GREATER MEKONG SUBREGION
ECONOMIC COOPERATION PROGRAM

STATUS AND POTENTIAL FOR THE DEVELOPMENT OF

BIOFUELS

AND RURAL RENEWABLE ENERGY

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Abbreviations

Agifish	–	An Giang Fisheries Import and Export Joint Stock Company
ASEAN	–	Association of Southeast Asian Nations
CCS	–	commercial cane sugar
CDM	–	clean development mechanism
CER	–	certified emission reductions
D	–	dong
EU	–	the European Union
FAO	–	Food and Agriculture Organization of the United Nations
GSO	–	General Statistics Office
IEA	–	International Energy Agency
IIC	–	Institute of Industrial Chemistry
ktoe	–	thousand tons of oil equivalent
Lasuco	–	Lam Son Sugar Company
mbbl/d	–	million barrels per day
MOIT	–	Ministry of Industry and Trade
mt	–	million ton
OECD	–	Organisation for Economic Co-operation and Development
OPEC	–	Organization of Petroleum Exporting Countries
Petrosetco	–	PetroVietnam General Services Joint Stock Company
PRC	–	the People's Republic of China
US	–	the United States
WTO	–	World Trade Organization

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Background

Oil prices increased to over $140 per barrel in mid-2008 despite sufficient world oil supply, normal operations of oil-exporting countries, and the lack of sudden embargoes. World oil demand continues to increase, and tension in the global oil market is predicted to worsen in the coming years. The International Energy Agency (IEA) forecasts that by 2030 the world's oil consumption will have increased by 35%—equivalent to an additional 11 million barrels per day. This target must be met in the next 2 decades. However, discovering and exploiting new oil reserves will also take decades, and the Food and Agriculture Organization (FAO) of the United Nations forecasts the exhaustion of world oil reserves between 2050 and 2060.[1]

Experts warn of a coming oil crisis if nothing is done to address the problem of rapidly increasing demand and increasingly limited supplies. Rising concern about energy security, lack of energy diversification, global warming, and the unstable politics and terrorism that accompany oil dependence has encouraged many countries to evaluate the production and use of biofuels and other renewable energy sources.

The biofuel industry has been launched with active government support beyond the normal regulatory role. For example, the European Union (EU) has set quantitative targets for biofuels introduction, the Philippines passed the Biofuel Law in 2005, and Brazil has developed sugarcane as a biofuel feedstock to become the world's largest producer and exporter of ethanol. Biofuel-based fuel currently meets 40% of Brazil's domestic energy requirements. In 2005, Brazil and the United States (US) together produced about 9 million gallons of ethanol, contributing 90% of the total world ethanol output (Appendix 1).

While member countries of the Organisation for Economic Co-operation and Development (OECD) were early developers of biofuels, developing countries are catching up. The People's Republic of China (PRC) and India—two enormous consumers of energy—have also stepped up activities to expand biofuel production. Around the world, sugarcane, corn, rapeseed, sugar beet, wheat, sorghum, and soybean are the main feedstocks for biofuel production.

Currently, 1%—about 14 million hectares (ha)—of the world's cultivated land is used to grow feedstock for biofuel production. This is likely to rise to more than 3.5% in the near future (footnote 1). The IEA has forecast that in 2030, internal combustion engines all over the world may consume 85–195 billion gallons of biofuel, equivalent to 10%–24% of predicted total fuel consumption. Global production is projected to reach 80 billion liters (l) of ethanol and 20 million tons (mt) of biodiesel in 2012.

Viet Nam's economic boom and growing population will require greater amounts of energy; however, the country's oil reserves are limited. The volume of oil exploited declined to 91% of the 2004 level in 2005, and 86% in 2006.[2] To meet future oil demand, Viet Nam needs to import at an increasing rate of 11%–20% in 2020 and 50%–60% in 2050. Meanwhile, the world oil price continues to fluctuate and could rise to levels which may prove prohibitive for developing countries. Therefore, to prevent energy insecurity, Viet Nam needs to diversify its fuel sources, with a particular focus on green energy.

Biofuels could begin to partially replace the traditional fossil fuel in the near future. Among the members of

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1 FAO. 2007. *Bioenergy—Rather Positive than Negative Impact.* www.agroviet.gov.vn

2 General Statistics Office. 2007. *Statistical Year Book: Data on Industrial Performance.* www.gso.gov.vn

the Association of Southeast Asian Nations (ASEAN), Indonesia, Malaysia, the Philippines, and Thailand have moved fast to develop biofuels. Viet Nam has just started and is assumed to be at least 10 years behind its ASEAN neighbors. In South Asia, India plans to develop 10 million ha of jatropha plantations by 2010 to produce 7.5 mt of biodiesel.

The Government of Viet Nam is giving increasing attention to biofuel development to promote socioeconomic development. In the Second East Asia Summit in Cebu, Philippines, Prime Minister Nguyen Tan Dung and 15 leaders of ASEAN countries signed the Cebu Declaration on East Asian Energy Security. The declaration noted that "biofuel and hydropower resources are renewable and as such harnessing these resources is an important aspect of our national energy policies."[3] Accordingly, the 16 nations agreed to work together to "reduce dependence on conventional fuels through intensified energy efficiency and conservation programs, hydropower, expansion of renewable energy systems and biofuel production and/or utilization, and for interested parties, civilian nuclear power" (footnote 3). The declaration also considered two important measures to achieve the goal. These are

(i) to "encourage the use of biofuels and work towards freer trade on biofuels and a standard on biofuels used in engines and motor vehicles'', and

(ii) to "encourage collective efforts in intensifying the search for new and renewable energy resources and technologies, including research and development in biofuels'' (footnote 3).

In November 2007, the Government of Viet Nam approved the Strategy for Biofuel Development to 2015 and Vision 2025, which creates legal corridors, institutions, policies, and an investment plan for biofuel development.

A number of studies on biofuel production have begun, such as the production of diesel from soybean, sesame, used oils, fish oil, and jatropha; and the production of ethanol from sugarcane, maize, rice, and cassava. Currently, studies and production of clean energy have been assigned to agencies such as Petrolimex, PetroVietnam (the Vietnam Oil and Gas Corporation), and Da Nang Technical University. Initial results have been encouraging. The Polytechnical University of Ho Chi Minh City tested and proved that bioethanol can replace gasoline in internal combustion engines. The Ministry of Science and Technology assigned a company to undertake a study on technology for biofuels production and compounds originating from plants. This was successful in the laboratory and is now at the experimental stage to examine its application to transport on a large scale. The Institute of Food Industry has been assigned to conduct a study on producing bioethanol from agricultural residues using second-generation technology involving enzymes and microorganisms.

In addition, several industrial bioethanol plants began construction in 2007. The Vietnam Bioethanol Joint Stock Company invested in an industrial alcohol plant in Dak Lak Province with a capacity of 66,000 cubic meters per year. The Bien Hoa Sugarcane Company and Fair Energy Asia of Singapore have signed a memorandum of understanding for cooperation in an investment to build a bioethanol plant with a capacity of 50,000 tons per year (t/year). The plant will be constructed in the industrial zone west of Vam Co Dong River in Tay Ninh Province. The PetroVietnam General Services Joint Stock Company (Petrosetco), which belongs to the PetroVietnam Oil and Gas Group, and the Itochu Corporation, Japan, are implementing an $80 million–$100 million project to construct an ethanol plant in the Hiep Phuoc Industrial Zone of Ho Chi Minh City. This will have an annual capacity of 100,000 l and will use cassava as feedstock. The American company, Superior Biotechnologies, cooperated with Petrosetco to develop bioethanol from sugarcane-derived cellulose and biodiesel from fish fat for export to the US.[4] The plant will have a capacity of 200 million l/year.

As the development of biofuel in Viet Nam is in the early stages, there is a need to study the current situation and determine world trends in the development of the green energy industry. Viet Nam should assess the potential role of renewable energy sources, such as biofuels, in meeting future energy demand.

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[3] Cebu Declaration on East Asian Energy Security, 2007. Cebu, Philippines, 15 January. www.aseansec.org/19319.htm

[4] Superior Biotechnologies Corporation. 2008. News. *Superior Signs Strategic Biofuels Deal in Vietnam*. www.superiorbiotechnologies.com/links/news_12-21-2007.asp

This study aims to provide a preliminary assessment of the long-term commercial viability of a biofuel program in Viet Nam. Its four main objectives are

(i) to identify promising areas for investment in biofuel development in Viet Nam;

(ii) to assess the implications of biofuel development for crop diversification, land use patterns, farm restructuring, and cross-border contract farming;

(iii) to determine appropriate public–private partnerships that will help promote market-driven business ventures in the biofuels subsector; and

(iv) to review current country policies on bioenergy and provide policy recommendations for a new national strategy.

To meet these objectives, this study surveys and evaluates the

(i) market outlook for biofuels with a review of prospects for supply and demand development;

(ii) characteristics of the biofuels resource base, including biofuel feedstocks and production technology;

(iii) prioritization of biofuel development based on simple cost–benefit analysis;

(iv) biofuels business options and alternative agribusiness models; and

(v) policy, regulatory, and institutional support, and policy gaps in agricultural planning and legislation for biofuel development.

Market Outlook

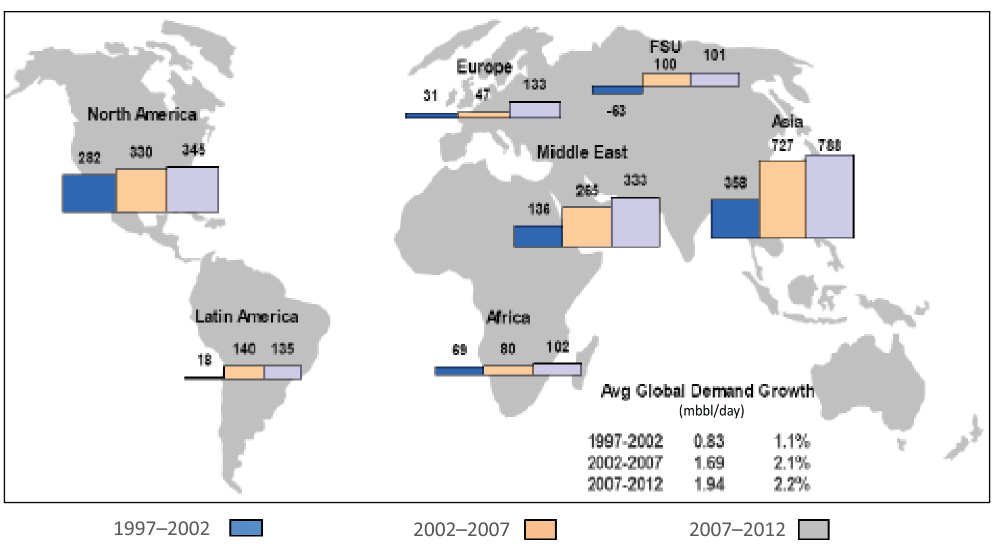
International Energy Market Outlook

Oil Market Outlook

World demand for oil in 2007 was 85.8 million barrels per day (mbbl/d) and is forecast to rise to 87.5 mbbl/d in 2008.[5] The growth in demand is due to increased oil demand from all economies; however, the rapid economic growth in the People's Republic of China (PRC) and India alone is responsible for 0.8 mbbl/d of the increase. In the short term, countries in South Asia, Latin America, and the Middle East are projected achieve high rates of economic growth, and hence, to greatly increase their demand for oil (Figure 1).

According to the Australian Bureau of Agricultural and Resource Economics,[6] world oil demand is projected to reach 95.1 mbbl/d in 2012. The International Energy Agency (IEA)[7] predicts that global oil demand could reach 116 mbbl/d in 2030—a 35% increase from 2007. The increase in global oil demand could lead to growing world energy insecurity, especially for countries that rely on oil and gas imports. The Middle East and the Russian Federation are forecast to be the dominant oil producers, and the price levels they set will have a major impact on the economies of developing countries. Sources from outside the Organization of Petroleum Exporting Countries (OPEC) may contribute 56.3 mbbl/d of the 95.2 mbbl/d

Figure 1: Average Global Demand Growth for Oil, 1997–2002, 2002–2007, 2007–2012 ('000 barrels per day)



mbbl/day = million barrels per day.
Source: International Energy Agency.

5 IEA. 2008. *Oil Market Report: A Monthly Oil Market and Stocks Assessment*. France. www.oilmarketreport.org

6 Australian Bureau of Agricultural and Resource Economics. 2007. *Australian Commodities: Outlook 2007 Conference Commodity Projections to 2011–2012*. Australia.

7 IEA. 2007. *World Energy Outlook 2007: China and India Insights*. Executive Summary. France.

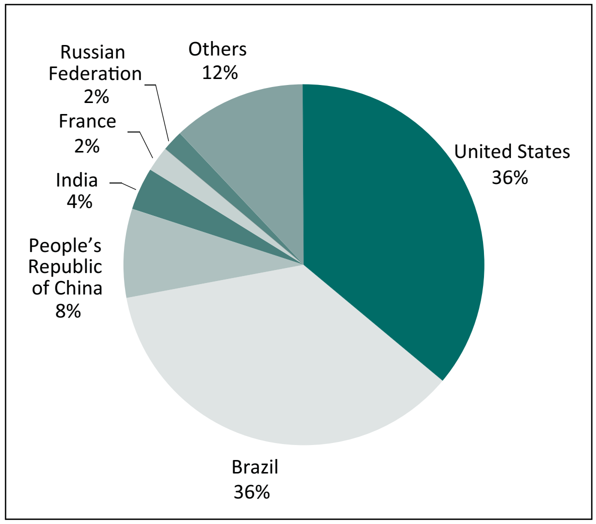
production forecast for 2012, while OPEC countries may add 38.9 mbbl/d in 2012 (footnote 7).

According to the IEA, the world's oil resources should be enough to satisfy the demand in 2030. The share of output from OPEC countries is projected to rise from 42% of world oil supply in 2008 to 52% by 2030. OPEC's collective output of conventional crude oil, natural gas liquids, and non-conventional oil (mainly gas-to-liquids) is projected to be 46 mbbl/d in 2015 and 61 mbbl/d in 2030. Non-OPEC production will rise slowly and level off at around 47 mbbl/d by mid-2010, with a large proportion coming from non-conventional sources, such as Canadian oil sands (footnote 7).

International Market Outlook for Biofuel

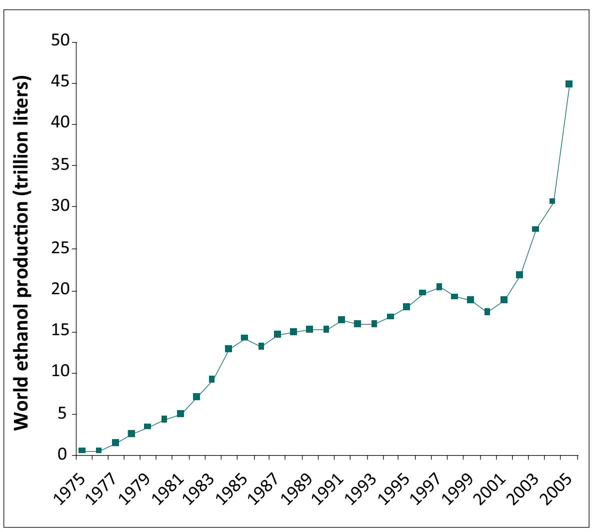
While fossil fuels still account for more than 95% of the global transport fuel market, biofuel production is growing at a rate of roughly 15% per year—over 10 times that of oil. Under mounting pressure to improve domestic energy security and combat global climate change, countries are now turning to the two main bioenergy sources—bioethanol and biodiesel—as fuels for road transport (Figures 2, 3 and 4). In 2005, the volume of biofuel produced globally was around

Figure 3: World Ethanol Production by Country, 2005 (%)



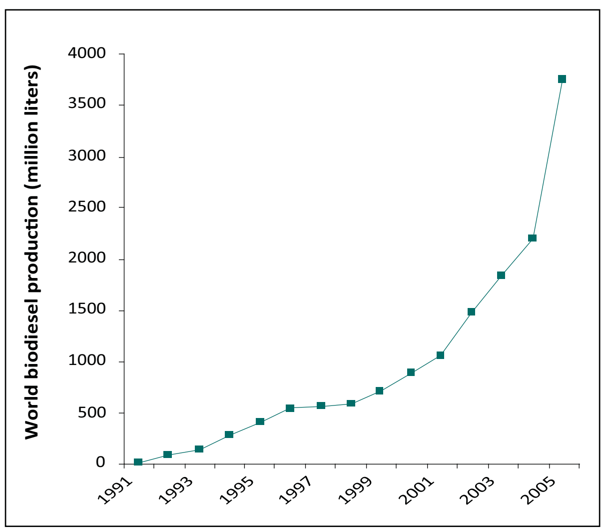
Source: Earth Policy Institute. 2006. *Supermarkets and Service Stations Now Competing for Grain.* www.earth-policy.org/Updates/2006/Update55_data.htm

Figure 2a: Global Bioethanol Production (trillion liters)



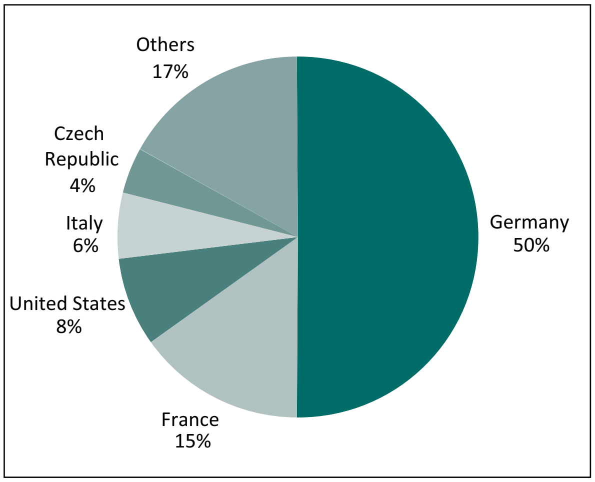
Source: Foerster, E. 2007. GFA Consulting Group.

Figure 2b: Global Biodiesel Production (million liters)



Source: Foerster, E. 2007. GFA Consulting Group.

Figure 4: World Biodiesel Production by Country, 2005 (%)



Source: International Energy Agency. 2007.

0.65 mbbl/d, or 1% of the total fuel consumption for road transport (footnote 6).

In the European Union (EU) and the United States (US), biofuel development is being supported to promote growth in agriculture and forestry, reduce energy insecurity, and minimize global warming. In the PRC, in addition to these challenges, greater importance is attached to coping with the increasing energy consumption of the growing economy.

Assuming that crude oil remains under pressure and there is broad-based support in many countries with agricultural surpluses, biofuels are likely to continue to receive much attention.[8] The US plans to double the 2012 mandatory biofuels share of 7.5 billion gallons per year (equivalent to 490,000 bbl/d) required by the 2005 Renewable Fuels Act to 15 billion gallons (980,000 bbl/d) by 2015. It is proposed that by 2022 the renewable share of the total energy mix in the US will more than double to 36 billion gallons. In the EU, a 10% mix of biofuels in transport fuels is likely to become mandatory by 2020, increasing from the probable mandate of 5.75% in 2010. Several other countries, such as Australia, Canada, the PRC, India, and Japan, will require shares of between 5% and 10% by around 2010. In addition, existing subsidies (usually tax breaks) and import tariffs, at least in the EU and the US, are likely to stay in place at least until 2009.

The sharp increase in agricultural prices in 2007 and 2008 could have a significant impact on the economies of developing countries, where spending on food consumes a high proportion of income. Rising food prices have the potential to lift wage demands, thus raising inflation and labor costs. Therefore, there is a need to revisit the effects of first-generation biofuel[9] policies on global food availability and prices, not only from the perspective of domestic production surpluses and local energy security concerns, but also from the regional and global perspectives.

Viet Nam Energy Market Outlook

Energy Demand in Viet Nam

Energy consumption in Viet Nam is reflected in the various forms of use, including electricity, fuel combustion for operating machines and motor vehicles, heating from biomass, and solid fossil (coal) and gaseous forms. Consumption of each type of energy has increased over time, and the country's total energy consumption rose at an average rate of 4.8% per year during 1996–2005. The average increase in commercial energy consumption—coal, natural gas, electricity, and petroleum products—was 9.0% per year. Petrol and its associated products also increased their share of final energy consumption (Table 1).

Biomass is the most important energy source in Viet Nam. It supplies around 60% of the country's energy needs on average, and considerably more in the islands, mountains, and other remote areas. The volume of biomass used has remained stable since 1996 (Figure 5). It is used for cooking by 70% of the 80% of the population that lives in rural and remote areas.

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[8] IEA. 2007. *Short-Term Energy Outlook*. June.

[9] First-generation biofuel is fuel produced from feedstocks sourced from food crops.

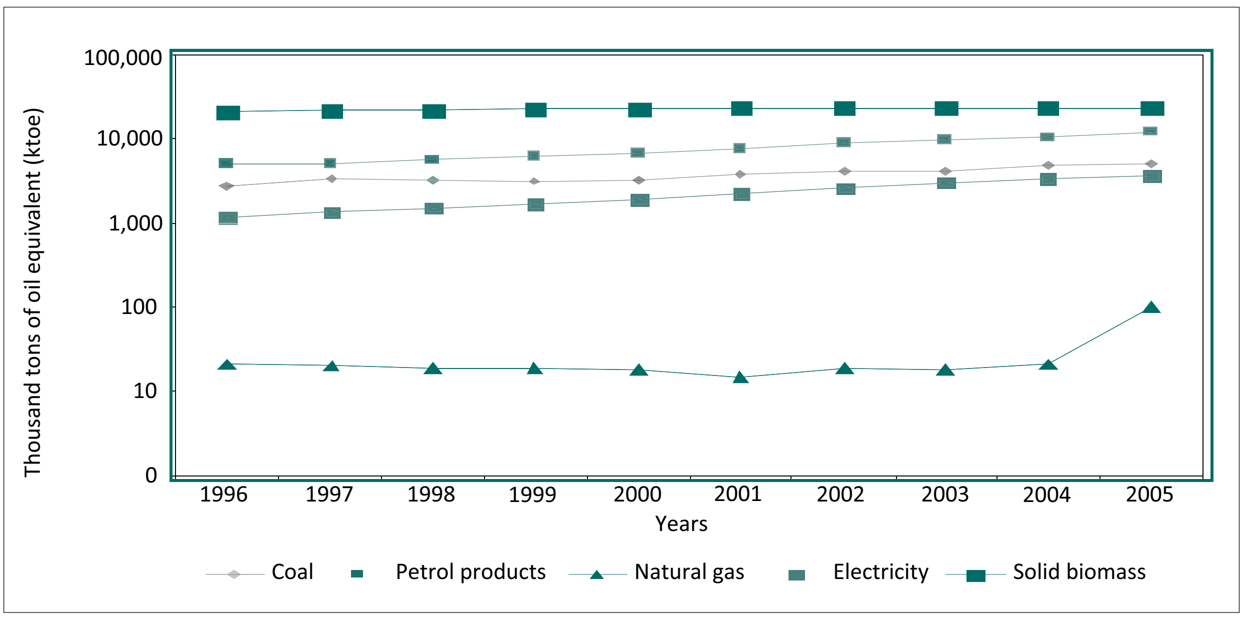
Table 1: Commercial Energy Consumption in Viet Nam
(ktoe)

Energy types	1996	2000	2001	2002	2003	2004	2005	CGR (%)
Coal	2,692	3,223	3,743	4,017	4,105	4,851	4,950	6.3
Petrol products	986	6,759	7,456	8,761	9,639	10,317	11,864	9.0
Natural gas	21	18	15	19	18	21	100	16.9
Electricity	150	1,927	2,214	2,586	2,996	3,437	3,697	12.4
Total	**3,849**	**11,927**	**13,428**	**15,383**	**16,758**	**18,626**	**20,611**	**9.0**

CGR = compounded growth rate, ktoe = thousand tons of oil equivalent.

