GREATER MEKONG SUBREGION
ECONOMIC COOPERATION PROGRAM

STATUS AND POTENTIAL FOR THE DEVELOPMENT OF

BIOFUELS

AND RURAL RENEWABLE ENERGY

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NOTES

The fiscal year (FY) of Myanmar starts on 1 April and ends on 31 March in following year. FY before a calendar year denotes the year in which the fiscal year ends, hence, FY2007 ends on 31 March 2007.

In this report, “$” refers to US dollars.

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Abbreviations

ACMECS	–	Ayeyarwaddy–Chao Phraya–Mekong Economic Cooperation Strategy
BCF	–	billion cubic feet
CSO	–	Central Statistical Organization
FAO	–	Food and Agriculture Organization of the United Nations
GDP	–	gross domestic product
ICRISAT	–	International Crops Research Institute for the Semi-Arid Tropics
ktoe	–	thousand tons of oil equivalent
kVA	–	kilovolt-ampere
Lao PDR	–	the Lao People’s Democratic Republic
MEC	–	Myanmar Economic Corporation
MIC	–	Myanmar Investment Commission
MOAC	–	Ministry of Agriculture and Cooperatives of Thailand
MOAI	–	Ministry of Agriculture and Irrigation of Myanmar
MOST	–	Ministry of Science and Technology
mt	–	million ton
NEDO	–	New Energy and Industrial Technology Development Organization
PRC	–	the People’s Republic of China
TCD	–	tons crushed per day
UNESCAP	–	United Nations Economic and Social Commission for Asia and the Pacific

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Introduction

Agroecological Zones and Administrative Divisions

Myanmar covers an area of 678,500 square kilometers (km^2) (261,789 square miles), making it the largest mainland country in Southeast Asia. It can be divided into five broad physiographic regions: the Shan Plateau in the eastern part, the northern and western folded hills, the landlocked central belt, the long coastal strips of Rakhine and Tanintharyi, and the fertile delta area. Agricultural development has been mainly concentrated in the delta and extensive fertile alluvial plains of the central belt, which comprises the lower and middle basins of Ayeyarwady River, the lower reaches of Chindwin River, the Sittaung River and the Bago River basins. Myanmar is endowed with rich natural forest cover. The 1989 Landsat Thematic Mapper images indicate that closed and degraded forests cover 343,767 km^2, or approximately 51% of the total land area of the country. The principal river basins constitute a catchment area of 737.8 km^2 and offer vast water resources amounting to 1,081.89 km^3 of average annual surface water, and 494.7 km^3 of estimated ground water potential.[1]

The country is divided administratively into seven states and seven divisions. These are subdivided into 64 districts, which are further divided into 324 townships. The townships are subdivided into 13,759 village tracts, which form the basic administrative unit in Myanmar.

Land Use

In 2007, 11.38 million hectares (ha) (28.12 million acres) of the country were planted to crops (Table 1). According to the Settlement and Land Record Department of the Ministry of Agriculture and Irrigation (MOAI), about 6 million ha—8.8% of the total land area—is still available for expansion of the arable area. A substantial portion of this land could be used to grow biofuel crops. The distribution of cultivable wasteland in the country by state and division is shown in Figure 1. Kachin, Eastern Shan, and Chin states have land resources with potential for arable area expansion. Much of the fallow lands and cultivable wastelands are gradually being cultivated in the remaining divisions of the country. Between 1996 and 2001, the MOAI planned to reclaim 0.28 million ha of fallow land. The total area to be planted is targeted to reach 15.93 million ha.

Table 1: Land Use in Myanmar, FY2007

Land Use	Million Acres	Million Hectares
Net planted area	28.12	11.38
Fallow land	0.73	0.29
Cultivable wasteland	14.76	5.97
Reserved forests	40.68	16.47
Other forests	41.97	16.99
Other lands	40.92	16.57
Total	**167.18**	**67.68**

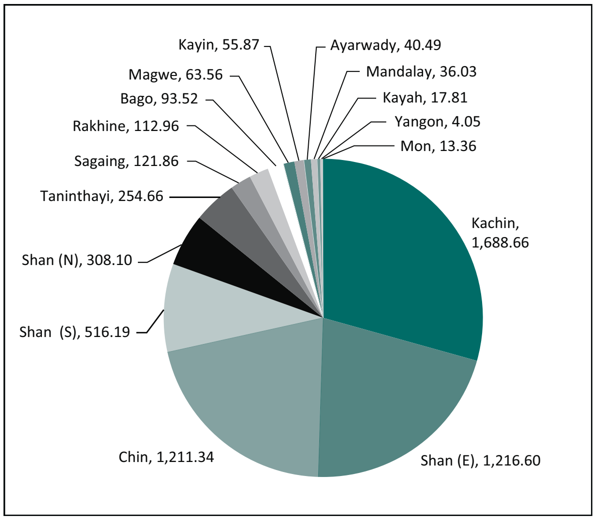
Source: *Myanmar Agriculture in Brief 2008*, Ministry of Agriculture and Irrigation.

Workforce in Agriculture

Official government statistics for fiscal year (FY) 2002 estimated a population of 51.1 million and an annual growth rate of 2.02%. The Asian Development Bank's (ADB) estimate for the same year was 52.2 million, with a growth rate of 2% per year. The population of Myanmar was estimated at about 54.5 million in

[1] Water Resources Utilization Department, Ministry of Agriculture and Irrigation.

Figure 1: Distribution of Cultivable Wasteland by State and Division, January 2008 (‘000 ha)



ha = hectares.

Note: Total cultivable wasteland is 5,755,060 ha. Kachin, Shan (E), and Chin still have potential for horizontal expansion.

Source: Oo, T. H. 2008.

FY2007. In 1995, the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) estimated that Myanmar’s population will reach 61.5 million in 2010. Population density is 76 people per km^2.

Of the total population in FY2002, 18.36 million (39.4%) made up the workforce, of which 11.51 million (63%) were engaged in agriculture. Almost 75% of the population lives in rural areas.[2] The ratio of arable land per person is 0.34 ha, and farms average 2 ha in size.

The size of the labor force and the rate of unemployment by sex were projected on the basis of information collected in the 1990 Labour Force Survey (Table 2). With changing economic conditions and labor mobility patterns, the reliability of the projected labor force and unemployment rates is in question.

Although the aggregate labor force can be projected, its characteristics—such as labor force by education level, employed population by occupation, by industry, and by employment status—are rather difficult to project. The structural characteristics of the labor force—the employed population by occupation and by industry groups, projected from the 1990 Labour Force Survey—are presented in Tables 2, 3, and 4.

Table 2: Projected Labor Force, Labor Force Participation Rate, and Unemployment Rate

Indicator		2004	2005
Total labor force (million)	Male	16.29	16.75
	Female	10.06	10.34
	Total	**26.35**	**27.09**
Labor force participation rate (%)	Male	80.05	80.57
	Female	48.60	48.84
	Total	**64.17**	**64.56**
Unemployment rate (%)	Male	3.62	3.64
	Female	4.67	4.64
	Total	**4.02**	**4.02**

Source: Ministry of Labour.

Table 3: Employed Population by Occupation

Occupation	Number (‘000)	%
Legislators, senior officials, and managers	39.2	0.4
Professionals	294.1	2.8
Technical and associate professionals	211.0	2.0
Clerks	221.5	2.1
Services, shop and market sales workers	1,078.6	10.1
Skilled agricultural and fishery workers	3,503.7	32.8
Craft and related workers	1,235.5	11.6
Plant and machine operators and assemblers	367.0	3.4
Elementary occupations*	3,717.1	34.8
Total	**10,667.7**	**100.0**

*Elementary occupations include those that are less skilled, such as forestry, fisheries, mining, construction, and street vending.

Source: Ministry of Labour.

[2] Soe Win Maung, 2001. *Overview of Agriculture Sector in Myanmar*. Paper contributed to the National Seminar on Food and Agricultural Statistics in Myanmar. Yangon, Myanmar. 29–30 January 2001.

Table 4: Employed Population by Industry Group

Industry	Number ('000)	%
Agriculture, hunting, forestry, and fishing	6,024.3	56.5
Mining and quarrying	101.7	0.9
Manufacturing	1,212.4	11.4
Electricity, gas, and water	18.9	0.2
Construction	281.1	2.6
Wholesalers, retail trade, restaurants and hotels	1,686.7	15.8
Transport, storage, and communication	403.3	3.8
Financial institutions	28.5	0.3
Community, social, and personal services	824.4	7.7
Activities not adequately defined	86.4	0.8
Total	**10,667.7**	**100.0**

Source: Ministry of Labour.

Table 5: Changes in Irrigated Area by Crop, 1997–2007 ('000 hectares)

Crop	1997	2006	2007
Paddy	1,535	2,100	2,419
Wheat	17	53	44
Maize	5	37	44
Pulses	40	154	156
Groundnut	6	23	28
Sesame	57	76	95
Sunflower	5	26	18
Cotton	21	13	15
Jute	30	18	11
Sugarcane	6	10	10
Kitchen crops	59	152	142
Other crops	83	214	252
Total	**1,866**	**2,877**	**3,232**

ha = hectares.

Source: Ministry of Agriculture and Irrigation. 2008. *Myanmar Agriculture in Brief*.

Expansion of the Irrigation Network

At present, less than 10% of the total water resources of 870 million acre-feet available annually is used. Since 1988, following dramatic economic changes, the government invested in dams, reservoirs, and pump irrigation facilities throughout the country using available domestic resources and expertise. The total irrigated area reached 3.2 million ha following the completion of 211 irrigation projects, 307 pumping stations, and 7,578 tube wells between FY1989 and FY2007 (Table 5). Total irrigable area reached 17.8% of the total net sown area in FY2007, rising from 12.6% in FY1989.

Food Security Situation

Rice is the main food crop for the people of Myanmar. The annual per capita consumption is 190 kilograms (kg)—the highest rate of consumption in Asia. In FY2007, out of a total production of 30.5 million tons (mt), about 17 mt of rice were consumed domestically. The self-sufficiency ratio is 179.4%.[3] Edible oil is the second most important food item in the traditional diet of Myanmar. Per capita consumption in FY2008 was 9.8 kg,[4] and total demand for edible oil was estimated to be 643,103 tons (t). Total production from oilseed crops was 337,208 t. The unmet demand was 305,895 t, which was partially supplemented by importing 282,673 t of palm oil. The self-sufficiency ratio for edible oil is 52.4%.[5]

Pulses are the third most important food, with an estimated annual per capita consumption of 13 kg. The change to market economy system led to an increase in total land area planted to pulses from 0.73 million ha in FY1989 to 4.02 million ha in FY2007. Three pulse crops—green gram, black gram, and pigeon pea—account for 80%–90% of total export crops by value.

[3] Self-sufficiency ratio = total production divided by total consumption (seeds, waste, other uses, consumption by local population) multiplied by 100.

[4] Tun Saing, 2002. *Oil-Seed Crops Production: Prospects and Potential in Myanmar*. (In Myanmar version). Mimeographed copy. Ministry of Agriculture and Irrigation. Yangon, Myanmar.

[5] Organization of Petroleum Exporting Countries-funded edible oil project appraisal, 2008.

Rice, oilseed crops, and pulses dominate agricultural production in Myanmar. Overall, Myanmar produces a surplus of food, but due to geographical differences, there are pockets of areas that are food deficient. The regional demand and supply analysis indicates rice-deficit areas in some parts of Myanmar's central dry zone and Shan and Chin states.[6]

Little work has been done to assess food security in Myanmar, except for a study done by the Food and Agriculture Organization of the United Nations (FAO) and the World Food Programme (WFP) for the Food Insecurity and Vulnerability Information and Mapping System program.[7] The report states that out of 324 townships, 52 were classified as very highly vulnerable, 49 as highly vulnerable, 62 as moderately vulnerable, and the remaining 122 as having a relatively low level of vulnerability. Of the 52 very highly vulnerable townships, 29 are located in Shan State. All townships in the state of Chin and two-thirds in the state of Kachin were also reported to be highly vulnerable. Bago, Mon, and Yangon were reportedly the least vulnerable. Townships with good infrastructure were less likely to be vulnerable compared with remote townships.

Rationale and Objectives

Myanmar relies mostly on domestic energy resources to sustain its economic development. Its energy resources are crude oil, natural gas, hydropower, coal, biomass, wind, and solar power. These resources (except wind and solar) fulfill domestic energy requirements.

Under the new economic policy, infrastructure development, construction, and investment in all sectors of economy are growing at a faster pace, and demand for energy has risen correspondingly. To boost crop production, farm machinery is increasingly being used in the rural areas for land preparation, cultivation, threshing, and harvesting. Consequently, demand for fuel—mostly in the form of diesel—is also increasing. With growing fuel demand from industry, machinery, and motorized vehicles, it is estimated that 524 million gallons (gal) of gasoline and 1,392 million gal of diesel will by needed annually by FY FY2030. Because of rising world fuel prices, biodiesel has become a focus of interest in Myanmar. The country plans to produce biodiesel as a substitute for imported diesel oil to help reduce its reliance on imported fuel.

Potential crops for biofuel production fall into two categories—those for making biodiesel and those for making bioethanol. Biodiesel is processed from vegetable oils derived from edible and inedible crops. Edible crops include oil palm, coconut, Thit-seit, Sie-tha-pyay (*Simarouba gluca*), rapeseeds, sunflower, sesame, groundnut, rice bran oil, niger, soybean, safflowers, and *Moringa oleifera* (commonly known as moringa). Inedible crops include *Jatropha curcas* (commonly known as jatropha), the castor oil plant, the neem tree, and Indian beech (*Pongamia pinnata*). Bioethanol is processed from sugarcane, cassava, and other crops such as maize, sweet potato, yam, sorghum, and rice. All of these crops are available in Myanmar.

To increase fuel supplies without endangering food security, jatropha plantations are targeted to reach 3.44 million ha (8.5 million acres) by 2010. The promotion of jatropha cultivation for biodiesel production is intended to help rural households reduce their dependence on fossil diesel. Its potential as a cooking oil and lighting fuel will also be studied. Although the oil content of jatropha seeds is high (36%–38%), and experience can be drawn from Indonesia, India, and African countries, the economics of growing and processing jatropha requires further study in the Myanmar context.

This study provides recommendations for decision makers to assist in the development of a national biofuel program for the commercial development and long-term viability of biofuels. The study aims to help strengthen existing activities and to institute a country biofuel system that would support energy security without adverse effects on food security.

The objectives of this study are to:

(i) identify the energy market outlook, resource base for biofuel production, and policy gaps in biofuel development planning and legislation;

6 Food and Agriculture Organization of the United Nations, Representative Office in Myanmar.

7 UNEP–MYA, Report No. 03/059, 2003.

(ii) determine appropriate regulatory measures and institutional framework;

(iii) determine the priority feedstocks for biofuel production and the necessary market-enabling measures;

(iv) specify appropriate business options relevant to the Greater Mekong Subregion, and to foster business ventures involving private–public partnerships; and

(v) specify strategic activities for the long-term well-being of the rural poor.

The study reviewed specific issues related to environmental concerns, and the issue of food security versus energy security. It also investigated the existing energy supply and demand, energy balances, potential alternative sources, risks and benefits, characteristics of resource base, and business models and their relevant policies. Regulations related to energy and institutional arrangements were also reviewed to determine the policy levers and to suggest a sound regulatory and institutional environment for biofuel development. The biofuel development policy, regulations, and institutional arrangements of other countries were observed to assist in the formulation of the recommendations.

The study assessed the existing national program for large-scale growing of biofuel crops, and the policies to encourage growers, to determine their impact on the well-being of the rural poor. It also investigated the feasibility of establishing small-scale extraction plants that can generate income and job opportunities in rural areas. Existing medium- and large-scale biofuel processing plants were observed to understand the process of establishing plants, and to learn the business arrangements and mechanisms to encourage public–private participation in biofuel production and distribution. Existing sector-based supply and finance arrangements were observed to find ways to mitigate hindrances in business operation, and to study coordination mechanisms to streamline the energy security of the country. The study also considered cooperation opportunities with neighboring countries in the areas of biofuel development, transfer of technologies, and cross-border contract farming in the Greater Mekong Subregion.

The study also reviewed the efforts of various agencies to boost the development of biofuel technology. This was undertaken with a view to improving integration and establishing coordination in research and development, in order to mitigate technical problems, and reduce economic, environmental, and social risks.

The outcome is a biofuel country assessment report that reviews and analyzes the policy options and institutional development, prioritization issues, business options, market outlook, and the characteristics of the resource base. It also identifies recommendations and a master plan for a national strategy for biofuel development.

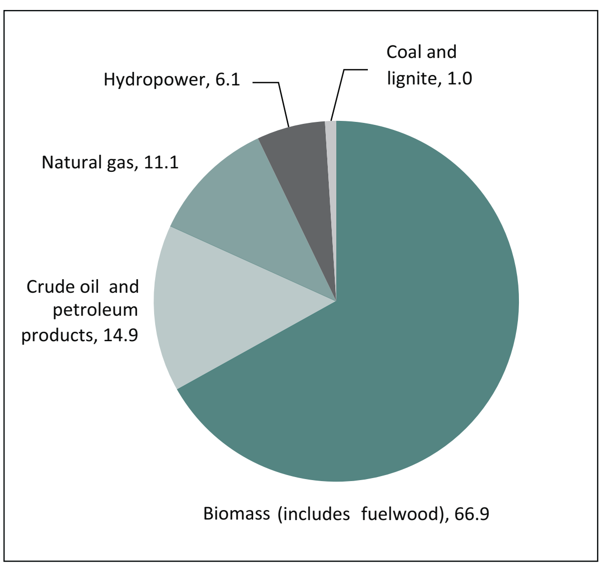
Energy Market and Outlook

Energy Supply and Demand

Energy Supply

Myanmar's diverse energy resources consist of crude oil, natural gas, hydropower, coal, and renewable energy sources such as biomass, geothermal, biofuel, wind, and solar energy (Table 6). Figure 2 shows the major sources of energy supply. Biomass accounts for 66.9% of the estimated annual energy supply of Myanmar, while crude oil and petroleum products (chiefly diesel and gasoline) account for 14.9%. Natural gas accounts for 11.1% of the total, hydropower accounts for 6.1%,[8] and coal and lignite provide 1%.

Figure 2: Energy Supply by Source, 2004 (%)



Source: Energy Planning Department, Ministry of Energy. 2002.

Biomass. Energy use in Myanmar traditionally depends upon energy sources such as wood fuel, charcoal, and biomass. An area of 344,232 km^2—half of the total land area—is covered with forest. The potential available annual yield of wood fuel is up to 19.12 million cubic tons, and 18.56 million acres of land could generate residues, by-products, or direct feedstock for biomass energy. Agricultural by-products, such as pigeon pea stocks, sugarcane burgesses, rice straw, rice husks, sesame stalks, and palm leaves, offer limited sources of energy. However, the use of energy sources such as fuelwood and charcoal aggravates deforestation and consequently threatens the environment.

Crude oil. Crude oil production declined by 0.15% during 1991–2006 (Figure 3). In the same period, domestic production of gasoline increased by 9.9%, but production of diesel declined by about 0.3%. There is a shortfall in domestic supply of crude oil, especially in the transport sector where the number of vehicles is increasing at a rate of 19.3% per year. Domestic consumption of crude oil far exceeds production, and Myanmar needs to focus on the development of crude oil and gas to develop its economy.

In 2008, about 10,000 barrels per day of crude oil were produced from onshore fields. The country's three refineries have a combined capacity of 57,000 barrels per day, although they operate at one-third of this capacity due to old age. Petroleum products produced locally from crude oil include motor spirit, diesel, liquefied petroleum gas, furnace oil, aviation turbine fuel, kerosene, and petroleum coke. A downward trend in the domestic production of these petroleum products is evident, except for motor spirit and aviation turbine fuel.

[8] Hydropower will be discussed in the chapter on Potential Alternative Sources of Energy.

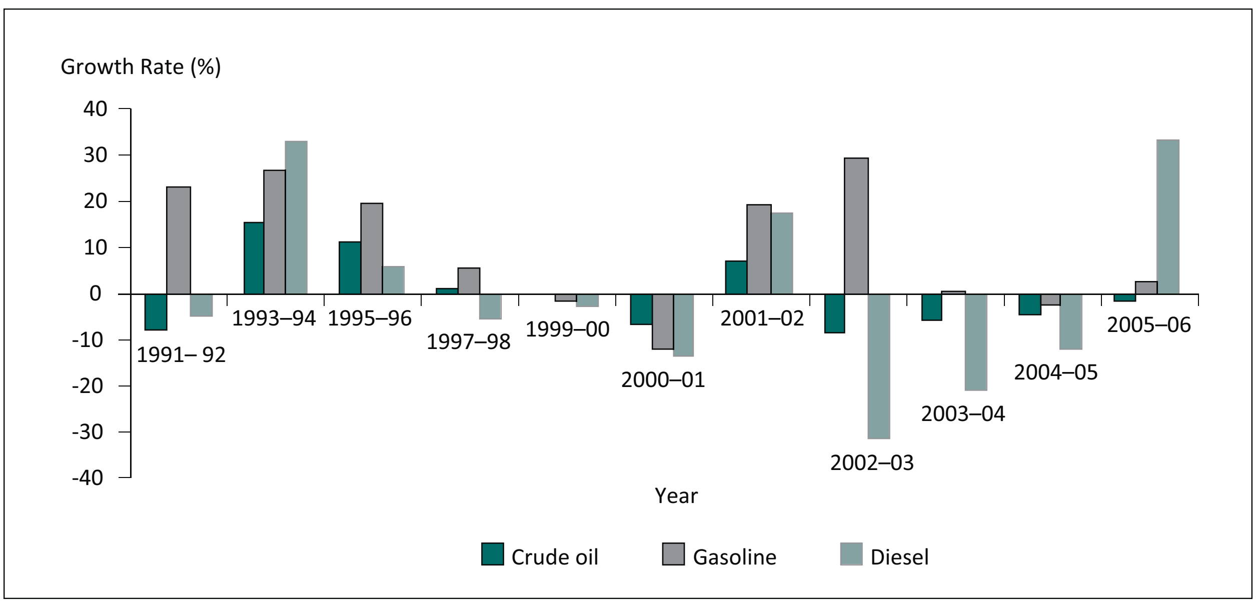
Table 6: Energy Resources

Energy Resource	Quantity
Crude oil (offshore and onshore, proven and probable)	648.6 million barrels
Natural gas (offshore and onshore, proven and probable)	122.5 trillion standard cubic feet
Hydropower	108,000 megawatts
Coal	711 million tons
Biomass	344,232 km^2 covered with forest accounting for 50.8% of total land area Potential available annual yield of wood fuel up to 19.1 million cubic tons 18.6 million acres of land could generate residues, by-products, or direct feedstock for biomass energy 103 million head of livestock could generate animal waste for biogas
Wind	365.1 terawatt hours per year * Coastal strip of 2,832 km with southwesterly wind: 9 months Northeasterly wind: 3 months
Solar power	51,973.8 terawatt hours per year *

* 1997 Estimates by the New Energy and Industrial Technology Development Organization.

