ENERGY RESOURCES AND DEVELOPMENT IN VIETNAM

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INTRODUCTION

Vietnam is facing an energy crisis. There are acute shortages nationwide (1). The industrial sector and household users in the south struggle through electricity blackouts that extend over 3–4 days of the week (Interview I;

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Figure 1 Oil, gas, hydropower, and peat energy resources as well as mineral resources in Vietnam. Additional titanium, chrome, tin, copper, and manganese deposits have been surveyed, but are not indicated here. Coal reserves are extensive, and are detailed in Table 2. Producing and projected offshore oil and gas fields are presented in Figure 8. The map is adapted from a study by the Institute of Energy Economics, Japan, 1992 (23).

Some parts of central Vietnam and rural areas throughout the country lack access to electric power (1, 2). It is estimated that more than half the population remains disconnected from the national power system (II), which itself is fragmented. The regional availability and distribution of oil are also limited (2). Vietnam is a low-income country with GNP estimated at roughly US$ 200 per capita (3), and commercial energy purchases are therefore beyond the means of much of the population. It is
perhaps not surprising then, to find that Vietnam’s per capita energy consumption, which was 109 kWh in 1989, is nearly the lowest in the world and is considered low even in the context of its technical stage of development (1, 4).

A lack of energy for industrial use is clearly slowing Vietnam’s economic growth (1). The situation seems likely to worsen as the population grows. Despite a decline in fertility over the past two decades, the current population of 64.4 million (1989) is still growing by more than 2% annually (5). In some areas, notably the Red River Delta, the population density exceeds 1000 persons/km² (6). In 2010, a population of 90–95 million is projected, and the energy demands of this group will far exceed the presently anticipated supply (7). Shortages of capital, technology, and sound management have reduced the efficiency of the energy production and delivery systems (7). Vietnam’s susceptibility to extremes of climate and its unpredictable weather (3) further complicate planning how to best manage resources and to spur national development.

Vietnam does have extensive energy resources and potential capacity, which includes 1.5–3 billion barrels of oil (8), two billion tons of coal, and an impressive capacity for hydropower (2), all of which could go a long way toward meeting the nation’s immediate and even long-term development needs. Vietnam’s planners face the challenge of implementing economically viable means of harnessing the rich energy and mineral resources of the country (Figure 1) while limiting environmental damage to levels that will not adversely affect future economic growth (9–13).

In this review we present a compilation of biomass, fossil-fuel, and renewable energy resource estimates for Vietnam. We examine the national near-term potential for development with particular attention to the environmental risks associated with the present dynamic international political and economic situation, which may see a lifting of the US embargo and normalization of relations between the United States and Vietnam.

ENERGY AND ENVIRONMENT IN VIETNAM

The environmental consequences of energy generation are just beginning to be officially recognized in Vietnam. Up to the present, there have been no legal requirements for environmental impact studies in the planning of electricity generation projects or in proposals for mineral exploration and extraction. Such legislation has been formulated and awaits government approval (IV, 13). Environmental damage due to energy production has several facets. There is deforestation for woodfuel as well as for wood for such purposes as supports for mine shafts (3) and small-scale enterprise. Wood resource scarcity is not so much due to a lack of sufficient biomass
to satisfy demand, but rather because of the competing needs for biomass and because the supply is distributed widely across the country, whereas the woodfuel market is concentrated in regions of high population.

Cooking fuel in rural areas, home to 80% of the 65–70 million Vietnamese (14, 15), consists almost entirely of biomass. Some areas are so completely deforested that the people rely on rice straw for all of their biomass energy requirements. This results in reduced soil fertility (16).

