It is charged with implementing a number of pilot projects in some provinces and disseminating the sustainable wood energy policy to the public.

The Forestry Administration plans to introduce fuelwood coupes[28] to meet the demand from urban households and industrial users. Specific areas of forestland are to be auctioned annually to private companies to supply fuelwood and charcoal for urban households. In addition, the government is encouraging private investment in plantations to supply fuelwood and charcoal. In the future, the fuelwood supply is expected to come from privately owned plantations to reduce natural deforestation.

**The Better Wood Energy Utilization Program.** Some NGOs are working to improve the efficiency of cook stoves as a means to reduce deforestation. The Cambodian Fuelwood Saving Project has been conducting research to improve the efficiency of stoves. For example, the "New Lao" stove introduced by the Groupe Energies Renouvelables, Environnement et Solidarités can reduce the use of charcoal by 22% compared with the "Traditional Lao" stove. The Cambodia Energy Strategy includes the use of agricultural waste to substitute for fuelwood. More studies are required to implement the Better Wood Energy Utilization Program effectively.

## Land Policy

The government will implement a coordinated set of laws, programs, and institutional arrangements regarding land to help achieve the national goals of economic development, poverty reduction, and good governance.

### Legal and Institutional Reforms

The government has prioritized three main tasks: land administration, land management, and land distribution. The Land Law clearly defines the types of land ownership and provides guidelines on how to manage state land. Institutional strengthening is also on the agenda of this reform. In particular, the Land Law gives provincial and municipal authorities the power to distribute social land concessions to the genuine rural poor.

### Agricultural Land Concession

The Land Law states that agricultural land concessions must not be larger than 10,000 ha. Larger agricultural land concessions approved before the Land Law was passed may be reduced. Any concession that is not exploited within 12 months after the approval will be cancelled. Also, the government requires concessionaires to produce a master plan to facilitate monitoring. This mechanism allows the government to take back land concession rights if it finds that the master plan is not followed. It also leaves some space for genuine agricultural investors, especially in biofuel crops.

### Partnership between Agro-Industry and Smallholders

It does not make sense to distribute land to the poor or to agriculture firms without ensuring livelihood and economic development. The government acknowledges the strong relationship and complementarities between smallholders and agro-industry. Given their limited resources, smallholders are unlikely to obtain the full benefits from their social land concession. Likewise, agro-industry needs the

[28] Fuelwood coupes are operated under the agreement between the authority and private companies. Under these agreements, the Forestry Administration auction some parcels of forestland to private companies for sustainable exploitation.

support of the community to maximize production. This could lead to the issuance of economic and social land concessions in adjoining areas. It is widely recognized that such partnerships have had significant success.

### Types of Ownership and Land Rights

Land ownership in Cambodia can take the form of individual ownership, communal ownership, undivided ownership, co-ownership, and joint ownership. The rights attached to land ownership may include use and habitation rights, usufruct rights, easements, mortgages, pledges and charges, and specified contractual rights agreed upon by interested parties. A proper regulatory and institutional framework is necessary to protect the legal rights of owners.

The benefits from appropriate interventions to strengthen property rights and tenure security can be significant, both in terms of equity and reduced expenditure on land protection and in terms of economic growth resulting from improved access to credit and higher investments among the landholders. However, to increase the security of property rights, legal and institutional issues need to be considered in the context of the broader social and economic environment within which land rights are embedded. On the legal side, the definition of property rights to land and the way in which people can acquire and transfer such rights must be clear and equitable, consistent with traditions and practices, and defined over sufficiently long periods of time. The risk of losing the rights due to discretionary bureaucratic behavior must be minimized. On the institutional side, the procedures need to be simple, transparent, and accessible, and the services should be provided effectively and at low cost.

### Land Disputes

The policy on land disputes aims to prevent or resolve land disputes in a rapid and cost-effective manner. The high incidence of land disputes is the result of a number of factors, including poverty, destruction of land records, public ignorance about the legal framework, informal acquisition of land, economic and power imbalances in the land market, and corruption. The National Land Dispute Resolution Commission was set up in 1999 to research and set up mechanisms for resolving land disputes in provinces and municipalities. This was subsequently replaced by the Cadastral Commission of the Ministry of Land Management, Urban Planning and Construction, which has more power and resources. Where the Cadastral Commission cannot resolve land disputes, the case is heard in the court. Institutional strengthening and capacity building are being prioritized to improve the commission's efficiency.