Source: Energy Planning Department, Ministry of Energy. 2005.

Figure 3: Percentage Rate of Growth in Production of Crude Oil, Gasoline, and Diesel (%)



Source: Energy Planning Department, Ministry of Energy. 2007.

Natural gas. The Yadana gas field holds reserves of 7.84 trillion cubic feet of natural gas, and the Yetagon gas field contains an estimated 4.35 trillion cubic feet. Total production of natural gas increased more than ten-fold from 33.6 billion cubic feet (BCF) in FY1991 to 377.4 BCF in FY2005. Onshore gas production is, on average, 0.1 BCF. Offshore, both Yadana and Yetagon gas fields produce a combined 1,200.0 BCF per day of natural gas. In addition, Yetagon produces more than 12,000 barrels of condensate from offshore.

Coal. There are 16 major known coal deposits in the country, located in the Ayeyarwady and Chindwin river basins, and in the south. Production and consumption of coal were insignificant in the past due to the remoteness of the coal reserve areas and the lack of sufficient investment. The Myanmar Mines Law of 1994 allowed the private sector to participate in the mining industry. The seven companies operating under large-scale mining permits yielded coal reserves of up to 711 mt (Table 6), and an increase in coal production from 0.99 mt in FY2005 to 1.12 mt in FY2008 (according to the Ministry of Energy). Coal is used in domestic industries or is exported. Several coal-fired cement plants operate in the coal mining area and a new one recently opened in Shan State.

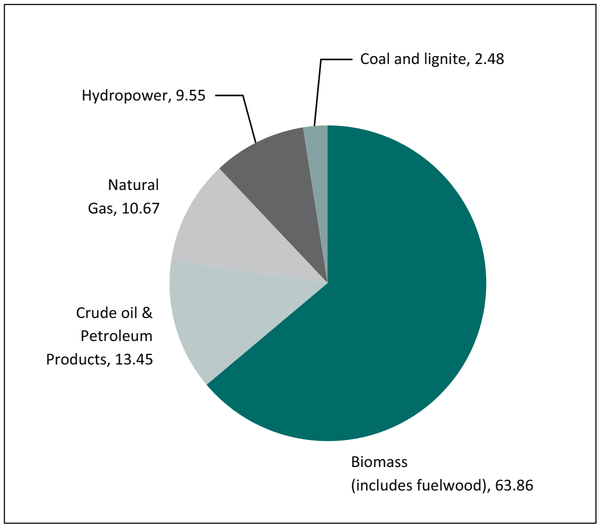
Energy Consumption

Total energy consumption in Myanmar in FY2008 was 14,889 thousand tons of oil equivalent (ktoe). Crude oil accounted for 1,789 ktoe, natural gas 1,721 ktoe, and hydropower generated 1,541 ktoe of electricity. The remaining energy consumed—principally biomass and coal—accounted for 9,838 ktoe.

Biomass is the most important national energy source in terms of consumption. In FY2007, renewable energy from biomass sources—predominantly fuelwood, charcoal, agricultural waste, wood waste, and animal dung—amounted to 63.9% of total energy consumed. The remaining 36.1% of energy consumption came from fossil fuels and water resources (known as commercial energy) (Figure 4). Biomass energy is predominantly derived from wood fuel and agricultural wastes, such as cotton and pigeon pea stalks, sugarcane biogases, rice straws, rice husk, sesame stalks, and palm leaves. It was estimated in 1999 that the use of primary solid biomass (including wood fuel) was 9,504 ktoe.

A survey of annual biofuel consumption per household in rural areas indicated about 8.8 dry tons of biomass. This was made up of 3.7 t of wood fuel, 2.3 t of pigeon pea stalks, and 1.2 t of sesame stalks (Table 7).

Figure 4: Sources of Energy Consumption FY2007 (%)



Source: Ministry of Energy. 2002.

Table 7: Biomass Primary Energy Consumption, per Household, per Year in Rural Areas

Biomass Source	Dry Ton	%
Wood fuel	3.8	42.7
Pigeon pea stalk	2.3	26.2
Cotton stalk	0.5	5.6
Sesame stalk	1.2	13.6
Coconut or palm leaves	0.6	6.8
Rice husk	0.3	3.0
Sawdust	0.1	0.8
Bamboo	0.1	1.3

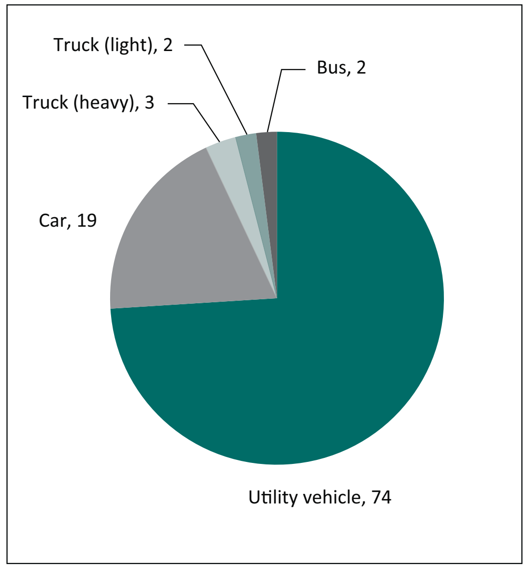
Source: Forest Research Institute. 1996. *Regional Wood Energy Development Programme in Asia*. Report No. 33, 1997. The National Training Workshop on Woodfuel Trade in Myanmar.

The population of Myanmar is projected to increase from an estimated 57.65 million in FY2008 to 60 million in 2010. According to the United Nations Development Programme, approximately 1,000 kilograms of oil equivalent of energy are needed per capita per year to ensure an acceptable standard of living. UNESCAP estimated that per capita energy consumption in Myanmar was only about 430 kilograms of oil equivalent. The Ministry of Energy's estimate for 2000 was about 240 kilograms of oil equivalent, largely from wood fuel, agricultural residue, and animal waste.

Figures for energy consumption by sector (Table 8) are indicative of the current level of development in the country. In 2005, households accounted for 74.3% of total energy consumption, followed by transport with 10.1%, and services and industries with 7.0%. The low energy consumption by industry explains the slow growth in that sector. Agriculture consumed 1.1% of total energy in 2003, declining to almost 0.01% in 2005.

Transport data for FY2005 show that approximately 74% of vehicles are motorcycles, tricycles, and *trawlergi* (utility vehicles) (Figure 5). Motorcycle numbers grew annually by 46.2% and tricycles by 22.6%. Much of the total growth could be attributed to the increased purchase of motorcycles and tricycles during the period. An increased number of utility vehicles will lead to further increases in fuel consumption in the future.

Figure 5: Different Types of Vehicles, 2005 (%)



Source: Ministry of Energy.

The Central Statistical Organization (CSO) conducted a household income and expenditure survey in 1997 to determine the levels and patterns of household expenditure in urban and rural areas, and the standard of living of the households. Wood fuel was found to be the main source of cooking fuel, followed by charcoal and gas. Fuelwood was the major energy

Table 8: Energy Consumption by Source and Sector, 2005 (ktoe)

Sector	Petroleum Products	Natural Gas	Coal	Renewable and Waste	Electricity	Consumption (%)
Industry	187	441	82	304	121	7.0
Transport	1,334	3	—	—	—	10.1
Residential	153	—	—	9,566	126	74.3
Commercial and public service	—	—	—	—	68	0.5
Agriculture and forestry	1	—	—	—	—	0.01
Other sectors	65	605	9	—	—	6.6

— = not applicable, ktoe = thousand tons of oil equivalent.

Source: International Energy Agency. 2007. *Energy Statistics*. www.iea.org source for 73% of total households (42% urban and 93% rural), charcoal for 17% of households (42% urban and 4% rural), and gas for less than 1% of households.

The use of electricity or kerosene for cooking is mainly limited to urban areas. The proportion of households using wood fuel for cooking is much lower in the capital city than in the rural areas, where wood is still the major energy source. Wood fuel consumption for cooking purposes results in deforestation of large areas, creating severe ecological and socioeconomic problems. Introduction of fuel-efficient stoves can significantly reduce firewood consumption. The use of solar cookers and biogas are still limited due to technical and handling problems.

The 1997 CSO survey found that 37% of households had access to electricity for lighting, and 72% of urban households and 18% of rural households had access to electricity. About 10% of urban households and 32% of rural households used batteries for lighting. Electricity was found to be the main source of light for urban households. Battery charging and generators were also used to provide electricity for households. More than 70% of the rural population still had difficulty accessing electricity. A 2008 study by UNESCAP found that the electrification rate was only around 11%, and only 5.7 million people had access to electricity, while 45.1 million people were without access.

The CSO conducted the Household Income and Expenditure Survey in 1989, 1997, and 2001. This investigated the level and patterns of expenditure of households in urban and rural areas and provided data on the standard of living of households. It also showed how households in Myanmar use different kinds of energy sources for cooking. Fuelwood is the major energy source for 73.3% of households in the country, and it was the major source of energy for 42% of urban households and 93% of rural households. 17% of the households surveyed—42% urban households and 4% rural households—used charcoal as a source of energy for cooking. Less than 1% of the country's households used gas.

To improve living standards, Myanmar should make greater use of energy in the form of electricity, gas, petroleum, or fuel oil. Data on production and distribution of petroleum oil and natural gas should be examined to help assess the country's energy security. Myanmar is in a favorable position to produce a substantial amount of natural gas from both inland and offshore reserves totaling 454,799 million cubic feet. Annual export of natural gas is increasing. Gas export jumped from 65,359 million cubic feet in FY2001 to 335,525 million cubic feet in FY2005. There might be a trade-off between the purchase of diesel and the export of natural gas. Table 9 shows the annual production, refining, and distribution of petroleum and diesel.

Electricity Production

Between 2000 and 2004, electricity production in Myanmar grew at an average annual rate of 5.9%.

Table 9: Annual Production, Refining, and Distribution of Petroleum and Diesel
(million gallons)

	Refining and Production			Distribution	
Fiscal Year	Crude oil	Petroleum	Diesel	Petroleum	Diesel
1996	241.6	65.1	116.6	63.5	175.7
1998	268.2	77.7	123.1	75.9	210.6
2000	270.6	82.0	116.1	93.1	198.6
2001	270.1	80.6	112.6	102.8	325.6
2002	252.0	70.8	97.2	92.1	334.2
2003	269.9	84.3	114.0	97.8	334.7
2004	246.7	109.0	77.9	113.3	314.6
2005	232.3	109.4	61.6	115.1	304.0
2006	221.5	106.7	54.1	113.4	271.5
2007	217.7	109.3	72.0	112.3	293.3

Source: Energy Planning Department, Ministry of Energy. 2008.

Per capita consumption of electricity was 45 kilowatt hours in 2004. Total installed capacity increased from 1,173.3 megawatts (MW) in FY2000 to 1,718.56 MW by the end of FY2008. The share of diesel as an energy input in power stations decreased to 4.1% in FY2008 from 5.6% in FY2000.

The share of electricity generated by hydropower increased from 30.7% in FY2000 to 46.7% in FY2008. The share generated by gas and steam turbines was 42.2% in FY2008 (Table 10). Net production narrowly meets consumption (Figure 6).[9] Historicaly, the generation, transmission, and distribution of electricity has been a government responsibility; however, the heavy costs incurred in constructing power plants prompted the entry of the private sector into electricity generation.

Private-sector participation in rural electrification is limited. Few private diesel generators, gasifiers, biogas, and solar vendors exist in rural areas. The rural electrification program aims to supply electricity to homes and villages located beyond the operational areas of local authorities and to enhance the quality of life and living standards in rural communities. Increased use of electricity is expected to raise productivity and income in agriculture, industry, and commerce; effect modernization; and create a change of attitude in rural areas.

Fuel Exports and Imports

Figure 7 shows energy trade as a percentage of gross domestic product (GDP) from FY1986 to FY2005. Fuel imports, which accounted for 0.17% of GDP in FY1986, declined to 0.04% in FY2001, increased by 0.10% in FY2002, and again decreased by 0.01% in FY2005. The United Nations Conference on Trade and Development reported that in 2005, Thailand and India had imports in the range of 3%–5% of GDP in FY2004. Oil imports of the People's Republic of China (PRC), although a significant factor in the world energy

Table 10: Installed Electric Capacity
(MW)

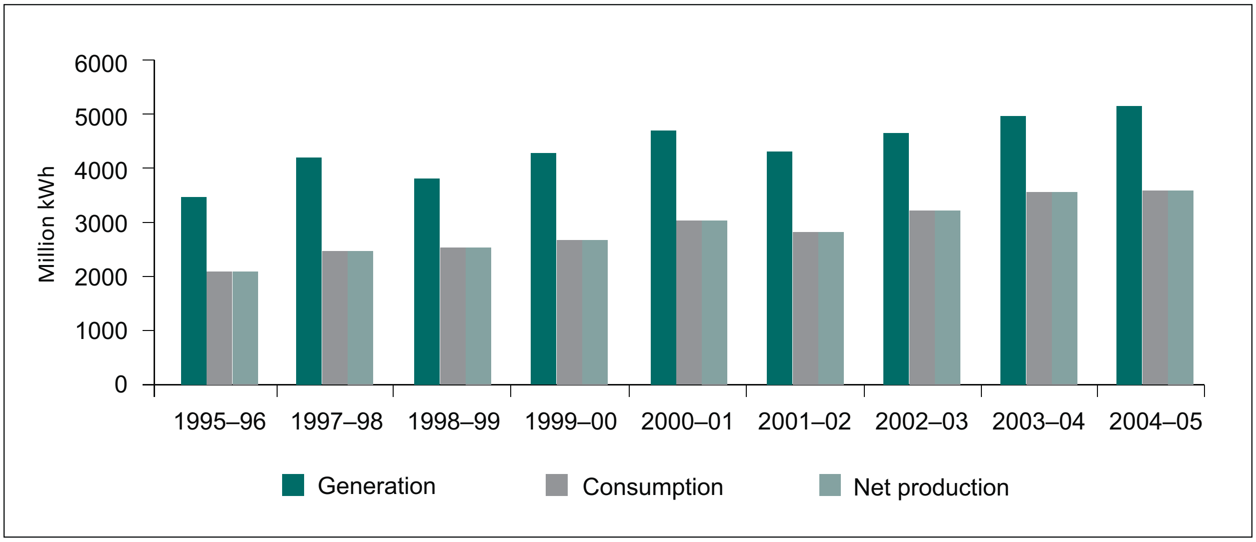
Item	Installed capacity	Hydroelectric	Gas and Steam Turbines	Coal	Diesel
Before 1988					
Grid system	504.7	224. 0	280.7	—	—
Isolated	147.1	4.3	59.4	—	83.5
Total	651.8	228.3	340.0	—	83.5
Percentage	100.0	35.0	52.2	—	12.8
1999–2000					
Grid system	1,032.6	327.0	680.6	—	25.0
Isolated	140.7	33.3	67.0	—	40.4
Total	1,173.3	360.3	747.6	—	65.4
Percentage	100.0	30.7	63.7	—	5.6
2007–2008					
Grid system	1,601.9	767.0	714.9	120.0	—
Isolated	116.7	36.0	10.9	—	69.8
Total	1,718.6	803.0	725.8	120.0	69.8
Percentage	100.0	46.7	42.2	7.0	4.1

— = little or none, MW = megawatts.

Source: Myanmar Electric Power Enterprise. 2008.

9 Generation minus losses equals net production.

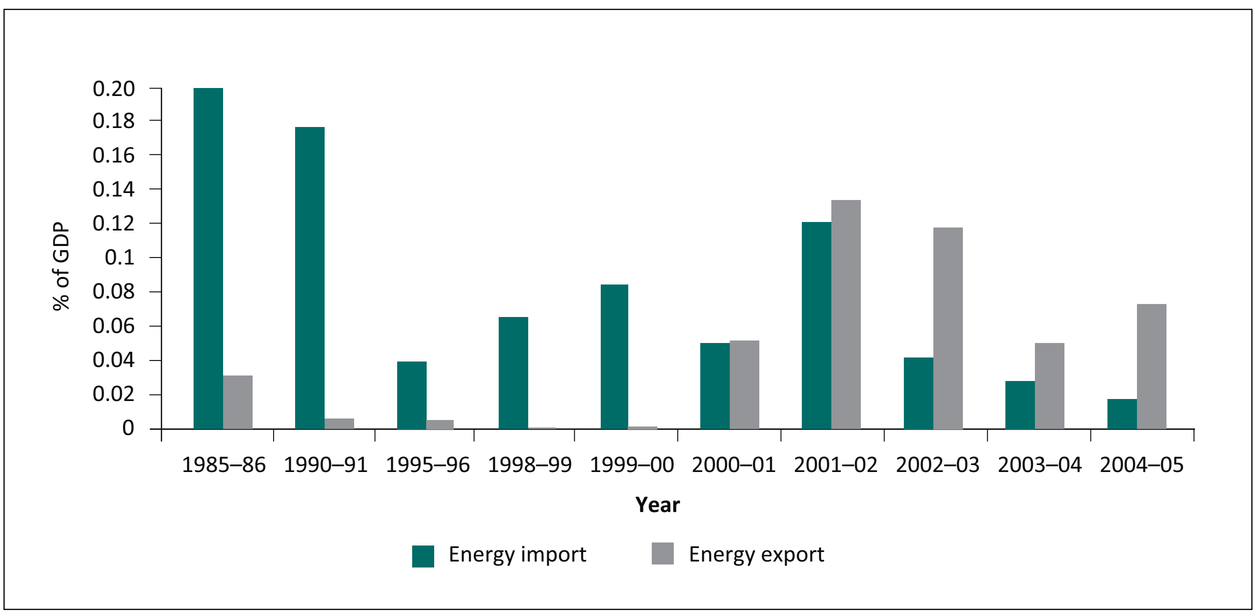
Figure 6: Electricity Generation, Consumption, and Net Production
(million kWh)



kWh = kilowatt-hours.

Source: Central Statistical Organization. 2005. *Statistical Yearbook*. CSO. Ministry of National Planning and Economic Development.

Figure 7: Energy Import and Export as a Share of Gross Domestic Product
(%)



Source: International Energy Agency. 2005.

market, constituted only 2.5% of the country's GDP. The energy export of Myanmar was 0.03% of its GDP in FY1986. It increased to 0.12% of GDP in FY2002. By comparison, Malaysia's energy export was more than 10% of its GDP, while Indonesia's was 4.5% of its GDP in FY2004.

Table 11 shows Myanmar's annual production, consumption, export, and import of fuel in ktoe in FY2005. Total fuel exports accounted for 8,704 ktoe, including 399 ktoe of crude oil, 7,712 ktoe of natural gas, and 593 ktoe of coal. The volume of crude oil exported was very low compared to that of natural gas. Imports of energy consisted exclusively of 1,289 ktoe of petroleum products. The value of crude oil imports for FY1991–FY2005 is shown in Figure 8. Imports can be seen to decline after FY2002.

The volume of petrol oil and lubricants exported and imported in various years (Figure 9) shows that imports of petroleum products are comparatively higher than exports. Figures 9, 10, and 11 illustrate the amount and value of refined mineral oil, lubricants, and related materials exported and imported. In FY2002, some 296 million gal (5.9 million barrels) of refined mineral oil were imported. This shrank to 94.7 million gal (1.9 million barrels) in FY2004 and rose again to 176.4 million gal (3.5 million barrels) in FY2005. Imports fluctuated depending on government budget and domestic demand.

Table 11: Production, Export, and Import of Fuel in FY2005
(ktoe)

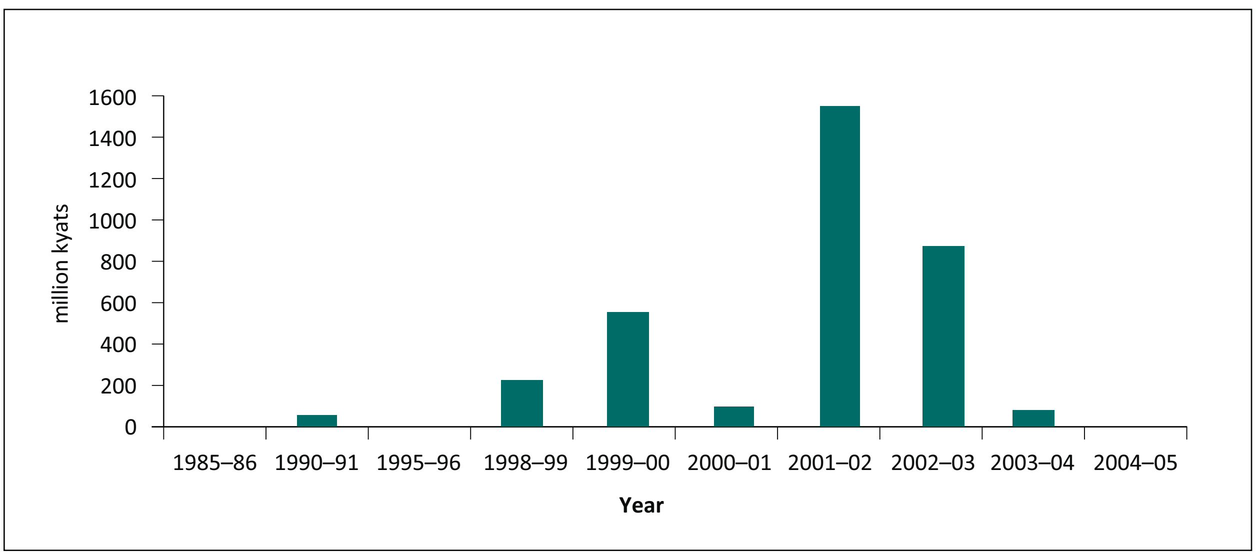
Item	Total Energy	Crude Oil	Natural Gas	Electricity	Coal	Waste*	Petroleum Product
Production	22,143	1,123	9,830	258	684	10,249	—
Consumption	14,725	725	2,118	258	91	9,870	—
Export	8,704	399	7,712	—	593	—	—
Import	1,289	—	—	—	—	—	1,289

— = data not available, ktoe = thousand tons of oil equivalent.

* Combustible renewable and waste.