Mine slag has been dumped onto previously fertile land, and toxic chemicals leach from the slag (3). Air pollution is accumulating from waste gas and ash from thermo-electricity generating plants (10), the burning of gases from offshore oil wells, the use of biomass and coal for household cooking and heating, and the exhaust from motorcycles (V, VI). Oil spills resulting from recent exploitation of the offshore reserves have already caused damage to the west coast of the southern tip of the country, Minh Hai Province (VII). The construction of reservoirs for hydropower stations has necessitated the flooding of forests and thus has affected regional ecosystems. In addition, the associated dams have changed the flow regimes of several rivers and affected the deposition of sediment in the deltaic regions, as well as the salinity of estuaries (3).

In addition to the obvious impacts of energy generation on the environment, environmental deterioration directly impacts energy generation in Vietnam. Environmental damage reduces the efficiency of hydro-electricity generating plants. Deforestation in the catchment areas produces downstream silting of the reservoir, significantly reducing generating efficiency and operational lifetime. Furthermore, deforestation results in more erratic river flow regimes, making the regulation of hydropower stations more difficult. Trees are also needed as pit props for coal mines (3). In the long term, environmental damage may result in regional climatic changes, which would have impacts on electricity demand and on such climate-sensitive resources as hydropower.

The responses of Vietnamese policy-makers to energy demands and the environmental situation reflect a variety of interests and concerns. The official position, made explicit at the 7th National Congress of the Communist Party of Vietnam, emphasizes environmental protection (13). Vietnam has formulated a National Plan for Environment and Sustainable Development (13), which follows on the heels of a National Conservation Strategy published in 1985 (12). In practice, however, few of the recommendations of the 1985 report were carried out (VII). For many policy-makers, environmental protection is seen as a luxury that Vietnam cannot afford; although clearly at least some level of attention to environmental pollution would likely lead to significant long-term savings.

Developing state-of-the-art power generation or refinement equipment is
not a realistic option for Vietnam. Nuclear power is financially and politically out of reach for the Republic of Vietnam, and the prevalent attitude among Vietnamese scientists, politicians, and the general public is of post-Chernobyl distrust of nuclear power (VIII, IV, 9). At present, Vietnam lacks a significant oil refinery. Therefore, although it has important oil reserves in its continental shelf, Vietnam must import transportation-grade fuel oil (14). Hydropower might seem to be the best compromise between environmental concerns and energy demands at present, but its climate-sensitive nature, its requirement for large amounts of capital, and its effects on the environment are sources of concern to Vietnamese planners. New and renewable sources of energy other than large-scale hydropower are actively supported by the Vietnamese government, but funding for development and dissemination of these is very limited (VI, III). In practice, the impact of renewables is restricted to a scattering of micro-hydro plants in rural areas, which are used primarily for irrigation (1). The government priorities for energy development lie more towards massive hydro projects and the exploitation of the oil reserves (7, III, IV).

While small-scale new and renewable energy systems are not being emphasized by Vietnamese policy-makers, current plans do lean towards the development of hydropower. At the moment, the two primary population centers are not connected by a national power grid (1, I, III). Furthermore, the two main segments of the grid run at different voltages of 220 V and 110 V (1). The north has a relatively stable electricity supply, principally from the Hoa Binh hydropower generating station (2). The south, which is the industrial heartland of Vietnam, has little electricity, and industrial facilities rely primarily on the local grid or a combination of in-house diesel generators and wood-burning furnaces. A controversial high-tension power line is being constructed between Hoa Binh and the south (I, II, III, IV, IX). The north does not have a gross excess of electricity, and this high-tension line would be a very expensive stopgap measure, were it not for plans to build a massive 3000–3600 MW hydropower station at Son La on the Da river in the north (2, I, VII). If constructed, Son La would produce roughly 18 TWh annually (2). For comparison, total electricity consumption in 1989 was approximately 9 TWh and at present is expected to rise to 17–18 TWh by 1995 (1).