Source: Ministry of Industry and Trade. 2006. *Energy Import of Vietnam.* Ha Noi, Viet Nam.

Figure 5: Energy Consumption by Source in Viet Nam (ktoe)



ktoe = thousand tons of oil equivalent.

Source: Ministry of Industry and Trade. 2006; Earth Trend. 2006. *World Development Indicators.* www.earthtrend.org

Demand for energy is highest from industry, accounting for 36.7%, closely followed by transport (36%), agriculture (2.8%), and other sectors (5.6%).[10]

Viet Nam's population is growing rapidly. By 2010, per capita consumption of commercial fuel is predicted to be more than twice the level of 2000. By 2030, it will be 6–7 times greater than the 2000 level (Table 2).

It is projected that energy demand will escalate in the next 2 decades. Total commercial energy consumption will increase by 6.4% per year up to 2030. The pressure of development will require a 6.5% increase in petrol products and 16.6% in natural gas each year. By 2030, the country's commercial energy demand is projected to reach 10,507 thousand tons of oil equivalent (ktoe) for coal, 64,995 ktoe for petrol, and about 4,781 ktoe for natural gas (Figure 6).

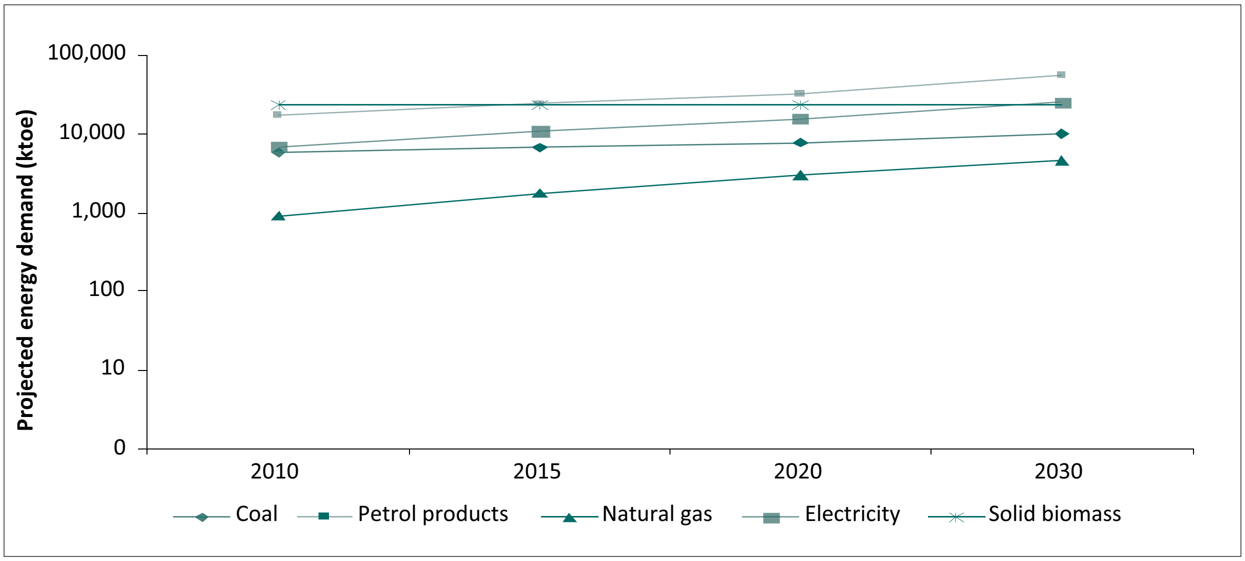
[10] Ministry of Industry and Trade. 2007. *Biofuel and Energy Security*. Workshop. December 2007. Ha Noi, Viet Nam.

Table 2: Projection of Energy Consumption per Capita in Viet Nam
(kgoe/person/year)

Energy Consumption per Capita	Year				CGR
	2000	2010	2020	2030	
kgoe/person/year	155	354–377	600–668	901–1048	4.8%–5.2%

CGR = compounded growth rate, kgoe = kilograms of oil equivalent.
Source: Ministry of Industry and Trade. 2006.

Figure 6: Projected Energy Demand for Viet Nam, by Type, 2010–2030 (ktoe)



ktoe = thousand tons of oil equivalent.
Source: Ministry of Industry and Trade. 2006.

The Ministry of Industry and Trade (MOIT) forecasts that in 2020, industry will account for the largest share of energy consumption, with 48.4% of the total (footnote 10). Transport will account for 31.6% of the total, and agriculture's share will be approximately 1.1%. The future economic development of Viet Nam will also bring about a large increase in household energy consumption (Figure 7) (footnote 10).

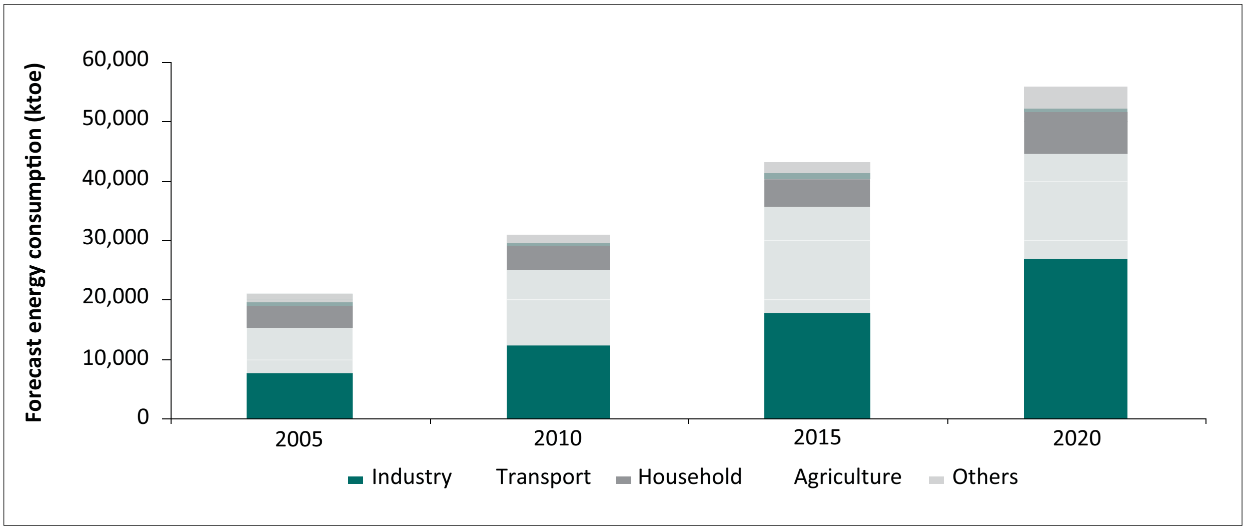
Energy Supply of Viet Nam

Energy supply in Viet Nam comes from both domestic and imported sources. Domestic sources include traditional energy and renewable energy. However, the use of renewable sources is just beginning and is currently very limited.

Traditional energy sources include hydropower, biomass, and fossil fuels. The dominant fossil fuels are coal, oil, and natural gas. Hydropower and fossil fuels are produced on a commercial scale. Biomass is not in commercial production and consists of residues from agricultural cultivation and livestock-raising.[11] Demand from all traditional energy sources in Viet Nam is increasing considerably, reflecting the escalating demand to meet the needs of both daily living and economic development.

[11] Tran Minh Tuyen. 2005. *Biomass Utilization in Vietnam*. Second Biomass Asia–Workshop. Bangkok, Thailand.

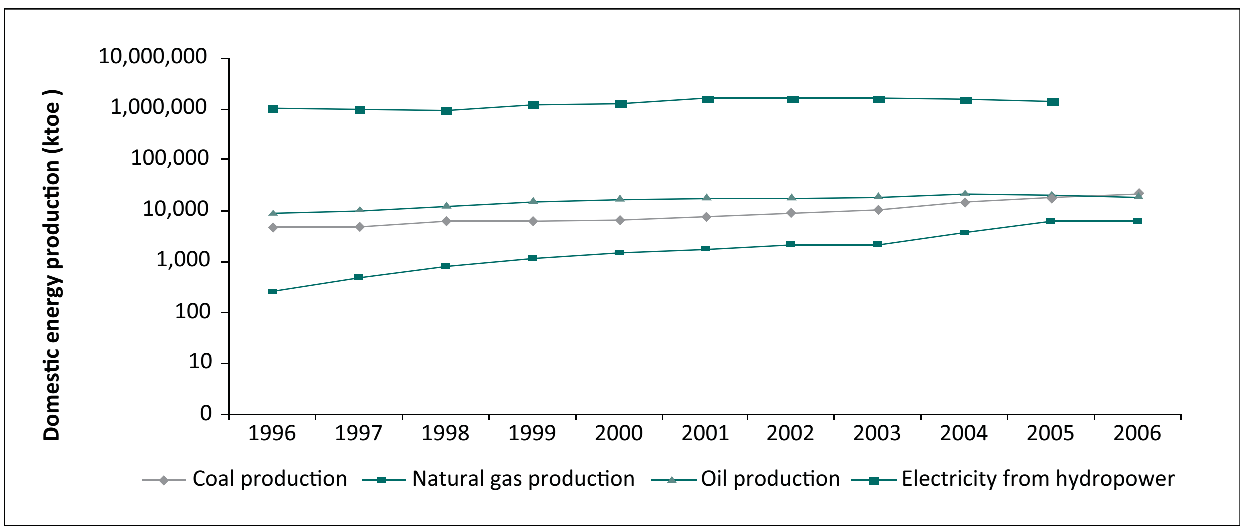
Figure 7: Forecast Energy Consumption, by Sector (ktoe)



ktoe = thousand tons of oil equivalent.

Source: Ministry of Industry and Trade. 2006.

Figure 8: Domestic Energy Production, 1996–2006 (ktoe)



ktoe = thousand tons of oil equivalent.

Source: Ministry of Industry and Trade. 2007; and Earth Trend. 2006.

In 2004, Viet Nam produced 1.07 million ktoe of energy from traditional sources. Hydropower contributed 97% of the total (equivalent to 0.96 million ktoe) (Figure 8). This contribution is forecast to increase as new hydropower plants become operational. Exploitation of underground and open cast mines for coal and oil drilling provided 0.02 million ktoe. Solid biomass, which plays an important role in rural areas, was estimated to contribute a stable 0.03 million ktoe per year. It may be noted that hydropower production is huge compared to actual demand because the transmission of electricity along the electrical wires incurs a rate loss of about 30% as a result of heat loss and the outdated distribution system.[12]

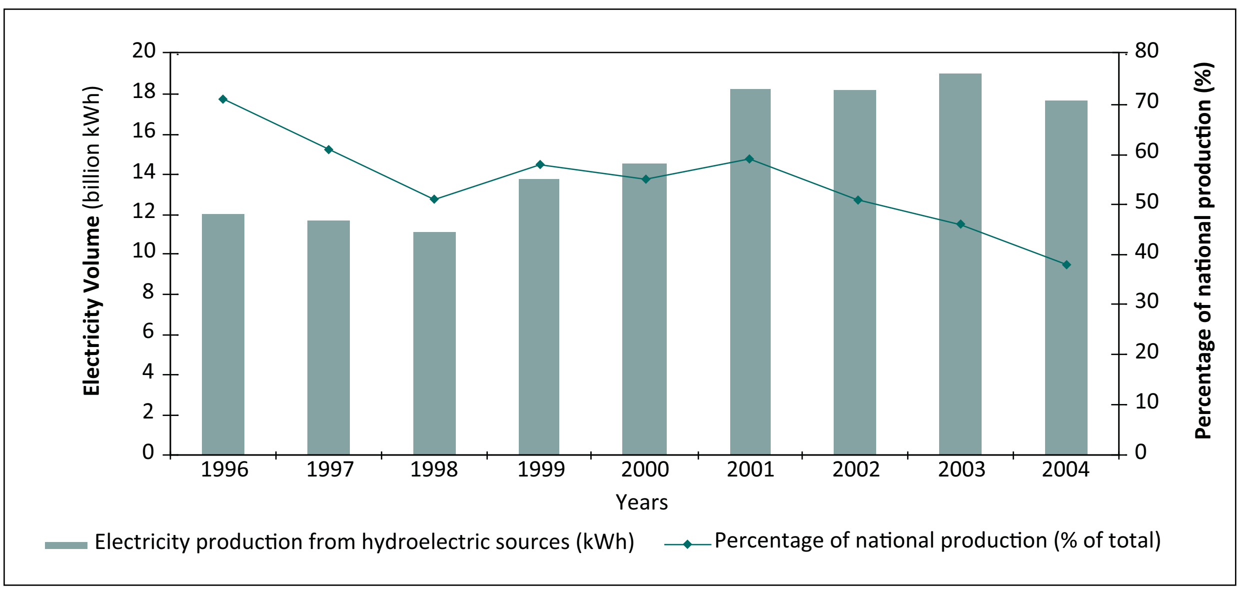
Hydropower and biomass have traditionally supplied the country's major energy needs. Hydropower is used to generate electricity. Although domestic production of hydroelectricity has increased significantly, its share of the total production of national electricity has decreased markedly from around 70% in 1996 to around 37% in 2004 (Figure 9). Solid sources of biomass consist mainly of wood, waste from livestock, and the by-products of cultivation such as straw, rice husk, and bagasse.

Potential Renewable Energy Sources and Other New Energy Sources

Viet Nam's tropical monsoon climate is characterized by many days with long hours of sunshine and strong winds. Therefore, there is potential for the production of energy from wind and solar sources. Nevertheless, such forms of energy are not yet widely used.[13]

The government, in cooperation with private and international bodies, has developed wind power plants in windy locations, such as along the coastal zone and on offshore islands. Total potential wind-based electricity is estimated to be 513,360 megawatts (MW) and would be 10 times the total electricity capacity in 2020.[14] The two locations with the highest potential for production of wind power are Son Hai in Ninh Thuan Province and Ham Tien in Binh Thuan Province.[15] The only wind-based electricity station operating in Viet Nam currently is in Hai Phong Province (Bach Long Vi power station) and has a capacity of 800 kilowatts per year (footnote 15). Since the cost of wind-generated electricity is high compared with hydroelectricity, the wind-based electricity station had difficulty operating. Although wind power is increasing in popularity and global significance, it could not become a major source due to its dependence on the wind regime and climatic circumstances. In addition, wind power stations are noisy during operation and destroy the natural beauty of an area, which may impact tourism (footnote 15).

Figure 9: Percentage and Volume of Hydroelectricity Production in Viet Nam, 1996–2004



kWh = kilowatt-hour.

Source: Earth Trend. 2006.

[12] Tran Quoc Khai. 2005. Energy Losses Cause the Increasing Price of Electricity. *Vietbao Newspaper.* 25 January.

[13] Nguyen Quang Thien and Nguyen Hong Son. 2006. *Biomass in Vietnam: Case Study*. Workshop on Utilization of Biomass for Renewable Energy. Kathmandu, Nepal.

[14] The World Bank. 2007. *Vietnam: Potential Wind Power in South East Asia*. www.thiennhien.net/?c=148&a=1264

[15] Thien Nhien. 2007. *Vietnam: The Most Potential Wind Power in South East Asia*. www.thiennhien.net/?c=148&a=1264

The central part of Viet Nam enjoys long days of high-intensity sunshine. No solar power station has been built, nor has there been a study of Viet Nam's solar capacity. However, a few hundred households in Ninh Thuan Province have started to use solar power for cooking and heating.[16]

Another renewable energy program being implemented involves biogas from cattle manure. The program is funded by the Government of the Netherlands. The project has committed to build 37,000 biogas tanks, estimated to supply 2,800 terajoules per year of clean energy—a small proportion of the total energy supply of Viet Nam.[17] This energy source would be suited to households rather than industry. Sources of cattle manure are scattered around the country, and the majority of gas tanks are in remote or rural areas.

Nuclear power is being researched and promoted as a potential solution to the likely future energy deficit. However, even if Viet Nam's first nuclear power plant is established, its 2,000 MW capacity would contribute only 3.3% of the electricity demand in 2020. If a second nuclear plant is built, bringing the total capacity to 4,000 MW, nuclear energy would contribute only 4.7% of the electricity demand in 2025 (footnote 15).

Each renewable source has limitations. Hydropower and new renewable sources, such as wind, solar, and biogas, do not provide the final form of fuel for transport and other conventional fuel uses. Wind power and solar power depend on natural conditions that are beyond human control; biogas production is suitable for supplying households, but not industry; and the further expansion of hydropower would compromise the irrigation system on which the vital agriculture sector depends. Therefore, these options do not hold much promise for replacing conventional oil, especially for transport.

Energy Export and Import

Viet Nam has exported increasing amounts of coal since 1996. In 2005, this export volume amounted to 11.6 million tons (mt), which was a three-fold increase over coal exports in 1996 (Table 3). The country lacks an oil refinery, therefore all of its domestic crude oil was exported and refined oil was imported. Reliance on imported petrol products is expected to ease when its first oil refinery—the Dung Quat plant—begins operation in 2009.

Viet Nam's main fuel imports consist of diesel, gasoline, and petrol. The volume of imported energy increases significantly every year (Figure 10), and is estimated to have grown at an annual average rate of 10.4% during 1996–2005. To meet domestic demand, Viet Nam is expected to continue importing oil products up to 2020.[18]

Prospects for Viet Nam's Energy Supply and Demand Balance

This section analyses future scenarios for the energy sector of Viet Nam based on available data for the main types of commercial energy produced—electricity and oil or gasoline.

Prospects for domestic electricity. Viet Nam has been harnessing hydropower to generate electricity for

Table 3: Energy Exports of Viet Nam (million tons)

Item	1996	2000	2001	2002	2003	2004	2005	CGR (%)
Crude oil	8.7	15.4	16.7	16.6	17.1	17.1	19.5	8.4
Coal	3.6	3.2	4.3	6.1	6.3	7.2	11.6	12.4

CGR = compounded growth rate.

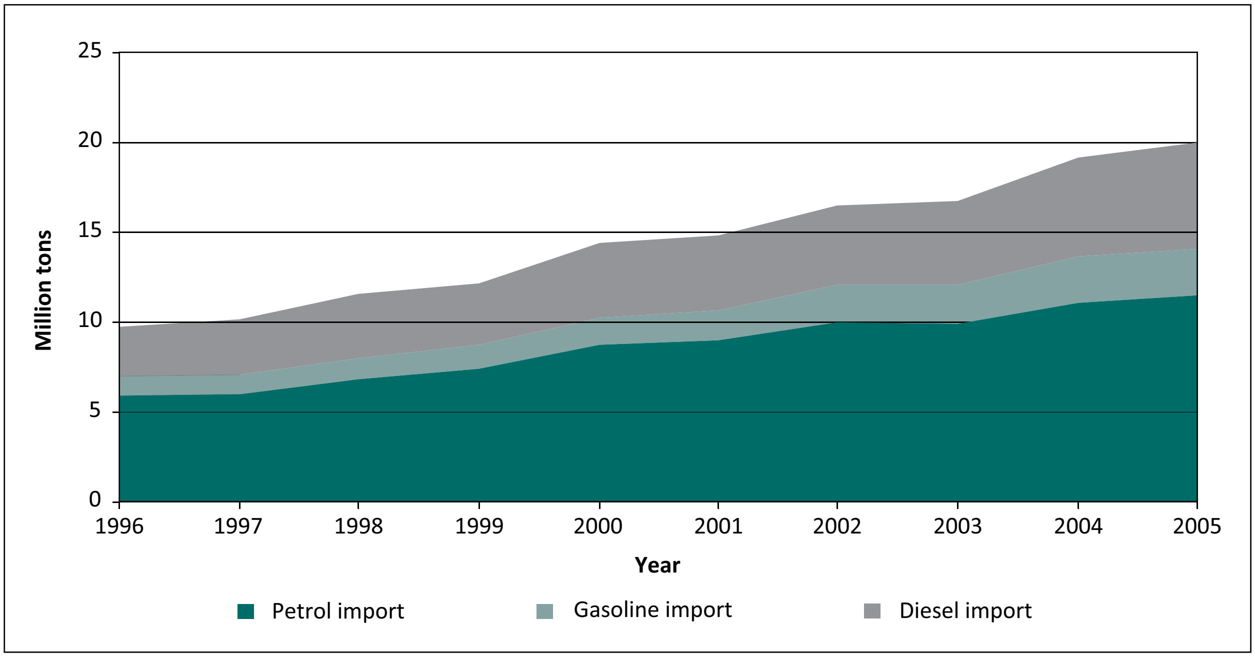
Source: Ministry of Industry and Trade. 2006.

[16] Anh Thi. 2005. *Cooking by Solar Power.* www.vnexpress.net/GL/Khoa-hoc/Cho-cong-nghe/2005/05/3B9DE449/

[17] Ministry of Agriculture and Rural Development. 2006. *Biogas Projects*. Ha Noi, Viet Nam.

[18] Dang Tung. 2007. *Orientation Relating to Investment Policy for Biofuel Development and Use in Vietnam.* International Workshop on Biofuel and Energy Security. Ha Noi, Viet Nam.