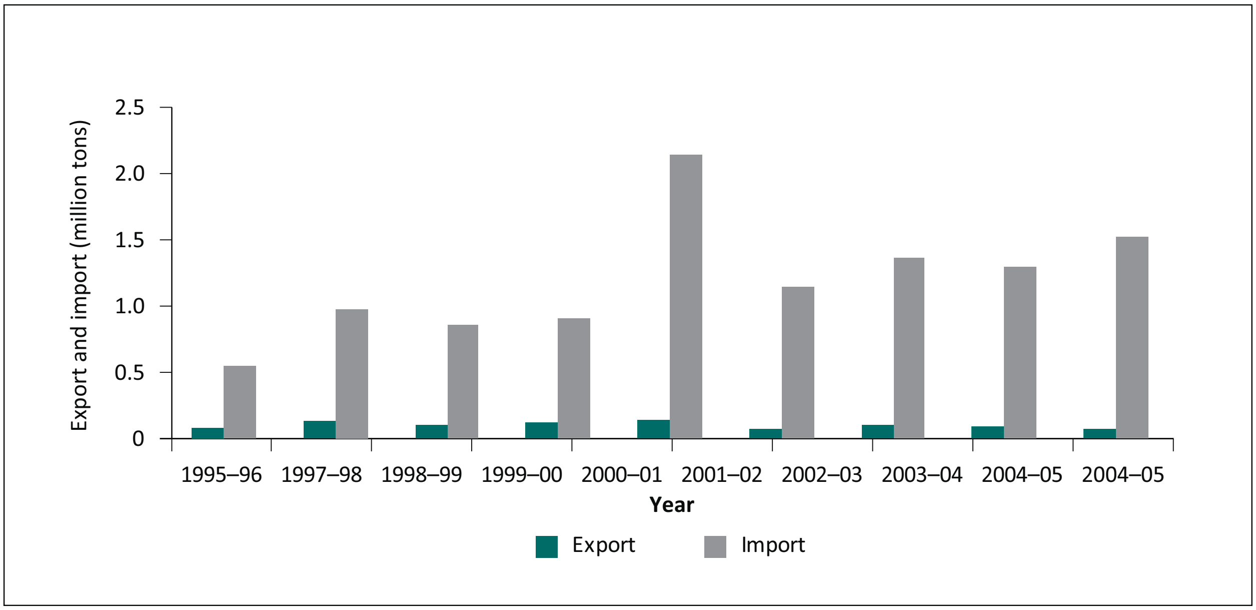
Source: International Energy Agency. 2007. *Energy Statistics*. www.iea.org

Figure 8: Crude Oil Inports, FY1996–FY2005
(million kyats)



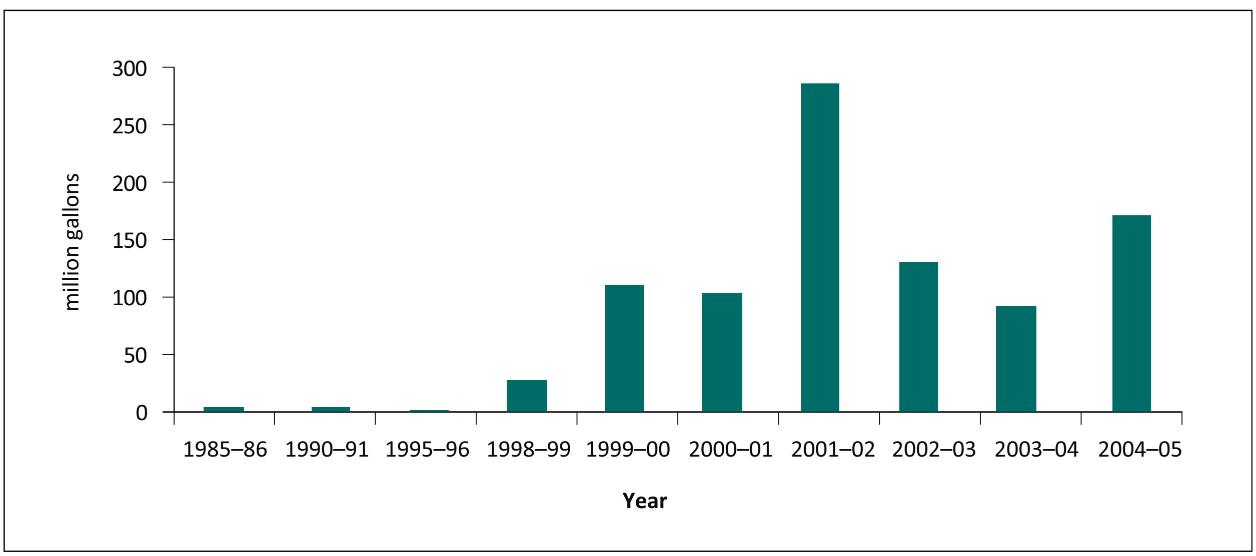
Source: Central Statistical Organization. 2005.

Figure 9: Exports and Imports of Petroleum Oil and Lubricants, FY1996–2005
(million tons)



Source: Central Statistical Organization. 2005.

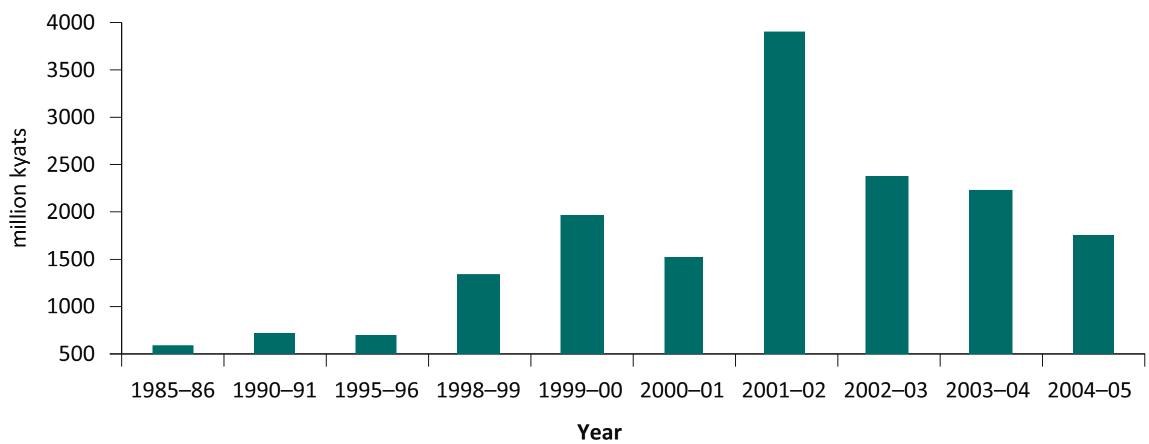
Figure 10: Imports of Refined Mineral Oil, FY1996–FY2005
(million gallons)



Source: Central Statistical Organization. 2005.

Some 1.2 billion cubic feet per day of natural gas produced from offshore areas are exported to Thailand. According to British Petroleum's Statistical Review of World Energy 2007, Myanmar ranks tenth in pipeline export. A pipeline connection has been installed to transport the host country's entitlement from the present reserves and its entitlement from future discoveries to domestic consumers for

Figure 11: Import Value of Mineral Fuels, Lubricants, and Related Materials, FY1996–FY2005
(million kyats)



Source: Central Statistical Organization. 2005.

Table 12: Actual and Projected Energy Consumption by Source of Energy
(ktoe)

	Coal		Crude Oil		Natural Gas		Electricity		Others		Total	
Year	Base Case	High Case	Base Case	High Case	Base Case	High Case	Base Case	High Case	Base Case	High Case	Base Case	High Case
1980	126	126	1,167	1,167	84	84	90	90	—	—	—	**1,467**
1990	37	37	594	594	225	225	149	149	8,389	8,389	**9,393**	**9,393**
2000	72	72	1,518	1,518	324	324	281	281	9,010	9,010	**11,205**	**11,205**
2010	64	66	2,764	2,757	537	570	745	875	10,069	10,090	**14,179**	**14,307**
2020	109	117	4,057	4,312	787	942	1,202	1,966	11,122	11,198	**17,257**	**18,535**
2030	169	190	5,783	6,528	1,074	1,756	1,790	4,454	12,286	12,420	**21,102**	**25,348**

— = no data, ktoe = thousand tons of oil equivalent.

Source: Ministry of Energy.

industrial establishments and power-generating facilities.

Projected Energy Production and Consumption

According to the Ministry of Energy, the demand for petroleum products has been increasing rapidly. Demand for diesel is projected to increase by 25% per year and for motor gasoline by 20% per year. Tables 12 and 13 show the projected energy consumption and production by source of energy. The trend between 1980 and 2030 under a base case scenario showed that energy demand will increase by 12.6% (21,102 ktoe) by 2030. However, energy supply for the same period will increase by 10.49%. There could still be a supply–demand gap, and Myanmar needs to be concerned about its energy security since limited supplies and high prices may constrain economic growth.

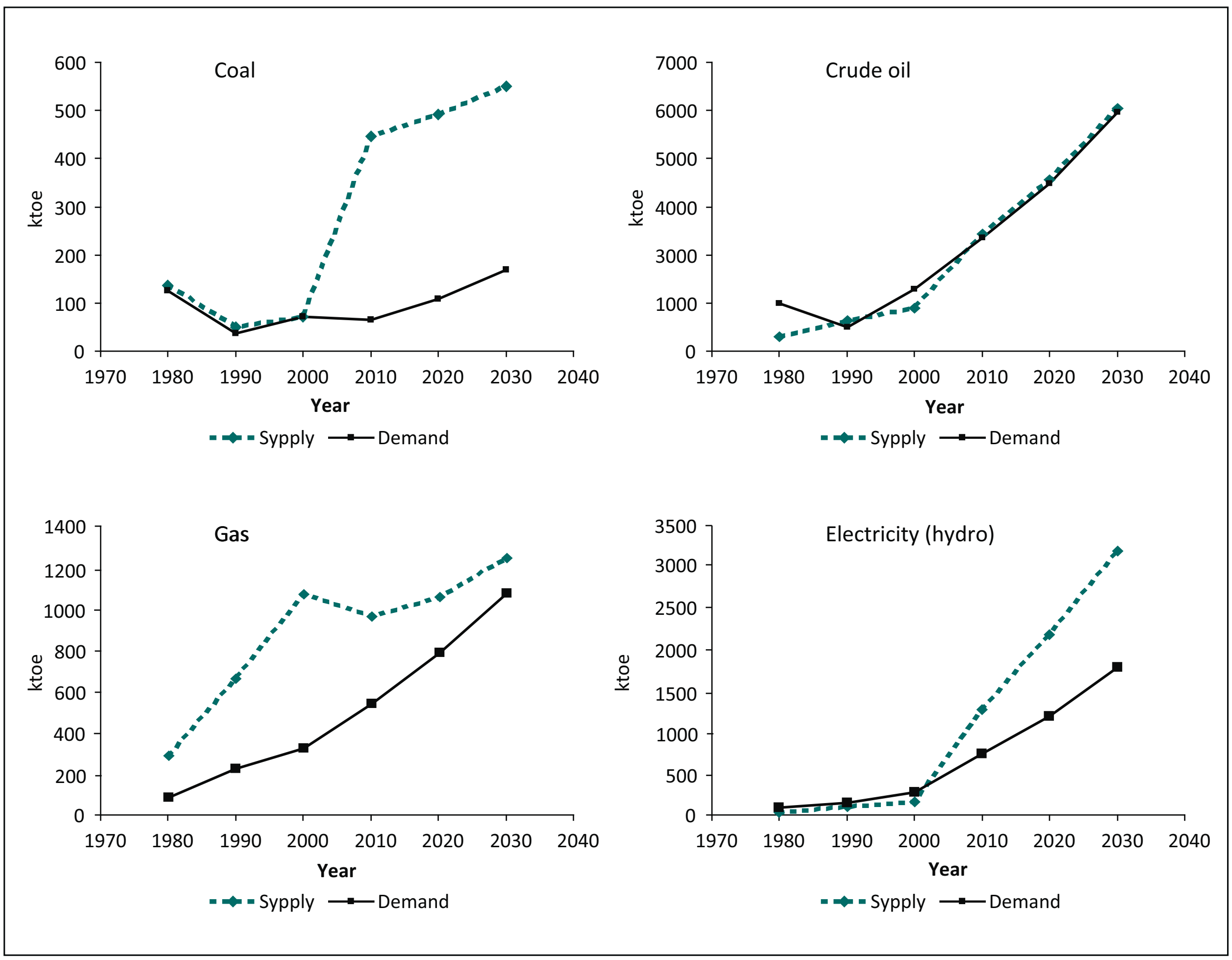
Table 13: Actual and Projected Energy Production by Source of Energy (ktoe)

Year	Coal		Crude Oil		Natural Gas		Hydro		Biomass		Total	
	Base Case	High Case	Base Case	High Case	Base Case	High Case	Base Case	High Case	Base Case	High Case	Base Case	High Case
1980	136	136	368	1,368	286	286	30	30	7,572	7,572	9,392	9,392
1990	49	49	762	762	659	659	103	103	9,021	9,021	10,594	10,594
2000	72	72	1,055	1,055	1,068	1,068	163	163	9,175	9,175	11,533	11,533
2010	446	312	2,852	2,870	960	982	1,281	1,570	10,069	10,099	15,618	15,583
2020	491	363	4,150	4,372	1,054	1,133	2,184	3,217	11,122	11,198	19,011	20,283
2030	551	512	5,871	6,603	1,244	1,899	3,192	6,364	12,286	12,420	23,144	27,798

ktoe = thousand tons of oil equivalent.

Source: Ministry of Energy.

Figure 12: Projected Supply and Demand of Coal, Crude Oil, Natural Gas, and Electricity (ktoe)



ktoe = thousand tons of oil equivalent.

Source: Ministry of Energy.

Data on supply and demand for coal, crude oil, gas, and electricity are shown in Figure 12. The projected supply of coal, gas, and hydroelectricity is significantly higher than the projected demand, while the projected supply of crude oil just satisfies the projected demand.

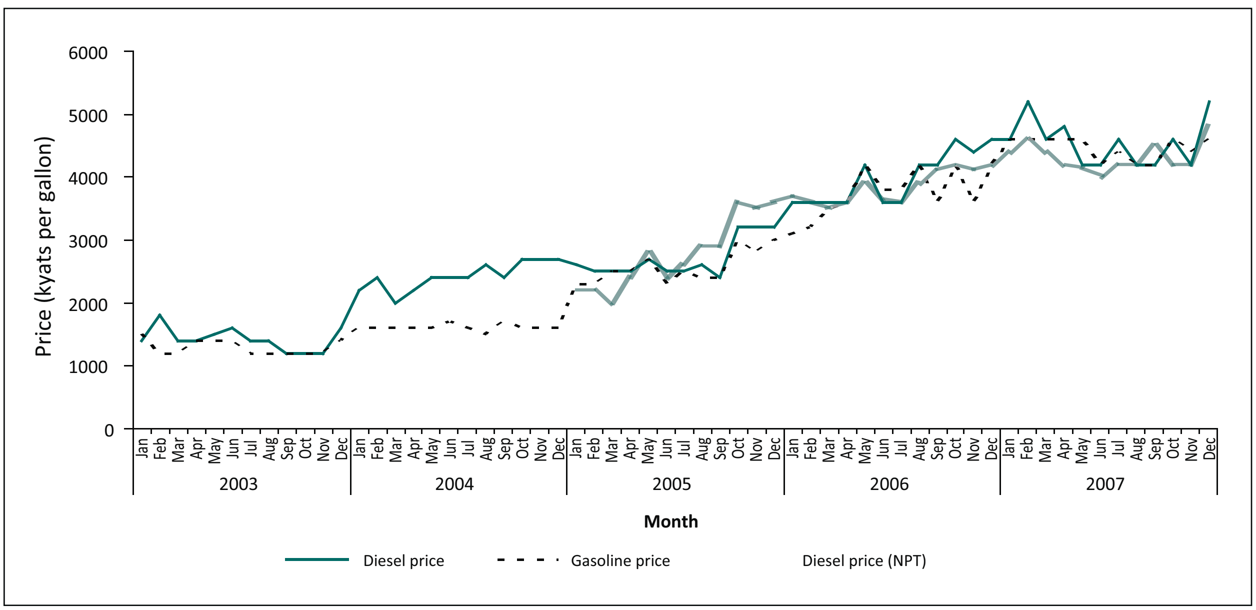
Rising Fuel Prices

Energy deprivation is a defining characteristic of poverty and a formidable barrier to its resolution. The role of energy in people's lives needs to be considered to understand the impacts of oil prices on the poor. In Myanmar, the majority of the population lives in rural areas with little or no access to electricity and is unable to afford fuels, such as kerosene, for essential lighting. Although the urban poor may appear to have better access to fuels and electricity, many continue to rely heavily on inferior biomass for cooking. Biomass remains the single largest source of energy especially among the poor who cannot afford modern energy alternatives.

Fuel prices increased from Kyat (MK) 1,400[10] ($1.42) in 2003 to MK5,200[11] ($4.62) per gal in 2007 for diesel; and MK1,500 ($1.52) in 2003 to MK4,600 ($4.08) per gal in 2007 for gasoline. Figure 13 illustrates the change in world monthly market prices of crude oil, diesel, and gasoline, indicating that fuel prices fluctuated between 2005 and 2006 and started to increase in 2007.

The rising cost of domestic fuels and public transport have affected poor households severely. Before oil prices began their upward trend in 2003, the government regulated the price of many oil products, and subsidized prices to ensure that the poor could afford them. However, as the price of crude oil in world markets surged (Figure 14), and the gap between the international cost and domestic price of

Figure 13: Change in Collected Monthly Market Prices of Oil Products at Two Locations
(kyats per gallon)

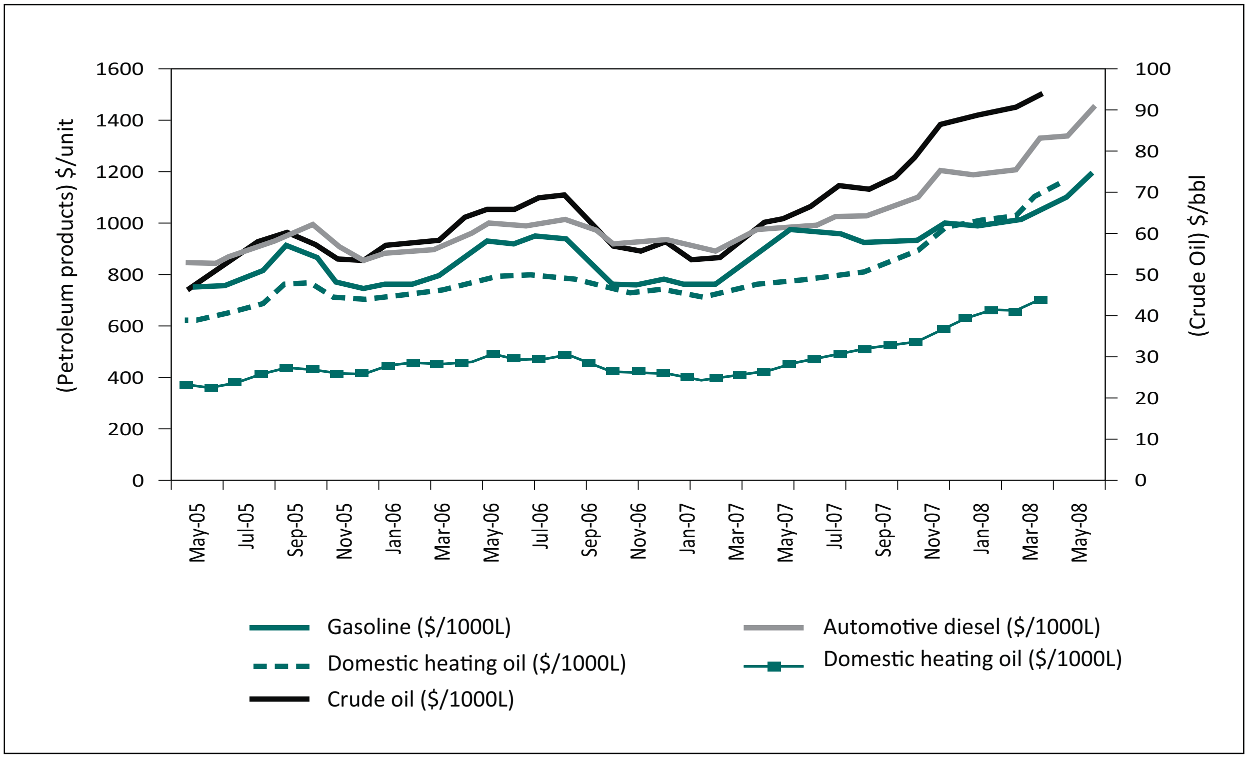


Source: Personal interview (unofficial source) 2008.

[10] $1 = MK983 in 2003.

[11] $1 = MK1,125 in 2007.

Figure 14: Change in World Monthly Market Prices of Crude Oil, Diesel and Gasoline ($)



bbl = barrel, l = liter.

Source: International Energy Agency. 2008.

oil products widened, the capacity of the government to maintain subsidies has been stretched. The government responded by moving domestic prices closer to world market prices, approaching the process of price liberalization.

However, mounting pressure from world markets forced the government to hike domestic prices in larger increments. On 14 August 2007, without prior announcement, it officially increased the price of compressed natural gas by 500% and that of gasoline and diesel by more than 100%—MK2,500 per gal ($2.17) for gasoline, and MK3,000 per gal ($2.61) for diesel. Nevertheless, these official prices are still lower than international prices. The government continues to subsidize petroleum products, especially kerosene and liquefied petroleum gas, which are commonly used in household cooking and lighting, and by the transport sector. This can be very costly. The fuel price hike triggered an increase in bus fares and sent prices of essential commodities soaring. Retail prices jumped sharply and a public backlash occurred, posing a dilemma for the government. However, in the last quarter of 2008, fuel prices in the domestic unofficial market were lower compared to 2007 so the price of commodities went down.

Potential Alternative Sources of Energy

Greater use of renewable energy technologies is one of the promising ways to reduce oil price vulnerability. In recent years, the country began to exploit more renewable energy sources, particularly solar, wind, small hydropower, geothermal, and biomass. Investments in these renewable energy sources have been growing rapidly because of significant oil price increases and climate change concerns.

Hydropower Resources

The electric power sector supplies the electricity crucial for social, commercial, and industrial development. The government plans to develop about 2,000 MW of hydropower in 2012. Hydroelectric power is generated and distributed through the national grid system, which connects the major cities and strategic areas in the central and southern regions of the country. In the past decade, major efforts were made to expand the power system in the grid and off-grid areas. Local and foreign private power companies have been allowed to participate. However, private sector participation failed because of low tariff rates and heavy line losses. Local private companies have again begun to show interest in selected power projects that would be of mutual benefit to the state and the private sector.

Myanmar has abundant resources for electricity generation by small hydropower plants and turbine generators. Appropriate renewable energy technologies and the skills to design and build such systems are available. A relatively small hydroelectric power development can provide not only local electrification but can also enhance local prosperity. It contributes to the local community, for example through the electrification of a hospital and schools, which in turn improves the local economy and uplifts the living standard of the local population. Paletwa township, for instance, has a diesel generator station with an output of 75 kilowatts (kW), which operates only 3 hours per day and provides electricity 24 hours a day. Some 160 sites are suitable for small hydropower with a total potential output of 170 MW. In addition, numerous village sites have the potential for hydropower generation of less than 50 kW and turbine generator installations of 1 kW or less in hilly regions.