The proposed aerial high-tension line (Figure 2) is scheduled for siting and construction from 1991 to 2005 and is planned to extend over 1500 km (2). It will carry a DC voltage of 500 kV. Hoa Binh, Son La, and Yali would be the principal on-line generating stations (2). The cost of this line is estimated at US$ 500 million (I, III). At present, funding for such ventures is not within the budget of the Vietnamese government (VII), and Soviet aid is no longer forthcoming. As a rough guide to the cost of hydropower
generating stations, the official estimate for the Hoa Binh station with a capacity of 1920 MW is more than US$ 1.5 billion (1). Independent estimates for the cost of the Son La facility range far higher, on the scale of the controversial Three Gorges Project in China. Although the Son La generating plant plays the most important anticipated role in the future of Vietnam’s electricity system (2), it is not clear at present whether it will ever be constructed.

The countries of the Council for Mutual Economic Assistance, principally
the former Soviet Union, have contributed about $US 1 billion in trade surpluses to Vietnam in recent years, while direct aid levels ran at roughly US$ 1 billion per year at least until 1986. By contrast, only approximately US$ 500 million was received in Official Development Assistance (ODA) from 1986 to 1990 (1). However, the vacuum of capital and technology that might have developed in Vietnam in the wake of the collapse of the Soviet Union is being filled by investors and aid agencies from other industrialized countries (2, IV, VII, VIII, IX), notably Japan. Changes in Vietnam’s constitution that seem to guarantee a free market have resulted in a rapid growth in foreign investment (17–20), as have efforts to end the embargo against Vietnam.

Vietnam’s oil and gas resources are of particular interest to foreign investors. While much of the choicest offshore exploration blocks have already been leased to Japanese, Canadian, Finnish, Belgian, Indonesian, Australian, British, and French concerns, Vietnam has reserved several prime tracts for US joint ventures in the hope of speeding the normalization of relations with the United States (8, 18).

A second international political issue that is a source of uncertainty for Vietnam’s future energy policy is the intense interest in the oil reserves, and the dispute over mineral rights on the Spratly islands. These islands are located in an oil-rich region that is claimed by Vietnam, China, Taiwan, the Philippines, Brunei, and Malaysia. Vietnam and China battled over the area in 1988, and it is not inconceivable that China might resort to military action to protect its stake (19, 20, X). Considerable progress, however, has been made in this issue through a series of internationally facilitated South China Sea conferences at which co-exploration agreements have been proposed (XIII).

In the following sections, the individual sectors comprising Vietnam’s energy resource base are described in detail. Data indicating current energy demand and forecasts for future production are presented, and the extent to which new and renewable sources of energy can contribute to energy needs is examined.

ENERGY RESOURCES AND CURRENT PATTERNS OF CONSUMPTION

The principal sources of inanimate energy in Vietnam are biomass, coal, hydro-electricity, gas, and oil (Figure 3). Biomass is the most important of these, being the principal source of fuel for the rural populace. Per capita consumption of commercial fuel is minimal, at about 120 kg oil-equivalent in 1989. Total energy consumption per capita is also very low, at 340 kg oil-equivalent (2.5 barrels per year) as reported in 1989 (14), indicating the
lack of industrialization, and the reliance on animate sources of power. The low baseline and slow growth in fossil fuel use, shown in Figure 4, is expected to change rapidly during the mid-1990s.

The distribution of energy consumption by sector in Vietnam reflects the outdated condition of its machinery and technology; the energy generation and industrial production sectors of the economy consume about two-thirds of all commercial energy. As shown in Figure 5, the local craft/household

Figure 3 National energy resource mix as of 1990.

Figure 4 Growth in national fossil-fuel consumption over the period, 1977–1990. A surge in consumption, ending 15 years of virtual stagnation, is expected in the mid-1990s (18).
Figure 5 Distribution of domestic Vietnam's energy consumption by sector. The energy production, industrial production (specifically, heavy industry), and light industry sectors consume more than three-fourths of all commercial energy, indicating a preponderance of outdated and inefficient equipment. "Localities" refers to a diverse set of small-scale manufacturing and service activities. The construction and transport sectors are dominated by human and animal sources of energy.

sector accounts for about 25% of energy, and agricultural activities and transportation the remainder.