### Better Utilization of Land

Land in Cambodia is categorized as either state land or private land. State land refers to land under the responsibility of the state. It has two subcategories: land of environmental and ecological importance such as forests, watersheds, and wildlife sanctuaries; and public land that is earmarked for allocation to the landless and the near-landless, who represent the bulk of the poor. Private land refers to parcels of land for which titles have been issued that legally recognize the full bundle of rights of the owner, as with any other private property. In Cambodia, the term "private land" does not necessarily signify private ownership. It is more an indication of the rights of decision making rather than of legal possession, which can either be by the individual, community, or some form of co-ownership. Short of ownership, other forms of land tenure in Cambodia include habitation rights, usufruct rights, mortgages, and pledges.

The Ministry of Land Management, Urban Planning and Construction is responsible for land management, which includes the development of land policy, land registration, and improving the management of state land. Land management in Cambodia involves a large number of stakeholders whose functions often overlap.

## Existing Law and Regulations to Support Biofuel Development

No specific law in Cambodia is designed to support biofuel development. However, as a signatory of the Kyoto Protocol, and therefore a proponent of its associated international environmental laws, Cambodia indirectly supports biofuel development; and all the components of agricultural development, poverty reduction, and environmental protection strategies play a supporting role to biofuel development in the country.

A specific legal framework is needed to directly promote biofuel development in the country. In Thailand, a nationwide mandate for a biodiesel blend of 2% took effect in April 2008, and the country plans to introduce a blend with 20% renewable fuel content by 2012. A similar mandate is needed in Cambodia to quickly advance the development of biofuel production while ensuring that the biofuel market will be profitable for farmers. The existing investment law in Cambodia will also encourage private investment in many areas.

## Organizational Setup

Currently, no specific institution oversees biofuel production. The MAFF is responsible for agricultural development while the MIME is responsible for energy development. Furthermore, local authorities have very little knowledge about biofuel production. The following organizations play a role in biofuel production in Cambodia.

### Council for the Development of Cambodia

The Council for the Development of Cambodia is the highest decision-making level of the government for private and public sector investment. The Cambodian Investment Board is its operational arm for private sector investment. The board reviews investment applications and grants concessions to investors and investment projects meeting the requirements laid out in the 1994 Investment Law. This law streamlined the foreign investment regime and provides generous and competitive concessions and incentives for direct private sector investment. The government is committed to speeding up new investment project approvals and making the Council for the Development of Cambodia a truly effective one-stop service unit. Large private investors who are considering large-scale biofuel-related investment activities in Cambodia should seek support from this organization.

### Ministry of Agriculture, Forestry and Fisheries (MAFF)

The MAFF serves as a national coordinating and supervising apex body for planning, integration, and implementation of agriculture policies and related projects. It is also tasked to ensure food security through productivity improvement and diversification. Increasing rural employment through the adoption of modern agricultural practices is also on its agenda. The MAFF provides high-quality infrastructure and government services that will enable farmers to produce and market products at low cost. More importantly in the biofuel context, the MAFF acts as the main decision maker in approving economic land concessions, which are vital to large fuel crop plantations.

### Ministry of Industry, Mines and Energy (MIME)

The MIME is responsible for developing, implementing, and managing the government's energy policy and strategy. It acts as the focal point for energy production and consumption in Cambodia, and monitors the quality standard of energy-related products. As biofuel production requires specialized technologies, the MIME should be involved most in the production process.

### Local Authorities

Local authorities, especially at the provincial and municipal levels, are the most influential bodies in promoting small-scale agricultural development. To decentralize investment decisions, the government has given them the power to approve agriculture investment projects covering less than 1,000 ha. They can also distribute land to the landless under the social land concession scheme. The recipients of these concessions can enter into contract farming with large plantation companies to jointly develop the biofuel subsector.

### Farmer Associations

There are many farmers' associations in Cambodia. Existing laws and regulations enable farmers to form associations easily. However, their operations are not significant due to a lack of financing and skills. There is a need to improve the decision-making abilities of farmer associations.