Solar Power

Myanmar's tropical location allows it to enjoy abundant year-round sunshine, especially in the central dry zone. Potential available solar energy is estimated at 51,973.8 terawatts per year. Experimental measurements by the Myanmar Electric Power Enterprise indicate that irradiation intensity of more than 5 kilowatt-hours per square meter per day was observed during the dry season. Of the many kinds of solar technology available, wind and solar hybrid home systems have the advantage of 24-hour electricity generation. However, the technology has drawbacks, including barriers to information awareness, the high initial investment cost, and high customs duty on imported parts of the solar home system.

Wind Energy

The New Energy and Industrial Technology Development Organization (NEDO) of Japan estimated the potential available wind energy in Myanmar to be 365.1 terawatt-hours per year.[12] A diesel and wind energy hybrid community power system and a wind energy power system were installed in two locations: the Chaungthar hybrid power supply system project under the Ministry of Electrical Power, and a hybrid system at Chaungthar by NEDO. The project can be used for street lighting, clinic lighting, and other economic and social activities.

Alternative Biomass Fuels

In FY2005, some 49.5% of the total land area of Myanmar was forested.[13] Wood fuel is the main source of energy for households and is the dominant energy source in the country. Its share in the commercial and noncommercial energy mix is approximately 63%. The majority of rural population can easily access traditional wood fuel, which is also cheaper than commercial fuels. Although wood fuel production increased from 16,700,000 cubic tons in FY1986 to 20,500,000 cubic tons in FY2005, the area of wood fuel plantations decreased. Charcoal production decreased to 225,000 cubic tons in FY2005.

Biogas

As an agriculture-based economy, Myanmar has many cows, particularly in Mandalay, Sagaing, and Magway divisions in the central region. On average, a medium-sized animal produces 10 kg of dung per day—enough to produce 0.5 cubic meters (m^3) of biogas through anaerobic biogasification. The biogas produced can be used for cooking, lighting, preserving grains, preparing fodder, and driving internal combustion

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12 From a 1997 NEDO study on renewable energy in the Mekong Basin countries.

13 CSO. 2005. *Statistical Yearbook*. Central Statistical Organization, Ministry of National Planning and Economic Development, the Government of the Union of Myanmar.

engines. Biogas plants are of two types: those with a movable gasholder, and those with built-in, fixed dome gasholder.

In 1980, the government launched a program to promote the use of biogas. A total of 867 family-size, floating-type biogas digesters were constructed in 134 townships in all 14 states and divisions, with highest figure in the central Myanmar region where wood fuel is rarely used. The main drawbacks of the floating-type biogas plant are the high capital investment, intensive maintenance, and short life span of the floating drum.

Yangon Technological University, under the Ministry of Science and Technology, has taken an active part in the dissemination of biogas technology for rural development. Biogas digesters are introduced to generate biogas from animal waste. If there are about 100 cows in a village, approximately 50 m^3 of biogas can be provided by 50 m^3 fixed dome-type biogas plant. Total estimated cost of a 50 m^3 fixed dome-type biogas plant is about MK2.5 million ($4,034),[14] including the cost of a 25-horsepower, 15-kilovolt-ampere (kVA) engine and other accessories for lighting (Figure 15). In a village of 300 households, each paying MK600 per month ($0.96) for one fluorescent tube, the investment needed for the biogas plant would be repaid within 1 or 2 years.

Animal excreta, crop stalks, vegetable waste, and leaves become thoroughly decomposed after fermentation when sealed in airtight biogas pits. Their nitrogen content is transformed into ammonia, which is easier for plants to absorb, thereby improving fertilization. From a 50 m^3 size fixed dome-type biogas plant, 420 gal or 8 barrels per day of effluent slurry are produced, and the digested effluent slurry can be applied as organic fertilizer in place of chemical fertilizers. About 2.87 t of nitrogen, equivalent to 125 bags of urea; 1.15 t of phosphorus pentoxide (P_2O_5), equivalent to 50 bags of superphosphate; and 2.87 t of potassium oxide (K_2O), equivalent to 96 bags of potash are derived from effluent slurry in 1 year. This amounts to annual savings of approximately MK2.3 million ($3,711). According to the research by the Ministry of Science and Technology, this could increase the yield of wheat by 16%, of rice by 15%, and of vegetables by 25%. The exhaust slurry provides ample fertilizer and a good base on which to grow crops.

Biogas technology has reached the stage of technological maturity. Its further uptake will require an effective promotion and dissemination strategy that (i) focuses on capacity building to enhance skills, (ii) creates awareness—particularly among local people—on the use of biogas, and (iii) creates awareness and expertise in ecosystem management, conservation of biodiversity, and sustainable use of natural resources. The services of social scientists, in addition to other scientists and engineers, are essential to remove the skepticism and sociocultural

Figure 15: Fixed Dome-Type Biogas Plant

Source: Authors.

[14] $1 = MK619.75 in 2001.

barriers hampering mass propagation and acceptance of biogas technology among rural people.

Rice Husk and Sawdust Gasification

Another alternative is to use a gasifier—in which biomass is only partially combusted—to generate producer gas. Producer gas is composed of hydrogen, carbon monoxide, and carbon dioxide. It is another low heating-value gaseous fuel that can be used for high-temperature heating applications. All types of biomass, including rice husk and sawdust, can be used to generate producer gas. Although the cost of grid electricity operated by the government is the cheapest source of electricity, the electricity produced by gasifiers is cheaper than that produced by diesel generators (Table 14). Because grid electricity cannot provide 24-hour electricity, small-scale industries in Mandalay are using gasifiers instead of diesel generators to generate electricity. The model used in a private sugar mill in Mandalay is imported from India. The rice husk gasifier consumes nine baskets of rice husk per hour to generate 100 kVA of electricity.

Table 14: Comparison of Cost of Electricity from Different Sources
(kyats per hour)

Source of Electricity	Kyats per Hour
Diesel generator	15,000 ($13.33)
Rice husk gasifier	7,000 ($6.22)
Grid electricity (EPC*)	2,500 ($2.22)

* Electric Power Corporation.

Source: Interview with a private entrepreneur.

Justification of Biofuel as an Alternative Energy Source

Modern energy services are essential to enable a country to achieve the Millennium Development Goals. Myanmar still needs a large amount of energy for its growing population and to meet the needs of its expanding vehicle fleet. A substitute for fossil fuel needs to be developed to meet this demand. In addition, the Government of Myanmar needs to (i) strengthen oil exploration and extraction and increase the capacity of refineries, (ii) raise the share of natural gas for power generation and transport, and (iii) develop clean coal technology as an option to generate energy. The development of some of these nonrenewable sources of energy is costly and therefore requires huge investment.

Renewable energy sources offer promising means to diversify the fuel supply and are becoming increasingly viable. They include small hydro, biomass, wind, solar, geothermal, and biofuels. The technology is developing fast, and in many contexts, small-scale renewable energy is now the cheapest option for

Figure 16: Rural Electrification with Solar Power

Source: Myanmar Engineers Society. 2008.

the poor (Figure 16). Renewable energy technologies are already being used to provide power to electrical grids. Most of this is supplied by large hydropower systems, but increasingly Myanmar is considering small hydropower installations and wind energy.

The other main source for grid electricity is biomass, using agricultural wastes such as bagasse, rice husk, and wood wastes. The national grid does not, however, always extend to the poor in the more remote areas, who typically have to rely on gasoline- or diesel-powered generators for electricity.

Another important option is the use of biofuels—either bioethanol, derived from maize or sugarcane; or biodiesel from refined vegetable oils, such as rapeseed, soy, palm, and coconut. One of the newer feedstock options for biodiesel is jatropha, a fast-growing, drought-resistant perennial. Pilot studies show it has high oil content and can be burned in a simple diesel engine without being refined. However, the economic viability and the ecological, environmental, and social impacts of jatropha need to be assessed as experience of cultivating this plant for commercial use has been limited. Some biofuels are already competitive with petroleum-based products. Others can compete only with the help of subsidies, though prices are decreasing with improved technologies and economies of scale.

The development of biofuels can result in significant savings in foreign exchange due to lower fossil fuel imports; hence it is expected to provide significant welfare gains to society. The creation of a biofuel market will also result in added costs such as the investment cost of biodiesel and ethanol plants, the cost of developing feedstocks, and the costs of hauling and delivery. Biofuel development will have repercussions for the cultivation of sugar and jatropha—the main sources identified for ethanol and biodiesel production. Increased demand for these feedstocks is expected to result in increased production.

Obstacles to the Development of Biofuels in Myanmar

Myanmar is in the process of evaluating the costs and benefits of biofuel development. Given that energy sources will be required to meet the demands of its growing population, biofuels represent a clean alternative with many possible benefits. The main market obstacles to the development of biofuels include

(i) lack of awareness about biofuels in the mainstream market;

(ii) lack of specific knowledge about biofuels as a fuels for heat, power, and transport;

(iii) their status as unknown products;

(iv) lack of consolidated demand;

(v) limited availability of feedstock;

(vi) high price relative to other fuels;

(vii) absence of buy-back arrangements from any company to procure biodiesel crops since these crops do not have any other market value;

(viii) lack of a minimum support price for the biodiesel crops;

(ix) limited research on biodiesel crop varieties to identify high-yielding varieties suited to the agroclimatic zones of the country;

(x) lack of training or workshop to create awareness among farmers and the alcohol industry about the alternative substrates and their economic importance; and

(xi) the need to provide capital subsidies to processing industries, subsidized interest rates to set up a biofuel plant, and tax concession for biodiesel producers.

Keys to a stronger biofuel market are provision of a guaranteed demand, promotion of competition between suppliers, establishment of more points of distribution, and granting of fuel tax exemptions.

Resource Base for Biofuels Production

Energy Security and Sustainability

Myanmar has modest reserves of fossil fuel energy and relatively large renewable energy resources (Table 6). The development of wind and solar energy is still at an early stage. Data on wind energy sources are insufficient to evaluate suitable sites for the construction of wind turbines. Moreover, the initial investment to tap such energy sources is exceedingly high. Hydroelectricity exploitation requires huge initial investment, yet due to the government's commitment, its contribution now accounts for 10.4% of total power generation.

Petroleum production matches consumption in any given year, but diesel production falls short of distribution by 4–5 times in most years. The Ministry of Energy projected the use of both petroleum and diesel in its 20-Year Plan. It was estimated in 2007 that petroleum demand will double by 2010 and quadruple by 2030. This projection may be very conservative if the rate of industrialization increases. Of the additional energy resources to be explored, the most important options are the renewable energy resources, including biomass.

Biofuel Options

Biofuel resources can be divided into three categories:

(i) crop resources such as sugar- and starch-based crops such as sugarcane, sweet sorghum, cassava, palm jaggery (obtained from palmyra tree, Borassus *flabellifer* L.), maize, switch grass, rice, and wheat, and oil-bearing crops such as palm oil, coconut, jatropha, rapeseeds, and groundnut;

(ii) unused biomass such as rice husk, straw, corn stover, corncob, biogases, coconut husks and shells, and palm oil fiber, including empty fruit bunch, sawdust, thinned wood, and wood waste; and

(iii) waste biomass such as animal dung, food waste (e.g., used cooking oil), peeling and scrap waste from the fruit and vegetable industry, waste paper from municipal waste, construction waste, pulp black liquor, and sewage sludge.

In 2008, the Ministry of Energy submitted a draft statement to the government which states the type of biofuel that private entrepreneurs, state, and cooperative agencies can produce, procure, transfer, blend, and deliver.[15] The five types of biofuel are:

(i) bioethanol—a substitute for gasoline, produced from sugar- and starch-based crops such as sugarcane and cassava;

(ii) gasohol or ethanol—a gasoline blend, referred to as anhydrous alcohol (at least 99.96%) blended with gasoline at a specified blended ratio;

(iii) biodiesel—referred to as diesel fuel obtained from inedible oil plants (e.g., jatropha) and edible oilseed crops (e.g., palm oil, coconut, rapeseed, and soybean) through a chemical reaction process;

(iv) biodiesel blend—biodiesel blended with diesel at a specified blended ratio; and

(v) diesohol or ethanol—a diesel blend obtained from mixing bioethanol and diesel.

[15] Advisory Committee to the Ministry of Energy for Issues of Production, Procurement, Transfer, Delivery, and Marketing of Biofuels, 2008.

Biodiesel Production

Crops for Biodiesel Production

Annual and perennial crops are oil palm (*Elaeis guineensis*), coconut (*Cocos nucifera*), jatropha, the castor oil plant (*Ricinus comminus* L.), neem seeds, thit-seit (*Bastard myrobalan*), Pongamia, Sie-tha-pyay (*Simerrula gluba*), Mese (Madhuca tree), rapeseed (*Brassica campestris* L. and other species), niger (*Guizotia abyssinica*), soybean (*Glyxine max* L.), and safflower (*Carthamus tinctarius* L.). Jatropha will be reviewed in detail as this inedible oil crop is a promising resource for the development of biofuels in Myanmar.

Jatropha

Domestic demand for edible vegetable oil is increasing, and every year, 200,000 t of palm oil must be imported for domestic consumption. Feedstocks for biodiesel production in Myanmar must therefore come from inedible oil crops. Among alternative bioenergy sources, jatropha is rated highly, and its cultivation is being pursued as a government priority. About 0.5 million ha (1.86 million acres) have been planted, and the 3-Year Plan of 2006–2008 calls for the expansion of jatropha over 3.4 million ha of land in all states and divisions of Myanmar.

For optimum production, jatropha requires between 900 and 1,200 millimeters (mm) of rainfall per year. It can, however, be grown in areas of low rainfall (600 mm per year) and in poor and degraded soils. Jatropha is a hardy, fast-growing plant that is easy to establish either from seeds or stem cuttings. It thrives in low fertility, marginal, degraded, fallow, or wasteland areas, such as roadsides, railway tracks, and field borders, where it can form a boundary fence or live hedge.

Jatropha is not browsed by animals. Being rich in nitrogen, the seed cake is an excellent source of organic manure. Seed cakes are, however, poisonous to animals and should not be fed to livestock without detoxification. Jatropha trees reach maturity and start to bear fruit 4–5 years after planting. The crop is environmentally beneficial as it sequesters carbon, storing it in its woody tissues, and assists in the build-up of soil carbon.

Jatropha seeds can also be processed into press cake and glycerin. The crop can therefore meet a number of objectives such as domestic energy needs, including cooking and lighting; and can be an additional source of household income and employment through marketing of fuel, organic manure, animal feed, medicine, and industrial raw material for soap and cosmetics. Jatropha trees can protect crops or pasturelands by serving as a windbreak. It can be produced under the Community Development Project for Improving the Living Conditions of the Rural People.

Biodiesel is being processed under a pilot project run by the research team of Myanma Industrial Crops Development Enterprise and the Ministry of Agriculture and Irrigation (MOAI) in Yangon. The output capacity of the pilot plant is 100 gal/day of biodiesel. Parallel attempts to fabricate prototype or model pilot biodiesel pants are being carried out at the Myanmar Agriculture Service, the MOAI and the Ministry of Industry No.2, the Ministry of Science and Technology, and the Ministry of Energy.

The oil content of jatropha cultivars was found to vary from 26% to 41% (Table 15). Genotypes with a high seed yield, high harvest index, high oil content, and resistance to pests and diseases need to be sought. The economic yield is expected to be obtained starting in the fifth year (Table 16). Based on seed yield of 1,000–1,200 kg/acre, processed seeds could yield 50–60 gal/acre.

The government's drive to increase biodiesel production from jatropha, under the direction of the regional commanders, was so extensive that cultivated area increased to more than 1.8 million acres within 4 years of the campaign.[16] To avoid possible conflict with the expansion of food crops, jatropha cultivation has been restricted to roadsides, farm boundaries, and all possible perimeters of villages and towns.[17] Rapid area extension has led to a high demand for seeds for new planting areas. There is no surplus generation of seeds for processing into biodiesel.

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[16] Myanmar Farms Enterprise initiated jatropha cultivation in 2005.

[17] The reported figures of jatropha cultivated area were calculated in terms of prescribed number of plants per acre. The standard plant population is 1,200 plants per acre.

Table 15: Oil Content of Jatropha Seeds from Various Locations, 2006–2007 (%)

Location	Oil Content (%)
Kayah	41.3
Shan (south), Banyin	39.6
Mandalay, Pyawbwe	39.5
India	37.0
Kayin (Thai variety)	36.1
Shan (south), Namlatt	35.1
Shan (north)	34.8
Sagaing (Monywa)	34.1
Sagaing	34.0
Magway	33.9
Big-M	32.8
Bago	31.0
Shan (east)	29.9
Ayeyarwady (Kyankhin)	27.1
Yakhine (Myaypon)	27.1
Sagaing (Tamu)	26.1

Source: Department of Agricultural Research. 2007. *Current Research and Activities in the Physic Nut.* Ministry of Agriculture and Irrigation. Yezin.

Table 16: Onset of Productive Years and Oil Yield of Jatropha

Plant Age (Years)	Seed Yield (kg/acre)	Oil Yield (gallons/acre)
1–2	32	2
2–3	280	14
3–4	600	29
4–5	4,800	40
5 onward	1,000–1,200	50–60

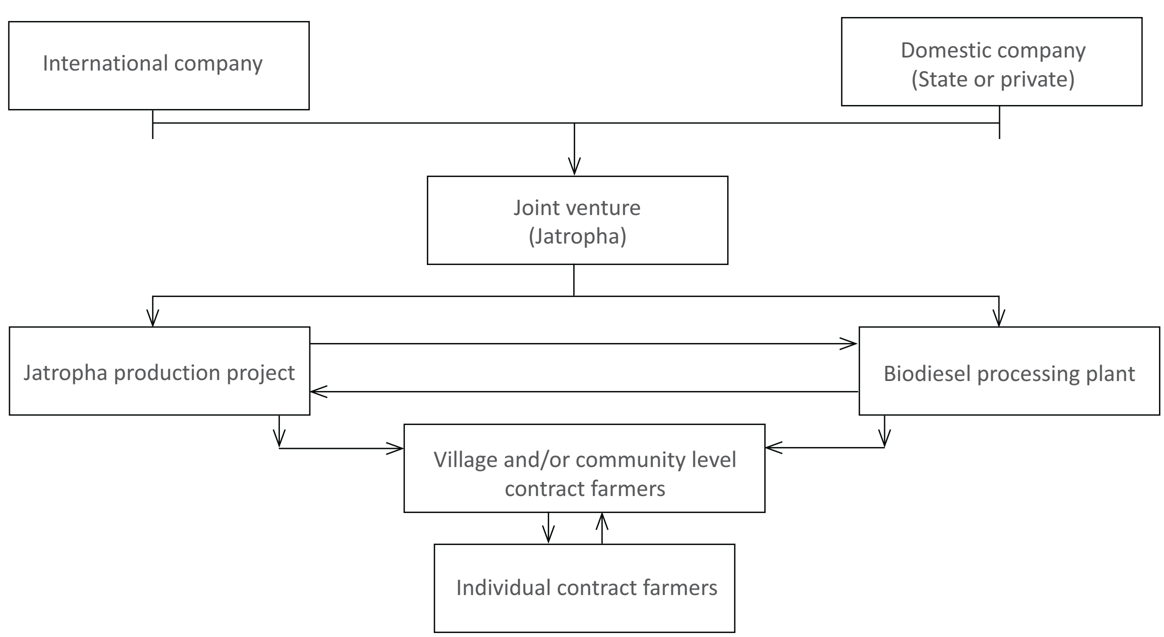
kg = kilograms.

Source: Myanma Industrial Crops Development Enterprise, Ministry of Agriculture and Irrigation.

The actual consolidated measurable planted acreage is estimated to be not more than 30,000 acres in the whole country.

The government's drive to expand the area planted to jatropha focused on both community and large-scale production business. However, the development for commercial processing, marketing, and utilization has been slow. Three or four prominent companies have established jatropha plantations. To accelerate the

Figure 17: Joint Venture Contract Farming Project: Multi-Partner Model



Source:

process, the partnership program shown in Figure 17 is proposed to carry out joint venture contract farming projects.

Other Crops for Biodiesel Production

Another source of inedible, oil-based feedstock for biodiesel production is rubber seed, which contains up to 26% oil. Seed production per acre of rubber plantation at a specified age needs to be assessed. Leaving aside the seed requirement for replanting purposes, the seeds from existing rubber plantations can provide the basis for biodiesel production.

Under current conditions, edible oils are unlikely to become a feedstock for the biofuels industry in Myanmar, as the supply of edible oil is always insufficient to meet demand. Although area extension of oil palm was started 8 years from the start of the program in FY2002, the price of crude oil palm still shows an upward trend. The domestic price is about 5 times higher than the world price. In 2003, the domestic retail price of palm oil was MK1 million/t ($1,032). At this price, the feasibility of diverting palm oil for biodiesel production is extremely low.

Sown Area and Production of Oilseed Crops in Myanmar

Oil crops constitute about 16% of the total crop-sown area in Myanmar, and cereal crops—mainly rice—account for 40% of the crop-sown area (28.98 million ha). In FY2007, of the 3,089,260 ha sown to oil crops, sesame accounted for 47%, groundnut for 25%, and sunflower for 10%.[18] Between FY1996 and FY2006, production of groundnut increased at 7% per year, sesame at 10% per year, and sunflower and soybean at 11% per year. Palm oil production grew at 76% per year, increasing from 5,000 t in FY1996 to 49,000 t in FY2007. Domestic oil supply (including rice bran and cotton oil) was estimated to be 302,051 t in 2007.[19]

Supply–Demand Balance Analysis of Edible Oil in Myanmar

The agriculture policy objectives of Myanmar, especially for the major crops (rice and oil crops), are to produce a rice surplus and to achieve self-sufficiency in oil crops. These crops are the strategically important national crops. Household expenditure is used mainly for rice (about 16% of the total budget) and edible oil (about 8% of the total budget). To maintain food price stability, Myanmar has adopted restrictive policies on the import and export of rice and oilseeds by private companies. However, large quantities of palm oil are imported each year to cover the shortfall in supply of edible oils. Palm oil is important for the majority of low-income consumers because it is usually mixed with other edible oils—such as groundnut, sesame—and sold at an affordable price. Despite long-term efforts to achieve self-sufficiency in edible oil, it is still a deficit commodity in Myanmar.

The Food and Agriculture Organization of the United Nations (FAO) calculated a 3-year (2001–2003) average food balance for edible oil in Myanmar, and estimated the self-sufficiency ratio to be 65% (Table 17).

Table 17: Food Balance of Edible Oil, 2001–2003
('000 tons)

Production ('000 tons)	(-) Export	(+) Import	(-) Other Uses	For Consumption	Self-sufficiency (%)
527	11	264	394	386	65

Source: Food and Agriculture Organization of the United Nations. 2007. Calculated by Dr. Dolly Kyaw, Assistant Professor, Yezin Agricultural University.

18 Department of Agricultural Planning, 2007.

19 The 2007 data is from the Oil Seed Crops Development Project in Myanmar funded by the Organization of Petroleum Exporting Countries, and takes into account the percentages of losses, seed requirement, snacks and other uses, seed export, percentages of oil extraction, and oil cakes. The study excludes the informal import and export data of oilseeds.