Figure 10: Energy Imports of Viet Nam, 1996–2005 (million tons)



Source: Ministry of Industry and Trade. 2006.

at least 30 years. As shown in Table 4, the amount of electricity generated in 2005 was just enough to provide for domestic consumption. After 2005, Viet Nam experienced power shortages, especially in 2007, due to a shortage of water for electricity generation. According to Electricity of Vietnam, the state-owned power utility aims to supply 88 billion–93 billion kilowatt-hours (kWh) of electricity in 2010, and 201 billion–250 billion kWh in 2020.[19] These figures represent the total supply of electricity in the country as Electricity of Vietnam is the sole supplier. Achieving a balance between supply and demand is vital. In the worst-case forecast scenarios, supply will fall short of demand in 2020 by approximately 3 billion kWh (Table 4).

Table 4: Projection of Domestic Demand and Supply of Electricity (billion kWh)

Demand and Supply	2005	2010	2015	2020	2030
Domestic demand	43.0	85.6	138.7	203.8	350.6
Optimal supply	45	93	—	250	—
Worst supply	45	88	—	201	—
Balance for optimal scenarios	+	+	—	+	—
Balance for worst scenarios	+	+	—	-	—

+ = surplus supply, - = shortage, — = data not available, kWh = kilowatt-hour.

Source: Ministry of Industry and Trade. 2006; Electricity of Vietnam. 2008.

Prospects for domestic oil. The outlook for oil is poor compared with that for electricity. Crude oil has been exploited in Viet Nam since the 1980s. In the beginning of 2000, annual production of crude oil reached between 17 mt and 20 mt. Optimistic estimates of the crude oil potential of Viet Nam put total reserves at 2.7 billion barrels, enough to satisfy domestic demand only up to 2030 if it remains constant at around 11–12 mt/year and if the domestic oil refinery is in full operation.[20] However, the projected internal demand for oil greatly exceeds this

[19] Electricity of Vietnam. 2008. www.evn.com.vn

[20] Tran Manh Tri. 2007. The Third Energy Crisis. *Tia Sang Newspaper*. 4 December 2007. Ha Noi, Viet Nam.

amount (Table 5); and these figures are supported by similar predictions from the Ministry of Science and Technology (footnote 20).

In the National Energy Development Strategy up to 2020 and Vision to 2050, the Ministry of Industry and Trade (MOIT) forecasts that oil demand could reach 17.4 mt/year in 2010, 32.6 mt/year in 2020, and 90–98 mt/year in 2050. This forecast is far above the current production capacity of 17 mt/year of crude oil. The rapidly rising demand for oil is attributable to the enormous foreign investments that have occurred since the country joined the World Trade Organization (WTO), high rates of economic growth, a growing population, and the rising number of vehicles on the country's roads.

It is forecast that from 2015 all crude oil produced in the country will be for domestic use and Viet Nam will import crude oil for its refineries. Total capacity of the refineries is estimated at 25–30 mt/year of crude oil. The operation of three refineries could only partially satisfy the demand for petroleum products, so Viet Nam will continue to import petroleum products if no other measures are taken to meet the huge demand (footnote 20).

In 2010,when the Dung Quat Refinery starts operation, Viet Nam will need to import 12.4 mt of petrol. By 2015, the deficit will increase to 12.5 mt, although oil will no longer be exported and two new oil refineries will begin operation. The deficit in 2020 will be twice that of 2015 and the trend will be the same in 2030 with a shortage of 44.2 mt (Table 5). After 2030, if nothing is done to keep up with future demand, Viet Nam will need to import all of its oil and a crisis scenario will unfold in which the country will be forced to seek imported sources of oil against a background of dwindling oil supplies and rising world shortages.

The PRC has experienced a similar oil consumption explosion. Before modernization in 1965, oil consumption was 0.2 mbbl/d. After the 1980s, oil consumption increased tenfold to 2.0 mbbl/d; and by 2000, the PRC consumed 6.0 mbbl/d. Consumption is expected to reach 20 mbbl/d in 2025. Similarly, the real oil consumption in Viet Nam could be much higher than estimates for 2020 and 2050 suggest, and the balance of demand and supply could break down, leading to an unavoidable energy crisis. If this problem occurs simultaneously in all countries, the price of oil will rise considerably, and developing countries like Viet Nam would be priced out of the oil market.

To mitigate an imminent crisis, a national energy strategy is needed to consider initiatives to achieve security and sustainability. Among alternative solutions for national energy security, the development of bioenergy is being seriously considered.

Biofuel Market of Viet Nam

Biofuels are being developed for wide-scale use in many countries due to their known benefits. They can help reduce greenhouse gas emissions and other harmful emissions, and allow the transfer of emission quotas through clean development mechanism (CDM) projects. The use of biofuels can also promote agricultural development as agriculture becomes integrated into the energy supply chain. The biofuel industry will generate jobs, maximize the cultivation of fallow and marginal land, and raise the value-added of agricultural products. The subsector will

Table 5: Projected Domestic Supply and Demand for Petroleum
(million tons)

Demand and Supply	2010	2015	2020	2030	2050
Domestic demand (petrol)	17.4	23.9	32.6	55.6	94.0
Domestic supply (crude oil)	18.2	18.2	18.2	18.2	—
Real domestic supply (petrol)	5.0	11.4	11.4	11.4	—
Petrol deficit in Viet Nam	(12.4)	(12.5)	(21.2)	(44.2)	—

( ) = negative number, — = data not available.

Source: Ministry of Industry and Trade. 2007; and Centre for Agriculture Policy. 2008.

also provide an additional avenue to help implement government policies on agricultural development, rural development, and livelihood improvement.

The technology used to produce biofuel from raw materials such as animal fat, oil plants, and sugar-producing plants is not as complicated as the technology for oil refineries or petrochemistry. The required investment is also much lower than that for the petroleum industry. Biofuel can be produced in various ways and is adaptable to different scales such as the household, clusters of households, and small- to large-scale plantations.

The Biofuel Market Development Plan of Viet Nam

Biofuel production in Viet Nam will complement traditional energy sources and will contribute to energy security and environmental protection. The government needs to formulate a legal framework to encourage the large-scale production and use of biofuels as substitutes for conventional fuels. Next, it must develop a plan for the use of biofuels as fuel substitutes in the transport, communication, and other industries. A demonstration model is needed to pilot the distribution of biofuel in selected provinces and cities.

Based on the Strategy for Biofuel Development to 2015 and Vision 2025, Decision 177/QD-TTg provides the following broad, three-stage plan for biofuel development in Viet Nam:

2010: Introduction, mastering of technology, and creating feedstock bases;

2011–2015: Expand the implementation initiative, research for technology and productivity improvement, experiment with B5 (a mixture of 5% biodiesel and 95% conventional diesel) and E5 (a mixture of 5% ethanol and 95% conventional gasoline), and training of human resources; and

Vision 2025: Improve technology to meet world standards, commercialization of the biofuel industry, biofuel to replace 5% of total demand for gasoline and diesel.

Table 6: Volume of Biofuel Production in Viet Nam, as Projected by Decision 177

Item	2010	2015	2025
Volume of biofuel ('000 tons)	7.5	250	1,800
Volume of E5 and B5 ('000 tons)	150	5,000	36,000
Ratio of pure biofuel to total petroleum demand (%)	0.04	1.00	5.00
Ratio of E5 and B5 to total petroleum demand (%)	~ 1.00	21.00	100.00

~ = up to, B5 = diesel blended with 5% biodiesel, E5 = gasoline blended with 5% bioethanol.

Source: Ministry of Industry and Trade. 2007

Along with these broad plans, Decision 177/QD-TTg sets out more specific biofuel production targets as shown in Table 6.

Market Outlook for Biofuel in Viet Nam

In assessing the market outlook for biofuels, it is assumed that if Viet Nam decides to produce biofuel to replace 5% of total demand for petroleum—through blending to attain E5 and B5 starting 2010 up to 2025—then the country may be ready to produce biofuel to meet 10% of local petroleum demand in 2030 and 20% in 2050. Table 7 presents the biofuel prospects as indicated in Decision 177 and estimated by the MOIT. It also shows the research team's own analysis of biofuel prospects in Viet Nam. The team's estimates are based on the capacity of a number of companies and factories set up during the last few years. These estimates are much higher than those planned by the MOIT, therefore the figures given by the research team are considerably higher than those of the MOIT.

Carbon Emission and Trading

In 2005, 80.4 mt of carbon dioxide (CO_2) was emitted in Viet Nam.[21] The International Energy Agency (IEA) calculated the carbon intensity (the ratio of carbon emissions produced to gross domestic product)

[21] Point Carbon Research. 2007. *Host Country Ratings CDM Investments*: Vietnam. www.pointcarbon.com/research/

Table 7: Volume of Biofuel Needed to Meet 5% of Total Petroleum Demand (‘000 tons)

Year	Decision 177 Scenarios				Research Team’s Scenarios			
	Total Biofuel (‘000 tons)	Ethanol (‘000 tons)	Biodiesel (‘000 tons)	% of Total Demand for Petrol	Total Biofuel (‘000 tons)	Ethanol (‘000 tons)	Biodiesel (‘000 tons)	% of Total Demand for Petrol
2010	7.5	5	2.5	0.04	—	—	—	—
2015	250	100	150	1	—	—	—	—
2020	—	—	—	—	1,631	540	1,091	5
2025	1,800	600	1200	5	2,880	960	1,920	8
2030	—	—	—	—	5,562	1,854	3,708	10
2050	—	—	—	—	18,800	6,300	12,500	20

— = data not available.

Source: Centre for Agricultural Policy. 2008; and Ministry of Industry and Trade. 2007.

that year to be 1.8 kilograms of CO_2 per $2,000 (footnote 21). The Government of Viet Nam ratified the United Nations Framework Convention on Climate Change on 16 November 1994, and the Kyoto Protocol on 25 September 2002. Viet Nam has been one of the countries actively working to mitigate the effects of climate change since that convention.

Viet Nam has joined the market for carbon trading, and certified emission reductions (CERs) issued by the CDM have been offered on the Asia Carbon Exchange (Box 1). Currently, Viet Nam does not have any official trading ground or trading agencies, but an official market is expected to be formed in due course.

Viet Nam is investing in plantations for carbon sequestration, wood supply, and to produce CERs which can be sold on the Asia Carbon Exchange. For instance, the Commonwealth Scientific and Industrial Research Organisation, in cooperation with the Research Centre for Forest Tree Improvement of the Forest Science Institute of Vietnam, planted fast-growing trees on more than 8,250 ha in 2001. It is estimated that the plantations will remove an additional 21,500 t/year of CO_2 from the atmosphere, compared with other tree plantations.[22]

Viet Nam’s National Strategy Study for the CDM was conducted under the guidance of the Ministry of

Box 1: Examples of Initial Carbon Trade in Viet Nam

It was found on the Asia Carbon Exchange (ACX-Change) that around 1.5 million of Certified Emission Reductions (CERs) were offered online on 25 November 2005. These CERs came from 12 Clean Development Mechanism (CDM) projects, mainly in India and Viet Nam, in the field of renewable energy from 2007 to 2012. Five potential buyers participated in the auction. Most projects received bids with prices ranging from €3.75 per ton to €6.25 per ton and eight transactions were made for a total of 130,000 tons of CERs. One whole project had been sold in Viet Nam.

In 2006, on ACX-Change system, around 500,000 tons of forward CERs were offered from 5 CDM projects originating from 3 countries (India, Viet Nam, and Brazil) on 2 continents (Asia and South America) and the bid prices went from €5.05 to €11.75 depending on project details. ACX-Change successfully auctioned 240,000 primary CERs at €10.40 each in late January. They came from a Vietnamese hydropower project at the pre-validation or Project Design Document stage and were bought by a Japanese buyer.

Source: *New Values.* 2005. Press release. November 29. The World’s First Online Auction of CERS Successful. Amsterdam.

[22] World Rainforest Movement. 2001. *World Rainforest Movement Bulletin*. 45. April 2001. www.wrm.org.uy/bulletin/45/Vietnam.html

Natural Resources and Environment with funding by the World Bank and the Government of Australia. The results of the study are intended to help experts and policymakers develop Viet Nam's National CDM Strategy and integrate the CDM into Viet Nam's institutional and legal framework. Viet Nam has the opportunity to develop CDM projects in a number of sectors, including energy, agriculture, and forestry.[23]

In short, Viet Nam's legal institutions are moving toward being more environment-friendly by encouraging and prioritizing clean projects, which bring economic benefits while enhancing the quality of the environment. By planting trees for fuel extraction, the country not only secures a fuel resource, but also receives extra credit by selling CERs.

[23] Ministry of Natural Resources and Environment. 2005. *Environmental Management.* Ha Noi, Viet Nam.

Resource Base for Biofuels Production

Land Use and Agricultural Production

The land area under agriculture and forestry expanded rapidly from 16.4 million hectares (ha) in 1990 to 24.8 million ha in 2005—an increase of 8.4 million ha. Agricultural land increased from 7.0 million ha in 1990 to 9.4 million ha in 2005, land for annual crops increased from 5.4 million ha to over 6.3 million ha, and land for perennial crops increased from 1.1 million ha to 3.1 million ha in the same period.[24]

In 2005, rice-growing land comprised 4.2 million ha (Table 8), accounting for 44% of the country's agricultural land. Other annual crops (such as maize, sweet potato, and legumes) accounted for 2.2 million ha; perennial industrial crops, 1.8 million ha; and perennial fruit, 0.5 million ha.

According to the 2006 census of agriculture, forestry, and fisheries, total agricultural land in Viet Nam was 24.7 million ha, an increase of 16% (3.47 million ha) from

Table 8: Land Use by Ecological Region in Viet Nam, 2005
('000 ha)

Land Category	Country	NE	NW	RRD	NCC	SCC	CH	SE	MRD
Agricultural land ('000 ha)	9,409.7	978.6	499.8	763.8	802.3	584.0	1,593.6	1,608.0	2,579.3
1. Rice	4,165.2	390.1	134.4	631.4	409.8	222.6	160.7	307.7	1,908.4
Paddy rice	4,033.5	372.1	80.0	631.3	392.6	207.5	141.9	307.1	1,900.7
Upland rice	131.6	18.0	54.4	0.0	17.2	15.1	18.8	0.6	7.6
2. Grass for animals	49.4	24.0	3.1	1.3	7.3	4.7	4.6	3.6	0.7
3. Other annual crops	2,148.2	274,5	310.7	59.5	226.2	235.7	576.4	329.5	135.6
4. Perennial industrial crops	1,792.0	102.1	14.0	3.7	59.3	47.9	784.9	710.3	69.8
5. Perennial fruit crops	524.6	98.4	24.4	24.0	17.4	19.9	9.2	110.3	220.9
6. Other perennial crops	730.3	89.4	13.2	43.9	82.3	53.2	57.7	146.6	244.0
7. Unused hilly land ('000 ha)	4,300	1,150	1,260	—	540	880	490	63	—
8. Inefficient state-owned farm land ('000 ha)	5,500	—	—	—	—	—	—	—	—
Average agricultural land per household (ha)	0.97	0.67	1.19	0.37	0.53	0.77	2.12	2.11	1.29

— = data not available, CH = central highland, MRD = Mekong River Delta, NCC = north central coast, NE = northeast, NW = northwest, RRD = Red River Delta, SCC = south central coast, SE = southeast.

Source: General Statistics Office of Viet Nam. 2006; and Dang Kim Son. 2008.

[24] General Statistics Office. 2006. *Land Use Survey*. www.gso.gov.vn

2001. Cultivated land accounted for 9.44 million ha, increasing by 0.56 million ha (6%) over the 2001 figure, mainly due to the reclamation of unused land. The rice-growing area declined by 0.04 million ha/year because of shift from paddy rice to aquaculture and other uses.[25]

Forest land covered 14.51 million ha in 2006, an increase of 2.69 million ha (23%) compared to that in 2001, mainly due to conversion from unused hilly and mountainous land. Aquaculture occupied 0.72 million ha, an increase of 0.21 million ha, due to the conversion of rice fields into fish ponds.

Unused land is concentrated in upland areas. A land use survey conducted by the Ministry of Natural Resources and Environment and the General Statistics Office (GSO) in 2005 found 4.3 million ha of bare, hilly, and mountainous land in the country. Of the total area of unused land, 1.26 million ha were in the northwest, 1.15 million ha in the northeast, 0.54 million ha in the central north, 0.90 million ha in the central south, and 0.49 million ha in the central highlands (footnote 24). Furthermore, there were 314 inefficient state-owned farms covering 5.50 million ha.[26]

Viet Nam is one of the members of the Association of Southeast Asian Nations (ASEAN) with a high proportion of irrigated land. According to the 2006 agricultural census by the GSO, the country has 13,643 water-pump stations for agriculture, forestry, and fisheries nationwide. The Department of Water Resources states that there are 6.8 million ha of irrigated rice and 1.1 million ha of industrial crops and upland crops. The irrigated land surveyed represents about 60% of the cultivated area. Farmers have also invested in a significant number of wells.

Crop Production

Production of annual crops. In 2006, the total area of annual crops reached 10.88 million ha, comprising 8.36 million ha for cereals, 0.70 million ha for root crops, and 0.84 million ha for annual industrial crops (groundnut and soybean) and other crops. Total annual crop production in 2006 was 39.65 million tons (mt), of which rice accounted for 35.80 mt. Trends in the sown area, productivity, and production of selected crops from 1995 to 2007 are shown in Table 9.

Table 9: Production of Annual Crops, 1995–2007

Indicators	Rice	Maize	Cassava	Sugar-cane	Ground-nut	Soy-bean	Sesame	Cotton
1995*								
Area (‘000 ha)	6,765.6	556.8	277.4	224.8	259.9	121.1	—	17.5
Productivity (100 kg/ha)	36.9	21.1	79.7	—	12.87	10.1	—	7.3
Production (‘000 tons)	24,963.7	1,177.2	2,211.5	10,711.1	334.5	125.5	—	12.8
2000*								
Area (‘000 ha)	7,666.3	730.2	234.9	302.3	244.9	124.1	—	18.9
Productivity (100 kg/ha)	42.4	27.5	86.7	497.7	14.5	11.6	—	10.1
Production (‘000 tons)	32,529.5	2,005.9	2,036.2	15,044.3	355.3	143.5	—	19.1
2005*								
Area (‘000 ha)	7,326.4	1,043.3	274.7	266.4	269.6	204.1	52.8	25.8
Productivity (100 kg/ha)	48.9	36.0	179.4	552.9	18.1	14.3	5.2	13.0
Production (‘000 tons)	35,790.8	3,756.3	4,927.2	14,730.5	489.3	292.7	27.4	33.5

continued on next page

[25] General Statistics Office. 2006. *Census of Agriculture, Rural and Fishery*. www.gso.gov.vn

[26] Dang Kim Son. 2008. *Vietnam: Agriculture, Farmer and Rural.* Ha Noi, Viet Nam.

Table 9: continued

Indicators	Rice	Maize	Cassava	Sugar-cane	Ground-nut	Soy-bean	Sesame	Cotton
2006								
Area (‘000 ha)	7,324.4	1,031.6	474.8	285.1	249.3	185.8	44.4	20.5
Productivity (100 kg/ha)	48.9	37.0	162.5	549.9	18.6	13.9	5.4	12.6
Production (‘000 tons)	35,826.8	3,819.4	7,714.0	15,678.6	464.9	258.2	23.9	25.9
2007								
Area (‘000 ha)	7,201.0	1,067.9	497.0	288.1	246.7	185.6	—	20.9
Productivity (100 kg/ha)	49.8	38.5	160.7	580.3	18.7	13.9	—	13.7
Production (‘000 tons)	35,867.5	4,107.5	7,984.9	16,719.5	462.5	258.1	—	28.6

— = data not available, ha = hectare, kg = kilogram.

* General Statistics Book 2006 provides continuous data coverage from 1995 to 2006.

Source: General Statistics Office. 2007. *Statistical Year Book: Data on Annual Crop Production*. www.gso.gov.vn

Viet Nam exports 4.5 mt–5.0 mt of rice each year. The rest of the rice harvest is used domestically as food and animal feedstock. The by-products of rice processing—broken rice and rice bran—could be used to produce biofuel, although currently they are used as animal feed.

Maize production in Viet Nam is insufficient for animal feed processing, so about 0.5 mt of corn is imported annually. The government plans to develop maize to meet the demand for animal feed, and not for biofuel. There may be an opportunity to grow maize as a feedstock for biofuel production after 2012, when the commercial cultivation of high-yielding, genetically modified maize varieties will be allowed in Viet Nam.

All root crops grown in Viet Nam, with the exception of cassava, are used for human and animal consumption, and none is left for biofuel production. Groundnut, soybean, and sesame are suitable oil-bearing crops for biodiesel production, but they are not produced in sufficient quantities for food and animal feed. Oil processing factories and companies cannot buy these products as their production is limited, and there is competition from the export market which offers relatively higher prices.

Sugarcane is an important annual industrial crop. Most of the sugarcane harvest is processed into sugar. Currently, sugar produced in Viet Nam cannot compete with sugar produced in Thailand. The cost of sugar production in Thailand is always D300/kilogram (kg) lower than the cost of sugar produced in Viet Nam, because Thailand has lower sugarcane prices and more modern production technology. As a result, 400–500 t of sugar is smuggled across the border between Viet Nam and the Lao People’s Democratic Republic every day. Also, Viet Nam imported 58,000 t of sugar in 2008 in compliance with commitments to the World Trade Organization (WTO) and the Asian Free Trade Agreement.[27] Millions of farmers suffer because the domestic sugar processing plants have had to reduce the price of refined sugar and sugarcane purchasing prices. A significant number of sugar mills have been working perfunctorily, and a few have had to shut down. Conditions in the sugar industry would worsen if low-cost sugar products flood in under the tariff tax concession of the WTO agreement. Therefore, four state-owned sugar plants in Kon Tum, Tra Vinh, and Soc Trang are expected to be converted into public limited companies soon in order to operate more efficiently (footnote 25).

[27] Ha Huu Phai. 2008. Sugar Cane Farmers aren’t Making Profit: Sugar Association. *Viet Nam Net Bridge online*. english.vietnamnet.vn/biz/2008/04/780713/

Production of perennial crops. The area of perennial crops is 2.50 million ha, of which 0.50 million ha are located in the north and 2.00 million ha is in the south. These include 1.66 million ha of industrial crops, 0.78 million ha of fruits, and 0.06 million ha of other crops. The growing area and production data of some key crops are shown in Table 10.[28]

Although Viet Nam has a variety of perennial crops, only coconut has suitably high oil content for biofuel processing. Coconut is easy to plant, low-cost, well-adapted to the climate and soil conditions of the country, and can be developed on a large scale, especially in the Mekong River Delta and in the central southern region.

Forestry Production

Viet Nam has a variety of forestry plants used for timber, herbal medicine, wood, and handicrafts. Some forestry plants have a high oil content and can be used to produce biodiesel. Examples are *Vernicia montana*, species of *Camellia*, and *Jatropha curcus*.