## Policy Implications

### Reduced Reliance on Oil Imports

The surge in domestic consumption and the low level of exports are expanding Cambodia's trade deficit. The current account deficit rose to 15% of gross domestic product in 2008. As Cambodia is rich in uncultivated land, the potential for fuel crop cultivation in the country is high. If biofuel is produced domestically and the blending of biofuel with fossil fuel is mandated, the country could reduce its oil imports and lessen its dependence on the international oil market. The effect would be more significant if the oil price is high, and the favorable environment would attract more foreign direct investment in biofuel production.

### Reduction of Reliance on Fuelwood

Biofuel is considered an alternative source of source to fuelwood. The government's policy on forestry concentrates on sustaining the supply of fuelwood and conserving forests, so planting biofuel crops is seen as an effective measure to supply an affordable source of energy. If properly managed, biofuel plantations can help the government tackle illegal forest logging and achieve the target of 60% cover as stated in Cambodia's Millennium Development Goals. However, the government should clearly identify the types of land that can be converted into biofuel plantations so that biofuel expansion does not clash with forestry protection.

### Poverty Reduction and Rural Development

Biofuel can help developing countries reduce poverty incidence through employment, extra income, and lower energy costs. However, the price of fossil fuel, even with government intervention, heavily influences the viability of this business. Due to the considerable variation in the price of land and other agricultural inputs among GMS countries, and the high volatility of fossil fuel prices, the impact of biofuel on poverty reduction should be analyzed carefully. A comprehensive study is needed to assess the impact of biofuel crops on poverty reduction and food security in the region.

### Greenhouse Gas Emissions

Studies on greenhouse gas (GHG) emissions from biofuel use are conflicting. Life cycle analysis indicates that biofuel use substantially reduces GHG emissions. According to Conservation of Clean Air and Water in Europe's (CONCAWE) European well–to–wheel study, first generation biofuels can reduce GHG emissions by 60% and second generation biofuels can bring about 80% reductions.[29] However, a study conducted by the University of Minnesota claims that biofuel production increases GHG emissions by 17–420 times. In the study area, rainforests, peat lands, savannas, and grasslands were converted into fuel-crop plantations in Brazil, Southeast Asia, and the United States. Another study conducted at Princeton University shows that corn-based ethanol nearly doubles GHG emissions over 30 years. Further studies are needed to determine more precisely the impact of biofuel production on GHG emissions.

## Policy and Institutional Recommendations

With regard to the institutional setup, two alternatives scenarios should be considered in promoting biofuel development in the country. First, cooperation between relevant ministries and institutions should be strengthened, especially in the areas of information exchange, technical cooperation, financial support, and capacity building. It would save time and money for developing human resources, building new offices and infrastructure if, for example, an existing department under the umbrella of the MAFF were given more power to include biofuel development in its agenda.

Alternatively, Cambodia could follow its model for rubber development. Currently, the General Directorate of Rubber Plantations has the main responsibility for promoting rubber development. Its functions include monitoring of state and privately owned rubber development, coordinating aid related to rubber, reporting to the government, cooperating with regional rubber entities, and providing technical assistance to smallholders. Although this option is costly and time-consuming, the final outcome would be a new department dedicated to biofuel programs.

It is vital that the right foundation is put in place for biofuel development. Cambodia cannot adopt biofuel on a large scale if quality standards are not guaranteed or do not meet requirements. If biofuel products

[29] Institute for Environmental Sustainability. 2006. *Well-to-Wheels*. European Commission Joint Research Center. http://ies.jrc.ec.europa.eu/WTW; First generation biofuels are made from sugar, starch, vegetable oil, or animal fat using conventional technology. Second generation biofuels are made from nonfood crops such as waste biomass, the stalks of wheat, corn, wood, and special-energy-or-biomass crops using more advanced technology.

are hurried onto the market, any failure will have a prolonged and painful effect on production. The experience of some countries shows how low-quality biofuel products that are rushed to the market without extensive testing can damage or significantly reduce engine life. This undermines public support for the new fuel. Endorsement by an internationally recognized laboratory is an important step to convince users that the fuel is safe to use in their machinery or vehicles.