According to estimates conducted under an edible oil project by the Myanmar Agriculture Service, the balance sheet of edible oil demand and supply yields a self-sufficiency ratio of 47% for FY2007 and of 52% for FY2008 and FY2009.[20]

Bioethanol Production

Encouraging results are noted in research and development and in the pioneering work of bioethanol entrepreneurs. Alcohol distillation technology is well established in Myanmar. Several participants are entering the sugar production business and the resultant surplus sugar output is being diverted to bioethanol production. Feedstocks for bioethanol production include sugarcane, maize, cassava, potato, sweet potato, yam, and sweet sorghum.

Sugarcane: Meeting the Dual Purpose of Food and Fuel

Sugarcane production is being expanded primarily by horizontal expansion. Sugar production increased markedly after FY1998, following its emergence from import substitution and the shift to export-oriented production. New participants joined the industry while the domestic sugar price was highly attractive; but in 2006, with the fall in domestic sugar price from MK800/kg to MK430/kg, producers accumulated stockpiles. The declining sugar price may become an opportunity for diversion of part of the crop to ethanol production.

In 2000, the Myanmar Sugarcane Enterprise (now the Sugarcane Development Department) set up the first gasohol plant in the country, with a capacity of 500 gal of 99.5% ethanol per day. It was too early to start production as there was no market for the factory's output. At that time, the government-controlled price of gasoline was MK1,500/gal. The production cost of gasohol at the factory was MK3,000—equal to the black market price; hence demand for the factory's product was low. Subsequently, this gasohol plant was converted into a business that produces beverage alcohol. This occurred before the time of renewed interest in bioethanol.

Table 18 indicates the production of sugar in Myanmar. In recent years, overproduction caused a sugar surplus. The emergence of two standard sugar mills in the private sector had led to production in excess of domestic consumption. Direct consumption of sugar appeared to reach saturation point. This is an indication that sugarcane can be diverted to bioethanol production. A regulatory mechanism could be exercised to balance sugar and bioethanol production to avoid conflict with food security. At a certain level, production of bioethanol from sugarcane will not conflict with food security.

Table 18: Estimated Balance of Sugar Stock at End of Fiscal Year 2008
(million tons)

Sugar Producer	Production	Sale	Balance
Ministry of Agriculture and Irrigation	28,316	4,198	24,118
Myanmar Economic Corporation	40,972	18,727	22,245
Union of Myanmar Economic Holdings	15,000	4,000	11,000
Ministry of Industry No.1	Own use		
Private (estimated)	120,000	60,000	60,000
Total	**204,288**	**86,925**	**117,363**

Source: Sugarcane Development Department, Myanma Industrial Crops Development Enterprise. 2008.

[20] Dolly Kyaw 2008. *Feasibility Study for Multi-oil Crops Processing Plant at Mandalay and CPO complex at Kawthaung*. Oil Crops Development Project, FAO, Yangon.

Existing ethanol producers include the Myanmar Economic Corporation—a military-based commercial entity which established two large bioethanol plants with a total annual capacity of 1.8 million gal of sugarcane-based ethanol. Commercial production, distribution, and use commenced in April 2008. Great Wall—a large private company—is also completing the establishment of a factory with a capacity of 3,700 gal/day of sugarcane-based anhydrous alcohol, and another new factory will be constructed by Shwe Li Energy Company in Katha township.

In addition, regional commanders are assigning degraded forestlands and arable lands to private entrepreneurs and army camps for bioethanol production. In some cases, the land has been cleared and factories are under construction. The primary feedstocks selected are sugarcane, maize, sweet sorghum, and cassava. There is room for further expansion of arable lands. On equipment supply, the Myanmar Chemical Engineering Group of local entrepreneurs started to design and fabricate bioethanol plants with gasifiers. The technology is based on the method of azeotrophic distillation, though some entrepreneurs employ the molecular sieve method. The German company, Fritz Werner, offered bioethanol plants with state-of-the-art technology, but at a high price. The present technology is in its infancy.

The area under sugarcane cultivation in FY2007 was estimated at almost 240,000 acres (97,560 ha), and cane production was about 5 mt/year. Based on these figures, the amount of molasses by-products available from both large factories and small and medium-sized sugar plants was 122,500 t. If one-third of the molasses were converted into bioethanol, 1.65 million gal of 95.5% ethanol would be produced. But actual production from large-scale factories would not be more than 50,000 t of molasses because capacity is underused in most sugar factories. Recently, private companies established bioethanol plants by annexing the existing sugar factories in the same compound.

If the sugarcane pricing system could be improved with an equity ratio in favor of sugarcane growers, and if the government could formulate and lay down an appropriate sugar policy and sugarcane act, the cane supply could be increased; and molasses-based ethanol production could increase to reach the potential capacity of the aging sugar factories.

Existing bioethanol plants operated by Great Wall and by the military-based companies could produce 2.3 million gal of bioethanol using molasses as feedstock. No additional cane area is required. Nevertheless, private entrepreneurs are now opening up the assigned lands, mostly in Mandalay and Sagaing divisions. Even if these lands are cultivated, bioethanol will be produced from crops grown on newly opened land. Therefore, conflict between food security and energy security would be avoided.

In a proposal submitted to the Ministry of Energy for the formulation of a bioethanol price, sugar was equated to ethanol based on the current sugar price and the conversion standard of sugar and bioethanol from cane. The suggested sugar-to-ethanol conversion rate is 90 kg sugar equals 60 liters of bioethanol, (or 55 viss of sugar equals 14.25 gal of ethanol in the local units of measurement).

In this proposal, 10 factors that could affect price of bioethanol were identified:

(i) the government-controlled price for gasohol (currently MK2,500/gal) (approximately MK1,100 per $);

(ii) the market price of gasoline of MK3,500/gal (petroleum from government gas stations sold on the informal market);

(iii) the raw food price of competition crops (e.g., the use of maize for animal feed and biofuel production);

(iv) the equity ratio between miller and grower for producing feedstock;

(v) the technological level of crops and conversion ratio of feedstock to bioethanol;

(vi) the anhydrous level of bioethanol (95.5% or 99.9%);

(vii) the blending ratio (e.g., E20, E25);

(viii) non-price factors such as infrastructure, electricity, and fuel feedstock;

(ix) user acceptance of the new product; and

(x) the retail price of beverage alcohol.

There are other ways to produce bioethanol from sugarcane besides using molasses. Sugarcane can be crushed and the cane juice converted directly to ethanol. The conversion rate is about 14.25 gal/ton. If sugarcane processing is directed to the production of both sugar and ethanol, the primary juice (first expressed juice) from the mill could be processed into sugar, while the second and third expressed juice and some of the molasses could be processed into bioethanol.

Bagasse output as by-product of sugarcane processing is about 250 kg per ton of cane (at 50% moisture content). The gross calorific value is 4,600 kilocalories per kg. A rapid assessment of cogeneration potential,[21] which has been made for all existing large sugar factories, is as follows:

Cogeneration potential assessment

1.	Installed capacity of 17 sugar factories	= 27,100 tons crushed per day (TCD)
2.	Potential crushed cane per year	= 4,336,000 t
3.	Potential steam generation (1 kg of burned bagasse 1,000 kg cane produced 260 kg bagasse fiber)	= 732,784 mt = 5 kg production of steam
4.	Potential electrical power output (steam 19 kg per hour = 1 kW)	= 38,567 GWh

Cogeneration actual assessment based on present cane crushing

5.	Actual sugarcane crushed (in 2006–2007)	= 1,071,241 t
6.	Actual output steam	= 181,040 t
7.	Actual electrical power output (steam 19 kg per hour = 1 kW)	= 9,528 GWh
8.	Potential excess electrical power	= 29,039 GWh

The large discrepancy in cogeneration is primarily attributed to the amount of available cane to be crushed. If the present declining boiler efficiency is considered, there will be a large power gap. The industry needs to improve the energy input–output system. Myanmar's sugar industry is small compared with other countries, thus sugarcane can offer one energy source, and the country needs to rely on multiple feedstocks.

Current activity in the bioethanol industry is dominated by companies and large-scale entrepreneurs. However, since this is a new industry, early access should be made available to small growers in the communities. A scheme for community-level production of bioethanol has been proposed by Sein Thaung Oo of the Myanmar Engineering Association. The area of sugarcane required to produce a specified level of bioethanol has been computed and an ethanol plant of appropriate capacity has been designed and fabricated for custom-made, small-scale production (Table 19).

Processing uses the azeotrophic distillation method using cyclohexane. The method could be found in gasohol plants of Myanmar Sugarcane Enterprise (now known as Sugarcane Development Department) and Taungzinaye Plant under the Myanmar Economic Corporation. Some entrepreneurs use molecular sieve technology to produce anhydrous alcohol.

Ethanol from Rice By-Product

Rice is grown almost everywhere in Myanmar. Broken rice—a by-product of rice milling—offers a good source of feedstock for bioethanol production at the current conversion rate of 87 gal/ton. The total output of broken rice in FY2006 was 2.35 mt. It is commonly used as animal feed. Some 0.62 mt of broken rice was sold during FY2003.[22] Unrecorded data from informal channels indicate that 1.0 mt of broken rice was allotted to animal feed and 1.4 mt was used to produce beverage alcohol and as input for other

[21] Cogeneration is the recycling of wastes from the production process such as bagasse or heat, to produce electrical power, which can be used by the plant or sold to the community.

[22] Tin Htut Oo and Toshihiro Kudo, ed., 2003. *Agro-Based Industry in Myanmar: Prospects and Challenges.* Chiba, Japan: Institute of Developing Economies, Japan External Trade Organization, ASEPD No. 67.

Table 19: Planting Area Required for Sugarcane to Produce a Desired Amount of Bioethanol at the Community Level

Particular	Bioethanol Production per Day (gallons)				
	100	200	300	400	500
Sugarcane requirement for bioethanol production per day (tons) (ethanol production rate per ton of cane stalk is 8 gallons)	12.5	25.0	37.5	50.0	62.5
Sugarcane requirement for syrup production per day (tons) (100 kg [0.1 ton] of syrup per ton of cane)	21.3	42.6	63.9	85.2	106.5
Total cane requirement per day (tons)	**33.8**	**67.6**	**101.4**	**135.2**	**169.0**
Syrup requirement for bioethanol production per day (tons)	2.1	4.3	6.4	8.5	10.7
Total syrup production (tons)	383.4	766.8	1,150.2	1,533.6	1,917.0
Sugarcane area required for 1 day's production (acres) (cane yield = 20 tons per acre)	1.7	3.4	5.1	6.8	8.5
Sugarcane area requirement for 1 year's production (acres)	**202.8**	**405.6**	**608.4**	**811.2**	**1,014.0**

kg = kilograms.

Source: Adapted from Oo, S. T. 2007. *Practical Experience on Bioethanol Production*. Myanmar Chemical Engineering Group. Yangon.

traditional rice-based food delicacies. Of this amount, 0.5 mt of broken rice could be diverted to produce 43.5 million gal of bioethanol per year.

Rice is a politically important crop in Myanmar, and the rice trade is a sensitive issue. Rice and its by-products must be used for food; hence only broken rice may be processed into beverage alcohol. The government tightly monitors rice use and restricts its transfer (including broken rice) from rice-producing areas to deficit areas. Furthermore, the cost of moving bulky feedstock is high and would add to the cost of bioethanol production. For this reason, most of the beverage alcohol plants are situated near rice-producing areas. The processing of broken rice to bioethanol awaits a definitive pronouncement from the government.

Ethanol from Maize

Maize is another potential feedstock for bioethanol production. Myanmar's total maize production in FY2007 was around 1 mt (Table 20). A significant increase in maize production was achieved by introducing high-yielding hybrid maize and providing financing for contract farming. According to a report from the Livestock Department of the Ministry of Livestock Breeding and Fisheries, about 13,000 t of maize were used as livestock and poultry feed in FY2003. The livestock industry continues to expand and it is most likely that the annual feed used is much greater than the amount reported. A portion of maize production is also exported (Table 21). The annual surplus of maize production is estimated at 300,000 t. This amount could be diverted to fuel alcohol production. Using a rate of 70 gal/ton, the expected bioethanol production from this volume of maize is 21 million gal. If maize is cultivated close to ethanol plants, the maize stover would be available as boiler feedstock. Although its efficiency is lower than sugarcane bagasse, maize stover could partially supply the fuel needed to power the bioethanol plant.

Bioethanol Production from Sweet Sorghum

In the dry zone areas of Myanmar, sweet sorghum is also a promising new crop for bioethanol production. It was assessed at the Pyinmana Sugarcane Research Center, Taungtwingyi and Hmawbi township in November 2007 (Table 22). An evaluation of sweet sorghum varieties developed by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India, showed that NTJ-2, E36-1 and S-35 varieties possessed both high stalk yield and high sugar content. The variety NTJ-2 would perform well in both wet and dry seasons. Varieties from the United States—M81E and Della—showed good stalk yield and high sugar content (Table 22).

Table 20: Maize Production by State and Division, FY2007
(tons)

State or Division	Production (tons)	% of National Level
Kachin State	26,695.2	2.6
Kayah State	23,575.0	2.3
Kayin State	47,683.9	4.7
Chin Stae	66,538.6	6.6
Sagaing Division	206,280.6	20.4
Tanintharyi Division	0	0
Bago Division(East)	3,768.9	0.4
Bago Division (West)	1,809.6	0.2
Magway Division	104,018.6	10.3
Mandalay Division	51,578.1	5.1
Mon State	0	0
Yakhine State	61.2	0
Yangon Division	5.0	0
Southern Shan State	174,638.3	17.3
Northern Shan State	238,323.7	23.6
Eastern Shan State	29,462.4	2.9
Ayeyarwady Division	37,375.2	3.7
Total	**1,011,814.5**	**100.0**

Source: Settlement and Land Record Department, Ministry of Agriculture and Irrigation. 2007.

Table 21: Maize Exports
(tons)

Fiscal Year	Export	Fiscal Year	Export	Fiscal Year	Export
1997	102,540	2000	88,846	2003	219,000
1998	49,972	2001	148,000	2004	151,000
1999	174,375	2002	90,000	2005	255,000

Source: Central Statistical Organization. Ministry of National Planning and Economic Development, the Government of the Union of Myanmar. 2000, 2001, 2002.

The ratooning ability[23] of two American sweet sorghum varieties was found to be 5–7 t/acre (Table 23). Despite its low stalk yield, the ratoon plant gave enough seed yield for the next season's planting.

The commercial test run to determine the feasibility of producing bioethanol from sweet sorghum yielded encouraging results (Table 24). All sweet sorghum varieties produced an alcohol yield in the range

[23] Ratooning refers to the ability of the plant to regrow from the stubble of the harvested sugarcane or sweet sorghum.

Table 22: Quantitative and Qualitative Evaluation of Exotic Sweet Sorghum Varieties at Pyinmana, Taungdwingyi, and Hmawbi

	Pyinmana (19–28 November 2007)					
	Yield		Qualitative Characters			
Name of varieties	Stalk Stripped (ton per acre)	Seed (kg per acre)	Brix (%)	Pol (%)	Purity (%)	Total sugar (%)
Sweet Sorghum						
M 81E	15.9	1,738	13.5	5.9	43.9	8.8
Della	10.1	1,750	14.3	6.9	48.2	9.3
NTJ -2	14.6	1,731	13.2	5.0	37.8	8.1
E 36-1	14.6	1,156	13.6	7.2	52.7	9.1
S-35	14.0	1,280	13.8	7.4	53.7	8.9
ICSR 93034	13.4	816	10.5	4.5	43.4	5.8
ICSR 93091	15.6	880	11.6	5.5	46.4	6.7
ICSV 93046	9.9	865	10.5	4.8	45.5	6.0
ICSV 700	9.6	764	13.2	5.7	43.1	7.4
SPV 1411	10.9	1,279	13.8	7.2	51.0	8.1
SPV 422	10.6	1,082	13.5	6.4	47.5	7.4
Sugarcane						
Guitang-11	20.0	—	19.2	16.2	84.6	17.7
Taungdwingyi (15–30 November 2007)						
NTJ -2	21.9	1,530				
Hmawbi (1–15 November 2007)						
E 36-1	15.8	2,500				

— = no data, kg = kilograms.

Source: Pyinmana Sugarcane Research Center, Sugarcane Development Department. 2007.

Table 23: Ratoon Productivity of Two American Sweet Sorghum Varieties

Particular	Unit	M 81 E	Della
Yield per acre			
Stripped stalk	ton	6.8	5.2
Seed	kg	491	382
Qualitative character			
Brix	%	15	16
Pol	%	6.3	6
Purity	%	42	37
Total sugar	**%**	**9.1**	**9.7**

kg = kilograms.

Source: Pyinmana Sugarcane Research Center, Sugarcane Development Department. 2007.

Table 24: Laboratory Analysis of Fermentation Process Using Sweet Sorghum and Sugarcane as Feedstocks, Pyinmana, 2007

Feedstock	Juice Extraction[a] %	Juice pH	Initial Brix[b] %	Fermentation Duration hours	Final Brix[c] %	Alcohol Output %
Sweet sorghum						
M 81 E	28.5	5.5	13.2	48	5	6.3
Della	15.0	5.6	15.2	48	5	5.3
NTJ-2	26.2	5.5	14.5	48	7	6.8
Sugarcane						
Guitang-11	26.7	6.2	18.7	48	10	8.3

[a] Juice extraction % is computed from the first juice extracted.
[b] Initial brix is the brix (total soluble solids) in the expressed juice.
[c] Final brix is the brix content after the juice is fermented.

Source: Pyinmana Sugarcane Research Center, Sugarcane Development Department.

of 5.3%–6.0% per ton of stalk. This level could be increased with improved technology. If juice extraction is increased from 40% to 60% (Tables 25 and 26), the ethanol yield would be much improved.

The detailed cost–benefit computation is shown in Table 27. Of the net profit per acre of MK147,475, the farmer's share is calculated to be MK68,225 per acre and processor's share is MK43,900 per acre.

Biomass Energy Consumption from Wood Fuel

The Forest Research Institute in Yezin conducted a survey in Yamethin District to access the annual consumption and cost of wood fuel.[24] The total annual quantity of wood fuel consumed by cottage industries (excluding food stalls and state-owned industries) in the study area was estimated at 9,179 t, and the cost was calculated to be MK11.5 million (Table 28).

If wood fuel consumption of state-owned sugar mills was included, the amount of wood fuel consumption was 18,418 t and the cost was MK21.0 million. The total production value of cottage industries was estimated to be MK588.8 million per year.

Wood fuel requirements vary for different types of industry. To compare the different requirements of the various industries, a cost analysis was made (Table 29). Variations in the cost of fuel used per unit value of each product were calculated. Results showed that the lime industry had the highest fuel costs in proportion to value produced (45.5%). When compared with the types of biomass fuels used by the sugar industry, those using plum kernels as a biomass fuel were found to have lower fuel costs (0.7%) than those using wood fuel (1.1%). Bamboo was found to be a cheaper biomass fuel (1.1%) than wood fuel (1.8%) in two different milk industries. Thus, it was evident that wood fuel was more expensive than other biomass fuels.

24 Forest Research Institute. 1996. *Regional Wood Energy Development Programme in Asia*. Report No.33, 1997. The National Training Workshop on Wood Fuel Trade in Myanmar. Yezin.

Table 25: Comparative Results of Distillation of Sweet Sorghum and Sugarcane by Pot Still Equipment

	Sweet sorghum	Sugarcane
Particular	NTJ-2	Guitang-11
Stalk weight (kg)	4,500	290
Juice production Volume (liter)	1,502	120
Juice weight (kg)	1,260	117
Juice extraction (%)	28	40
Juice brix (%)	14.36	16.13
Initial brix (%)	10	10
Fermentation duration (hours)	44	44
Final brix (%)	6	5
50% Ethanol production (gal)	28.8	2.29
95% Ethanol production (gal)	15.15	1.21
95% Ethanol production (gal) per ton of stalk	3.37	4.16

gal = gallons, kg = kilograms.

Source: Pyinmana Sugarcane Research Center, Sugarcane Development Department.

Table 26: Comparative Results of Distillation of Sweet Sorghum and Sugarcane by Mini Vacuum Pan Boiling and Distillation Plant in Pyinmana

	Sweet Sorghum			Sugarcane
Particular	M 81 E	Della	NTJ-2	Guitang-11
Stalk weight (kg)	2785	560	277	900
Juice production volume (liter)	996	310	117	400
Juice weight (kg)	976	303	115	352
Extraction (%)	35.05	54.25	41.5	39.2
Juice brix (%)	14.25	16	13.5	16
Initial brix (%)	9.5	14	12	16
Fermentation time (hours)	48	48	60	48
Final brix (%)	6	7	5	6
95% ethanol production (liter)	40.7	17.5	4.75	19.3
95% ethanol production (liter) rate per ton of stalk	3.22	6.88	3.79	4.72

kg = kilograms.

Source: Pyinmana Sugarcane Research Center, Sugarcane Development Department.

Table 27: Cost of Production of Bioethanol from Sweet Sorghum, 2007

Particular	Number	Rate (kyat)	Total Cost (kyat)
Income			
Stalk yield per acre x 95% ethanol production per ton of stalk 20 tons per acre x 5.05 gal per ton x sale price, kyats per gallon	101	3,500	353,000
Cost			**206,025**
Cost of cultivation per acre			**120,775**
Land preparation		15,200	
Cultivation		3,800	
Maintenance		6,200	
Harvest cost		60,000	
Input cost		35,575	
Cost of bioethanol distillation			**105,550**
(i) Crushing	20	2,000	40,000
(ii) Distillation	101	250	25,250
(iii) Handling			2,000
Net profit per acre			**147,475**
Operating ratio			**57.3**

Source: Pyinmana Sugarcane Research Center, Sugarcane Development Department.

Table 28: Total Annual Consumption and Cost of Wood Fuel by Cottage Industries, Yamethin District (with corresponding production values)

Industry	Wood Fuel Consumption (ton)	Cost of Wood Fuel (kyat)	Total Production	Units	Production Value ('000 kyat)	Remark
Lime	4,122.4	3,508,657	2,805	ton	7,714	
Sugar	3,411.4	5,757,557	6,455	ton	457,858	
			3,277	ton	60,235	Molasses
Condensed milk	533.3	899,998	252,000	viss*	504,000	
Alcohol	355.5	599,999	216,000	bottle	7,128	
					70	
Brick	636.0	665,905	1,925,000	piece	3,766	
Ceramic	80.0	75,758		piece	300	
Cook stove	40.0	37,879	8,000		800	
Total	**9,178.5**	**11,545,753**			588,271	
State sugar Mill (1)	6,600.0	6,749,952	12,600	ton	893,278	
			7,200	ton	4,352	Molasses
State sugar Mill (2)	2,640.0	2,699,981	15,000	ton		
Total	**9,240.0**	**9,889,933**				
Grand total	**18,418.5**	**20,995,686**				

*1 viss = 1.63 kilogram.

Source: Ministry of Forestry.