V. montana and *Camellia* have been used in past state-funded reforestation programs. They are grown in the provinces of Nghe An, Thanh Hoa, Ha Giang, Lang Son, and Quang Ninh. Production of *V. montana* seeds in 2005 was 1,200 t. By 2010, it is expected that 12,600 t of seeds will be produced from a planted area of 28,000 ha. (footnote 18) The nut contains 25%–30% high-quality oil.

In 2005, the area for camellia was about 20,000 ha and production was 900 t. The planted area is forecast to grow to about 100,000 ha in 2010, with production ranging from 18,000 to 72,000 t/year. The area of camellia in 2006 was 6,200 ha and yield was 1.6–2.0 t/ha, but the area is declining (footnote 18). No detailed studies have yet been done on processing the oil of these plants for biofuel production.

Table 10: Area and Production of Perennial Crops, 1996–2007

Indicators	Industrial Crops	Fruits	Coffee	Rubber	Tea	Citrus	Coconut
1996							
Area ('000 ha)	966.7	348.8	254.2	254.2	74.8	74.4	181.1
Production ('000 tons)	—	—	316.9	142.5	46.8	491.5	1,317.8
2000							
Area ('000 ha)	1,445.6	544.7	561.9	413.8	86.9	68.6	161.3
Production ('000 tons)	—	—	802.5	290.8	314.7	426.7	884.8
2005							
Area ('000 ha)	1,633.6	767.4	491.4	480.2	118.4	87.2	132.0
Production ('000 tons)	—	—	767.7	468.6	546.2	606.5	977.2
2006							
Area ('000 ha)	1,657.1	774.7	497.0	522.2	122.9	62.3	132.6
Production ('000 tons)	—	—	985.3	555.4	648.9	611.0	982.2
2007							
Area ('000 ha)	1,726.3	—	506.4	549.6	125.7	64.6	134.6
Production ('000 tons)	3,542.3	—	961.2	601.7	704.9	662.0	11,046.8

— = data not available, ha = hectare.

Source: General Statistics Office. 2007.

[28] GSO. 2007. *Statistical Year Book: Data on Perennial Crop Production.* www.gso.gov.vn; GSO. 2006. *Land Use Survey.* www.gso.gov.vn

Jatropha is considered to have the highest potential for biodiesel production. A wild plant from Mexico, it was imported and has been grown in Viet Nam for a long time.[29] The plant initially received no attention and was known as a fence or hedgerow plant. It was also planted for medicinal uses. It grows on marginal semi-arid and arid lands that are prone to erosion if not protected by plant cover. For farmers, jatropha offers the opportunity of combining soil conservation with cash crop production. It is ecologically suited for the northern and coastal zones. Incomplete data show that jatropha has been grown in many provinces such as Dong Nai, Lam Dong, Ninh Thuan, Binh Thuan, Khanh Hoa, Quang Tri, Thanh Hoa, Lao Cai, Lai Chau, Dien Bien, Son La, Hoa Binh, and Lang Son.[30] About 200 ha of land are under trial production programs for selected varieties.

Recent studies and trials have determined the agronomic requirements of jatropha as feedstock for biodiesel production. The Institute of Natural Products Chemistry, Thanh Tay University, and the Institute of Tropical Biology are among those conducting basic research on this crop to assess its potential and to scale up its production.

Animal Husbandry and Fish Production

Data on animal production from 2005 to 2007 are presented in Table 11. Cattle increased significantly while the buffalo numbers were unchanged. Poultry and pig numbers fluctuated slightly due to diseases, such as bird flu and foot-and-mouth disease.

According to the Ministry of Agriculture and Rural Development, fishery production in 2007 registered 3.9 mt, with an export value of $3.8 billion.[31] Processed catfish fillet for export weighed 0.4 mt, equivalent to about 1.0 mt of fish. Total fishery output in 2008 was predicted to be 4.1 mt, or an export turnover of about $4.25 billion, 13.3% higher than in 2007. Production of catfish is expected to increase and the volume of by-products from processing will continue to rise. Among the fishery industry by-products is a considerable amount of fish fat, which could become an important feedstock for biodiesel production.

Table 11: Animal Production, 2005–2007
(‘000 heads)

Year	2005	2006	2007
Buffalo	2,922	2,921	2,996
Cattle	5,540	6,511	6,725
Pig	27,434	26,855	26,561
Poultry	219,910	214,565	226,027

Source: General Statistics Office. 2007. *Statistical Year Book: Data on Livestock Production*. www.gso.gov.vn

Assessment of Biofuel Feedstock Production

Crop Products

Conditions in Viet Nam are favorable for producing biofuel from biomass. Bioethanol can be produced from rice, maize, cassava, sweet potato, and sugarcane. Biodiesel can be produced from oil-bearing plants such as groundnut, soybean, sesame, sunflower, coconut, and cotton. However, these products are in high demand for both human and animal consumption. Rising food prices, the risk of national and international inflation, and limited land for food crops are the challenging issues. National food security is the highest priority, so of the agricultural crops listed, only cassava and sugarcane offer potential for biofuel development.

Biofuel from sugarcane. The choice of sugarcane for ethanol extraction in Viet Nam needs to consider sugar production in the country, as sugar is needed for food security, and the plant uses a lot of irrigation water, which has other competing uses. Sugar consumption in Viet Nam increased from 5 kg per capita in 1992 to 17 kg per capita in 2006 (Table 12). This consumption rate is still below the world average

[29] Nguyen Cong Tan, 2007. *Jatropha and Prosperity for Biofuel Development in Vietnam*. www.agro.gov.vn/news/newsDetail.asp?targetID=5860

[30] Le Vo Dinh Tuong. 2007. *Preliminary Study on Physic Nut (Jatropha curcus L.) to Produce Bio-Diesel and By-Products and to Cover Wasteland with Green and Anti-Desertization in Vietnam.* International Workshop on Biofuel and Energy Security. Ha Noi. December.

[31] Ministry of Agriculture and Rural Development (MARD). 2008. Annual report of MARD for 2007. Ha Noi, Viet Nam.

of 22 kg per capita. Total sugar consumption in Viet Nam is projected to be 1.5 mt by 2010 and 2.1 mt by 2020. According to Decision 26/2007/QD-TTg, the government has set a target to increase the planted area of sugarcane to 300,000 ha by 2010 to meet the capacity of domestic sugar processing plants and to catch up with domestic demand.

The average yield of sugarcane feedstock in Viet Nam is 55.3 t/ha. This figure is 67% of the world average yield, and is much lower than that of some countries in the region such as Thailand (75 t/ha) and the People's Republic of China (PRC) (72 t/ha) (footnote 27). Furthermore, the commercial cane sugar (CCS) concentration of Viet Nam's sugar is just 8–10 CCS (100 t of sugarcane produce 10 t of sugar), while the CCS of the PRC is 12–14 and that of Thailand is 14–16.

Diversified, high-yielding canes with a high sugar content grow in parts of Viet Nam. These include the ROC series Que duong, Dai duong, Viet duong, and Vietnamese varieties VN84-422 and VN85-1859. However, the new varieties are only used in about 30% of the cropping area, and most are cultivated in nonirrigated areas.

Some models of intensive and irrigated sugarcane farming yield 100 t/ha (in Lam Son District, Thanh Hoa Province) or 150 t/ha (in Phung Hiep District, Hau Giang Province).[32] At present, Viet Nam has nearly 300,000 ha of land planted to sugarcane. If the average yield can be raised to 65 t/ha with a CCS of 11, the surplus sugarcane production for bioethanol processing would be about 6 mt (Table 12). If the average yield is raised to 80 t/ha by 2020, with a CCS of 12, about 6.5 mt of sugarcane would be available for ethanol production.

Domestic bioethanol is currently produced from molasses, a by-product of sugar processing. However, processing technology needs to be improved to allow more efficient production. For example, the production cost per liter of molasses-based ethanol is about D6,000 for refined ethanol at the refinery gate price, and D3,500 for crude ethanol. The selling reference price ranged from D8,000 to D10,000 per liter of refined ethanol in 2005.[33] Total estimated production of ethanol in Viet Nam in 2008 was 45 million liters (l), but it was mainly for export as there is little use for it domestically. Surplus sugarcane output and by-products for bioethanol production on a larger scale are, therefore, comparatively abundant in Viet Nam.

Table 12: Sugar Consumption and Possible Sugarcane Surplus in Viet Nam

Year	**Sugar consumption** (kg/ person/year)	**Sugar total consumption** (million tons)	**Cane production for sugar** (million tons)	**Total cane area** (ha)	**Yield of cane** (tons/ha)	**Total cane production in country** (million tons)	**Surplus cane production** (million tons)
1992	5	0.34	3.40	—	—	—	—
2002	13	1.03	10.34	—	—	—	—
2006	17	1.43	14.31	285,000	55	15.68	—
2010	19	1.50	13.64	300,000	65	19.50	5.86
2015	21	1.80	15.00	300,000	70	21.75	6.75
2020	22	2.10	17.50	300,000	80	24.00	6.50

— = data not available, ha = hectare, kg = kilogram.

Source: Centre for Agriculture Policy. 2008. *Projection on Area of Sugarcane Meeting Biofuel Demand of Vietnam*. Ha Noi, Viet Nam; Ministry of Industry and Trade. 2007. Decision 26/2007/QD-TTg. Ha Noi, Viet Nam; Dang Kim Son. 2004. *Profile of Sugarcane in Vietnam*. Report. Ha Noi, Viet Nam.

[32] *Hau Giang Newspaper*. 2007. Prosperity of Sugarcane Variety VD 93-159. www.haugiang.gov.vn/baohaugiang/?news=1524

[33] Petrosetco. 2007. *Biofuel Development Program.* Viet Nam.

Sugarcane cultivation does not have any negative impacts on the environment, but its use for the production of bioethanol is considered undesirable because each liter of ethanol produced requires 30 l of water. No impact from the distribution and consumption of bioethanol from sugarcane has been reported.

Biofuel potential of cassava. Cassava has a high potential for biofuel production, but there is competition for the crop from other enterprises which process cassava for starch, produce animal feed, and export of cassava chips. Currently, farmers grow many new varieties (Table 13), which have high yield and quality, and high starch content (above 25%). The cassava area has expanded in recent years because of high demand from starch factories and for the export of dry chips. Although land suitable for cassava cultivation is still available, the government discourages cassava expansion because of the resultant soil degradation and water pollution from cassava processing.

Cassava production for other purposes can be increased on the current planting area. The current yield in Viet Nam is only 16 t/ha, which is much lower than the yield in other countries (up to 50 t/ha). The yield of cassava can be doubled by applying nutrients, installing irrigation, and selecting more suitable planting areas.

Biofuel potential of maize. In 2007, over 1 million ha were planted to maize. Average production was 3.7 t/ha, giving a total production of 3.8 mt. The bulk of maize produced in 2005 and 2006 was used to manufacture animal feed (Table 14); however, domestic production was insufficient to meet the needs of the livestock sector and the animal feed industry. There were 124 animal feed factories with a total capacity of 10.5 mt/year in 2006. However, they usually operate at 58% of capacity, producing 6.1 mt of mixed and condensed feeds, equivalent to 7.7 mt of mixed feeds.[34] Domestic maize production met only 85% of requirements in 2006, and the country had to import the remaining 15%, equivalent to 0.7 mt.

High-yielding maize varieties are cultivated on 90% of all areas planted to maize. In the near future, if high-yielding genetically modified maize varieties are introduced and maize farmers apply advanced agronomic techniques—such as irrigation, fertilizer, and mechanized soil preparation and harvesting—average productivity can be raised to 5–6 t/ha, yielding a total of 5.5 mt. The 0.5 mt maize surplus (after accounting for the 5 mt required for animal feed) could be considered for biofuel production. However, this quantity would be insufficient for large-scale biofuel production. Therefore, this study concludes that extracting biofuel from maize is not a feasible option for Viet Nam at present.

Table 13: Yield Variations of Some High-Yielding Cassava Varieties in Viet Nam (tons/ha)

	Yield (tons/ha)			
Variety	**Cu M'gar – Daklak**	**Quang Hiep – Daklak**	**Tan Canh – Kontum**	**Average**
KM 140	38.7	35.5	32.0	35.0
KM 98-5	35.6	34.6	28.7	33.0
KM 98-1	24.3	25.5	26.7	25.5
KM 94	31.5	28.9	26.0	31.0

Source: Institute of Agricultural Sciences for Southern Vietnam. 2007. *Level of Fertiliser Application for Some Crops of Vietnam*. Ho Chi Minh, Viet Nam.

Table 14: Use of Maize in Viet Nam ('000 tons)

Indicators ('000 tons)	**2005**	**2006**
Domestic production of maize	3,756	3,819
Domestic maize for producing Animal feed	3,401	3,437
Maize import for domestic Animal feed	—	565

— = data not available.

Source: Ministry of Agriculture and Rural Development. 2006.

34 MARD. 2006. *Production of Animal Feed.* Ha Noi, Viet Nam.

Forestry Products

V. montana and *Camellia* are two forestry crops with moderate potential as feedstocks for biodiesel production. According to the Department of Forestry, there is plentiful land available for these tree crops. However, jatropha has greater potential for biofuel production, so its potential cultivation will now be considered in some depth.

Jatropha is easy to grow on sloping land with low fertility where other crops cannot be grown. The economic cycle of this crop is 30–50 years and it takes 4–5 years to mature fully in nutrient-poor and marginal soils. Jatropha has wide adaptation and does not demand many specific conditions for growth. It can grow in almost all tropical and semi-tropical countries within latitudes 28° north to 30° south, altitudes from 7 meters to 1,600 meters above sea level, average temperatures of 11°–28°Celsius, and annual rainfall of 520–2,000 millimeters. Research indicates that it can be cultivated in northern, central, and southeast Viet Nam (Table 15). Biodiesel crops have been referred to as a “quiet revolution”, due to their potential to be economically viable without large capital investments or fertile land, and with little maintenance.[35]

Jatropha seeds (Figure 11) contain more than 30% oil. In Viet Nam the seed yield from jatropha is 5–10 t/ha. When distilled, this can yield 1.5–3.0 t of biodiesel, of a quality equal to that of fossil diesel. After the oil is extracted from the seed, the residue can be used as fertilizer or animal feed as it has a protein content of 30% (footnote 35).

The PRC buys seeds at a price equivalent to D3,500/kg; therefore if the poor soil in Viet Nam can yield 5–10 t/ha of seeds, farmers could earn D17.5–D35.0 million/ha/year. Based on experiments in some

Table 15: Assessment of Jatropha Cultivation in Viet Nam, by Region

Item	Northern Mountainous	Central North	Central South	Central Highland	South East
Climate	Hot summer, cool winter High rainfall High number of sunny hours	Hot summer, cool winter High rainfall High number of sunny hours	Hot weather, no winter Lower rainfall High number of sunny hours	Hot weather, no winter High rainfall High number of sunny hours	Hot weather, no winter High rainfall High number of sunny hours
Soil condition	Moderate fertility Sloping	Poor land Sloping	Poor land Sloping	Fertile soil Slightly sloping	Fertile soil Slightly sloping
Bare upland (hectares)	2,371,300	537,140	803,300	488,900	63,900
Competitiveness with other crops in the same conditions	Can generate more income than other fruit, industrial crops, and other forestry plants	Can generate more income than other fruit, industrial crops, and other forestry plants	Can generate more income than other fruit, industrial crops, and other forestry plants	Difficult to compete with industrial crops, fruit crops such as tea, coffee, rubber, pepper	Difficult to compete with industrial crops, fruit crops such as tea, coffee, rubber, pepper
General assessment	Can be developed on a large scale and be sustainable	Can be developed on a large scale and be sustainable	Can be developed on a large scale and be sustainable	Difficult to develop on a large scale	No potential for development on a large scale

Source: Nguyen Cong Tan. 2008.

[35] *Ecoworld.* 2006. India’s Biodiesel Scene: The Latest Biodiesel Developments in a Nation Determined to Achieve Energy Independence. 6 April. www.ecoworld.com/home/articles2.cfm?tid=385

Figure 11: Jatropha Nuts and Seeds

Source: Nguyen Cong Tan. 2007.

of the northern provinces, farmers can easily establish a plantation with a very low investment (around D3 million, or $200/ha). Jatropha cultivation does not require a high level of technical skill, and the basic techniques of cultivation can be taught to farmers to ensure achievement of maximum production. The preliminary work of removing the seeds from the fruit can be done by households, but transporting the seeds should be done by intermediaries or the manufacturers.

Jatropha is not considered a threat to food security or animal husbandry in Viet Nam because, unlike in India, Indonesia, and Thailand, where jatropha is planted even on agricultural land or fertile soil in pursuit of their vision of biofuel production, Viet Nam considers jatropha only for bare, hilly land or degraded forestland. Moreover, soil improved by jatropha can benefit subsequent crops.

In 2008, there were no policies for developing jatropha in Viet Nam. But the government is likely to provide support to help secure the energy supply and reduce greenhouse gas emissions from the use of fossil fuels. Petrosetco estimated the cost of investment in different feedstocks for biodiesel production in Viet Nam (Table 16). An important finding is that the potential for a large feedstock base from jatropha is far greater than that for other biodiesel sources because of the availability of extensive tracts of bare and infertile land. This potential to grow and give high yields on bare land makes jatropha a priority biofuel crop.

Livestock Products

The livestock industry in Viet Nam is changing with the rapid development of larger-scale (industry-based) and farm-based raising (non-individual) for the market. Animal fat is a livestock by-product that can be used in biofuel processing; but there have been no studies or trials to date on how to process it into biofuel. However, the processing of animal waste into biogas has begun to spread in the rural areas.

Aquaculture Products

The annual output of tra and basa[36] catfish is increasing. Catfish has the highest potential among aquaculture products as feedstock for biodiesel production. Many researchers have stated that "besides a race in exporting fillet, there is a silent race in converting by-products into cash."[37] According to Do Van Nghiep, Director of An Giang Fishery Trading, 1,000 grams of fish produces an average of only 300 grams of fillet for export. The remaining 700 grams of by-products include head, bone, skin, belly, fat, and gut (footnote 37).

Table 16: Biodiesel Capacity and Investment Costs for Different Feedstocks

Feedstock	Firm's Capacity (million liters)	Costs per Firm ($ million)	Cost per Liter ($)
Jatropha	580	98.5	0.17
Palm oil	150	27.0	0.18
Cottonseed	80	18.0	0.23
Catfish	40	9.0	0.23

Source: Petrosetco. 2007.

[36] Tra and basa are species of freshwater catfish native to the Mekong River.

[37] *Saigon Marketing Newspaper*. 2007. Agifish Succeeded on Biodiesel Extracted from Catfish. November. Ho Chi Minh, Viet Nam.

There were about 70 catfish processing factories in the Mekong River Delta in 2007, producing nearly 1 mt of catfish and 0.6 mt of by-products. The fat content of catfish averages 15%–20% by weight, which is equivalent to 150,000–200,000 t of fish oil (footnote 37). In 2006, the government set the target for total catfish catch at 1 mt for 2010 onward. Catfish processing will provide an abundant source of fat which could be used for biodiesel production. However, it is reported that the first generation of fish oil biodiesel produced in Viet Nam did not satisfy the proposed standard for the new energy source, though the quality has subsequently been improved and small-scale commercialization has been achieved. Only fish oil produced by households fails to meet standards and has been found to generate emissions harmful to the environment and to human health.[38]

The price of fish fat increased from between D2,000/ kg and D3,000/kg before 2006, to between D4,500/kg and D5,000/kg in 2006. It increased further to over D6,000/kg in 2007 when many processors began to produce biodiesel from fish fat. In An Giang Province—the biggest source of fish oil—the An Giang Fisheries Import and Export Joint Stock Company (Agifish) has invested in a production line of biodiesel with a capacity of 30 t/day (B100) produced from 300 t/day of fish oil. Another biodiesel plant in the city of Can Tho, operated by Minh Tu, has a capacity of 2–3t/day. Recently, Navico—a major catfish exporter—bought from the Institute of Chemical Industry of Vietnam a biodiesel production line with a capacity of 60 t/day. A simple estimate in Table 16 shows that the initial investment for small-scale production of diesel from catfish fat is $90 million for a capacity of 40 million l/year (footnote 37).

Fish fat is also exported to Cambodia and Taipei,China. The surplus production of fish fat shows that catfish oil has great potential for biodiesel production in the Mekong Delta region, but the volume must be large enough to be economically viable. There has been no reported impact of fish oil use on food security, but the ongoing trend of converting agricultural land for aquatic cultivation needs to be examined. Competition for income arises when agricultural land is given over to aquaculture. The returns are high, but so are the risks, due to the response of the market, natural disasters, and diseases. The possible impacts on livelihood security of more widespread aquaculture need to be determined. Fish oil and residues are also used in cattle feed, therefore the impact on animal husbandry of any large-scale development of fish oil biodiesel should also be assessed.

There were no clear policies for biodiesel from fish oil in 2008, but the technology and industrial standards for biodiesel have been improved by government institutions and private enterprises. While fossil fuel prices remain high, there is a clear market potential to make money from cheaper residues. The market for fish oil biodiesel is currently mostly domestic, and production is on such a small scale that there is still room for many enterprises. The product is traded because it is welcomed by petroleum distributors. However, at the selling price of D8,300/l ($0.53/l), biodiesel is still not cost-effective for business.

Potential Biofuel Feedstocks

Sweet Sorghum

Sweet sorghum belongs to the Gramineae family. Originating in Ethiopia, it is now widely grown in tropical and semitropical regions of the world. Some new hybrid sorghum varieties have been imported and tested in the Mekong River Delta, the central highlands, and northern region for various purposes, such as their yield of grain, leaves, and green biomass.

Sweet sorghum has a 4-month crop cycle. The plant has a high sugar content and large biomass production potential. When crushed, sorghum stalks yield a sweet juice that contains 15%–20% sugar. This can be distilled and transformed into ethanol. Sweet sorghum is known as a "smart crop" because it provides food, fodder, and ethanol. It is adapted to dry, salty conditions and is heat-tolerant. The plant grows to a height of 12 feet and looks like corn without ears. The grain is used for food and the crushed stalks are used for animal fodder. Significantly, since sweet sorghum is not an internationally traded commodity, its use for bioethanol production is not likely to compromise food security and inflate food prices.

[38] Vietnam Association of Seafood Exporters and Producers. 2007. Oil Manually Extracted from Catfish Causes Damage to Boat Engine? Press release: *Agriculture Today Newspaper*. November.