The current legal framework is adequate to promote biofuel development in the country as the government encourages investment in all sectors and relies on agriculture as the main source of employment and means for poverty reduction. The Agriculture Development Policy, Rural Development Policy, and Energy Sector Policy clearly outline the government's support and favorable environment for potential biofuel investors. Moreover, the existing trade policy provides a good opportunity for fuel-crop farmers and investors. Cambodia's membership of regional and global bodies such as Association of Southeast Asian Nations (ASEAN), the GMS, and the World Trade Organization should inspire foreign investors' confidence in terms of both business operations and the potential market.

Both the natural and socioeconomic environment in Cambodia are conducive to biofuel development. Nevertheless, the government should make a formal declaration of support in order to gain investors' confidence. A qualified biofuel company should be granted a large enough economic land concession to start its operation. The grant should be transparent and should not be too difficult for investors to obtain. In addition, access to financing should be inexpensive and timely for both farmers and investors.

As the biofuel industry is new to Cambodia, human resource development is greatly needed. Currently, very few people are involved in biofuel projects, and there are still fewer technicians. The government must seek the cooperation of experienced countries or organizations to provide training in the areas of biofuel production, regulation, marketing, and competition.

Another important consideration relates to food security. Some fuel crops, such as jatropha, give very low yields in the first few years. Poor farmers who opt to plant jatropha must be made aware of this to avoid a food crisis. If they choose to plant jatropha, they should be given financial support to ensure that their food security and basic needs during the low-yield stage are not severely affected.

The mandate to blend biofuels with fossil fuels must be clearly stated. In the short run, Cambodia can export biofuels to foreign countries and import back the blended fuels. In the long run, however, it will be more economical if this is done domestically.

In short, the government should ensure that biofuel development is led by the private sector. However, it can play an active role to encourage the establishment of the market. Biofuel investment should be encouraged, for example, through trade facilitation, investment incentives, approval of economic land concessions, distribution of social land concessions, provision of protection, provision of basic services to rural workers, construction of rural and agricultural infrastructure, and provision of technical and financial support to farmers. More importantly, poverty reduction must be taken into account during each step of policy formulation and implementation. The government must also ensure that the general population will benefit from the industry through employment generation, higher standards of living, cheaper energy, and a higher rate of economic growth.

# Framework for Biofuel Development in Cambodia

Cambodia possesses domestic resources for the production of electricity from clean sources; however, it takes time to bring oil and gas reserves on stream to fuel the growing demand from transport. Biofuel is one option for use in transport, and biofuel will remain a worthwhile option for a diversified energy supply even after the country's oil reserves become available. In the short-to-medium term, both urban and rural electricity supply will continue to be dominated by oil-fired generators.

By introducing a 5% biofuel blend from 2011 to 2015 and a 10% blend to 2020, 300,000 t and more of imported fuel could be saved every year. At current yields, Cambodia needs to plant 200,000 ha of jatropha to meet this demand. This would create around 200,000 new jobs. Already-cleared forest areas, unused land, and forest areas that have been converted to agricultural use are available for planting jatropha. The planting of jatropha in these areas should not create competition with other food crops. However, the effect of biofuel development on prices of other agricultural products should be studied especially in the light of the possible threat to food security.

There is no shortage of labor to promote biofuel development. The subsector's potential for employment growth warrants greater government attention. Given the 2.4% of labor force growth in rural areas, biofuel development could reduce migration within and outside the country. Currently, Cambodia has 5 million people in rural areas that could work in agriculture at low wage rates.

Jatropha and cassava are two top-priority crops suitable for biofuel development in the context of Cambodia. Jatropha can be planted almost anywhere due to the suitable climate, the fact that it does not compete directly with food crops, its reasonably high yield, and its level of technology which is suited to the family farm. Cassava is also a promising crop for bioethanol production, because it can be produced cheaply in Cambodia. For the same yield, the Cambodian farmer spends less in terms of fertilizer and labor than farmers in Viet Nam and Thailand. Moreover, cassava is widely cultivated and some private companies could set up bioethanol plants using cassava chips as feedstock. Biogas production is also a good option to aid development in rural areas, especially for the generation of electricity for lighting, or gas for cooking and lighting.

The technology for biofuel production is not new and has been evolving in Cambodia through various uncoordinated experiments. The technology for basic oil extraction and processing is locally available, but facilities for purification are lacking. Some plants have been established with private funding where company vehicles are used to test the quality of the biofuel product. The technology required is readily adaptable in the Cambodian context, and the level of skill needed is not high.