Table 29: Comparison of the Fuel Costs of Different Types of Industry

Industry	Annual Production Value (million kyat)	Biomass Fuel Used	Unit Cost of Biomass Fuel (million kyat)	Total Annual Cost of Fuel (million kyat)	Cost of Fuel as % of Value Produced
Lime	7.7	Wood	851.1/ton	3.51	45.5
Sugar (private)	518.1	Wood	1,687.8/ton	5.68	1.1
Sugar (state)	1,028.1	Wood	1,687.8/ton	6.75	0.7
Condensed milk	50.4	Wood	1,687.8/ton	0.90	1.8
Alcohol	7.1	Wood	1,687.0/ton	0.60	8.4
Brick	3.8	Wood	350.1/ton	0.67	17.7
Ceramic	0.3	Wood	947.0/ton	0.08	25.3
Cook stove	0.8	Wood	947.0/ton	0.04	4.8
Alcohol	51.8	Rice husk	75.0/cart	0.69	1.3
Sugar	131.5	Rice husk	75.0/cart	0.43	0.3
Evaporated milk	6.3	Bamboo	7,000.0/truck	0.07	1.1
Sugar (private)	24.6	Plum kernel	20.0/basket	0.18	0.7

Source: Ministry of Forestry.

Prioritization of Feedstocks

Priority Feedstocks for Biodiesel Production

In terms of oil yield per acre, oil palm has the highest potential, followed by coconut, avocado seed, macadamia nut, jatropha, rice bran oil, safflower, sesame, mustard, soybean, cotton seeds, and rapeseed (Table 30). Biodiesel can be produced from high-yielding oil crops such as oil palm, coconuts, rapeseed, and inedible crops such as jatropha and pongam, which may not compete with food crops in Myanmar.

The edible oil self-sufficiency ratio for Myanmar was estimated at 52.4% in FY2007 and 52.0% in FY2009. The edible oil deficit was 23,220 t in FY2007 and 23,100 t in FY2009. Although edible oil production from domestic oil palm increased by 25% in FY2008 (production was 8,400 t in 2007 and 10,500 t in 2008), increasing demand necessitates the importation of 230,000 t of palm oil each year. Consequently, palm oil is not an appropriate feedstock for biodiesel production in Myanmar.

Table 30: Oil Yield of Oil-Bearing Crops
(gallons per acre)

Name of Crop	Latin Name	Oil Yield (gallons per acre)
Oil palm	*Elaeis guineensis*	610
Coconut	*Cocos nucifera*	276
Avocado	*Persea americana*	270
Macadamia nut	*Macadamia terniflora*	230
Jatropha	*Jatropha curcas*	194
Castor bean	*Ricinus communis*	145
Rapeseed	*Brassica napus*	122
Opium poppy	*Papaver somniferum*	119
Peanut	*Ariachis hypogaea*	109
Sunflower	*Helianthus annus*	98
Tung oil tree	*Aleurites fordii*	96
Rice	*Oriza sativa L.*	85
Sesame	*Sesamum indicum*	71
Mustard	*Brassica alba*	59
Soybean	*Glycine max*	46
Cotton	*Gossypium hirsutum*	33
Kenaf	*Hibiscus cannabinus*	28
Rubber seed	*Hevea brasiliensis*	26
Cashew nut	*Anacardium occidentale*	18
Maize	*Zea mays*	18

Source: Adapted from Joshua Tickell. 2000. *From the Fryer to the Fuel Tank: The Complete Guide to Using Vegetable Oil as an Alternative Fuel*. Tickell Energy Consulting. Tallahassee, Florida.

Coconut

Coconut production (raw coconut fruit) in Myanmar increased by 4.5% from 1,243 t in FY2008 to 1,299 t in FY2009. Some copra is exported, but most is retained for domestic use. If the technology for biodiesel processing were available, coconut might be second in priority—after jatropha—for biodiesel production in Myanmar.

Cotton Seed

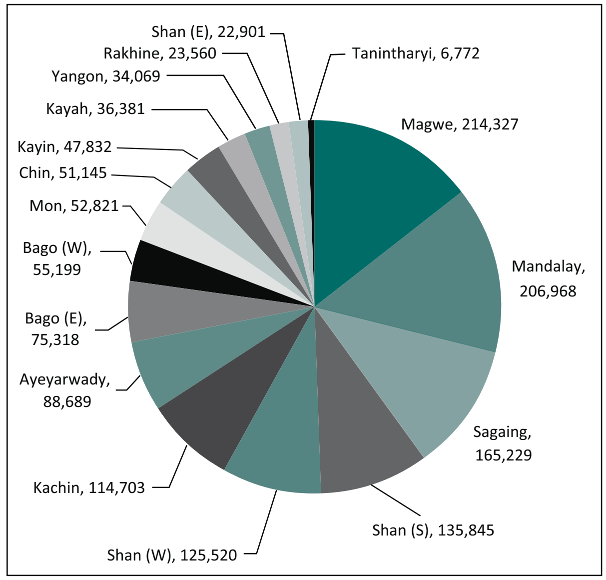
Cotton is grown mainly along the Ayeyarwaddy River in the central dry zone. The total area planted to cotton is about 325,000 ha.[25] Cotton seeds contain about 22% oil and the residual cake contains about 27% protein. Cotton seed—the by-product of the ginning process—significantly contributes to the stocks of oilseed that are crushed for oil and protein meal. However, oil yield is only 33 gal/acre, so it may not compete with oil palm and jatropha. In 2008, the cotton seed surplus after seed utilization for cultivation comprised about 180,000 t, most of which is crushed and used for edible oil, particularly for deep frying. Domestic demand for this long-lasting frying oil is high, so it too may not be available for biodiesel production in Myanmar.

Jathropa

Jatropha ranks fifth among oil-bearing crops in terms of oil production at 194 gal/acre (Table 30). The use of jatropha as feedstock has a number of advantages: it can be grown in different ecological areas and under different soil conditions; it can be cultivated up to 5,000 feet of altitude; it can easily be propagated; seed crushing and oil extraction are not complicated since they can be done with a simple expeller; processing biodiesel from the seed can be easily done by using the transesterification method; and biodiesel produced can be easily blended with fossil diesel.

Jatropha is currently cultivated primarily in the dry zone area. A large area of jathropa cultivation is found in the southern Shan states. Further expansion of jathropa can occur in other marginal areas, especially in Magwe Division and in upper part of Bago Division.[26]

Figure 18: Jathropa Cultivated Area by State and Division, FY2008 (acres)



Source: Department of Agricultural Planning.

Research findings from the Department of Agricultural Research show that the Taungngyu (Eastern Bago) land race has the highest oil content (up to 46%) among the varieties grown in Myanmar. Land races from Magwe Division have an oil content of 32%–44%, Mandalay land races have 23%–42%, and Southern Shan State land races have 21%–41%. Among the exotic varieties, Thailand (D-2) has been found to have the highest oil content (43%). The 72 land races were planted in a field nursery, where characterization of each variety, including oil content and yield, is being carried out. The oil content of the different germplasms is given in Appendix 1.

Pongam

Pongam (or *Thin-win Phyue* in Myanmar) is another potential oil-bearing crop, which is well known and has shown promise in India. According to research conducted at the National Biofuels Center at the Petroleum Conservation Research Center, India, it can be grown in humid and subtropical environments, and thrives in areas with an annual rainfall of

[25] Average for the last 5 years.

[26] As suggested by the Department of Agricultural Research, Ministry of Agriculture and Irrigation.

500–2,500 mm. It can grow in most soil types, from stony to sandy to clay, including Vertisols. Highest growth rates are observed in well-drained soils with assured moisture. Natural reproduction is by seed or by root suckers. It is a medium-sized tree that generally attains a height of about 8 meters and a trunk diameter of more than 50 centimeters. The tree is generally short, with thick branches spreading into a dense hemispherical crown of dark-green leaves. The leaves are eaten by cattle and goats. However, in many areas, the plant is not commonly eaten by farm animals. Its fodder value is greater in arid regions. The oil cake, which remains when oil is extracted from the seeds, is used as poultry feed. Oil yield of pongam is 25% of volume and this is obtained using a mechanical expeller; however, manually run crushers at the village level have an average yield of 20%. The oil can also be used as a lubricant, water-based paint binder, pesticide, and in the soap-making and tanning industries. It can easily be processed into biodiesel using the transesterification method for use as a substitute for fossil diesel.

Pongam can support the growth of other plants through its ability to fix nitrogen. It matures and bears fruit after 10 years. It is already grown in several areas of Myanmar such as the Ayeyarwaddy Delta, the coastal areas, and some parts of Mandalay, Sagaing and Bago divisions. Some areas planned for jatropha cultivation may be planted instead to pongam, or the two crops may be intercropped.

Priority Feedstocks for Bioethanol Production

Sugarcane, maize, cassava, potato, sweet potato, yam, and sweet sorghum are some of the promising energy-yielding crops for bioethanol production.

Sweet Sorghum

Sweet sorghum is recommended by ICRISAT for cultivation in the countries of the Greater Mekong Subregion. Since all crops for bioethanol production are seasonal, it is important to keep feedstock available during the off-season. Feedstock can be made available year-round by making concentrates of either sweet sorghum juice or sugarcane juice during their respective season. It is appropriate to grow and harvest sweet sorghum during the off-season period of sugarcane production. Sweet sorghum can be introduced easily outside the sugarcane area following the existing farming system, particularly in the dry zone of Myanmar. Small growers at the community level can produce bioethanol from sweet sorghum. The planting area requirements of sweet sorghum are shown in Table 31.

Comparison of Bioethanol Feedstocks

A comparison of feedstocks for bioethanol production is shown in Tables 32 and 33. In terms of land area required and input cost, sugarcane is found to be the most promising feedstock. However, feedstocks with high potential, such as sweet sorghum and cassava, will be introduced for large-scale commercial production in the coming years. Maize is used to produce many products such as edible oil, corn powder, and corn-based products by the Ministry of Industry at Taun-dwin-gyi township, Magwe Division. In addition, demand for maize in the livestock sector is increasing, so it can not be considered a potential feedstock for bioethanol production. Export of maize to the People's Republic of China (PRC) and Thailand is also increasing yearly. Similarly, demand for broken rice from the ever-growing livestock and aquaculture sectors is also increasing. Consequently, bioethanol production may not be a suitable option for Myanmar.

Table 31: Requirement of Sweet Sorghum Planting Area

	Bioethanol Production per Day (gallons)				
Particular	**100**	**200**	**300**	**400**	**500**
Sweet sorghum requirement for bioethanol production (tons per day). (Ethanol production rate per ton of cane stalk is 5.05 gallons)	19.8	39.6	59.4	79.2	99.0
Sweet sorghum area requirement for 1 day's production (stalk yield = 20 tons per acre)	1.0	2.0	3.0	4.0	5.0
Sweet sorghum area requirement for 1 year's production (acres)	118.8	237.6	356.4	475.2	594.0

Sources: Myanmar Sugarcane Enterprise and Myanma Industrial Crops Development Enterprise. 2008.

Table 32: Crop Acreage Required to Produce 1 Million Gallon of Bioethanol

Feedstock	By-Product Yield (tons per acre)	Bioethanol Productivity gallons per ton of feed stock	Bioethanol Productivity gallons per acre	Acreage Required for 1 million gallons of bioethanol
Sugarcane	20–25	14.25	285–356	3,509–2,809
Maize	1.75–2.50	70	123–175	8,130–5,714
Cassava (tuber)	5	—	—	—
Cassava (powder)	3	100	300	3,333
Sweet sorghum	18	7	126	7,936
Broken rice	0.113	87	9.8	102,041

— = data not available.

Source: Myanmar Sugarcane Enterprise, Myanma Industrial Crops Development Enterprise. 2008.

Table 33: Cost of Feedstock Component for the Production of 1 Gallon of Bioethanol with Different Types of Feedstock in FY2008

Feedstock	Bioethanol Outturn gallons per ton of feedstock	Market Prices of Raw Material ($) (FY2008)		Cost of Feedstock Component in 1 Gallon of Ethanol ($)	
		Low	High	Low	High
Sugarcane (direct)	14.25	10.71	14.29	0.75	1.00
Sugarcane (by-product–molasses)	50	67.46	107.14	1.35	2.14
Maize	70	128.8	136.09	1.84	1.94
Cassava	100	79.37	198.41	0.79	2.00
Sweet sorghum	7	—	—	—	—
Broken rice	87	150.63	—	1.73	—

— = data not available.

Source: Myanmar Sugarcane Enterprise, Myanma Industrial Crops Development Enterprise. 2008.

Agribusiness Models

Existing Biofuel Business Model

Based on the findings of a rapid appraisal conducted by the study team, rural industries and the agribusiness model for biofuels in Myanmar can be categorized into three groups according to scale:

(i) Community-based, small-scale industries, e.g., village biogas projects; prototype jatropha crude oil processing machines which, with improved research and development, can become sources of biodiesel for villages; small-scale ethanol plants using feedstock such as sugarcane, cassava, and corn; and bio-digesters (gasifiers) using rice husk and wood chips, which are readily available in the villages (see case studies on biogas, jatropha processing, and a pilot ethanol plant).

(ii) Small- and medium-scale industries, which include ethanol plants with a capacity of 300–2,000 TCD (3,600–25,000 t/year of ethanol) using sugarcane, molasses, and sugar syrup (see case study of ethanol plants in Northern Shan State and Sagaing Division); gasifiers with a capacity of 100 kVA using rice husk and wood chips with capacity of 5 assorted generators (220–500 kVA) as described in the case study of Mandalay Industrial Zone.

(iii) Large-scale industries, such as the Great Wall Ethanol Factory in Sagaing Division and Shweli Swan In Factory (36,000 t/year of ethanol) in Shan State (see case studies of large-scale ethanol plants).

Opportunities and Constraints to Biofuel Business Development

Legal Framework and Agribusiness Environment

In the decade that followed the introduction of a market-oriented economic system in 1988, 27 new business-related laws were promulgated and 9 existing laws were amended to encourage the development of private and state-owned enterprises. Prominent among them were the Union of Myanmar Foreign Investment Law (1988), the State Enterprises Law (1989), the Private Industrial Enterprise Law (1990), the Promotion of Cottage Industries Law (1991), and the Myanmar Citizens Investment Law (1994).

Prerequisite laws for small and medium-sized enterprises. A characteristic feature of the pattern of industry in Myanmar is the predominance of small-scale agro-based industries in general and food processing in particular. However, to encourage the development of such small-scale agribusiness industries, and to enhance the spirit of entrepreneurship and competitiveness among them, the government still needs to develop pragmatic laws governing small and medium-sized enterprises.

Lack of special privileges for biofuel pioneers. At the time of writing, special privileges are yet to be considered for those engaged in biofuel business. In Myanmar, it is usual to award incentives for the pioneer entrepreneurs in a reactive rather than proactive manner. For example, the 36,000 t/year ethanol plant in Sagaing Division was due to begin operations in March 2008, even though the permit from Myanmar Investment Commission (MIC) is yet to be released. Investors do not expect the incentives and support normally given to biofuel business in neighboring countries, such as the People's Republic of China (PRC) and Thailand (e.g., price support per ton of ethanol, classification as special interest business, free excise tax, free income tax for 8 years, and freedom from tariffs on imported equipment).[27]

New laws for foreign investors. According to MIC officials, there will be some modifications and improvements in foreign investment law in the future. Preparation of the draft Special Economic Zones Law (10th edition) is also under way.

Since 2007, foreign investors from the PRC, the Republic of Korea, Malaysia, and Singapore who are interested in investing in the biofuel business in Myanmar have discussed with the Ministry of Agriculture and Irrigation (MOAI) the need to conduct initial feasibility studies. One company from the Republic of Korea signed a memorandum of understanding with the MOAI to establish a center in Yangon for research and development on biofuel crops such as jatropha, cassava, and sugarcane. This initial project is to be incorporated into a future project that envisages development of a large-scale biofuel plantation of 150,000 ha in Myanmar.[28]

Contract Farming, Cross-Border Links, and Trading Environment

Local contract farming practice in the sugarcane and ethanol production is well-established in Myanmar. To promote domestic and cross-border trade in contract farming for the biofuel business, it is important to consider carefully the present trade and investment policies that are the sole facilitators of trade flows and for stakeholders involved in the biofuel market chains.

Trading environment. The Trade Council is responsible for the current trade policy. It is also the decision-making body for the granting of export and import permits. The Ministry of Commerce issues export and import permits based on the decision of the Trade Council. Two subcommittees of the Trade Council—the Export Import Coordinating Committee and the Export Import Supervising Committee, organized by the Ministry of Commerce—check the export and import applications submitted by private and government organizations and recommend them to the Trade Council for approval. In general, the principal export policy is to ensure a surplus beyond the domestic consumption level in order to maintain the stability of domestic prices.

Besides dealing with export and import matters, the Trade Council handles cases submitted by the MIC on domestic and foreign investment. It also deals with special cases, such as tax incentives, the use of large tracts of land by an investor, and importation of machinery and equipment for an investment project before and after MIC approval.

Cross-Border Trade and the Ayeyarwaddy-Chao Phraya-Mekong Economics Cooperation Strategy

The Department of Border Trade, under the Ministry of Commerce, is tasked with the export-import affairs of 13 border posts set up at the borders between Myanmar and its neighboring countries—Bangladesh, the PRC, India, and Thailand. The PRC has the largest share of border trade with Myanmar.

Under the Ayeyarwady–Chao Phraya–Mekong Economics Cooperation Strategy (ACMECS)—which involves Cambodia, the Lao People's Democratic Republic (Lao PDR), Myanmar, Thailand, and Viet Nam—Myanmar is responsible for the sector's working group and is a coordinating country for agriculture and industrial cooperation among the members. Activities identified as common projects under the group's agricultural and industrial cooperation include a feasibility study on cooperation in agriculture (particularly cash crops such as soybean, maize, coffee, beans, and livestock); contract farming in agricultural products, including biofuel crops; a feasibility study on the establishment of national accreditation boards, including the creation of verification centers; and cooperation between the standard bodies of the member countries.

[27] Nattasombon, N., 2008. *Biofuel Policies and Future Direction in GMS*. Office of Industrial Economics, Ministry of Industry, Bangkok, Thailand.

[28] Trade and Investment Section, Department of Agricultural Planning, Ministry of Agriculture and Irrigation.

Contract Farming under the Ayeyarwaddy-Chao Phraya-Mekong Economic Cooperation Strategy. Among the common projects, a framework agreement for contract farming to be implemented between Myanmar and Thailand was approved by the Foreign Affairs Policy Committee of Myanmar in 2007. Negotiation between the two countries was still in progress at the time of writing. The framework agreement includes cooperation in the area of biofuel crops such as jatropha, sugarcane, cassava, and soybean. Scenarios are summarized as follows and may be considered not only for Myanmar and Thailand but also for other neighboring countries such as Bangladesh, the PRC, India, and the Lao PDR, since the nature of their investment and trading environments do not differ greatly from those of Myanmar.

Scenario 1. Cross-border contract farming under conventional trade: contract farming deals between the two parties are done under the present trade policy.

(i) Thai entrepreneurs stay in Thailand and make contract deals with Myanmar entrepreneurs in Myanmar. Thai entrepreneurs have their ACMECS special privileges given by the Government of Thailand. Myanmar entrepreneurs do not have special privileges given by the Government of Myanmar.

(ii) Myanmar entrepreneurs then enter into contracts with Myanmar farmers who have their own land, or who will work on virgin lands to be developed by Myanmar entrepreneurs.

(iii) Products of the contract farming, whether raw or processed, are exported to Thailand by Myanmar entrepreneurs according to the contract terms under the present trade policy, i.e., Myanmar exporters apply for export and/or import licenses through the Trade Council.

(iv) The Ministry of Agriculture and Cooperatives (MOAC) of Thailand and the MOAI of Myanmar act as focal ministries to coordinate and facilitate the arrangement.

Scenario 2. Cross-border contract farming under the MIC Law of Myanmar. Contract farming deals between the two parties are done under the Union of Myanmar Foreign Investment Law (1998).

(i) Thai entrepreneurs enter Myanmar and form a company under the MIC Law.

(ii) Thai entrepreneurs make contract deals with either Myanmar entrepreneurs or Myanmar farmers who acquire the land and incentives provided under the MIC Law.

(iii) The products of contract farming, either raw or processed, are exported to Thailand by Thai entrepreneurs according to the contract terms under the present trade policy.

(iv) The MOAC of Thailand and the MOAI of Myanmar act as focal ministries to coordinate and facilitate the arrangement.

Scenario 3. Cross-border contract farming under the ACMECS Special Privileges of Myanmar (A): contract farming deals between the two parties are done under the ACMECS Special Privileges to be given by the Government of Myanmar.[29]

(i) Thai entrepreneurs enter Myanmar and form a company under the ACMECS Special Privileges to be given by the Government of Myanmar.

(ii) Thai entrepreneurs make contract deals with Myanmar entrepreneurs. Myanmar entrepreneurs then make contract deals with Myanmar farmers on the farmers' own land or on the virgin land to be developed by Myanmar entrepreneurs.

(iii) The products of contract farming, either raw or processed, are exported to Thailand by Thai entrepreneurs according to the contract terms under the ACMECS Special Privileges to be given by the Government of Myanmar.

[29] ACMECS Special Privileges to be given by Myanmar is imaginary (i.e., yet to be considered by the policy makers), but should be similar to those of Thailand.

(iv) The MOAC of Thailand and the MOAI of Myanmar act as focal ministries to coordinate and facilitate the arrangement.

Scenario 4. Cross-border contract farming under the ACMECS Special Privileges of Myanmar (B): contract farming deals between the two parties are done under the ACMECS Special Privileges to be given by the Government of Myanmar.

(i) Thai entrepreneurs enter Myanmar and form a company under the ACMECS Special Privileges to be given by the Government of Myanmar.

(ii) Thai entrepreneurs make contract deals with Myanmar farmers on their own land or on the virgin land to be developed by Thai entrepreneurs.

(iii) Products of the contract farming, either raw or processed, are exported to Thailand by Thai entrepreneurs according to the contract terms under the ACMECS Special Privileges to be given by the Government of Myanmar.

(iv) The MOAC of Thailand and the MOAI of Myanmar act as focal ministries to coordinate and facilitate the arrangement.

Since the special privileges to be given by Myanmar to businessmen from both sides are still to be formulated by the government, the best possible option at present would be under the MIC Law, or under the Special Economic Zones Law, which is now under draft and to be adopted in due course.

Integration of Small Farmers into the Agribusiness Chain and Options for Promoting Biofuel Business Ventures

The Bioethanol Business

Because agribusiness depends heavily on agricultural raw material production, there is considerable scope for small farmers to be integrated into the production chain of community-based, small-scale industries and small-, medium-, and large-scale industries.