Moringa

Moringa oleifera (commonly known as moringa) belongs to the Moringaceae family that originated in Uttar Pradesh, India. This woody plant is popular in tropical and sub-tropical regions. It is non-toxic and has multiple uses such as food, medicine, feed, and fuel from its oil-bearing seeds. Moringa is tolerant to a wide range of temperatures from 0° to 40°Celsius, and rainfall of 250–1,000 millimeters. It is also tolerant to salinity, waterlogging, drought, and mild frost.[39] The trees start to produce seed after 6–8 months and produce flowers and fruit year-round. The seeds contain 35%–40% nondrying oil, and the remaining seed cake after extraction is very high in crude protein (nearly 60%), making it a desirable source of animal fodder (footnote 39). It is estimated that 1 ha of moringa may produce 1,000–2,000 l/year of biodiesel. Moringa grows in the southern provinces from Da Nang to Kien Giang and is said to be suited to many other parts of Viet Nam.

Production of Biofuels in Viet Nam

In the Viet Nam context, there are three main areas of potential biofuel production: bioethanol from starch, biodiesel from fish fat and plant-based oil, and biogas from animal wastes. Bioethanol and biodiesel have potential for commercial production, while biogas is being promoted for environmental protection and rural development benefits.

The technology to convert starch-based feedstocks into ethanol can be divided into three levels of technological sophistication. First-generation biofuels use conventional technology to convert feedstocks such as sugarcane, maize, wheat, barley, sorghum, and cassava, into biofuel. Second-generation biofuels, or cellulosic biofuels, use non-food biomass such as crop residues, and forest residues, such as husk, stalk and leaves, wood chips, or switch-grass, as feedstock. Enzyme catalysis breaks down lignocellulose to make ethanol. Second-generation biofuel technology is expected to become available on a commercial scale in 2010.[40] Third-generation biofuel uses biomass crops designed specially for the requirements of the bioconversion process, for example using special algae or weeds. At present, Viet Nam uses only first-generation technology.

Bioethanol Production in Viet Nam

Bioethanol production from sugarcane. According to the Department of Agriculture, Forestry and Fishery Processing and Trading (footnote 31), there are 39 sugar processing factories in Viet Nam with a total sugar production of 1.2 mt/year. Besides this main product, the factories also produce other products from by-products of sugar milling such as microorganism fertilizers from waste, bioethanol from molasses, and plywood from sugarcane dregs.

Ethanol production from all factories increased from 16 million l in 2003 to 45 million l in 2008. Total capacity of all sugar factories was 53 million l/year of ethanol in 2008 (Table 17). The ethanol is mainly exported, since domestic consumption is limited to medical and chemical uses.

Bioethanol production from cassava. The amount of ethanol produced from cassava is very limited

Table 17: Bioethanol Production in Sugar Factories in Viet Nam, 2008
(million liters/year)

Factory	Province	Capacity (million liters/year)
Hoa Binh	Hoa Binh	2.0
Lam Son	Thanh Hoa	25.0
Viet Tri	Phu Tho	0.5
Song Con	Ha Tinh	0.5
Quang Ngai	Quang Ngai	2.5
Binh Dinh	Binh Dinh	2.0
Tuy Hoa	Phu Yen	6.0
Hiep Hoa	Long An	2.5
Long My Phat	Hau Giang	6.0
Van Phat	Phu Yen	6.0
Country capacity		**53.0**

Source: Ministry of Agriculture and Rural Development. 2007.

39 Wikipedia. 2008. *Moringa Oleifera*. http://en.wikipedia.org/wiki/Moringa_oleifera

40 Novozymes. 2008. *Bioethanol and the Need for Sustainable Energy*. Denmark.

compared with that from sugarcane. This is partly due to the use of cassava feedstock by starch or glutamate processors. Nevertheless, some ongoing projects are investing in ethanol production from cassava chips.

In 2006, 52 cassava starch factories with a capacity of between 50 t/day and 3,426 t/day were operating mainly in the southeast and the central highlands. In addition, there were about 4,100 small starch producers, located mostly in Ha Tay Province.[41]

In 2008, the estimated capacity of cassava-based ethanol was 320 million l/year, with capital investment drawn from foreign and private enterprises. Of that capacity, 6 million l/year are from cassava feedstocks from Vietnam Sugar Corporation II in Xuan Loc district, Dong Nai Province. Two other factories are run by Dong Xanh (Tam Ky, Quang Ngai) and Petrosetco (Dong Nai).

Petrosetco and Itochu have invested in a $100-million joint project to produce bioethanol from cassava chips.[42] The factory will be based in Hiep Phuoc Industrial Park, Ho Chi Minh City, with a designed capacity of 100 million l/year, and will be completed by the second quarter of 2009. Recently, Petrosetco also signed a contract with the Bronzeoak Group to build a 150-million-l/year factory producing bioethanol from cassava chips in Dung Quat Economic Zone with an investment capital of D2,200 billion.[43] According to the Ministry of Industry and Trade, Vietnam Bioethanol Joint Stock Company has invested in a factory that will produce 66,000 cubic meters of ethanol per year in Dak Lak.

Bioethanol from sweet sorghum. As stated, sweet sorghum does not compromise food security. It has all the necessary characteristics of a biofuel crop for poverty reduction and industrialization in rural areas. Mark Winslow, agronomist from the International Crops Research Institute for the Semi-Arid Tropics, describes sweet sorghum as “a win–win situation for developing nations since it allows them to save money they now spend on oil imports and invest it in sweet sorghum-ethanol production in dry areas.” [44]

Table 18: Comparison of Sweet Sorghum, Sugarcane, and Maize

Parameter	Sweet Sorghum	Sugarcane	Maize
Crop duration	4 months	12 months	4 months
Water requirement	4,000 m^3	36,000 m^3	8,000 m^3
Grain yield (tons/ha)	2.0	—	3.5
Ethanol from grain (liters/ha)	760	—	1,400
Green stalk cane yield (tons/ha)	35	75	45
Ethanol from stalk cane juice (liters/ha)	1,400	5,600	—
Stillage/stover (tons/ha)	4	13.3	8
Ethanol from residue (liters/ha)	1,000	3,325	1,816
Total ethanol (liters/ha/year)	9,480	8,925	9,648
Cultivation cost (with irrigation) ($/ha/crop)	238	995	287

— = not applicable, ha = hectare, m^3 = cubic meter.

Source: Badger, A. 2002. Ethanol from Cellulose: A General Review. In J. Janick and A. Whipkey eds. *Trends in New Crops and New Uses.* Alexandria, Virginia: ASHS Press.

41 Department of Agriculture, Forestry and Fishery Processing and Trading. 2006. *Annual Report of 2006.* Ha Noi, Viet Nam.

42 Petrosetco. 2007. *New Launching Ethanol Project.* www.petrosetco.com.vn

43 Petrosetco. 2008. *Joint Stock Company of Petrol and Tourism Register for Ethanol Production in Binh Dinh Province.* www.petrosetco.com.vn

44 International Crops Research Institute for the Semi-Arid Tropics. 2007. *Sorghum Crop.* www.icrisat.org/sorghum/sorghum.htm

Table 18 compares the ethanol-bearing capacity of sweet sorghum, sugarcane, and maize with a similar ethanol yield/ha/year. The cultivation costs are comparable, however, the advantage of sweet sorghum is that it grows in dry and hilly areas and does not compete for land with food crops.

Theoretically, sweet sorghum is suited to conditions in Viet Nam; however, to make it a practical feedstock source for biofuel production, further studies should be undertaken on high-yielding varieties, competitiveness, processing technology, and market prospects.

Biogas Production

The Biogas Project, supported by the Government of the Netherlands, is the only program involved in biogas production in Viet Nam. The potential for biogas production is still enormous, particularly given the growth of the livestock sector. Developing the biogas industry is attractive because it not only brings economic value but it can also protect the environment.

The Biogas Project is implemented by the Department of Livestock Production in three stages. Period 1 (2003–2006) was carried out in 12 provinces, period 2 (2006 bridging stage) in 8 provinces, and period 3 (2007–2011) is being implemented throughout the country (footnote 17). The objectives of the project are to create a clean and cheap source of energy for farmers, to reduce deforestation and the use of fossil fuel, and to gradually form a socioeconomic organization of professional biogas traders.

However, to develop and trade biogas commercially, large biogas-producing systems need to be built, together with pipelines, gas containers, and distribution containers. These issues have not been studied. In the Viet Nam context, this energy source would be ideal at the household level, rather than on an industrial scale. Sources are scattered around the country and most gas tanks are in remote or rural areas where transport is difficult. Therefore, biogas is not recommended for development on a commercial scale in the long term.

Biodiesel Production

Research and production of diesel from plant oil. In 2005, the Institute of Industrial Chemistry (IIC) conducted research on biodiesel production technology using different feedstocks and analyzed the quality of a mixture of biodiesel and diesel. The research used two typical resources: refined coconut oil and fat from basa catfish. After the research, the IIC collaborated with the APP Company to produce biofuel on a small scale of 10 and 60 l/day from coconut oil. In 2006, the IIC transferred the biodiesel processing technology for basa catfish fat to Nam Viet Joint Stock Company’s 60,000 t/year processing line.[45]

In addition, the IIC is cooperating with Minh Son to transfer biodiesel processing expertise for jatropha seeds. Minh Son is coordinating with the Institute of Tropical Biology to grow jatropha in a trial area of 50 ha in the north of the country. Thanh Tay University is also collaborating with Minh Son and Nui Dau in a demonstration project on 150 ha in the provinces of Son La and Lang Son. Analysis of the diesel sample processed from jatropha indicates that some petrochemistry indexes such as the acid index, iodine index, and chemistry composition, fully meet the draft Vietnamese standard of B100 (100% biodiesel) (footnote 45).

The Ministry of Agriculture and Rural Development is also involved in jatropha research and development. It funded a project of the Center for Forest Biotechnology of the Forest Science Institute of Vietnam to conduct research on jatropha from 2007 to 2010. In 2007, the project had some interesting findings on propagation techniques, nurseries, and pruning. Two good varieties were selected for their high yield, high rate of growth, and suitability as biodiesel feedstock.

Green Energy Vietnam has also invested in a jatropha development project and biodiesel processing factory. The company has cooperated with the Center for Forest Biotechnology of the Forest Science Institute in setting up 38 ha of experimental farms in eight provinces. The company has made a commitment to

[45] Vu Thi Thu Ha. 2007. *Results from Evaluating Status of Biodiesel Production Technology in Vietnam*. Report.

invest in a production project that will rapidly expand the jatropha feedstock area and evaluate the success in testing and refining biodiesel.

Currently, moringa is not the subject of any research or trials. But in India, its great potential for yielding oil from seeds is already recognized. Therefore, further in-depth studies on moringa are recommended to evaluate its potential for biofuel production in the Viet Nam context.

Production of biodiesel from fish fat. In late 2007, the Vietnam Association of Seafood Exporters and Processors named only two enterprises in the Mekong River Delta that have satisfactory processing equipment and are licensed to produce biodiesel from tra and basa catfish. These are Agifish, in An Giang Province; and Minh Tu, in Can Tho Province. In the near future, Navico will invest in producing biodiesel from tra and basa catfish fat. In addition, some small manual biofuel processors operate in this catfish-producing area.

Agifish has carried out biodiesel research and development since 2004. In 2006, after more than 2 years of research and trial, the company successfully produced biodiesel from tra and basa catfish fat. The product has been tested by the Quality Assurance and Testing Center 3 and found to meet the full requirements for diesel engine fuel. Since January 2006, many customers have been using the product to run diesel engines. Factories producing bricks in Long Xuyen and Chau Thanh districts reported that the use of biodiesel could save up to D50,000 per 1,000 bricks.

In 2007, biodiesel produced by Agifish was tested and accepted by Ho Chi Minh City's Department of Science and Technology. The company has cooperated with Saigon Petro in planning to market a commercial product of B5 and B50 (a mixture of 50% biodiesel and 50% of conventional diesel) with a projected output of 30 t/day. Agifish also opened a processing factory in Chau Thanh District, Tien Giang Province, using basa catfish fat. The plant has an area of 2 ha, an investment capital of D10 billion, and a processing capacity of about 30 t/day. Another factory with a similar capacity will be built in Tra Noc Industrial Park, Can Tho Province. An Giang Province is the largest catfish fat feedstock producer in the Mekong River Delta and Agifish is the biggest fishery processing corporation with a capacity of 300 t/day of basa catfish and 30 t/day of fat.[46] This amount is sufficient feedstock for the factory's feedstock processing capacity and does not take into account other potential sources of catfish fat in Can Tho and Tien Giang provinces.

Since 2004, Minh Tu has invested in research and development for biodiesel processing using tra and basa catfish. The process is similar to that of Agifish: fat is warmed up and then made to react with methanol in an esterification with catalysts such as hydroxide natri to produce biodiesel. The company produces 2,000–3,000 l/day of biodiesel. The product has been certified by Petro Mekong to have the same quality as fossil fuel. Minh Tu has signed a contract to supply biodiesel to Mekong Petrochemistry Company, Can Tho Cement Enterprise, some rice milling factories, and various construction projects. However, with a production cost of about D8,200–D8,300/l (in 2007), biofuel is not very competitive, and this may discourage producers from venturing into the business.[47]

Processing and use of biodiesel by manual producers. Many farmers and small manual producers use the by-product of tra and basa catfish after fillet processing to distill into fat. They then mix the fat with fossil fuel to run engines. Small processors also buy the by-product from fish processing factories then pulverize it, use it as it is, or cook it. The fatty matter that floats is removed, and the residue can be used as animal feed or fertilizer. Small processors sell this fat to animal feed factories as fatty matter supplement, or to manual producers of biodiesel. According to the Vietnam Association of Seafood Exporters and Processors, biodiesel produced by manual mills does not meet quality standards because the processing equipment is rudimentary (footnote 38). The mills use pans to heat the feedstocks and then put them through four to six filter tanks. Because the product does not meet technical requirements, the engines of the fishing boats in which it is used deteriorate and soon break down.

Challenges to Developing Biofuel in Viet Nam

Biofuel is not yet readily available in commercial volumes in Viet Nam. All the feedstocks cited for

[46] *Vietnamnet*. 2006. Production Cost of Bio-Diesel from Catfish in Vietnam. Ha Noi, Viet Nam.

[47] *The Youth Newspaper.* 2007. Bio-Diesel Extraction from Catfish in Mekong Delta Region of Vietnam. Ho Chi Minh, Viet Nam.

biofuel production are at the trial phase—except moringa and sweet sorghum, which are not yet grown in Viet Nam. Viet Nam currently uses first-generation technology and has not yet invested in second- and third-generation technologies. Biofuel is produced on a small scale by individual households with limited landholdings. The land system in Viet Nam is characterized by small and scattered parcels, and this is likely to pose problems for industrial-scale production. The small scale of landholdings will result in scattered production, unhomogeneous products, high transaction costs of dealing with a large number of growers, and difficulty in applying modern farming technology and crop management techniques.

Furthermore, agricultural extension support is weak because of underdeveloped technical skills, a shortage of staff, and difficulties in upgrading to modern technical horticulture. The biofuel industry receives little support from research institutes, which have limited funding and lack human resources in the technical processing field. Furthermore, the national universities do not provide training in the special skills needed in the biofuel industry.

The government approved the strategy for biofuel development in Viet Nam, but it did not stipulate the main feedstocks to be used. In addition, feedstocks for biofuel have not yet been included in agricultural land use planning by the Ministry of Agriculture and Rural Development and the Ministry of Natural Resources and Environment.

Finally, small traders dominate the collection and purchasing of agricultural output, creating layers of intermediaries between farmers and the mills. This causes a lack of transparency in the market, a wide gap between the farm gate price and the purchase price by mills, speculation resulting in price instability, and a disconnect between the farmers and the mills (footnote 33).

Prioritization of Feedstocks

This section further analyzes the resource base and prioritizes potential feedstocks for the development of the biofuel industry in Viet Nam. Some 11 feedstocks are analyzed in depth: coconut, sugarcane, cassava, corn, other grains, rice, *V. montana*, *C. sasanqua*, jatropha, fish oil, and livestock wastes. Table 19 lists 10 criteria and ranks the crops from 1 to 10; where a higher rank indicates greater potential for biofuel production in the Viet Nam context (see Appendix 2 for an explanation of the indicators). The top three potential biofuel feedstocks, in descending order, are jatropha, sugarcane, and fish fat. A long-term strategy for these priority feedstocks is presented. Sweet sorghum and moringa may be additional options if they are found to be suitable for biofuel production in Viet Nam.

Other alternatives such as coconut, rice, cassava, other grains, animal waste, *V. montana*, and *C. sasanqua* have some inherent disadvantages and were considered by this study to have low priority as biofuel feedstocks. Coconut satisfies several criteria but its area is limited, it takes a long time to mature, and its productivity is uncertain. It is therefore risky to invest in coconut solely as a biofuel feedstock.

Rice production is sufficient for domestic use and for export. Residues from rice processing contain oil, but the amount is small compared with the protein content. It is unwise to use rice residues for oil extraction because they are more cost-effective and bring more benefits when used as feed for cattle.

Other grains, such as corn and soybean, are used as food and animal feed. The area for growing these crops is still very limited and its extent has not been confirmed by inventories and research. Food shortages are more urgent than the energy crisis and thus food security takes priority over biofuel production with regard to soybean and corn.

Forest species such as *V. montana* and *C. sasanqua* have a high oil content but low ecological adaptation. Popularizing them may not be possible because the area suitable for their cultivation cannot be expanded. These species can be integrated locally into agroforestry models for diversified output, but they are not recommended as raw materials for biofuel production in Viet Nam.

Waste residues from animal husbandry have been used successfully to generate biogas in rural areas. The Netherlands development organization, SNV, has strongly supported this approach, but it should take into account the impact of epidemics, which periodically significantly reduce the number of livestock and hence the amount of waste available. This has made farmers hesitant to invest in biogas plants. Commercial production of biogas requires a large biogas complex, complete with a pipeline system, gas containers, distribution containers, and a stable supply. Currently, no study has been made of these details. Thus, the production system is more suited to the household, rather than an industrial scale. Therefore livestock waste is not an attractive feedstock for commercial bioenergy development in Viet Nam.

Cassava is a promising alternative due to its high productivity. Petrosetco's biofuels program will use cassava for bioethanol production up to 2010, after which the company will focus on cultivating jatropha to create a stable supply base. In the next phase, the company aims to produce biofuel from a wide variety of source materials, rather than relying on cassava and jatropha. However, cassava degrades the soil, and after it has been grown farmers find it difficult to grow other plants without substantial applications of fertilizer. Thus, the government has not encouraged the expansion of the area for cassava. Undoubtedly, existing biofuel processing plants based on cassava will face a feedstock supply shortage if the company tries to increase its capacity. Hence, cassava is only a temporary option and is not recommended as a long-term feedstock for Viet Nam's biofuel portfolio.

Table 19: Criteria for Prioritizing Biofuel Feedstocks in Viet Nam

Criteria	Subcriteria	Coconut	Sugarcane	Cassava	Corn	Other Grains	Rice	Vernica montana	Camellia sasanqua	Jatropha	Fish Fat	Animal Residues
1. Adaptation and/or availability of feedstock		5	8	7	8	7	10	5	5	5	5	5
2. Productivity		6	6	8	6	4	8	3	3	10	10	5
3. Ability of self-development by farmer	3.1. Self-funding	5	5	7	5	5	5	5	5	10	5	5
	3.2. Technical issue	5	4	7	5	5	5	5	5	5	5	5
4. Conversion to other alternatives		3	8	2	5	10	3	3	3	7	5	1
5. Competition and/or impact on food security or animal husbandry		6	5	3	2	1	0	10	10	10	8	10
6. Support from government to produce biofuel from current variety	6.1. Policy support from government	5	5	5	5	5	0	5	5	5	5	5
	6.2. Infrastructure support	0	5	0	0	0	0	0	0	0	0	5
	6.3. Technology support	0	5	0	0	0	0	0	0	0	0	5
7. Impact on environment and/or humans	7.1. In production	10	10	10	10	10	10	10	10	10	10	10
	7.2. In preliminary treatment	10	5	5	10	10	10	10	10	10	10	10
	7.3. In distribution and consumption	10	10	10	10	10	10	10	10	10	5	10
8. Having added value or by-product		5	5	0	2	1	1	3	3	0	5	2
9. Supply chain for bioenergy industries	9.1. Regularity of feedstock supply	3	5	5	3	0	0	1	1	7	7	2
	9.2. Possibility of enlarging production	3	5	1	4	1	0	3	3	10	8	2
10. Market potential of current feedstock for biofuel	10.1. Good price	2	5	7	5	2	0	0	0	7	7	2
	10.2. Trade potential	2	8	8	0	0	0	0	0	7	7	0
Total		**80**	**104**	**85**	**80**	**71**	**62**	**73**	**73**	**113**	**102**	**84**

Scale: 10 = top rank; 1 = lowest rank; 0 = no chance or is impossible.
Source: Analysis by the research team. 2008.

Sugarcane

The government does not have a policy for developing ethanol from sugarcane or its by-products. Ethanol plants based on sugarcane are run on a trial basis by corporations in partnership with international enterprises. Large projects using sugarcane as feedstock for bioethanol production have received investment from Petrosetco, the General Corporation of Sugar Production, and partners such as Superior Biotechnologies. The bioethanol produced is mainly exported for D8,000–D10,000/l ($0.50–$0.70). The cost of sugarcane-based production is about $0.60/l of ethanol, of which feedstock comprises 50% of the total cost. The equipment cost for a mill with a capacity of 215 million l/year of ethanol is $160,000 (footnote 33).

At present, Viet Nam does not have a reliable supply of sugarcane due to the low productivity and dispersed sources of the crop; however, production could be expanded and productivity improved. It is calculated that if yields of over 100 tons per hectare (t/ha) are achieved (as in Lam Son in Thanh Hoa Province, and Phung Hiep in Hau Giang Province), total production could meet the demand for both biofuel extraction and domestic sugar consumption (Table 20).

The Ministry of Industry and Trade and the Centre for Agricultural Policy projected ethanol production from 2010 to 2050 (Table 7). Table 20 projects the size of the area and the volume of production needed to meet the projects demand for ethanol. The same table also indicated the yield levels required to ensure the production of enough sugar to meet the demand for food as stated in Decision 26/2007/QD-TTg.