Biofuel development brings two concerns: the possible threats to food security, and pressure for further forest clearance. Jatropha is a nonfood plant, so there is a trade-off in terms of land allocating for food and for jatropha. Jatropha does not conflict with rice production as it does not tolerate waterlogged conditions; so there is little likelihood that jatropha will replace the staple food crop. Jatropha lends itself to cultivation in forested mountainous areas. However, conflicts with forest conservation should not arise if land concessions are denied in these areas. Forest clearance is the result of a lack of law enforcement and weak monitoring of land use, rather than opportunities to diversify crops.

Although Cambodia provides a supportive policy environment for biofuel development, there is no specific institution dedicated to this subsector. Investors and households would benefit from incentives that cover the agriculture sector as the whole. Within this policy environment some companies have already set up biofuel-related businesses, although they depend very much on world market conditions and the investor country.

The development of the biofuel industry will require government commitment and investment in (i) building more market infrastructure, (ii) research and development in biofuel, (iii) quality assurance, and (iv) building trust between farmers and investors if contract farming is used. A clear mandate on blending biofuel for road transport and electricity generation will also be needed. This is hard to apply if the retail oil price declines below the cost of biofuel production. Similarly, unless the government is clear that it can assure and enforce quality standards, it will not find it easy to take action on this mandate.

Because jatropha is a nonfood crop, its marketing needs to be organized very well. The market needs to be developed so that a no-buyer situation is avoided, and it should not rely wholly on foreign buyers. Market infrastructure and linkages need to be put in place, and farmers need to know where and at what price they can sell their output. This is particularly important where contract farming is involved. Moreover, trust should be built between smallholders and private companies to strengthen the relationship among these players.

Finally, biofuel development could achieve maximum benefits if it involves small farmers. As a plant which can be grown anywhere, jatropha has great potential to provide benefits for small farmers, but the market price and infrastructure must be good enough to induce effort and investment by farmers. Different business models provide different levels of farmer involvement in different stages of development. Community-based enterprise is the best option for small farmers, but it requires the government to take a more active role and takes longer to set up.

In summary, Cambodia should consider biofuel as one of its options for energy source diversification. However, further pilot projects are needed to demonstrate the feasibility of the associated technology, and evaluate alternative means of implementation. Biofuel development should extend to electricity generation, focusing not only on industrial supply, but also outreach to households. A dedicated institution should monitor technological progress, extend the existing technology, and undertake more adaptive research in this field. This institution should include representatives from key ministries such as the MIME, the MAFF and the Ministry of Commerce. The structure could be copied from the General Directorate of Rubber Plantations. There should be a division of labor between the key institutions, in which the MAFF is responsible for production and primary processing, while the MIME is responsible for quality assurance and blending enforcement. The Ministry of Commerce could arrange the market infrastructure and distribution.

Biofuel development should tread cautiously, because it is closely linked to oil price and food security. In the short term, Cambodia must maintain food security, but also encourage diversification into other crops to increase income. Farmers have to decide for themselves and make judgments based on price signals. Contract farming will be needed for new crops while the market remains uncertain. In this regard, law enforcement is needed to assure farmers of fair treatment. In the meantime, the government should encourage pilot testing and pilot projects for biofuel development, and develop biofuel processing for export by taking advantage of mandated fuel mixes in neighboring countries. Cambodia should not rush to set a mandate in the short run.

In the medium term, Cambodia should develop a renewable fuels mandate with clear technical standards, and develop a dedicated institution for the development of biofuels. With this accomplished, smallholders should then be encouraged to become involved in biofuel crop cultivation. In the long term, Cambodia must enforce a mandate to develop the biofuel industry and invest more in research and development in this industry. Research should aim to simplify the technology so that it can be used to create community-based enterprises.

**Status and Potential for the Development of Biofuels and Rural Renewable Energy: Cambodia**

This report contains a detailed assessment of the status and potential for the development of biofuels in Cambodia 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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6 ADB Avenue, Mandaluyong City
1550 Metro Manila, Philippines
www.adb.org
ISBN 978-971-561-832-8
Publication Stock No. RPT090356

ISBN 978-971-561-832-8
9 789715 618328

Printed in the Philippines