Biomass

Biomass consumed in Vietnam consists of wood, vegetation, and agricultural waste. The quantity of biomass used annually has been estimated at tens of millions of tons, far exceeding equivalent commercial fuel use (3). About 90% of the total fuel supply for Vietnam's households is from vegetation, and most biomass-burning stoves are rather inefficient, with the traditional three-stone fire and simple tripod types still common. High population densities in the agricultural zones also limit the potential for expansion of the utilization of agricultural residues (Table 1). The new and renewable energy program is disseminating three models of high-efficiency stoves for biomass or coal burning, with some success (14). The stoves are affordable, popular, and highly effective (III, IV, VI).

The current sustainable level of biomass production, including wood and agricultural materials suitable for combustion, is estimated to be more than 80 million tons per year (1). This well exceeds current levels of local demand for biomass energy, although agricultural and domestic applications are also important. Domestic consumption of woodfuel is 20 million tons per year, and agricultural and domestic consumption of agricultural waste is 30 million tons. Industrial consumption is insignificant by comparison,
at 1.5 million tons of wood and 0.5 million tons of agricultural residue (XII). Local scarcity of biomass due to high population densities (Table 1), local deforestation, and multiple uses, however, can be severe, and is one of the most pressing energy problems facing Vietnam.

Vietnam has 7.0–9.5 million hectares of forest (XII), which account for about 27% of the total land area (2). Forest cover has been reduced by 10% over the past 15 years, partly as a result of woodfuel harvesting (3). A complex scheme to enlist local woodfuel users as paid custodians of tracts of forest, making them self-interested regulators of sustainable harvesting, has proven somewhat effective (XII), but is useful only where agriculture is not feasible. In a drastic move, exports of raw cut and sawn wood were banned at the beginning of 1992 (IV, XII). Additionally, official felling was to be reduced by 88%. Total official production is planned to be stabilized at 600,000 cubic meters per year, half of which would be directed to the export market in the form of value-added goods such as plywood (XII). It remains to be seen if these reforms will be carried through. The supply of raw materials for bamboo pulp and lumber for domestic use would also be severely tightened, perhaps by as much as 90% (21).

In 1991, about 40 million cubic meters of wood was extracted for timber and woodfuel, resulting in the deforestation of an area of approximately 100,000 hectares (1). This represents roughly one-half of the total annual deforestation. Of the harvested wood, about 88% was used as fuel (21). This fuelwood constitutes about 40% of the total biomass used as fuel, with the remainder composed of agricultural residues (XII). Roughly one million cubic meters was exported, mostly in the form of lumber and plywood (21). The reforms of the Ministry of Forestry, if implemented, will require the restructuring of the forestry and construction industries and will cost Vietnam roughly US$ 100 million in foreign exchange (21), but will not address the dominant and ever-growing threat to the forests, which is the household demand for woodfuel.

Table 1  Population and agricultural density

<table>
<thead>
<tr>
<th>Region</th>
<th>Population/ km²</th>
<th>Hectares in food crops per agricultural laborer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red River Delta</td>
<td>1045</td>
<td>0.34</td>
</tr>
<tr>
<td>Mekong Delta</td>
<td>369</td>
<td>0.51</td>
</tr>
<tr>
<td>Central Highlands</td>
<td>47</td>
<td>0.41</td>
</tr>
<tr>
<td>All other regions</td>
<td>161</td>
<td>0.36</td>
</tr>
<tr>
<td>Vietnam</td>
<td>200</td>
<td>0.40</td>
</tr>
</tbody>
</table>

*Data based on 1992 land survey and 1989 population census (5).
Production targets from the current five-year plan and current rates of wood use and deforestation were used to estimate the effect of these timber and biomass reforms on deforestation. It was calculated that the national level of extraction for timber and woodfuel would be reduced by about 10%. Since fires, clearing for agriculture, and other unplanned activities contribute half of the deforestation, the effect of the reforms would be to decrease deforestation by roughly 5% (21). Vietnam's fast-growing population requires wood to build homes and to cook food. Clearly, afforestation on a large scale is urgently required to create plantations for the sustainable harvesting of biomass near centers of population. This is envisioned in the National Plan for Environment and Sustainable Development, 1991–2000 (13). The eventual solution to the woodfuel crisis, of course, must involve population control, and affordable alternatives to biomass for the preparation of food must be developed.