As can be seen from the table, the scale of ethanol production projected by Decision 177 will be met until 2020. After 2020, the surplus sugarcane production from the increased yield will meet only a portion of the ethanol demand because the expansion of sugarcane may begin to reduce the land area for food crops, due to its requirements of fertile soil and

Table 20: Sugarcane Production for Bioethanol Demand under Decision 177 and Scenarios of the Centre for Agricultural Policy

Feedstock Base Area and Feedstock Production	2010 (MOIT)	2015 (MOIT)	2020 (CAP)	2025 (MOIT)	2025 (CAP)	2030 (CAP)	2050 (CAP)
Ethanol ('000 tons) by Decision 177 and CAP	5	100	540	600	960	1,854	6,300
Production of cane for ethanol ('000 tons)	92	1,832	9,890	10,989			
Plantation area to meet ethanol demand (ha)	1,409	26,164	37,500	109,890			
Possible yield of sugarcane (tons/ha)	65	70	80	100	100	100	150

CAP = Centre for Agricultural Policy, ha = hectare, MOIT = Ministry of Industry and Trade.

Note: Crossed-out cells indicate there is no available sugarcane for that quantity of ethanol, within the limit of 300,000 ha of sugar plantations stipulated by the Government of Viet Nam to ensure the country's food security goal (MOIT 2007).

Source: Ministry of Industry and Trade. 2007. Decision 26/2007/QD-TTg. Ha Noi, Viet Nam; Centre for Agriculture Policy. 2008. *Projection on Area of Sugarcane Meeting Biofuel Demand of Vietnam.* Ha Noi, Viet Nam; Ministry of Industry and Trade. 2007. *Decision 177/QD-TTgs.* Ha Noi, Viet Nam.

intensive irrigation. Based on Table 7, about 6.5 million tons (mt) of sugarcane is needed for bioethanol production after meeting the sugar demand in 2020, which is 60% of real demand for ethanol by that year (around 9.9 mt of sugarcane in Table 20). Sugarcane is to provide a portion of feedstock for ethanol production in Viet Nam, for suitable areas in the Mekong Delta region and in the northern central coast need to be developed to achieve higher sugarcane yields.

Jatropha

Jatropha has been grown successfully in some countries to produce feedstock for biodiesel production. It is possibly the most favored option for producing biodiesel in Viet Nam. Although it is available in the country, and its benefits to the soil are well known, jatropha has never been used as a feedstock for biofuel production. In 2008, only trial plantations of jatropha existed, with investments from Minh Son (with 150 ha in Lang Son and Son La provinces), and Green Energy Vietnam (with 38 ha of plantations in eight provinces).

The head of a jatropha research program funded by Daimler Chrysler—Professor Klaus Becker—has challenged people to find any disadvantages of jatropha and its use for biofuel.[48] No complaints were raised on the impact of production, distribution, and consumption of jatropha-based biofuel in countries that successfully produce it, such as India, Indonesia, and Thailand. It is claimed that using B100 reduces carbon emissions by 50% and using B20 (20% biodiesel mixed with 80% petroleum diesel) reduces emissions by 20% compared to fossil fuel (footnote 48).

Jatropha can help poorer households rise out of poverty. Just as poor people in India and Indonesia have found new livelihoods planting jatropha on their poor soil, so the poor in Viet Nam can improve their lives if there is sustained market demand for jatropha. Furthermore, farmers who plant jatropha on a large scale may earn carbon credits, which can be traded internationally.

Jatropha can be grown on the 4.2 million ha of bare land and land that is currently idle. These are found predominantly in the north of the country, the central coast and central highlands, and the north central coastal areas. The development of these areas would generate a large supply of seeds for biofuel production while improving the quality of the bare land. However, the parcels of land are widely dispersed in remote areas where infrastructure is not well developed. The land inventory in Viet Nam is not up-to-date and it will take time to assign land for jatropha. In addition, transporting seeds from remote areas will be difficult.

There is clear market potential for jatropha due to increasing demand for an environment-friendly source of energy. The rising production of jatropha biodiesel in India and Indonesia demonstrates the possible biofuel market in the future. Production has so far been oriented toward satisfying local domestic demand rather than export demand, and the international market remains open to all. Viet Nam should likewise plan to meet the domestic need before considering export opportunities.

Trial plantings of jatropha in Viet Nam yielded 5 t/ha of seeds. This is considerably less than India's experience, which shows a possible annual yield of 10 t/ha. The area required for jatropha to meet the biodiesel demand in Viet Nam is therefore projected on the basis of these two alternative yield scenarios (Table 21). If the annual yield can be raised to 10 t/ha, all biodiesel demand will be met up to 2050 within the available bare land of 4.2 million ha. However, if the yield remains at 5 t/ha, jatropha-based diesel will meet only a portion of the demand by 2050.

Fish Fat

Oil extraction from fish fat requires advanced technology and rigorous standards so that the product can be used in internal combustion engines. Biodiesel produced by households can generate harmful emissions and damage engines. Thus, if Viet Nam

[48] *Agroviet.* 2007. Jatropha va trien vong phat trien nang luong sinh hoc. www.agro.gov.vn/news/newsDetail.asp?trang=0&targetID=5860

Table 21: Area of Jatropha Required to Meet Biodiesel Demand Forecast in Viet Nam (tons/ha)

Item	2010 (MOIT)	2015 (MOIT)	2020 (CAP)	2025 (MOIT)	2025 (CAP)	2030 (CAP)	2050 (CAP)
Volume of biodiesel ('000 tons)	3	150	1,091	1,200	1,920	3,708	12,533
Area of jatropha ('000 ha) if yield is 5 tons/ha	1.42	85.71	623.42	685.71	1,097.14	2,118.85	7,161.90
Area of jatropha ('000 ha) if yield is 10 tons/ha	0.71	42.85	311.71	342.85	548.57	1,059.43	3,580.95

CAP = Centre for Agricultural Policy, ha = hectare, MOIT = Ministry of Industry and Trade.

Note: The crossed-out cell indicates that the area of jatropha plantation required for biofuel production exceeds the limit of 4.2 million ha of bare land.

Source: Centre for Agriculture Policy. 2008. Projection on Area of Jatropha Meeting Biofuel Demand of Viet Nam. Ha Noi, Viet Nam.

Table 22: Potential Catfish Production to Meet Biodiesel Demand in Viet Nam ('000 tons)

Item	2010 (MOIT)	2015 (MOIT)	2020 (CAP)	2025 (MOIT)	2025 (CAP)	2030 (CAP)	2050 (CAP)
Volume of biodiesel ('000 tons)	3	150	1,091	1,200	1,920	3,708	12,533
Catfish production ('000 tons)	13	750	5,455				

CAP = Centre for Agricultural Policy, MOIT = Ministry of Industry and Trade.

Note: 1. Crossed-out cells indicate catfish production exceeds the limit of the one million ton target according to Decision 242/2006/QD-TTg.
2. For 2025, the projections of both MOIT and CAP are shown.

Source: Centre for Agricultural Policy and Ministry of Industry and Trade. 2009.

aims to develop catfish fat as a feedstock for biodiesel production, advanced technology would be required.

Comparing biodiesel demand and catfish output based on Decision 242/2006/QD-TTg shows that all biodiesel demand can be met by catfish oil until 2015; however, in 2020 and beyond, catfish oil will be able to supply only a portion of the feedstock required because the catfish catch will be insufficient (Table 22). The Mekong Delta region is well-placed to produce biodiesel from catfish oil as fish processing mills are established there, making the collection of fish fat from processors straightforward.

The amount of fish fat will be insufficient to supply feedstock for a biodiesel industry based on fish oil but production could be increased by converting agricultural land to fish ponds and through offshore exploitation. However, attempts to increase the supply of fish fat for biodiesel production would necessitate huge investment and could affect food security. Other solutions, such as the use of genetically modified varieties or weight-accelerating feed, are not recommended on community health grounds and because of the sensitivity of the export market.

Sweet Sorghum

If sweet sorghum is grown in dry and infertile areas of Viet Nam, the yield could reach about 65 t/ha. Higher yields can be achieved if sorghum is cultivated in fertile soil or under better growing conditions. Table 23 shows the area of sweet sorghum needed to meet future bioethanol demand. The data shows that a single sweet sorghum cultivation can meet all

Table 23: Plantation of Sweet Sorghum to Meet Demand for Biofuel Production

Item	2010 (MOIT)	2015 (MOIT)	2020 (CAP)	2025 (MOIT)	2025 (CAP)	2030 (CAP)	2050 (CAP)
Volume of ethanol ('000 tons)	5	100	540	600	960	1,854	6,267
Plantation area ('000 ha) if yield is 65 tons/ha	2	40	216	240	384	742	2,507
Plantation area ('000 ha) if yield is 80 tons/ha	2	33	180	250	320	618	2,089

CAP = Centre for Agricultural Policy, ha = hectare, MOIT = Ministry of Industry and Trade.

Source: Ministry of Industry and Trade and Centre for Agricultural Policy. 2008. *Projection on Area of Sweet Sorghum Meeting Biofuel Demand of Vietnam.* Ha Noi, Viet Nam.

Table 24: Planting Area of Moringa to Meet the Demand for Biofuel Production

Item	2010 (MOIT)	2015 (MOIT)	2020 (CAP)	2025 (MOIT)	2025 (CAP)	2030 (CAP)	2050 (CAP)
Demand for biodiesel production ('000 tons)	3	150	1,091	1,200	1,920	3,708	12,533
Plantation area ('000 ha) if yield = 3 tons/ ha of seeds	2.4	142.0	1,033.1	1,136.4	1,818.2	3,511.4	11,868.4

Note: The crossed-out cell indicates that the required catfish production exceeds the limit of the 1 million ton target according to Decision 242/2006/QD-TTg.

Source: Centre for Agriculture Policy. 2008. *Projection on Area of Moringa oleifera Meeting Biofuel Demand of Viet Nam.* Ha Noi, Viet Nam.

bioethanol demand within the limit of bare, hilly land in Viet Nam.

Moringa

Table 24 shows projected planting area needed if moringa is used as feedstock for biodiesel generation. Demand figures show that a single moringa cultivation can meet all the demand for feedstock within the limits of bare, hilly land in Viet Nam. By 2050, however, the very high demand for oil would not be met because it would require too much land.

Discussion of Priority Feedstocks

Sugarcane and fish oil should receive immediate attention because they are readily available feedstocks. Jatropha, sweet sorghum, and moringa also show considerable potential to help increase the scale of biofuel production in Viet Nam.

Sugarcane is planted in the vicinity of the limited number of sugar factories in the country. More intensive cultivation and larger areas of land would be needed to generate a sustainable supply of raw material for ethanol production. Sugarcane plantations in Viet Nam are not irrigated, so there is considerable scope for yield improvement. Enlarging the area for sugarcane to provide feedstock for ethanol production could affect the area for food plants; but if the cost-effectiveness of sugarcane is higher, then expanding the area is acceptable at a certain level. Factories which combine the production of sugar and bioethanol will be an effective choice.

The amount of fish oil produced varies from 150,000 t/year to 200,000 t/year. When converted to biodiesel, this amount of feedstock can partially meet the diesel required for domestic transport. The production of fish oil is predicted to increase considerably as significant areas of agricultural land have been converted to aquaculture. Thus, biodiesel extraction capacity and technology should be established to enable the country to begin exploiting this source of feedstock on an industrial scale.

Preliminary studies show jatropha to be suited to the environment and climate in Viet Nam, and trial plantings are in progress. The area of forestland increased by 22% (14.5 million ha) between 2001 and 2006. Not all forestlands are effective for forest production; therefore, some will be assigned to other alternative uses, including the cultivation of biofuel feedstocks. There are still 4.2 million ha of bare or hilly land that can be recovered for the cultivation of plants that do not require fertile soils. In addition, there are 5.5 million ha in 34 inefficient state-owned farms. Reorganizing these farms and introducing new plant varieties could provide opportunities for further expanding jatropha cultivation. Although other countries also plant jatropha, they cannot satisfy domestic demand so there will be no competition on the international market. Viet Nam can learn from their experience and can benefit from technology exchange with other countries, thereby enabling the country to begin earlier large-scale biofuel production.

In evaluating feedstock alternatives for the biofuel strategy, their potential negative environmental, social, and economic impacts need to be carefully assessed. Biofuel cultivation consumes natural resources large-scale plantings can create monocultures, and perceived economic benefits of biofuel crop cultivation can drive the conversion of land for grain to biofuel plantations. These outcomes directly affect food security,[49] and as Thailand's experience shows, biodiesel production can have a pronounced impact on edible oil prices.

Strictly on an energy-equivalence basis, ethanol is competitive, without subsidies, at $60 per barrel in the United States, $35 per barrel in Brazil, and $115 in the European Union (the European Union estimates that biodiesel is competitive without subsidies at $65 per barrel) (footnote 35). However, the biofuel industry still depends on government support, and while that continues, related industries will be affected to some degree. If domino-style impacts occur and the ethanol industry contracts by 30%, the lower demand for feedstock to refine into ethanol could create significant changes in commodity prices, livestock feed, land values, and consumer food prices.[50]

[49] Osava, M. 2007. Energy: *Brazil Aims to Dominate World Ethanol Market.* InterPress Service. http://ipsnews.net/news.asp?idnews=37172

[50] *The Farm Gate*. 2007. Is the Bio-Fuel Industry Ready to Cut the Government Apron Strings? www.farmgate.uiuc.edu/archive/2007/06/is_the_biofuels.html

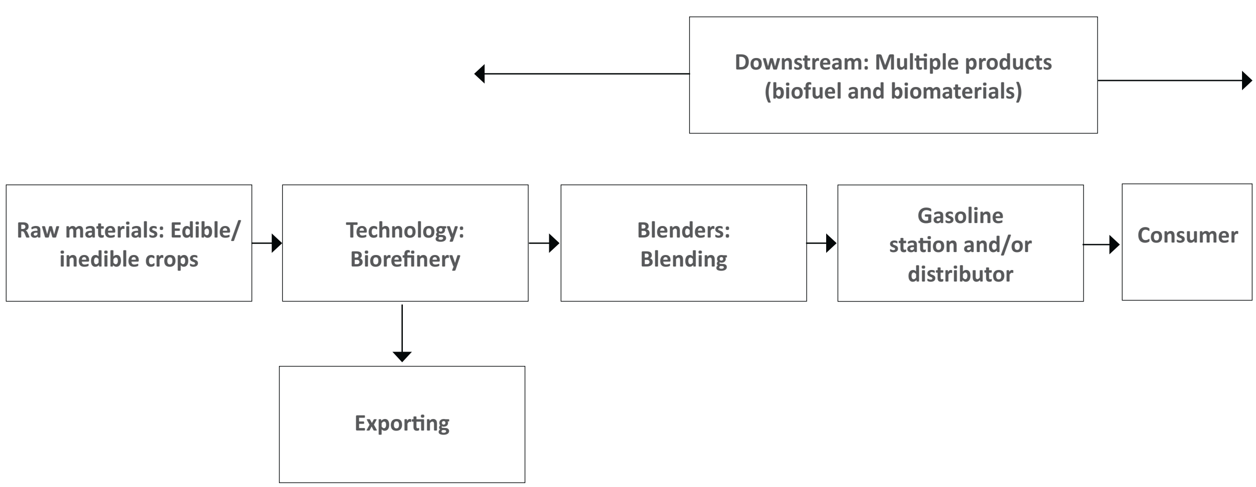
Biofuel Business Options

The value chain of biofuel products involves three main steps: (i) cultivation of edible or inedible crops such as sugarcane, corn, jatropha, oil palm, soybean, and rapeseed; (ii) processing of the raw materials by refineries, where equipment is installed for seed crushing, oil extraction, and processing of plants that yield oil, or squeezing liquid sugar and allowing fermentation in the case of crops that yield starch for ethanol production; and (iii) blending and distribution, where biofuel is mixed with conventional fuel, distributed and sold to domestic consumers or exported to other countries (Figure 12).

This section proposes biofuel business options, especially those involving the relationship between growers, who supply the raw materials for the processing enterprise, and the biofuel refiner. Other support services, such as credit, agricultural extension, and physical infrastructure, are discussed with a view to involving them effectively in the supply chain.

Sugarcane, jatropha, and fish fat are the three biofuel feedstocks currently being developed in Viet Nam, and two new feedstock crops—sweet sorghum and moringa—have the potential to expand biofuel production in the country. Sugarcane is expected to be the predominant source for bioethanol, whereas jatropha is expected to be the main source of biodiesel; thus, this section focuses on identifying agribusiness models for these two crops and briefly gives examples of business models for fish oil, sweet sorghum, and moringa. The models are based on successful experiences with these crops in other countries. Lessons from business models for other domestic products are also considered as these experiences may help launch the initial stage of biofuel development in Viet Nam. Finally, this section presents a comprehensive model for the biofuel industry in Viet Nam, covering production, processing, and trade.

Figure 12: The Biofuel Value Chain



Source: Adapted from Chris de Lavigne.

Successful Experiences from Leading Biofuel-Producing Countries

India's Experience in Developing Biofuel from Oil-Bearing Crops

In 2006, the Government of India introduced a biodiesel policy to encourage both investors and farmers to plant oil-bearing trees on 1.5 million acres by 2010. The government also created a risk fund to support small and marginal farmers with up to 5 acres of land who are willing to grow jatropha. The government is determined to promote contract farming and will buy all jatropha seeds produced by the growers. A minimum buyback price is fixed, depending on the quality and quantity of the produce, to encourage farmers to begin planting (footnote 35). Contract farming benefits both the growers and the processers as it guarantees a reasonable price for the farmers' output and maintains the supply of feedstock for the firms that process the seeds.

The government also mobilizes the participation of the private sector in biofuel trading through contracts with an intermediary company. For example, Southern Online Bio Technologies procures raw materials such as pinnata and jatropha seed, then sells the feedstock to government bodies that produce biofuel. The involvement of intermediaries in the supply chain has the dual advantage of reducing the number of transactions the refinery has to make and reducing travel time for the many growers who may be scattered over a large area.

Brazil's Experience in Developing Bioethanol

Brazil has become the world's largest producer of ethanol since it launched its ethanol production program in the mid-1970s. During periods when the oil price was low, ethanol production was criticized as being uneconomic; however, Brazil's ethanol industry today is seen as an efficient sector that brings substantial benefits to the Brazilian economy.[51] The business organization of the industry has been a key to its success: sugarcane is produced and processed exclusively by private companies, and sugarcane producers own the farms and mills and can, therefore, maximize profits from both and are able to diversify into other by-products from the sugar industry such as ethanol production, cogeneration of electricity, and sale of by-products for the gardening industry. International sugar prices have been highly volatile and have experienced a downward trend. Private companies can respond to these price signals by, for example, shifting from sugar to ethanol production if the world sugar price is low (footnote 51).

In addition to flexible private sector ownership, productivity improvements in the sugar industry have benefited ethanol production. During 1975–2000, sugarcane yields in the São Paulo region increased by 33%, ethanol content produced per unit of sucrose rose by 14%, and the efficiency of the fermentation process increased by 130%. Hence, the cost of producing ethanol declined by an annual average of 3.8% in 1980–1985 and 5.7% in 1985–2005 (footnote 51). Electricity production using the energy content of sugarcane residues leads to further cost savings. The cogeneration of heat and electricity from bagasse supplies most of the energy needs of the biofuel production process.

Building the parallel fuel distribution system is not an attractive investment from the point of view of service station owners due to very small number of users. Thus, the Government of Brazil provided incentives and installed a clear institutional framework to support the service. The government set technical standards, supported the technologies involved in ethanol production and use, provided financial advantages, and ensured appropriate market conditions.

Successful Business Organizations Involving Domestic Agricultural Commodities

Buy-Back of Tea Leaves from Handed-Over Tea Fields

The Cau Dat Tea Company is state owned and receives much support from the Government of Viet Nam.

[51] Moreira, J.R. 2006. Bioenergy and Agriculture: Promise and Challenges. Brazil's Experience with Bioenergy. International Food Policy Research Institute. *Focus.* 14. Brief 8 of 12. December. www.ifpri.org/2020/focus/focus14/focus14_08.pdf

Under the terms of a memorandum of understanding, the enterprise supplies land, tea plants, and all other inputs such as fertilizers and pesticides while farmers provide labor for planting, caring for the tea plants, and picking tea leaves. Under this model (Box 2), the farmers' benefits are proportional to the labor they expend. Since the initial investments of the enterprise and farmer differ, 70% of the returns go to the company and 30% go to the farmer (for a parcel of land with a standard yield of 4–5 t/ha). If the actual yield exceeds the standard level, the farmer enjoys the entire surplus. If the yield is below the standard level, the farmer has to pay 35% of the total deficit value and receives 30% of the output of tea leaves harvested while the company receives 70% of the total output.[52]

Box 2: How a Contract between Farmer A and Enterprise X Works

The enterprise supplies land, tea plants, fertilizers and pesticides while Farmer A supplies labor to care for a 2-hectare (ha) tea field and to pick tea leaves.

Under the farming contract, the floor price of buying back tea leaves is D500/kilogram, standard yield is 10 tons/ha of green leaves per crop. The standard output of Farmer A on 2 ha of tea plants is 20 tons of tea leaves per crop. Enterprise X receives 70 times 20 divided by 100 equals 14 tons of tea leaves per crop while Farmer A receives 30 times 20 divided by 100 equals 6 tons of tea leaves. Enterprise X then pays 6 times 1,000 times 500 equals D3 million to the farmer after harvest.

Scenario 1: At the end of a crop season, Farmer A harvests 22 tons of leaves per crop. If the standard surplus of 22 tons minus 20 tons equals 2 tons, Enterprise X has to pay Farmer A the following: 6 times 1,000 times 500 plus 2 times 1,000 times 500 equals D4 million.

Scenario 2: At the end of a crop season, Farmer A harvests 18 tons of tea leaves per crop. This is less than the standard output. So the standard deficit is: 20 tons minus 18 tons equals 2 tons. Farmer A receives 30% of total output from Enterprise X: 30 divided by 100 times 18 times 1,000 times 500 equals D2.7 million. Farmer A has to pay to Enterprise X the deficit value of 2 tons of tea leaves: 35 divided by 100 times 2 times 1,000 times 500 equals D0.35 million. In summary, Enterprise A only pays back to Farmer A the amount of D2 million per crop (D3 million minus D1 million equals D2 million)

Source: Centre for Agricultural Policy. 2006.

This farming contract has given a strong incentive to farmers working on their allocated land. The company is taking higher risks than the households, so the state-owned company will suffer all losses in the event of a natural disaster while households lose only labor days. This model has been in use since 1976 and has worked well. However, the binding articles do not bring much profit to the state and it is more beneficial to growers than to the company. This agribusiness model may be very effective for initiating production of a new biofuel crop.