Small farmers are already well-integrated into the bioethanol business in sugarcane-based ethanol industries because local factory owners erected their plants near sugarcane fields and had control over the production by small farmers primarily because of their proximity. For example, in large-scale sugar and ethanol plants in Sagaing Division, farmers can decide whether or not to take the advance payment from the mill according to the terms and conditions of the contract for growing sugarcane (at 2% interest rate per month). In 2006, sugarcane farmers seemed satisfied with the contracted cane prices (MK18,000/t paid by the mill, compared to the MK13,500/t paid to farmers in areas of government mills). However, falling domestic sugar prices spurred sugar mill owners and speculators to look for opportunities for export, which had been banned by the government previously. At the time of writing, a case-by-case initial permit for export of 350 t of sugar (industrial white) was allowed to a private company. Nevertheless, rural small farmers can be easily integrated into the current agribusiness models in the biofuel market chain due to their well-established relationship with mill owners.

The Biodiesel Business

A similar situation is not yet available in the biodiesel industry due to (i) lack of research and development for both feedstock production and commercial processing of jatropha oil, (ii) lack of clustered plantations, and most importantly (iii) lack of government support for organizing enterprises in the communities, such as farmers' cooperatives or organizations. The formulation of a national biofuel development policy and regional biofuel development policies will need support from the government to promote and sustain both community-based biodiesel and bioethanol production and use initiatives. This support could take the form of

(i) research and development on plantations and oil refining,

(ii) extension services for both feedstock production and oil processing,

(iii) subsidies and credit,

(iv) enabling policies to promote small business development,

(v) formation of genuine cooperative societies in the communities,

(vi) market access and an enabling trade environment, and

(vii) policies to strengthen public–private partnership to help establish business initiatives.

Options for Promoting Biofuel Businesses

Options for the promotion of biofuel businesses should consider both the perspective of small farmers engaged in energy self-sufficiency (for example, through the introduction of community-level biogas plants or biodigesters) and the need to promote large-scale biofuel business ventures—such as large-scale ethanol plants. These are the only options that can meet the nation's fuel needs. The strategy, therefore, must be two-pronged, and the community-based and large-scale elements should not be in conflict. A list of strengths and weaknesses (internal appraisal) and opportunities and threats (external appraisal) of Myanmar biofuel business ventures is provided in Boxes 1 and 2.

Almost every neighboring country of Myanmar has begun to formulate long-term visions and a sound policy framework, has started to invest in research and development, and has begun to encourage business development and to attract foreign direct investment. Myanmar, however, has yet to fully embark on biofuels development and still needs to analyze factors such as food price hikes that will have serious impacts on the urban and rural poor, conservation of biodiversity, deforestation, potential for depleting land and water resources, and the potential negative effects of greenhouse gas reduction.

Box 1: Internal Appraisal of Myanmar Biofuel Business Ventures: Strengths and Weaknesses

Strengths	Weaknesses
(i) Resource endowment: large tracts of unutilized agricultural land, water, cheap labor, and diverse agroecological conditions favorable for production of biofuel crops.	(i) Data difficulties for conducting economic and social assessment.
(ii) Attractiveness of those resources to initially establish factor-driven industries by local and foreign investors.	(ii) Weak interconnection and cooperation among government entities in formulating a sound biofuel policy.
(iii) Fair-sized domestic market: a population of 50 million.	(iii) Weak public–private interface.
(iv) Established legal framework, i.e., English language, English law, for doing business.	(iv) Lack of encouragement (or pragmatic laws) for small and medium-scale enterprises.
(v) Moderate infrastructure facilities (e.g., transport, telecommunications, and utilities).	(v) Lack of incentives for pioneer entrepreneurs (both local and foreign investors).
	(vi) Unhealthy investment environment for foreign investors who can bring capital and technology into the country.
	(vii) MIC Law needs to be modified.
	(viii) Rigid and tedious trade policy for export and import.
	(ix) Weak forward and backward links for marketing and cluster industry.
	(x) Distorted financial policy—multiple exchange rates, fixed and unrealistic interest rate, and high inflation.
	(xi) Poor research and development facilities and lack of budget for promoting biofuel crops.

MIC = Myanmar Investment Commission.

Source: Authors.

Box 2: External Appraisal of Myanmar Biofuel Business Ventures: Opportunities and Threats

Opportunities	Threats
(i) Strategic geographic location with cross-border trade market access to neighboring Bangladesh, the PRC, India, and Thailand, and strong energy demand from these countries.	(i) Fuel security versus food security.
(ii) Free-Trade Pacts (including AFTA, Early harvest scheme of ASEAN+3, BIMSTEC, ACMECS, GMS, and WTO).	(ii) Vulnerable local infant industries.
(iii) Highly interested foreign investors who want to come in for biofuel business along with their financial and technical capacities.	(iii) Negative attributes of multinational corporations: interest of the company versus interest of the local community; new breed of global company versus multi-domestic company.
(iv) Clean Development Mechanism and Certified Emission Reduction.	(iv) Transparency, consistency, accountability, and stability issues.

AFTA = ASEAN Free Trade Area; ASEAN+3 = Association of Southeast Asian Nations Plus Three; BIMSTEC = Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation; GMS = Greater Mekong Subregion; WTO = World Trade Organization.

Source: Authors.

Case Studies of Biofuel Ventures in Myanmar

Case Study of Community-Based Biogas Projects

The Ministry of Science and Technology (MOST) began research into biogas projects in 1995 to help fulfill the energy needs of communities where the wood fuel supply is being depleted. A project was started in 2002 at the cost of MK2,000,000 per 50 m^3 fixed dome-type unit (approximately $7,000) in a village near Kyaukse township, Mandalay Division under the supervision of Kyaukse Technology University (Figures 19 and 20). The MOST provided financial support (to be paid back in installments) for the initial projects, including cement at the government-subsidized price. The project used a 30-horsepower generator with an output of 15 kVA, which is sufficient to supply electricity for a 160-household village. The initial unit supported by the MOST is still in operation and supplies electricity for 2 hours in the morning and 4 hours in the evening. According to the project implementor, the electricity yield of Myanmar biogas units is higher than those she studied in the PRC.

A committee of community elders was also formed to charge every household based on the number of florescent lights, televisions (black-and-white or color) and VCD and DVD players used. The monthly charge rates are MK1,000 for a color television, MK500 for a black-and-white television, MK500 for a VCD or DVD player, MK500 for a florescent light, and MK1,000 for a satellite dish. The project's monthly income of approximately MK150,000 since implementation enabled it to break even after 3 years. The by-products—a waste liquid of cow dung—are returned in order of sequence to villagers who have supplied cow dung. The by-products are used in their fields as organic manure.

Figure 19: Fixed Dome-Type Biogas Tank (50 m^3) Under Construction

Source: Myanmar Engineering Service.

Figure 20: An Almost Completed Biogas Unit

Source: Myanmar Engineering Service.

The MOST has installed 126 biogas units: 98 in Mandalay Division, 8 in Magway Division, 19 in Sagaing Division, and 1 in Shan State. Due to the increase in the price of construction materials, a biogas unit now costs MK8 million and the MOST, now provides only technical, rather than financial, support. In addition to the concrete tanks, steel tanks imported from India have been introduced by the MOST, and are in private use.

The former Agricultural Research Institute (now Department of Agricultural Research) under Myanmar Agriculture Service of the MOAI also initiated biogas projects during the 1980s under the guidance of the socialist government. This program was later discontinued.

At the time of writing, 867 floating-type family-size biogas digesters have been constructed and are operational in 134 townships in all 14 states and divisions of Myanmar. The highest number is in the central Myanmar region where wood fuel is rarely used. If there are around 100 cows in a village, approximately 50 m^3 of biogas can be provided by a 50 m^3, fixed dome-type biogas plant.[30]

The present strategy to expand rural energy self-sufficiency based on the availability of animal waste seems reasonable in view of environmental concerns. However, the use of draught cattle in villages is decreasing due to a rise in the use of small-scale farm machinery. Moreover, cattle are increasingly being smuggled into neighboring countries, such as the PRC and Thailand, for food. Therefore, alternative sources of biomass other than animal waste should be considered in the longer term.

Case Study of Jatropha Crude Oil Processing Machines

At the time of this assessment, jatropha crude oil processing was only at the pilot and research stage. No commercial-scale biodiesel factory was found in Myanmar. The study team visited pilot jatropha crude-oil processing plants located at Hline Tet Farm, Myanmar Agriculture Service, Mandalay Division; North-Eastern Military Command, Lashio, Shan State; and Jatropha and Rubber Plantation in Man Pan Project (Hill 5), Lashio, Shan State.

A pilot jatropha crumde oil expeller and processing plant was donated to the Myanmar Agriculture Service by the Thailand International Development Cooperation Agency under a bilateral technical cooperation scheme between the governments of

Figure 21: Pilot Jatropha Crude Oil Expeller and Processing Plant at Hline Tet Farm

Source: Authors.

[30] Presentation by the Myanmar Engineering Society, 20 March 2008.

Myanmar and Thailand. The aim was to demonstrate the results of 3 years' research and development experience in producing biodiesel from jatropha seeds in Thailand. The mini-machine was installed in the Myanmar Agriculture Service's Hline Tet Farm in Mandalay Division where more than 400 acres of jatropha plants were planted 2 years earlier under the supervision of five farm managers. Jatropha plants grown from seeds were found to be with leaves, while those grown from stem cuts remained without leaves during the dry season.

The small demonstration plant is able to refine 100 liters of jatropha crude oil in 6 hours to produce 97 liters of refined biodiesel. The cost of the small plant is about $50,000 (MK55 million). The farm managers are conducting training and demonstration for jatropha plantation, and instructing nearby farmers and staff of the Myanmar Agriculture Service from other locations.

Under the same roof, another small demonstration plant for jatropha processing was also constructed and installed by Myanma Industrial Crops Development Enterprise. The machine was larger than the one donated by the Thailand International Development Cooperation Agency and was a manual batch type requiring labor to transfer the semi-finished product from one tank to another. The donated machine is a continuous type, though it has a smaller capacity. The refined jatropha oil was used in small hand tractors for demonstration purposes.

Another jatropha crude oil processing machine is located in the compound of the North-Eastern Military Command, Lashio (Figures 23 and 24). This demonstration machine is also a batch type and is able to refine 240 gal of jatropha crude oil in 24 hours. The cost of the machine is calculated to be MK10 million and its refined jatropha oil is said to be used in hand tractors, a trawler-G, and a Toyota Land Cruiser.

Figure 22: Pilot Batch Type Jatropha Crude Oil Expeller and Processing Plant, Hline Tet Farm

Source: Authors.

Figure 23: Jatropha Crude Oil Expeller in North-Eastern Military Command, Lashio

Source: Authors.

Figure 24: Refined Jatropha Oil from the North-Eastern Military Command Plant, Lashio, Shan State

Source: Authors.

Figure 25: Newly Built Batch Type Jatropha Oil Processing Plant in Man Pan Project (Hill 5), Lashio, Shan State

Source: Authors.

Another jatropha oil refining machine is found in Man Pan Project (Hill 5) of North-Eastern Military Command area (Figure 25). It is being implemented by Shan Yoma Peace Company. About 1,250 acres in the area are planted to rubber, jatropha, and macadamia trees.

Case Study of a Pilot Ethanol Plant

A pilot ethanol demonstration plant is located at the integrated farming project (Hill 1) in Lashio, Shan State (Figure 26). The plant was constructed with technical assistance of the Myanmar Engineering Society and is operated by the North-Eastern Military Command. Sugarcane, cassava, rice, and vegetable cultivation and livestock rearing were included in the integrated farming project in addition to the ethanol pilot plant, which has a capacity of 140 gal/day of ethanol (96%).

Licenses have been issued for 20 three-wheel motorbikes, each with a capacity to load 10 passengers, on condition that they are fuelled by 100% ethanol (96%) (Figure 27). A small pump station has been erected in front of the plant. According to the drivers of motorbikes and an engineer from the plant, the fuel distribution system of the engines must be modified due to the lower combustion ratio of bioethanol (1:9) compared to gasoline (1:12).

Figure 26: Pilot Ethanol Demonstration Plant in Lashio, Shan State

Source: Authors.

Figure 27: A Passenger Motorbike using Bioethanol

Source: Authors.

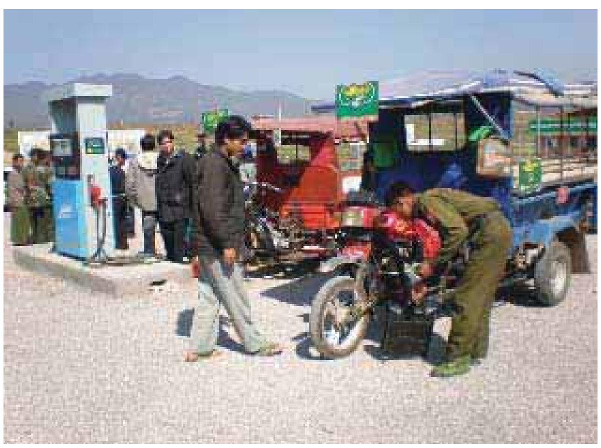
The plant had an initial outturn of 8–12 gal of ethanol per ton of sugarcane. This figure is quite low compared to commercial scale of at least 20 gal, and is mainly due to the efficiency of the rollers (Figure 28).

Due to the early stage of research, the production process does not fully reflect the international technology and practical applications. Most of the drivers are reluctant to use bioethanol because of

Figure 28: Rollers at the Demonstration Ethanol Plant

Source: Authors.

Figure 29: A Motorbike that Uses Ethanol



A military engineer adjusts the fuel system of a motorbike for ethanol use.

Source: Authors.

technical problems, the lower performance of the engine, and the higher volume of fuel used compared to gasoline (Figure 29).

Case Study of Ethanol Plants

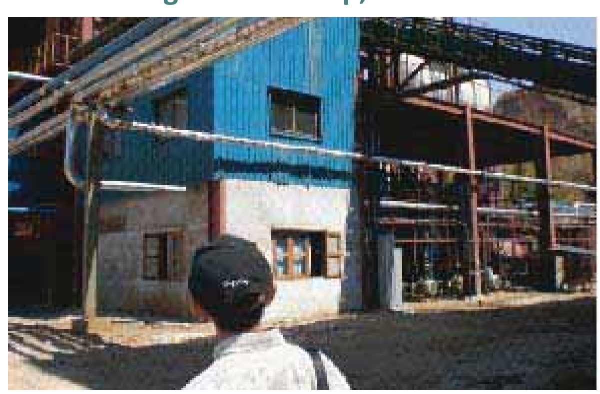
The privately-operated Ngwe Yi Pale sugar factory, which produces 1,500 TCD, is located in Naungcho township between Mandalay and Lashio. Shareholders of the company are expected to expand the present factory into a sugar-cum-ethanol factory if the markets are favorable. The expansion will entail an investment of MK7 billion and will employ 400 workers, both permanent and seasonal. Raw material for the factory is purchased from sugarcane farmers within a 30-mile radius of the plant. Contract farming between the factory and farmers is observed to be quite efficient, as small trucks carrying sugarcane are seen arriving at the factory day and night (Figures 30 and 31).

Figure 30: A Truck Piled High with Sugarcane, Naungcho Township, Shan State

A small truck piled high with sugarcane approaches the Ngwe Yi Pale Sugar Factory at Naungcho township, Shan State.

Source: Authors.

Figure 31: Ngwe Yi Pale Sugar Factory in Naungcho Township, Shan State



Sugarcane being received at Ngwe Yi Pale Sugar Factory in Naungcho township, Shan State.

Source: Authors.

The price of sugarcane paid to the farmers at the time of interview was MK15,000/ton, reduced from MK18,000 paid at the beginning of the crushing season because of the plummeting sugar price in the domestic market. The price of sugar fell from MK1500 per viss in 2007 to MK600 in 2008 mainly because of

(i) an influx of sugar onto the domestic market due to expansion of local small-scale (sugar syrup) industries;

(i) establishment of large-scale dual-purpose (sugar and ethanol) factories;

(iii) release of government-owned sugar factories to the profit-driven private sector, such as Myanmar Economic Holdings and Myanmar Economic Corporation, which are run by ex-military personnel, and other private companies; and

(v) the relatively lower demand for sugar from local foodstuff industries whose outputs are being downsized by sugar-based foodstuffs imported from neighboring countries, mainly the PRC and Thailand.

It was also learned that there was a small-scale sugar factory (100 TCD) near Ngwe Yi Pale factory, which used sugar syrup as a raw material. The future of this small factory appeared uncertain due to the expansion of Ngwe Yi Pale and the deterioration of the domestic sugar market and the cane syrup industry.

Another small-scale ethanol plant of 300 TCD capacity (Figure 32) was under construction by an entrepreneur from Mandalay at Tagaung township, Sagaing Division, only 40 miles from an ethanol-cum-sugar factory of 2,000–2,500 TCD capacity aiming to produce 10 million gal of ethanol per year. This underlines the need for an appropriate location selection policy in line with the national industrial and investment plan. Authorities who are in a position to allow permits for such industries should seriously consider such a policy to avoid unnecessary competition for raw materials between small- and large-scale factory owners.

Figure 32: Cane Juice Boiling Tanks of the Ethanol Plant Under Construction in Tagaund Township

Source: Authors.

Case Study of Gasifiers in Small and Medium-Sized Enterprises

Mr. Soe Min Naing, owner of the Man Myo Daw sugar factory (24 TCD) in Mandalay Industrial Zone, started manufacturing sugar in 1998 using sugar syrup purchased from brokerage houses in Mandalay as raw material.[31] Although the cane-to-syrup-to-sugar process has a 30% higher transaction cost than the conventional cane-to-sugar process, the business thrived since the domestic sugar price was higher than the international price at the time. With the flourishing of large-scale sugar factories away from the government sugarcane-planted area and the recent government policy on releasing state-owned sugar factories to the private sector, the price of sugar in the domestic market has ceased to be favorable for small-scale factories.

Mr. Soe had to cut production costs at the factory, principally by trimming energy costs. By adapting the gasifier to use rice husk instead of pure diesel, importing a 200–225 kVA gasifier from India (Figures 33 and 34), and modifying the existing diesel engine generator to use both diesel and gas, he was able to

[31] Sugar syrup, "Pwat Yay", is obtained from boiling sugarcane juice at the sugarcane farm, in this case, about 100 miles away north from the factories in Mandalay. This kind of industry appeared when the state-controlled cane pricing system was practiced during the socialist era, and continues to the present. In this way, private sugar factory owners could avoid the government's mechanism on fixed cane prices, although the cost of the cane-to-syrup-to-sugar process is quite high compared to the cane-to-sugar process.

Figure 33: Small-Scale Rice Husk Gasifier in a "Pwat Yay" Factory, Tagaung

Source: Authors.

Figure 34: Gasifier at Mann Myo Daw Sugar Factory, Mandalay

Source: Authors.

Figure 35: Making Wood Chips from Plywood Waste at JLC, Mandalay

Source: Authors.

Figure 36: Wood Chip Gasifiers and Generators at JLC, Mandalay

Source: Authors.

operate his factory using a gasifier at the running cost of MK6,800 per hour compared to MK15,000 per hour with pure diesel engine. The hourly cost of using the government-supplied electricity is very cost-effective at only MK2,500 but supply is limited.

The Jewellery Work Luck Company (JLC) in Mandalay Industrial Zone provides another example of the use of alternative energy for electricity production. As the company also manufactures plywood, the company's engineers are able to modify gasifiers to use the wood chips produced (Figures 35 and 36). With five gasifiers using wood chips, the factory has operated five generators (of 250–500 kVA) since 2006. Their research findings show that 1 kg of wood chips can produce 1 kilowatt-hour, while 1.8 kg of rice husk is needed to produce the same amount of energy. However, the availability of wood chips for commercial use is quite limited compared to rice husk, which is abundant in Myanmar.

Case Study of Large-Scale Ethanol Plants

A plant with a capacity of 100 t/day of ethanol (99.8%) began construction at Maunggone Village, Tagaung township, Sagaing Division in 2005 and was expected to be commissioned in March 2008 (Figures 37 and 38). At the time of construction, the crushing capacity was 2,000 TCD, but this is being expanded to 2,500 TCD. The plant will be the biggest in Myanmar to produce ethanol directly from sugarcane. Ethanol will be produced from molasses after the sugarcane cutting season ends to yield a total year-round production of around 10 million gal.

Since it began operation in early December 2007, the plant has produced 500 bags (30 viss) of sugar per day. Cane crushing ends in mid-May. By the end of February 2008, 130,000 t of cane had been crushed out of the 230,000 t contracted with the farmers. The recovery rate of the plant at the end of February 2008 was 10.53, lower than the previous year's recovery rate of 11.17. The managing director of Great Wall said he was thinking of using other raw materials such as corn and cassava as alternative feedstocks. From June to August 2008, the plant produced 80,000 gal of anhydrous ethanol. The distribution scheme for bioethanol was still unclear due to the lack of a national biofuel policy and to differentials among the government's quota prices on fossil fuels, outside market prices on fossil fuel, and privately produced ethanol prices.[32]

Figure 37: Ethanol Plant Under Construction at Maunggone Village, Tagaung Township, Sagaing Division

Source: Authors.

Another large-scale ethanol project is under construction about 50 miles away, on the bank of Shwe Li River, north of the first plant. This second plant is under the Shwe Li Swan In Company, with a cane crushing capacity of 5,000 TCD, but it plans to produce 10 million gal of ethanol—the same volume as the first plant.

These ethanol projects were implemented in 2005 under the guidance of the Prime Minister. Altogether, six cane-based ethanol projects were allowed to be implemented in areas where the sugarcane lands do not compete with state-owned sugarcane areas. Negotiations are under way between the Ministry of Energy and Great Wall to draw plans for the sale of ethanol to motorbike users in Mandalay City.

Pricing ethanol against the background of the government-fixed price of gasoline (MK2,500/gal [approximately $2.27]) was found to be a major obstacle in negotiations because the price of gasoline in the outside market was around MK5,000/gal (approximately $4.54/gal).[33] At the time of writing, the market price of ethanol (96%) was MK2,500–MK3,000/gal. According to sources at Great Wall, the cost of large-scale ethanol (99.8%) production is calculated to be MK2,300/gal without considering the tax-free status, government support, and other import and export incentives given to biofuel businesses by the governments of neighboring countries, such as the PRC and Thailand.

[32] On 2 August 2008, the government's quota prices were MK2,500 ($ 2.17) per gallon of gasoline and MK3,000 ($ 2.61) for diesel. The outside market prices were MK4,800 ($4.17) for gasoline and MK5,500 ($ 4.78) for diesel. The ex-factory price of ethanol (99.8%) was approximately MK2,500 ($2.17).

[33] MK1,100 for $1 at the black market exchange rate in March 2008 and MK1,180 in August 2008.

Figure 38: Maunggone Village Ethanol Plant, Tagaung Township, Sagaing Division

Sugarcane trailers carry and unload cane at the delivery section at Maunggane Village Ethanol Plant.

Source: Authors.