Current afforestation schemes cost US$ 300–650 per hectare in Vietnam (21), and the success rate in terms of land actually returned to forest cover has risen to about 80% (XII). The Ministry of Forestry, however, lacks the resources to respond to forest fires or infestations of pests (XII), and cannot police illegal logging. Vietnam's forests are mature, and the growth rate is only about one-tenth of current rates of extraction (1). Afforestation reclaims only half of the forest area destroyed each year, resulting in a net clearance rate of 100 thousand hectares annually (1). As discussed above, Vietnam is sacrificing scarce foreign exchange to limit the only form of consumption it can control at present: the official felling. Foreign aid and technical assistance for the forestry sector must be forthcoming if Vietnam is to avoid widespread loss of its valuable forest resource.

**Coal**

Coal is a plentiful resource, which is used directly for heat and cooking fuel, in industry, and in the generation of electricity. It is also exported (2, 22). Reserves, listed in Table 2, include more than two billion tons of anthracite coal (2, 3, 9). Most of these reserves are located in the north in the Quang Ninh basin (1). Two to three billion tons of brown coal is estimated to lie beneath the Red River delta (Table 2), but its great depth (1500 m) makes recovery uneconomical. The government estimates the design capacity of coal mines to be 8.8 million tons per year (1).

Coal production of five to seven million tons per year was typical until 1989 and 1990, when production decreased by about 30% and more poor-quality coal was mined (3); Figure 6. The decrease in production was associated with a reduction of about 25,000 in the number of people employed in coal production (23). Sixty percent of production is from open mines (1). Poor-quality, outdated equipment and perennial shortages limit
Table 2  The Vietnamese coal reserve, million tons

<table>
<thead>
<tr>
<th>Coal type/fields</th>
<th>Total estimated reserve (ICD, Japan)</th>
<th>Surveyed reserve Official estimate</th>
<th>ICD, Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthracite/Semi-Anthracite</td>
<td>6,600</td>
<td>3,104</td>
<td></td>
</tr>
<tr>
<td>Quing Ninh</td>
<td>6,500</td>
<td>2,500</td>
<td>3,021</td>
</tr>
<tr>
<td>Uong Bi</td>
<td>1,000</td>
<td>1,000</td>
<td>1,286</td>
</tr>
<tr>
<td>Hon Gai/Cam Pha</td>
<td></td>
<td>1,000</td>
<td>1,753</td>
</tr>
<tr>
<td>Bac Thai</td>
<td>85</td>
<td>100</td>
<td>78</td>
</tr>
<tr>
<td>Nong Son</td>
<td>25</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Bituminous</td>
<td>25</td>
<td></td>
<td>12</td>
</tr>
<tr>
<td>North</td>
<td>12</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Da River</td>
<td>10</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Ca River</td>
<td>3</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Lignite/Sub-Bituminous</td>
<td></td>
<td>244</td>
<td></td>
</tr>
<tr>
<td>Lower Red River</td>
<td>200,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Na Duong</td>
<td>120</td>
<td>146</td>
<td></td>
</tr>
</tbody>
</table>

*The lignite coal reserve in the Lower Red River Basin is at great depth, more than 1500 meters, and is thus uneconomical to exploit.

bICD: International cooperation department, Institute of Energy Economics, Japan (23).

cThe official estimates are from Interview VI.