Farming Contract for Nam Roi Pomelo

Upon its establishment in 2002, the Hoang Gia Private Enterprise immediately signed a contract with households growing pomelo in Binh Minh District, Vinh Long Province. The contract stipulates that the enterprise will buy the entire pomelo yield of all quality grades at a guaranteed price higher than the market price of about D300–D500/kg, paying an additional D1,000/kg for pomelos of the highest quality. There are certain conditions for pomelo cultivation, such as compulsory application of a type of fertilizer and pesticides, and wrapping each pomelo in the bag provided.

This contract between Hoang Gia and the farmers works well. The enterprise invests in the core stages of production by providing technical assistance, and supports a financial mechanism that provides planting materials and other physical inputs—rather than money—to support the households. The payment of a higher price is an incentive that brings the farmers to the company instead of the company having to go to the farmers. This model is practical only if the company is close to the production area, orchards are not too scattered, and the road network allows convenient travel from the company to the orchards. The company's brand name is famous in Viet Nam and its products are welcomed by consumers and stocked by almost all supermarkets in the country.

[52] Centre for Agricultural Policy. 2006. *Contract Farming: 30 Cases*. Ha Noi, Viet Nam.

Cooperative for Agricultural Services

Thanh Loi commune in Dong Thap Province is reached by water transport as it is far from the main road. The Loi Thuan Cooperative was formed to provide materials, fertilizers, and pesticides for paddy growers. In 2001, the cooperative signed a contract with the Tien Giang Food Company to procure rice for the company from local farmers. The cooperative made a verbal contract with local paddy growers to buy back their rice output. The cooperative extended materials, fertilizers, and pesticides to the farmers, which they repaid at harvest time (including both loan and interest). The cooperative received D30,000 per kg of rice sold to cover its operating costs. The cooperative bought only rice that met the standards set by Tien Giang Company, before selling it to the company.

However, farmers preferred to sell their rice to other intermediaries rather than to the cooperative as they were not strict about grain quality. Hence, the contract ran for only a short time, as farmers' grains could not meet the quality requirement (footnote 52). The contract failed because the farmers and the cooperative differed on quality standards. The cooperative acted as the representative of the ordering client as well as of the farmer selling the grains. The arrangement could have been successful if they had accepted their tripartite position from the start. Meanwhile, the contract between the Tien Giang Food Company and the farmers has been breached, but the contract between the cooperative and the farmers for the provision of agricultural materials still stands. In this example, the cooperative functions as an effective intermediary when the production area is remote and hard to access, and the buyer is located far from raw feedstocks.

Farming Contract of Lam Son Sugar Mills

Agribusiness for sugarcane has been in existence for a long time in Viet Nam as the sugar industry is one of the country's main economic activities. Lam Son Sugar Company (Lasuco) in Thanh Hoa Province provides a successful model. A farming contract is key to developing a stable and long-term production area, and to link the company's benefits to those of the farmers. Contracts are now signed between the mill and local farmers before the crop season to ensure stable markets. Lasuco provides households with seedlings, fertilizer, food, and cash advances. Farmers sell sugarcane to the mill at a price determined by negotiation. The company also sends technical staff to the commune to introduce intensive farming techniques, and annual training in cultivation methods is organized in each commune. This model is sustainable and has lasted for more than 20 years.[53]

Lasuco manages its farmers in an interesting and efficient way. Farmers living in contiguous areas are grouped into small sugarcane associations where they can exchange information and help each other. Each commune also has a sugar committee to oversee the sugarcane associations and monitor the sugarcane situation. Lasuco established 8 research stations based in 11 districts to support farmers with technical issues and monitor each household's investment. All stations provide agricultural extension, conduct inventory and planning of the feedstock area, protect the feedstock area, ensure the safety of the farmers' investment, and instruct the farmers in finance management. Young engineers working in the stations live in close proximity to the farmers to better understand their needs and wishes.[54] They have a very good relationship with local people and this helps Lasuco maintain a stable feedstock base.

Agribusiness Models for Integrating Feedstock and Biofuel Production in Viet Nam

The agribusiness models outlined in this section offer much potential both for the start-up stage and beyond. Business is expected to scale up or have a broader impact later. Farmers will not invest if they do not have a minimum guaranteed market, and the industry will not invest if it does not see a reliable feedstock supply. Therefore, a policy is required to address the needs of the prospective business at the early stage along with financial support during start-up.

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[53] ADB. 2005. *Making Markets Work Better for the Poor: Linking Farmers to Market through Contract Farming.* Ha Noi, Viet Nam.

[54] Information from a 2008 field visit to Thanh Hoa Province.

Box 3: A Description of Decision 80

…"The enactment of Decision 80 in 2002 by the Government of Viet Nam has attempted to increase the use of contracts to improve procurement and efficiency in the rural economy. The Government has attempted to provide incentives for parties to engage in contract arrangements by providing favorable access to finance, land, and infrastructure. However, contracts under Decision 80 have largely been unsuccessful to date.

Anecdotal evidence from the value chain studies conducted under the M4P Project for tea and cassava suggests that three main issues have compromised such contracts. First, farmers have been accused of reneging on contracts when higher prices are offered from traders. This has particularly been the case with cassava, where large factories have had difficulties procuring consistent volumes of cassava from producers, who tend to prefer sales to traders with more transparent buying arrangements. Second, when buyers are faced with oversupplies of products from contracted producers, quality standards are sometimes tightened so processors can reject unwanted output. Third, knowledge of contractual obligations by parties in the contract is often lacking."

M4P = markets for poor.
Source: Asian Development Bank, 2005.

This section assumes that the policy already exists and that the business relationship proposed is feasible and will be viable in the long term for providing feedstock to the processing plants.

Decision 80 QD-CP (Box 3) issued by the Government of Viet Nam theoretically supports and collaborates with farmers, scientists, and businessmen. However, only farmers and businessmen are legally bound; the others give only encouragement. Therefore, there is no practical and sustainable linkage among the four groups. Cooperation between traders and farmers is not always successful in the buyback of agricultural products. A consensus agreement between both parties (farmers and traders) is needed—one that reflects the win–win relationship in the examples of pomelo and tea. The involvement of researchers is encouraging the application of advanced science, while the government creates the legal environment to facilitate the establishment of legal contracts between the parties.

Business Option for Sugarcane Feedstock in the Biofuel Supply Chain

In Viet Nam, sugarcane is planted on flat land, rather than in sloping or mountainous areas, and traditionally small plots of land are cultivated. It is thus unlikely that a large enough contiguous area will be available for sugarcane production in the near future. The experience of Brazil suggests that the bioethanol industry must be attached to the existing sugar industry. It is difficult to invest in new sugar mills in Viet Nam due to lack of raw materials, the poor level of competitiveness, and the inefficiency of existing sugar mills. However, the best course of action, given the extensive experience of ethanol and sugar production in the country, is to salvage and upgrade the existing ethanol factories using sugarcane and molasses to develop bioethanol. Most ethanol mills are in the south. They account for 60% of the country's capacity, or 76 mt/year of ethanol. If farmers begin to cultivate high-yielding varieties, improve the irrigation systems on sugarcane farms, upgrade the technology used in the sugar mills, and expand current capacity, sugarcane-based ethanol would be a promising industry. Private enterprises could help increase productivity by introducing drip irrigation in sugarcane fields—a technology not currently found in Viet Nam.

The buyback model and sugar-producing model, in conjunction with the Lasuco model for the manufacture of ethanol are proposed for the expansion of sugarcane-based ethanol production in Viet Nam. In this Lasuco-type model, the enterprise provides households with seedlings, fertilizer, food, and cash advances. Farmers sell their sugarcane output to the mill at a price determined by negotiation. The company also sends technical staff to the commune to introduce intensive farming techniques. Training in cultivation techniques is organized every year in each commune. However, to ensure sufficient feedstock for the ethanol plants, it is necessary to state clearly the volume of sugarcane that individual households will sell to the mill. Also, the purchase must be at market price, with a minimum warranty floor price.

The contract must be comprehensive and must state the suggested minimum guarantee price and minimum volume of purchase. Depending on the location and conditions of the households, the processing mill may provide transport to collect the materials. The advance cost supplied by the company will be deducted during purchase at zero interest. In case of breach of contract, the law must take compensation or responsibility seriously. Moreover, organizing farmers into groups reduces transaction costs and makes it easier to manage the feedstock.

In the Brazilian experience, salvaging of by-products during ethanol production maximizes economic efficiency. However, this could be attempted later when the production of ethanol is stable. In the Lasuco model, the small-scale (less than 1 ha) cultivation of sugarcane seems to be ineffective; therefore, for economy and efficiency in growing sugarcane as feedstock for biofuel and sugar production, a landholding must be at least 1 ha in size.

Business Options for Jatropha Feedstock in the Biofuel Supply Chain

Experiences in the People's Republic of China (PRC) and India show that jatropha offers a win–win situation for businesses and the rural poor. The worldwide rise of microfinance schemes is proof that the private sector is capable of financing pro-poor investments. The same can be true for jatropha in Viet Nam. Options that may be explored are combining jatropha production by the local communities with advance purchasing guarantees, or the pooling of several small jatropha enterprises to achieve the necessary scale.

In mid-2006, Jatropha Lang Son carried out trial plantings in Son La Province in northern Viet Nam. A farming contract was established between the company and 100 households on more than 120 ha. The company provided seedlings, capital, and training in cultivation techniques; and households provided labor to care for the crop and harvest the seeds. The company will expand the business by coordinating with more households to develop 200,000 ha and constructing an on-site refinery. This section proposes two business options for the existing and new areas of jatropha cultivation.

Business option for expanding the existing market. In north of the country, the market for jatropha already exists. The next step is to scale up the business from the existing model. This study proposes further coordination and microfinance. Capital investment for jatropha is low during start-up, but it takes at least 2 years before the first harvest. Therefore, to facilitate the development of jatropha, the company or government should provide support to households during the period up to the first harvest, in addition to providing capital, seedlings, and training in cultivation techniques. The microfinance program would help the poor families meet their living expenses. The annual return on the harvest is high—around D30 million/ha according to estimates from 2005 and 2007. The family may repay the loan once the plantation reaches maturity. Therefore, the first contract is agreed upon by the farmers and the company during start-up, and once the jatropha plantation begins to bear fruit, a second agreement is entered into between the two parties.

The purchase price must be the market price, but is set up at the minimum warranty floor price to ensure a stable income for households and to assure the required feedstock volume for the company in advance. For example, when signing the contract, the floor price is set at D2,000/kg of jatropha seeds; but if at harvest time the market price is D2,200/kg, then company has to pay D2,200/kg to the farmer. If the market price is D1,900/kg, the enterprise must still pay the farmer D2,000/kg. The second round of contracts must be signed before the crop season, and all articles must clearly state the duty of each party. The company provides technical assistance and fertilizers to growers at the beginning of the crop year, and farmers are required to sell all their output to the mill. The contract must cover the price, timing, location, and volume of feedstock delivery. The advance payment is deducted when the raw material is purchased. In the event of a breach of contract or occurrence of risks, provisions relating to the party who breaks the agreement must be applied.

If needed, the company may sign a contract with extension workers in the farming areas to provide the farmers with technical assistance. The extension workers will supervise and monitor the farmers' fields during cultivation and caring for the plants, advise them on any technical issue emerging, and report back to the mill if unusual problems affect the agreed-upon volume of feedstock.

Business options for opening new planting areas for jatropha. New tracts of infertile land may be developed for jatropha in the northern provinces and the coastal arid zone. Because parcels of land are widely dispersed, cooperatives or farmer groups must be established locally to assemble the materials for the biofuel processing enterprise. This enterprise is responsible for supporting the formation of cooperatives or farmers' groups. The groups are representatives of the enterprise in these localities and are responsible for supplying feedstock to the enterprise. Formation of such a middle cooperative or interest group will reduce the enterprise's management and transaction costs. This model is based on the experience of the Thanh Loi cooperatives.

Since jatropha is a new plant in the target areas, farmers will be reluctant to take the risk of growing it. Areas targeted for introduction of jatropha are state-owned lands of very low fertility and arid coastal land. The tree will not compete with current agricultural land; therefore, it is likely that the government will give the biofuel processing enterprise permission to use the target land to develop large plantations of jatropha.

The enterprise will provide new land areas and other inputs, such as seedlings, fertilizers, irrigation, and advance payment through a representative cooperative, while households will provide labor to cultivate and care for the saplings. The setting period is expected to be 2 years, and the company may provide microfinance for households during that period. The loan from the microfinance program will be interest-free and farmers will repay the loan at harvest time. The start-up period will proceed according to the agreement between individual households and the enterprise.

When the jatropha plantation begins to bear fruit, a second agreement is negotiated by the two parties. Now, the cooperative, as a representative of the firm, provides only pesticide, fertilizer, water, and technical assistance at the beginning of the season while the partners contribute labor. The standard yield and minimum guaranteed price must be set before the season. Sharing of the output between the company and households will be split 70:30 based on the standard yield (5 t/ha). The division is fair, as the firm has a higher investment than the farmers. The price at purchase time should be market-determined, but should exceed the minimum guaranteed price. If the yield is higher than the standard, the surplus output will belong to the household. But if households obtain a yield below the standard, they have to pay for about 35% of the total deficit.

During first 2 years of jatropha cultivation, the firm provides finance for the cooperative to set up a new jatropha plantation and pay the salary of members of the cooperative as normal staff of the firm. However, when jatropha is ready for oil extraction, the firm will provide inputs for the cooperative and pay it a bonus based on the volume of seeds collected. A salary payment is no longer given. The bonus will be D300 per kg of oil seed that the cooperative purchases. The price of materials at the cooperative office will follow the market signal and must be transparent in the local area so that there is no pressure on the farmers who have only one buyer for their product in the local area.

The cooperative signs contracts with local extension workers to provide technical support for farmers. Extension staff should visit the jatropha fields often to supervise and monitor production and report back to the cooperative any emerging issues that may impact on the final output.

Business Option for Feedstock of Fish-Based Biodiesel

Domestic technology for producing biodiesel from fish fat is already established in the Mekong Delta region, but the market is primitive and production is on a small scale. Viet Nam's current fish fat output is only around 150,000–200,000 t/year. Rather than establish new factories, it is recommended that existing mills be expanded. The ease of travel in the Mekong Delta area and southern coastal zone means that transport is not a hindrance to the development of fish-based biodiesel.

The main input is the by-product of fish processing. Fish fat is collected from the fish processing factory or workshop. Producers of biodiesel may directly coordinate and purchase fish fat from fish processors through a contractual agreement. The biodiesel producer can estimate the fat output from the business plan of the fish-processing factory and can then sign a contract with the fish processor to purchase all of the fat produced.

The advantage of this business model is that biodiesel companies can work with legal bodies rather than with individual farmers, hence the number of the partners is greatly reduced. They are more professional, more knowledgeable on legal matters, and require fewer transactions. In addition, biodiesel companies do not have to invest much to obtain their raw material. The production of fish fat-based diesel therefore entails fewer costs and involves less risk than other oil sources.

This study also proposes another model for developing biodiesel from catfish fat. A new line of production in processing catfish is to salvage the fish fat after making fish fillet. In this model, the catfish-processing enterprise uses the fat residue from its fillet processing, and processes these residues into biodiesel. This option is effective only if the processing mill is operating on a large scale and is economically efficient so that the quantity of fat residue is large enough to produce biodiesel from this source.

Business Options for Feedstock of Sweet Sorghum-Based Bioethanol

Model 1: State-owned farm. The state-owned farm is part of the value chain supplying feedstock. Since Viet Nam has a considerable number of such farms working inefficiently, the conversion of agriculture and forestry state-owned farms into feedstock areas for planting sweet sorghum for ethanol production will optimize their use. State-owned farms may be leased to a private enterprise for 20–30 years. Employment for the staff of state-owned farms can be created by growing biofuel crops according to certain contracts (either wage-based or output-based). The enterprise supplies all inputs and technical assistance, invests in processing equipment, procures biofuel feedstock, and produces biofuel. The transport of biofuel by tanker to blending factories in central areas will facilitate its distribution to gasoline stations. Investment in infrastructure is needed to make these farms more accessible. Government support will be needed for infrastructure development, including a transmission pipeline when biofuel production has been successfully scaled up. Banks would referee contracts between state-owned farms and private enterprises, covering land leasing and selling sweet sorghum feedstock.

Model 2: State-owned farm becomes bioethanol processor. A state-owned farm can become a biofuel processor with the aid of government subsidies or by mobilizing funds to form joint-stock companies. The farm's staff can become investors who share the stocks of the company and earn dividends. Part of the land would belong to the government and part to private investors. Farmers would enter into a contract with the state-owned farm—now a company—to lease land and grow sweet sorghum. The output would be shared between farm and farmer on a ratio of 70:30, as has been done successfully in the case of Lasuco. At the beginning of the season, a floor price would be set for a certain quantity and quality. The distribution of the bioethanol produced would require government investment in infrastructure. Blending and distribution to stations are done by different entities.

Model 3: A concentrated feedstock area is set up. The establishment of a concentrated sweet sorghum feedstock area starts when contracts are signed between the enterprise or factory and the farmers in a potential area. The rules of the contract are strictly based on law, and a government bank acts as the referee. The enterprise provides inputs in the form of a deferred loan and technical assistance through a third party. Procurement is based on the market price and specified quality criteria. The enterprise sets up collection points if the cultivation area is large. It produces bioethanol, and then transports it to blending factories. This model needs support from provincial authorities in planning and projection, and a guarantee for contract implementation.

Business Option for Feedstock of Moringa-Based Biodiesel

Local authorities evaluate and make plans to use a specified area of idle land for biodiesel feedstock development. The government calls for bids to use the land for 20–30 years to grow moringa for biofuel. The successful bidder will fund and manage the business on the allocated land. The company signs a contract with local farmers to lease the land and share the output at a negotiated ratio, and sets the floor price for a certain quantity and quality of harvest at the beginning of the season. Banks again act as referees. The company can act as the collector to supply the biofuel crop output to a private biodiesel-processing enterprise. It also provides the farmer with inputs, such as fertilizers and cash advances. A third party, which may be the agricultural extension staff in the area, provides technical assistance paid for by the company.

Cross-Border Trading of Feedstocks for Biofuel Production

For a decade, Viet Nam has lagged behind neighboring countries—the PRC, India, Indonesia, and Thailand—in the green fuel industry. It is therefore unlikely to be able to compete with these countries in a future biofuel export arena. However, collaboration with neighboring countries is one way to initiate the domestic biofuel industry. For example, Viet Nam can participate in the global chain of biofuel production by growing feedstocks, such as jatropha, and exporting them to other countries, such as India or Indonesia, where they can be processed into biodiesel. The model of cross-border trading in agriculture has been used in the rubber industry, where Vietnamese companies planted rubber in Cambodia and the Lao People's Democratic Republic and later imported rubber milk for the domestic rubber processing industry.

If Viet Nam acts as a feedstock grower and becomes part of the global biofuel supply chain, a network of intermediaries will need to be established to bring the feedstock from the farmers to the country's border. In this case, the relationship between Vietnamese farmers and the international buyers is only sustainable if the farmers look for a market for their products while international traders look for a secure source of feedstock.

The applicable business option is similar to the model proposed for opening new planting areas for jatropha. However, the output for domestic jatropha will depend on the international market and may be variable due to the volatility of that market. Therefore, this solution is best only if an international company invests in growing jatropha and guarantees the output. The third domestic party will be a representative of the international investor, and the relationship between the representative and the jatropha growers can replicate the business model proposed for the opening of new planting areas.

Business Option for Biofuel Products in the Domestic Market

Development of biofuels for the domestic market should take priority over the development of a biofuel export market.[55] In Viet Nam, the government has introduced the Strategy for Biofuel Development to 2015 and Vision 2025, demonstrating its intention to explore and develop green energy. Under this strategy, the government aims to produce 100,000 t of E5 and 50,000 t of B5 in 2010 to meet 0.4% of the country's demand for petrol and diesel. To achieve this target by 2010, financial investment will be needed from government and private sources.

To secure a domestic market for E5 and B5, the government must establish blending facilities and should set minimum volume sales for E5 and B5 at gasoline stations in pilot cities. The blending facility and the pioneer gasoline stations should be located in big cities, such as Ho Chi Minh, Ha Noi, Da Nang, and Hai Phong. By 2010, Ho Chi Minh and Ha Noi will be the first to install E5 and B5 pumps at selected gasoline stations, and Da Nang and Hai Phong will follow. Existing distributors with large petrol and diesel depots, such as Petrosetco, could be responsible for blending biofuel with motor gasoline or motor diesel to make E5 and B5 and distributing them to gasoline stations by tanker. Each gasoline station will be equipped with two pumps reserved only for E5 and B5.

By 2010, the blending system will have been installed, but it may not be operating at full capacity. The initial cost is high and the private sector is unlikely to invest money in a blending system. Therefore, it is suggested that the government must provide financial support for private enterprises to set up the blending equipment. The capital investment can be shared 50:50 with government. In addition, there will be no tax on sales of E5 and B5 at gasoline stations. As a further incentive to encourage gasoline stations to sell E5 and B5, a law would mandate a tax deduction based on their biofuel sales volume. For instance, the tax for motor gasoline and diesel will be less than the standard tax or eventually zero for the same volume of sale of E5 and B5.

[55] Baur, H., et al. 2007. *Biofuel from Jatropha curcas: Opportunities, Challenges and Development Perspectives.* World Agroforestry Centre.

Policy, Regulatory, and Institutional Support

Overview of Current Biofuel Policies in Other Countries

Biofuel producing countries such as Brazil, Canada, the People's Republic of China (PRC), India, Thailand, and the United States (US), have introduced obligatory quantitative targets for the production of E5 and B5. Sweden has raised the mandatory level for ethanol to E85, and Germany has raised the mandatory level for biodiesel to B100. Government subsidies in the form of direct financial support or indirect tax incentives have been instrumental in establishing the industry. Australia, Germany, the Philippines, Sweden, and the US are some of the countries with legal provisions to promote E10 to B100 for suitable vehicles, along with actions for reducing federal industrial tax and local tax on ethanol-using vehicles. In the PRC, the European Union (EU), France, and Spain financial support has been provided for the cultivation of energy crops.

More specifically, the Government of Brazil provided three important initial drivers for the ethanol industry: guaranteed purchases by the state-owned oil company, low-interest loans for agroindustrial ethanol firms, and fixed prices of gasoline and ethanol where ethanol sold for 59% of the government-set gasoline price at the pumping stations.[56] These actions enabled ethanol production to be competitive without a government subsidy, and its price has been lower than that of gasoline. In brief, the Government of Brazil has specific incentives to promote biofuel: a guaranteed ethanol price which is lower than the price of gasoline, guaranteed remuneration to the producer, loans for ethanol producers to increase their capacity, tax reductions for ethanol-powered cars, mandatory ethanol sales in gasoline stations, and the maintenance of strategic ethanol stocks (footnote 56).