Policy, Regulatory, and Institutional Support for Biofuel Development

National Policies and Strategies for Biofuel Development

Agricultural and Rural Development Policy and Strategy

Food security, export promotion, and enhancing the income and welfare of farmers are the three major goals of the national agricultural policy of Myanmar. A policy was established in 1992 to improve the agriculture sector and uplift the national economy. The policy seeks to

(i) promote the production of food crops and industrial crops without restriction,

(ii) permit the production of industrial and plantation crops on commercial scale,

(iii) allow private investors and farmers to expand agriculture production on cultivable wasteland,

(iv) encourage the participation of the private sector in the distribution of farm machinery and other farm inputs, and

(v) use agriculturally unproductive land for other production programs.

Implementation of the policy involves five strategic approaches:

(i) development of new agricultural land,

(ii) provision and adoption of agricultural machinery,

(iii) provision of irrigation water,

(iv) development and adoption of modern agrotechnology, and

(v) development and use of modern crop varieties.

The agricultural development strategy supports the biofuel development program by allowing the cultivation of biofuel crops without restriction on new agricultural land and by promoting the introduction of modern biofuel-processing technology. The agricultural policy also clearly states that production of industrial crops on a commercial scale is permitted. Planting of jatropha on hillside fallow land in northern Shan State supports the development of land and reduces or prevents soil degradation.

In its efforts to eradicate poverty among the urban and rural poor and promote sustainable food security, the government has laid down agricultural policies, including free choice of crop production, granting of the right to cultivate to those who develop new agricultural land; provision of land for the cultivation of perennial crops to commercial growers; encouraging increased participation of the private sector in the distribution of agricultural machineries and other inputs; and provision of permits to do other businesses.

Energy Development Policy and Strategy

The current energy policy aims to reduce energy imports and prevent deforestation to support national economic development.

Electric power is a core power source for industrial development. Myanmar, with its rich water resources, is considering electric power generation from hydropower for its long-term energy development plan. To reduce demand for fossil fuel, the Myanmar Oil and Gas Enterprise arranged the distribution of compressed natural gas to some motor vehicles from state-owned enterprises and city public transport motor vehicles, since Myanmar is rich in natural gas. The government has also formed a national advisory group, composed of representatives from concerned organizations, tasked to find ways to develop, produce, and market biofuels for use in transport. This would substitute for a proportion of the oil requirement that the Ministry of Energy projects will increase twofold by 2020. Hence, this would reduce the importation of fossil fuel.

Environmental Policy and Strategy

Myanmar Agenda 21, formulated and published by the National Commission for Environmental Affairs, was adopted in 1997 to serve as a blueprint for the promotion of sustainable development. Other directives and notifications related to the environment, particularly greenhouse gas emissions, have yet to be explored. Currently, the most attainable option for curbing greenhouse gas emissions is the development of renewable energy resources, based on sound national environmental policy and strategies to encourage the efficient use of renewable energy, including biofuel and biomass. There is no specific plan for the production, supply, and distribution of biofuels in the medium and long term.

Development Program and Plans to Address Agriculture Sector Objectives

Agricultural Development Program

The current low yield levels of major crops and the existence of large areas of fallow land and cultivable wasteland encourage the participation of the private sector in large-scale farming developments. The government granted 2.04 million acres of fallow land and wasteland to 136 private companies for commercial farming.

Since 1988, when the market-oriented policy was adopted, the government laid down the foundation of the new economic policy by instituting drastic changes in production, manufacturing, and trade policies to maximize private sector participation and foreign investment. In agriculture, the production and marketing of crops have been deregulated, allowing farmers the freedom of choice in crop production and to sell their farm produce at prevailing market prices. These measures are conducive to the social and economic welfare of farmers whose livelihood heavily depends on agricultural production. They also create favorable conditions for implementing community development programs in rural areas.

In the context of biofuel development, the government is pursuing a national plan to expand the area planted to jatropha for biodiesel production to 3.44 million ha by 2012. The use of fallow and marginal lands for jatropha cultivation has been allowed since 2006.

Rural Development Program

The first national program of integrated rural development was implemented in the border areas in 1989. Its activities were coordinated and implemented by the Central Committee for the Development of Border Areas and National Races, formed in 1989. After achieving successful results in the border areas, the government adopted a rural development policy and strategy in 2001, and a nationwide rural development program was launched in all regions with the following themes:

(i) to strengthen and develop agriculture, livestock, and fishery production for economic development;

(ii) to provide proper social services such as health care, education, nutrition, and sanitation;

(iii) to provide irrigation water by available means;

(iv) to build roads and bridges for better communication and transportation within and outside the region; and

(v) to develop rural industry based on agricultural products and other available materials within the area.

Development of Agro-Industry

The Government of Myanmar established the Myanmar Industrial Development Committee in 1995 to encourage rapid industrialization through

(i) development of agriculture-based industries,

(ii) enhancement of the quantity and quality of industrial products,

(iii) development of new machinery and equipment,

(iv) production of machinery and equipment for industrial use, and

(v) creation of conditions to transform the country into an industrialized state.

To develop the private sector, the state allotted suitable plots of land scattered around the cities to private industry. Manufacturers of gasifiers in Mandalay enjoy these production advantages. Their products are in high demand by the small sugar mills from upper Myanmar.

Biofuel Development Program

Because of rising world fuel prices, biodiesel and bioethanol have become an important concern in Myanmar. Interest in renewable energy, particularly biogas and biofuels, has grown dramatically during the past few years. Besides their potential to reduce reliance on fossil fuels and enhance energy security, biofuels can mitigate environmental problems, promote the greening of wastelands, and create job opportunities.

There are plans to produce biodiesel as a substitute for fossil fuel. The area under jatropha cultivation is expected to reach 3.44 million ha (8.5 million acres) between FY2010 and FY2012. The promotion of jatropha cultivation for biodiesel production aims to help rural households reduce their dependence on diesel fuel. The potential of jatropha oil as a cooking and lighting fuel is also being studied. Research and development into oil extraction and refining of jatropha oil are being conducted by the Ministry of Agriculture and Irrigation (MOAI), the Ministry of Science and Technology, the Ministry of Energy, and the Myanmar Engineering Society.

The government has also encouraged private companies currently producing sugar to produce bioethanol. Biogas generation from animal residues is also encouraged in the rural areas. Since 1980, biogas generation has been implemented to alleviate wood fuel scarcity in the central Myanmar region. Biodigesters have been introduced for the generation of biogas from animal waste. Benefits from biogas development include the promotion of family-sized digesters in rural areas, reduced use of wood fuel to aid forest conservation, use of biogas residue as fertilizer, and control of pollution.

Program for Environmental Sustainability

To achieve the Millennium Development Goals, Myanmar aims to integrate the principles of sustainable development into its policies and programs and reverse the loss of environmental resources. However, the greater use of solid fuels—including charcoal, fuelwood, and their substitutes—is exerting increasing pressure on the country's natural resource base.

Links between household use of solid fuel, indoor air pollution, deforestation, soil erosion, and greenhouse gas emissions are well known. With the majority of the population using solid fuel (92%),[34] the greening of dry zone areas and the introduction of efficient wood fuel stove programs are significant efforts to promote environmental sustainability.

Institutional Analysis for Biofuel Development

Administering Institutions

There are no laws and regulations directly related to biofuel development. However, the Petroleum Act of 1934 defined petroleum to mean "any liquid hydrocarbon or mixture of hydrocarbons, and any inflammable mixture (liquid, viscous, or solid) containing any liquid hydrocarbon." Thus, bioethanol and biodiesel are included in this definition.

Petroleum Rules, promulgated in 1937 and amended on 1 January 1946, are primarily concerned with the storage, refining, and blending of petroleum. They state that no one shall store any petroleum except under a license granted under these rules, and that no person shall refine or blend petroleum unless the plans showing the general arrangement of required facilities have been approved by authority from concerned agency (the Myanmar Oil and Gas Enterprise). Since bioethanol and biodiesel are included in the category of petroleum, they are covered by the same rule, which requires the private sector to get permission for storage, refining, and blending.

An expert group, composed of representatives from government agencies, has been formed to review the existing conditions and explore possible ways to facilitate biofuel production, blending, storage, delivery, and distribution. However, specific regulations or directives are needed to administer the

[34] United Nations Development Programme, Ministry of National Planning and Economic Development, and the United Nations Office for Project Services, 2007. *Integrated Household Living Conditions Survey in Myanmar*. June.

import, export, storage, transport, handling, blending, and distribution of bioethanol and biodiesel under the market economic system. A working committee has also been formed to supervise research and development for jatropha cultivation and biodiesel production. The advice of the expert group and the working committee will be valuable in setting up appropriate regulatory measures and institutional arrangements for sustainable development of the biofuel industry.

A central steering body and working bodies are required to set up a long-term development program and to integrate and coordinate sector activities. They can give guidance to help formulate the biofuel energy policy, establish concerned institutions, direct appropriate regulatory measures to encourage business investment, and set effective mechanisms for public–private partnership.

Various organizations and private companies are also involved in research and development on renewable energy, including biofuels. These include the Myanmar Chemical Engineering Group, Kaung Kyaw Say Engineering Company, the Renewable Energy Association of Myanmar, the National Renewable Energy Group, the Myanma Industrial Crops Development Enterprise, the Myanmar Agriculture Service, the Department of Agricultural Research, the Technological Universities Yangon, Mandalay, Kyaukse (Ministry of Science and Technology); Ministry of Industry 1, and the Ministry of Energy.

The integration of research findings will help speed up the development of biofuel technology. Knowledge sharing should be arranged to acknowledge the effort of researchers and develop further research activities. Collaboration with other countries in biofuel technology is being sought, and assistance from international organizations is needed for the development of biofuel technology in Myanmar.

Appendix 2 shows a proposed institutional structure and implementation mechanism for biofuels development, indicating the responsibility of each leading government agency with regards to biofuels.

Market Institutions

To liberalize trade and open up private sector investment opportunities, Myanmar established a new economic system based on the market-oriented economy. The government promulgated the Union of Myanmar Foreign Investment Law and its related procedure in 1988. State-owned enterprises are solely responsible for the production, handling, delivery, and distribution of fossil fuels, natural gas, and electricity. Only the state-owned Myanmar Oil and Gas Enterprise is allowed to import fossil fuels. The government subsidizes petrol and diesel fuel prices. The Myanmar Economic Corporation (MEC) is the only agency established for biofuel distribution. MEC is the sole distributor of bioethanol (E25) blended in Taung Zin Aye sugar mill.

Business Opportunities

The Government of Myanmar is undertaking measures to increase private sector participation, attract foreign direct investment, and accelerate the growth and development of the agriculture sector. Efforts are being made to attract local and foreign investors to invest in mutually beneficial trade and business in the form of joint ventures or 100% investment. It means that investors are allowed to form joint ventures with state enterprises or national companies. On land use, state economic enterprises, joint ventures, cooperatives, and other organizations and private individuals are being granted the right to cultivate fallow lands and cultivable wastelands. The Central Committee for the Management of Culturable Land, Fallow Land and Waste Land was formed to prescribe the procedure for the right to cultivate or use land for agriculture and livestock production. Foreign investors can also apply for utilization of land at the Myanmar Investment Commission (MIC) through the MOAI. Depending on the type of investment, larger land areas of up to 50,000 acres can be allotted, subject to approval by the Cabinet through the MIC. The government provides exemptions and incentives to investors, such as exemption from land revenue for 2–8 years depending on the type of project, and 3-year income tax exemption starting from the first year of commercial run of business.

The Myanma Industrial Crops Development Enterprise, which is under the MOAI, initiated the establishment of small-scale biodiesel plants that are operated at the communities. A plant can extract 100 gal/day of biodiesel from jatropha, in 3 shifts of 3 hours per shift. In 2008, 12 plants were constructed. A Korean company submitted a proposal to establish a biodiesel crop plantation and a biodiesel control laboratory. The company applied for rights to cultivate 0.2 million–0.5 million ha of fallow land in Magwe Division and Kachin State.

Investment and Financing Arrangements

Some private banks provide credit for establishing small and medium-scale industries. Myanmar Industrial Bank, for instance, provides loans for industrial development. Investors need other sources of funding to establish large-scale industries. The absence of international finance institutions in the country slows down investment in biofuel development. The possibility of receiving financial support for research and development from international nongovernment organizations, donor agencies, and bilateral arrangement needs to be explored.

Seasonal loans are provided by the Myanma Agricultural Development Bank for the cultivation of major crops such as rice, groundnut, sesame, rapeseed, pulses, long staple cotton, sugarcane, jute, and maize. These seasonal crop loans are the major source of funding for farmers and are repayable within 1 year. Coverage of crops and the amount of loan for each farm household differ from region to region and from year to year. The amount of credit received per unit area remains low and cannot cover the cost of cultivation. The Myanma Agricultural Development Bank also provides short- and long-term loans for perennial crops and farm machinery. Use of such loans has not progressed because of the need for collateral. Currently, perennial crops (such as tea, coffee, orchids, rubber, and oil palm) and farm machinery (such as water pumps and hand tractors) are eligible for the loans. Development of biofuel will call for financial programs or investment loans for processing machinery.

The Way Forward

An indicative national biofuel program is outlined in Appendix 3. Future development of the biofuel industry will require the following institutional policy and regulatory actions:

(i) Establish a national authorized body or central steering body to guide policy on a national biofuel development framework, and bioenergy development program and plans.

(ii) Formulate the long-term biofuel development plan.

(iii) Review existing regulations to determine the need to amend, supplement, or formulate new regulations as necessary in the context of the national energy development plan to invigorate the biofuel development program.

(iv) Strengthen public awareness programs to promote the use of biofuels through demonstrations, exhibitions, and media discussions.

(v) Integrate the research and development activities of various agencies to improve biofuel production efficiency and product quality by establishing a biofuel research and development institute.

(vi) Establish small and medium-scale biofuel plants in rural areas.

(vii) Set up a government support program to include incentives such as tax exemption, tax holidays, and credit and loans for biofuel crop production and processing industries;

(viii) Promote public–private partnerships in production, distribution, marketing, and research on biofuel and biomass energy development.

(ix) Establish a pricing policy for bioethanol blends and biodiesel blends to enable fair competition.

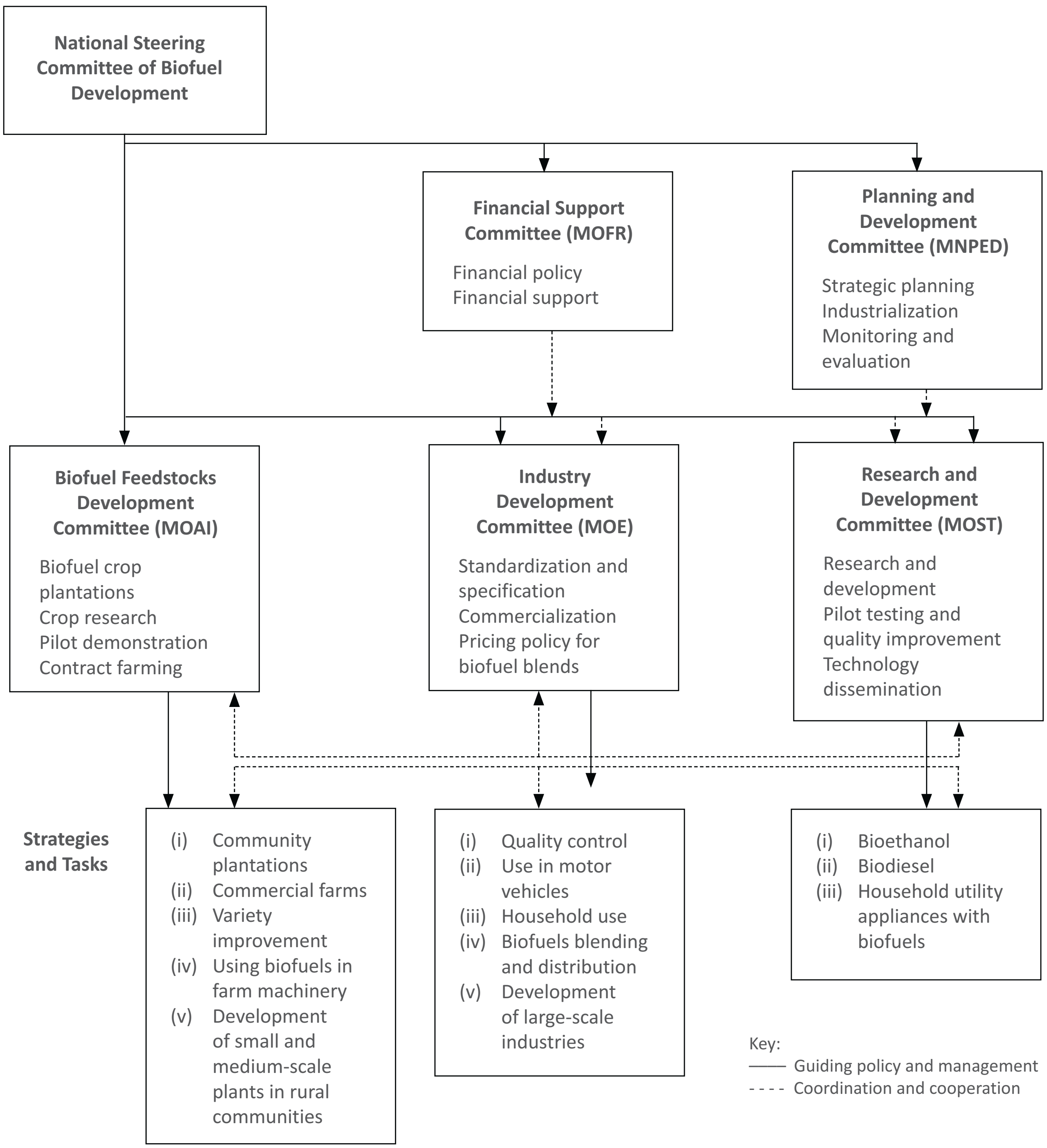
(x) Formulate projects that support the development of biofuels through research and development on variety improvement, agronomic practices, and biofuel processing; undertake human resource development and technology; upgrade laboratory facilities; standardize quality and control; and undertake research on the marketing and distribution of biofuels.

Appendix 1: Oil Content of Different Land Races of Jatropha Curcas

Land Race	Division or State	Oil Content (%)	Land Race	Division or State	Oil Content (%)
Kyaukpandaung	Mandalay	23.87	Kyinpontaung	Magwe	34.99
Kyaukcheck	Mandalay	24.91			
Leiway	Mandalay	27.62	Watphyuye	Southern Shan	38.34
Yelepauk	Mandalay	28.40	Naunglay	Southern Shan	35.41
Myaingyang	Mandalay	31.41	Pinngyo	Southern Shan	34.15
Nyaungoo	Mandalay	37.32	Nantse	Southern Shan	32.71
Tatgone	Mandalay	40.04	Sarlaein	Southern Shan	37.04
Nyaunglaybin	Mandalay	31.92	Banyinn	Southern Shan	36.19
Pyawbwe	Mandalay	38.06	Sesai	Southern Shan	40.70
Zeebwar	Mandalay	41.50	Pinmhyie	Southern Shan	30.55
Mile 57/4	Mandalay	35.73	Kyuneywa	Southern Shan	25.99
Kyatpyityar	Mandalay	38.91	Pinyintaw	Southern Shan	33.17
Nwgahtoegyi	Mandalay	35.35	Nyaunggone	Southern Shan	28.65
6 mile	Mandalay	23.01	Latpanpin	Southern Shan	23.48
Shawphyu	Mandalay	42.39	Yongtaung	Southern Shan	20.84
Kyauktadar	Mandalay	31.59	Mintaipin	Southern Shan	35.90
			Banyin farm	Southern Shan	41.27
Watkya	Magwe	43.87	Taunggyi	Southern Shan	39.06
Yenangkyaung 36	Magwe	39.16	Nammalat	Northern Shan	36.23
Magwe	Magwe	35.56			
Gyaycho	Magwe	30.73	TaungNgyu	Eastern Bago	46.41
Payapyo	Magwe	37.25	lapandan	Western Bago	38.70
Tamanntaw	Magwe	35.99	Africa	Exotic	35.73
Watmasaut	Magwe	35.79	Thailand	Exotic	37.55
Mindone	Magwe	32.80	Laos	Exotic	39.54
Yesagyo	Magwe	41.56	Thai	Exotic	43.40
			Indonesia	Exotic	35.54

Source: Department of Agricultural Research.

Appendix 2: A Proposed Institutional Structure and Implementation Mechanism for Biofuels Development



MNPED = Ministry of National Planning and Economic Development, MOAI = Ministry of Agriculture and Irrigation of Myanmar, MOE = Ministry of Energy, MOFR = Ministry of Finance and Revenue, MOST = Ministry of Science and Technology.

Source: Authors.

Appendix 3: Indicative National Biofuel Program for Myanmar

Vision
The country's energy security generated by renewable energy resources and competitiveness of the biofuel industry in the region.

Mission
Toward the realization of the vision, the country will accelerate the development of biofuel industry to achieve energy security without affecting food security, maintain environmental sustainability, and develop the national economy.

Objectives
To reduce dependency on imported fossil fuels

To increase economic activities

To improve energy efficiency

To generate rural employment

To augment farmers' income

Indicative National Biofuel Program Framework

Feedstock Development, Production, and Extension

Sugarcane, cassava, sweet sorghum, and jatropha prioritized and other potential feedstocks

Expansion of biofuel crop area

Allocation of fallow land to national and foreign investors

Encourage contract farming and joint ventures

Variety improvement

Crop research and development

Mechanization

Fertilization

Community awareness and participation

Biofuel Industry Development

Biofuels plan

Construction of large-scale plants and expansion of medium-sized and small plants in rural areas

Competitive pricing

Storage, transport, handling, and blending

Distribution and sales

Application development

Policy Formulation and Regulatory Framework

Enact biofuels energy law

Formulate enabling rules and regulations to comply with enacted Laws

Covers all major areas and strategies of the program

Investments, Incentives, and Promotion

- Government financing to establish industry
- Credit facilitation services
- Tax exemption, holidays, and incentives
- Market development services
- Human resources development
- Seminars, conferences, exhibitions, and workshops
- Media information
- Information technology

Research and Development

- Production process development
- By-products development
- Integration of research findings from research agencies
- Development of blend performance tests and standards
- Utilization efficiencies
- Pilot plants and showcase projects

Standard and Quality Assurance

- Cover technical and environmental compliance in the following areas:
  - Production facilities
  - Utilities and services
  - Biofuels and blends
  - Utilization technologies
- Enforcement:
  - Inspection and monitoring
  - Penalties

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

This report contains a detailed assessment of the status and potential for the development of biofuels in Myanmar 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.

About the Asian Development Bank

ADB's vision is an Asia and Pacific region free of poverty. Its mission is to help its developing member countries substantially reduce poverty and improve the quality of life of their people. Despite the region's many successes, it remains home to two-thirds of the world's poor: 1.8 billion people who live on less than $2 a day, with 903 million struggling on less than $1.25 a day. ADB is committed to reducing poverty through inclusive economic growth, environmentally sustainable growth, and regional integration.

Based in Manila, ADB is owned by 67 members, including 48 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance.

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