The Government of Indonesia has enacted legislation to facilitate the establishment of large-scale jatropha plantations financed by international organizations. The country also installed a national team for biofuel development with the task of making an implementation plan. A new law allows foreign investors to acquire land for an initial period of 60 years, and the government offers tax incentives and provides the option of creating special biofuel production zones. Current legislation in Indonesia especially favors large international companies that can provide the substantial capital required.

Although the conditions facilitate biofuel manufacture in all countries, the risk to economic efficiency that the development of ethanol entails should also be recognized. In the late 1980s, the ethanol program in Brazil began to experience problems. Due to the high rate of inflation and large fiscal deficit, economic reforms were introduced, including a cutback on ethanol production subsidies. Meanwhile, the world sugar price rose markedly, so farmers diverted their sugarcane production to the export market. Consequently, the volume of feedstock for ethanol production fell dramatically, adversely affecting ethanol producers. The government responded with a change in policy: public transport was manufactured to run on ethanol alone and the government gradually restored the incentive support to develop the bioethanol subsector after economic reform (footnote 56).

These and other lessons accumulated by the established biofuel-producing countries will be invaluable as Viet Nam takes steps to embark on biofuel production.

[56] Xavier, M.R., 2007. The Brazilian Sugarcane Ethanol Experience. Advancing Liberty: From the Economy to Ecology. *Competitive Enterprise Institute*. //cei.org/pdf/5774.pdf

Assessment of Current Biofuel Policy Initiatives in Viet Nam

Since the 1990s, research has been undertaken in Viet Nam on the production and use of bioenergy resources. However, the results have not moved beyond the laboratory and have yet to be applied. One of the main reasons is the lack of a government policy framework, such as policies for investment, price, tax, and a national standard on the quality of biofuel. The lack of such a policy is also the main barrier to private investment.

On 20 November 2007, the Government of Viet Nam issued Decision No. 177/2007/QD-TTg—the Strategy for Biofuel Development to 2015 and Vision 2025. This policy provides a plan for biofuel development by creating a legal corridor and a favorable environment to begin to expand the domestic biofuel industry.

Decision No.177 states that biofuel will replace a portion of conventional fuel. The strategy is prioritized into a detailed timeframe of short-, medium-, and long-term objectives (Table 25). In addition, four main missions outlined along with these objectives provide guidelines for enforcing the main objectives. The objectives include scientific research and technology development, implementation of successful demonstration programs, development of biofuel production as an industry, building a potential support mechanism, and international cooperation for the growth of the biofuel subsector. Each main task has an accompanying list of detailed tasks. Decision No. 177 also presents a number of solutions to help implement the targets. The roles of authorities, government bodies, provincial governments, private companies, and individuals are also specified.

The goal of this plan is to develop biofuels to meet the potential domestic demand, rather than international demand. It is estimated that Viet Nam will not export any biofuel before 2020. The production of biofuel can be targeted if the development of bioenergy in Viet Nam strictly follows its projected route and leaders remain committed. Energy consumption per capita is quite low compared with Malaysia and Thailand, but, with the current rate of economic development, it will be much higher in the coming years. Viet Nam can reduce its reliance on imported petroleum products and partly ensure energy security only by developing its own biofuel industry.

Advantage of Decision No. 177/2007/QD-TTg

There are seven target objectives in the short run. These focus mainly on shaping and perfecting the policy mechanism, which aims to draw investment, encourage production on an industrial scale, and raise public awareness on the use of biofuel. These objectives can be achieved if the government is highly determined.

Decision No. 177 opens a flexible and favorable environment for private companies and international organizations to invest in this profitable industry. During 2007–2015, investment incentives in biofuel production are provided. For example, the tax income of an enterprise investing in biofuel production will be zero for biofuel products in accordance with Decree 24/2007/ND-CP, dated 24 February 2007. In addition, enterprises producing biofuel will receive optimal concessions of 20 years' duration for renting and using land. The tax incentive is also applied to the import of materials, equipment, and machinery for biofuel production.

The strategy sets aside funds for facilitating biofuel development in Viet Nam, with D259.2 billion in 2007–2015 mainly to support basic scientific research, applied research, scientific research and technology development, innovation, technology transfer, and training. Meanwhile, private enterprises are encouraged to cover the capital investment required to develop the biofuel industry.

Disadvantage of Decision No. 177/2007/QD-TTg

Neither the issue of food security nor the choice of feedstock for biofuel production is clearly addressed in the strategy, although the intention to develop unproductive and low-fertility land is stated. The development of biofuel without addressing food security may be considered irresponsible given that more than 800 million people worldwide cannot meet the minimum dietary energy guidelines. There is evidence that more fertile land in the world is now used for cultivating corn and other feedstocks for biofuel manufacture than for other crops, including food crops. This practice has led to food price increases and has also had an impact on animal husbandry, as the price of animal feed rose due to the diversion of corn for ethanol production as countries such as the US endeavored to reduce their reliance on imported petroleum.

Table 25: Main Contents of Decision No. 177/2007/QD-TTg

Time Frame	Objectives	Policy Mechanism and Activities
To 2010	1. Building legal corridor to encourage industrial-scale biofuel production and using biofuel as replacement fuel in Viet Nam. Raising public awareness regarding role and benefit of biofuel. 2. Building road map to use biofuel as a spare fuel in transportation and other industries, and constructing pilot distributing stations in some cities. 3. Approaching and mastering technology for biofuel production from biomass, including blending technology; and improving the efficiency of transforming biomass into fuel. 4. Planning and developing raw material zones for biofuel production. 5. Training of human resources to handle the initial stage of biofuel development. 6. Building and developing trial models for producing and using biofuel with capacity of 100,000 tons of E5 and 50,000 tons of B5 per year; ensuring supply of 0.4% of total demand for E5 and B5. 7. Approaching and mastering high-yield variety technology for biofuel production.	Total funding from government is D259. 2 billion during 2007–2015; equal to D28.8 billion per year. Government fund mainly for basic scientific research, applied research, scientific research and technology development, innovation, supporting transfer of technology, and training of human resources. Private enterprises will take care of capital investment for developing the biofuel production industry.
2011–2015	1. Research, mastering, and production of materials, and additives for biofuel production. 2. Developing and using biofuel for replacing part of conventional fuel. Expanding scale of biofuel production and network of distribution for transport and other industries. 3. Developing material zones according to plan; planting on a large scale new varieties, which have high yield and pests and disease resistance, to ensure enough supply input for biomass transformation. 4. Successful application of modern fermentation technology to diversify feedstock sources for transforming biomass to biofuel. 5. Building and developing mills and using biofuel nationwide. To 2015, output of ethanol and oil-plants-based biofuel will be 250,000 tons (blending of 5 million tons E5 and B5), meeting 1% of total demand for gasoline and diesel. 6. Training of human resources in areas related to biofuel production and training of technical workers to meet human resources needed for biofuel production.	
Vision 2025	Technology for biofuel production in Viet Nam will be at an advanced level. Output of ethanol and biodiesel fuel reaches 1.8 million tons, meeting 5% of total demand for gasoline and diesel in the country.	

Source: Ministry of Industry and Trade. 2007.

Policy Recommendations for Developing Biofuels in Viet Nam

Decision No. 177/2007/QD-TTg sets the goals that will guide all biofuel development programs in the country.

It must be clear that to develop biofuel production, the government needs to provide the best political and economic environment rather than direct subsidies, which would conflict with Viet Nam's commitments as a member of the World Trade Organization. Trading companies, especially international and joint-venture companies, should be considered key actors in this process due to their available technologies, capital, and human resources. Again, the policy environment provided by the government would be the tool to balance the share of benefits among the subsector's stakeholders, especially the farmers.

All other relevant policy recommendations concerning tax support, technology development, human resource building, and standardization for energy products are given in Decision No. 177. However, much work is needed in the next few years to keep track of all the targets. The Ministry of Agriculture and Rural Development will address the task of feedstock development. Its most important mission will be to define, in collaboration with the Ministry of Science and Technology and the Ministry of Industry and Trade, the main feedstocks for Viet Nam's biofuel industry in the next 10 years. Given the pressure of increasing food prices, and with the target of making Viet Nam a strong agricultural commodities exporter, the country needs to focus on developing non-food biofuel feedstocks. To determine which products to develop, a comprehensive cost–benefit analysis for all potential feedstocks needs to be conducted as soon as possible.

A national biofuel board should be established to manage the biofuel industry. The board, having legal authority, would monitor the multiparty agreement signed by relevant stakeholders; and assist, encourage, and promote potential products as well as decide appropriate policies.

From the initial results of this study, bioethanol from sugarcane and biodiesel from jatropha and fish fat appear to offer much potential for Viet Nam in the near future. Sweet sorghum and moringa could be considered for the longer term. The following recommendations are based on the results of this study:

(i) Trading companies will be the key actors. Too much government involvement in the industry would cause distortion in the market. The subsidy—in this case for the reason of national fuel security—would be better used on farmer beneficiaries, who will ensure the supply of input for processors.

(ii) In developing feedstock, companies need to match their business objectives with a socioeconomic development plan at the provincial level, or better, at regional and interregional levels. Thus, companies will need to obtain documents of support from the provincial or state government.

(iii) Food security must be a key concern in all biofuel development programs. To ensure food security, Viet Nam needs 13 million ha of agricultural land. The country also needs 12 million ha for forestland. The remaining area is mainly bare or infertile which, if used for biofuel feedstock, will require species that can resist drought and thrive on infertile soil. Jatropha development can be part of the so-called 661 Program—the 5 Million Hectare Reforestation Program initiated in 1993—to cover 1 million–2 million ha of bare land. This solution will ensure the use of the current productive land for staple food crops.

(iv) Due to limited land, biofuel feedstock production should be intensified and processing made more efficient. Thus, high-yielding varieties and advanced seedling techniques, irrigation systems, and processing technologies are key factors for large-scale biofuel development. The government must lay down the most appropriate conditions for trading companies to extend technical support to farmers.

(v) Since it is proposed to develop non-food feedstock in remote areas, the government needs to develop basic infrastructure for transporting agricultural products from the feedstock base to the processing firms, especially between Ha Noi and the northern mountainous areas.

(vi) Cultivation of biofuel feedstock on state-owned farmland will be effective only if the current weak management is reoriented toward the commercial biofuel market.

(vii) A tax policy needs to be framed. Enterprises prefer tax awards rather than tax exemption. A company with a high tax contribution will receive an award equal to the taxes paid to the government; i.e., the enterprise would have enjoyed tax-free operation that year.

(viii) There is need for a more effective government land policy, which will help an enterprise rent land more easily and properly compensate farmers with sufficient land for jatropha cultivation.

(ix) There should be no single feedstock base; rather a mix of crops is desirable to maximize efficiency and reduce economic risk.

(x) There is potential for contract farming with neighboring countries such as Cambodia and the Lao People's Democratic Republic. Therefore, a policy is needed to encourage and enhance cross-border trading.

Further Studies

The study team recommends the formulation of a land policy to enable private companies to own land for biofuel production, and to allow land consolidation for large-scale plantations. In addition, quantitative analysis needs to be undertaken to analyze the suitability of different potential feedstocks. The value chain of potential biofuel feedstocks also needs to be analyzed, focusing on how the country's topography and soil conditions determine the biofuel production models to be used.

Further study is required to identify the appropriate processing technology based on collaboration with other institutes and related departments (e.g., the Institute of Development Strategy, the Ministry of Industry and Trade, the Forest Science Institute of Vietnam, the Ministry of Agriculture and Rural Development, and universities such as Thanh Tay University, and Hanoi Agricultural University No. 1). Expanding the study of the biofuel subsector from the national to the regional and interregional levels will encourage fruitful collaboration. It is also necessary to conduct a baseline survey of biofuel feedstock areas which could be used in the future to assess the impact of biofuels in Viet Nam.

Appendix 1
Policies Governing the Introduction of Biofuels, by Country

Region	Country	Mixing Ratio	Materials	Vehicle Provisions	Target and/or Obligation to Introduce Biofuels	Actions to Support the Development of Biofuels
North America	United States	E10/E85	Corn	E10-suitable vehicles marketed FFVs marketed	Obligatory quantitative targets for renewable fuels introduced were set under the Energy Policy Act in 2005. 2006: 4.0 billion gallons (about 15 million kiloliters (kl), equivalent to 2.8% of total gasoline distribution). 2012: 7.5 billion gallons (about 2.8 million kl) Quantitative targets for the introduction of renewable and alternative fuels were set in the US President's State of the Nation address in 2007. 2017: 35 billion gallons (about 1.3 billion kl).	Fuel tax credit action. Support and loan project for fuel manufacturers.
		B2–5/ B20/B100	Soybean and waste food oil	B10- and B100-suitable vehicles marketed		
	Canada	E5–10/ E85	Corn, wheat, and barley	E10-suitable vehicles marketed FFVs marketed	A quantitative target for the introduction of ethanol was set in the Ethanol Utilization Increase Program in 2003. 2010: 35% of the gasoline consumption will be replaced with E10.	Fuel tax reduction. Financial support for theconstruction of fuel manufacturing facilities.
Middle and South Americas	Brazil	E20/ E25/E100	Sugarcane	E25-suitable vehicles marketed FFVs marketed	A compulsory mixing ratio of 20%–25% ethanol to gasoline was imposed.	Actions for reducing the federal industrial tax and local tax on ethanol–using vehicles.
		B2	Soybean	B25-and B100-suitable vehicles marketed	A compulsory mixing ratio of biodiesel to light oil was imposed (2% by 2008 and 5% by 2013).	Fuel tax reduction.

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Appendix 1: *continued*

Region	Country	Mixing Ratio	Materials	Vehicle Provisions	Target and/or Obligation to Introduce Biofuels	Actions to Support the Development of Biofuels
Europe	European Union	—	—	—	Quantitative targets for biofuels introduction were set under the EU Biofuel Directive in 2003 and the EU Renewable Energy Road Map in 2007. 2005: A ratio of 2% biofuel to transport fuel. 2010: 5.75% biofuel to transport fuel (equivalent to 21 million kl). 2020: At least 10% biofuel to transport fuel. The obligatory introduction of biofuel is under consideration under the Biomass Action Plan of 2005 and the Biofuel Strategy of 2006.	Support for the cultivation of energy crops.
	Germany	ETBE	Rye and wheat		A quantitative target for biofuel introduction was set under the EU Biofuel Directive in 2003. 2005: A ratio of 2% biofuel to transport fuel.	Fuel tax reduction. Support for cultivation of energy crops.
		B5/B100	Rapeseed	B100-suitable vehicles marketed		
	France	ETBE6–7	Sugar beet and wheat		A quantitative target for biofuel introduction was set under the EU Biofuel Directive in 2003. 2005: A ratio of 3% biofuel to transport fuel.	Fuel tax reduction. Support for cultivation of energy crops.
		B5/B30	Rapeseed	B30-suitable vehicles marketed		

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Appendix 1: *continued*

Region	Country	Mixing Ratio	Materials	Vehicle Provisions	Target and/or Obligation to Introduce Biofuels	Actions to Support the Development of Biofuels
Europe	United Kingdom	E5	Corn	—	Quantitative targets for biofuel introduction were set under the EU Biofuel Directive in 2003. 2005: A ratio of 0.3% biofuel to transport fuel. 2010: A ratio of 5% biofuel to transport fuel (the compulsory introduction system will start to be implemented in 2008).	Fuel tax reduction. Support for cultivation of energy crops.
	Sweden	E5/E85	Wheat	FFVs marketed	Quantitative targets for biofuel introduction were set under the EU Biofuel Directive in 2003. 2005: A ratio of 3% biofuel to transport fuel.	Fuel tax reduction. Support for cultivation of energy crops.
	Spain	ETBE3–4 ETBE6–7	Wheat and barley	—	A quantitative target for biofuel introduction was set under the EU Biofuel Directive in 2003. 2005: A ratio of 2% biofuel to transport fuel.	Fuel tax reduction. Tax exemptions for fuel manufacturers. Support for cultivation of energy crops.
	Italy	B5/B30	Rapeseed and sunflower	B30-suitable vehicles marketed	A quantitative target for biofuel introduction was set under the EU Biofuel Directive in 2003. 2005: A ratio of 2% biofuel to transport fuel.	Fuel tax reduction. Support for cultivation of energy crops.

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Appendix 1: *continued*

Region	Country	Mixing Ratio	Materials	Vehicle Provisions	Target and/or Obligation to Introduce Biofuels	Actions to Support the Development of Biofuels
South Asia	India	E5	Sugarcane	—	Introduction of E5 for the entire country began in 2003. Final goal is to spread E10 all over the country.	—
		B5	Jatropha	—	2005 to 2007: Demonstration testing. 2007 to 2010: Supply area will be expanded, and B5 production and distribution facilities will be established. 2011 to 2012: Introduction of B5 over the entire country will begin.	—
East and Southeast Asia	People's Republic of China	E10	Corn and wheat	—	A quantitative target for biofuel introduction was set under the Ethanol-Gasoline Introduction Plan in 2004. 2005: E10 was adopted in 4 provinces.	Consumption tax exemption for ethanol producers. Support for cultivation of energy crops. Ethanol indirect tax refund action.
	Thailand	E10	Cassava	—	A quantitative target for biofuel introduction has been set. 2011: Introduction of E10 will be completed.	Excise tax exemption for ethanol. Support for E10 producers.
		B2	Palm	—	Quantitative targets for biofuel introduction have been set. 2006: B2 introduction was completed. 2011: B3 introduction will be completed.	—

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Appendix 1: *continued*

Region	Country	Mixing Ratio	Materials	Vehicle Provisions	Target and/or Obligation to Introduce Biofuels	Actions to Support the Development of Biofuels
East and Southeast Asia	Philippines	E5	Sugarcane	E10-suitable vehicles marketed since 1995	A quantitative target for biofuel introduction was set under the National Ethanol Fuel Program in 2005. 2010: Introduction of E10 will be completed.	—
		B1	Coconut	—	Compulsory use of B1 will be imposed on government vehicles.	—
	Malaysia	B2–5	Palm	—	A quantitative target for biofuel introduction was set under the National Biofuel Policy in 2005.	—
	Indonesia	B5	Palm	—	A quantitative target for biofuel introduction was set under the National Energy Management Law. 2025: Use of BDF will be 4.7 million kl.	—
Oceania	Australia	E10	Sugarcane	E10-suitable vehicles marketed	A quantitative target for biofuel introduction will be set under the Federal Government's Targets. 2010: 350,000 kl	A quantitative target for biofuel introduction will be set under the Federal Government's Targets. 2010: 350,000 kl

— = not applicable or not specified, B1 = diesel containing a 1% blend of biodiesel, BDF = biodiesel fuel, E10 = gasoline containing a 10% blend of bioethanol, ETBE = Ethyl Tertiary Butyl Ether, EU = European Union, FFV = flexi-fuel vehicle, kl = thousand liters, US = United States.

Source: United Nations Development Programme and the World Bank. 2005.

Appendix 2
Ranking of Criteria for Potential Feedstocks for Biofuel Production in Viet Nam

Criteria	Ranking Indicators
1. Adaptation or viability of feedstock	0 – No availability or not adapted to growing conditions in Viet Nam 5 – Either adapted or available in Viet Nam 10 – Very high adaptation and wide availability in Viet Nam
2. Productivity	0 – Very low, not significant compared with other countries 5 – Rather low, around 50% of productivity in other countries 10 – Very high, as much productivity as in other countries
3. Farmer's ability to develop the business himself	
3.1. Self-funding	0 – Farmers cannot afford the investment 5 – Farmers can afford around 50% of total investment 10 – Farmers can afford 100% of investment
3.2. Technical issues	0 – Farmers do not know cultivation technique or variety selection 5 – Farmers know the cultivation technique or variety selection at certain level, sometimes they need support 10 – Cultivation technique and variety selection are easy for farmers and they do not need support for these
4. Conversion to other alternatives	0 – Difficult to convert to other alternatives: takes time, big investment, impact 5 – Less difficult to convert, some problems can be overcome 10 – Easy, flexible to convert from one to other alternatives
5. Competition with and impact on food security or animal husbandry	0 – Strong competition with or impact on food security in terms of land 5 – Conflict is not significant, part of feedstock can be used for biofuel 10 – No conflict or impact can be observed

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Appendix 2: *continued*

Criteria	Ranking Indicators
6. Support from government to produce biofuel from current variety	
6.1. Policy support from government	0 – No policy at the moment and no chance of being supported by policy 5 – No policy but no limitation for developing feedstock 10 – There is clear policy for developing feedstock
6.2. Infrastructure support	0 – No infrastructure support at all 5 – Part of infrastructure for biofuel can be supported 10 – Government strongly supports infrastructure for the current feedstock
6.3. Technology support	0 – No technological support at all 5 – Part of technology for biofuel can be supported 10 – Government strongly supports the technology for current feedstock
7. Impact on humans and the environment	
7.1. During preliminary treatment	0 – Has strong impact on humans and the environment in preliminary treatment 5 – Impact on humans and the environment is under control in preliminary treatment 10 – Very low or no significant impact on humans and the environment in preliminary treatment
7.2. During production	0 – Has strong impact on humans and the environment in production process 5 – Impact on humans and the environment is under control in production process 10 – Very low or no significant impact on humans and the environment in production process
7.3. During distribution and consumption	0 – Has strong impact on environment and/or humans during distribution and consumption 5 – Impact on environment and/or humans is under control during distribution and consumption 10 – Very low or no significant impact on environment and/or humans during distribution and consumption

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Appendix 2: *continued*

Criteria	Ranking Indicators
8. Having added value or by-products	0 – No or very little added value or by-products from current feedstock 5 – Added value or by-product is significant and brings extra income 10 – High added value or by-product that strongly supports poverty reduction
9. Supply chain for bioenergy industries	
9.1. Regularity of feedstock supply	0 – Supply is not regular 5 – Supply is rather regular, sometimes it is interrupted 10 – Supply is regular and continuous
9.2. Possibility of expanding production	0 – No chance or impossible to expand production 5 – Possibility of expanding production is visible and reachable 10 – Production is now expanding
10. Market potential of current feedstock for biofuel	
10.1. Good price	0 – Price for feedstock is too low compared with price of other alternatives in the same area 5 – Price is reasonable and acceptable to farmers compared with price of other alternatives in the same area 10 – Price is high and farmers get high benefit compared with price of other alternatives in the same area
10.2. Trade potential	0 – Has low trade potential, no forms of trade for current feedstock 5 – Feedstock has trade potential, some forms of trade are available 10 – Feedstock has been traded locally and internationally

Source: Centre for Agricultural Policy.

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

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

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