![Figure 6](image-url)

Figure 6  Vietnamese coal production, in thousand tons, for selected years between 1976 and 1990. The implementation of the Doi Moi (Vietnamese "Perestroika") reforms coincide with the recent decline in output.
productivity. However, output remains in excess of demand, and annual exports of about 500,000 tons per year, mainly to South Korea and Japan, are typical (1). Modernization of the coal transportation infrastructure, including electrification of the railroad, standardization of rail-gauge to 1435 mm, and expansion of Cam Pha port are under way. Total planned capacity is 7 million tons (23). Foreign investment will be required to improve Vietnamese coal production so that targets of 8.5 million tons can be reached by 1995 (24). The estimated capital requirement is US$ 300 million over five years (1).

Coal production is controlled by the Ministry of Energy with the associated Geological Survey Division managed by the Ministry of Heavy Industry. The extent and distribution of the coal reserves are of considerable importance as Vietnam negotiates foreign exploration and extraction contracts. Table 2 summarizes the reserves as estimated by the Vietnamese government (9) and foreign industry analysts (23). Expansion of coal as a resource for domestic consumption is planned, and presumably will rapidly accompany privatization and growth of the market economy. Prior to Doi Moi, the Vietnamese “Perestroika” (15), all coal was sold by the government at a price determined as follows:

\[
\text{Selling Price} = \text{Extraction Cost} + 15\% \text{ profit} + \text{tax}.
\]

In 1991, the FOB (Foreign Overseas Buyer) price of exported coal was US$ 35 per ton (23), while the domestic price was 20–30% of the FOB price. As shown in Table 3, total domestic and individual household coal consumption are expected to grow by more than 30% and 60% respectively this decade.

<table>
<thead>
<tr>
<th>Sector</th>
<th>1990</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power generation</td>
<td>150</td>
<td>230</td>
</tr>
<tr>
<td>Cement, ceramic</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>Chemical industry</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Light industry</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Metallurgy/Machinery</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Food processing</td>
<td>70</td>
<td>20</td>
</tr>
<tr>
<td>Transportation</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Residential</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>Stock</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>Total</td>
<td>420</td>
<td>560</td>
</tr>
</tbody>
</table>

*Data taken primarily from (5).
Oil and Gas Resources

The General Department of Oil and Natural Gas has made estimates of the reserves of oil and gas resources based on data accumulated before 1989. These estimates are: for the Tonkin Gulf, 500 million tons; for South Conson, 400 million tons; for the Mekong Delta, 300 million tons; and for the Thai Gulf, 300 million tons (3, XI). International industry analysts estimate the total reserve in the 1.5–3 billion barrel range (8, 25). The estimates of one analyst for the various fields are listed in Table 4. The area covered by the oil reserves, shown in Figure 7, may be 500,000 km² and extend over the Red River Delta the Mekong Delta, The Bac Bo Gulf, the South China Sea near Hue-Danang, Nam Con Son, and east of the Thailand Gulf (7). From 1990 to 1991, oil production increased 56% to 72,000 barrels per day (26). Vietnam may see oil exports as a fast track to economic growth, and output targets for 1991–1995 are 20–23 million tons (22).

By the end of 1990, 10 long-term exploitation and exploration joint ventures had been established between Vietnam and foreign companies (3, 8). Of the foreign investment projects approved as of 1989, oil exploration constituted 45% of the total capital at US$ 288 million, which was more than double the investment level in any other sector. Vietnam has legalized cooperation with foreign investors and is negotiating contracts on the basis of product sharing with 100% foreign investment (22, 26, 27). Vietnam’s Law on Foreign Investment provides a legal framework for foreign investors and includes a moderate tax regime that industry analysts consider extremely favorable for foreign investors (1, 25). Typical contract terms and profit sharing call for 5000-km² offshore blocks, a five-year exploration period

<table>
<thead>
<tr>
<th>Field</th>
<th>Low</th>
<th>Best</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bach Ho</td>
<td>350</td>
<td>500</td>
<td>700</td>
</tr>
<tr>
<td>Rong</td>
<td>75</td>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td>Dao Hung</td>
<td>400</td>
<td>750</td>
<td>1000</td>
</tr>
<tr>
<td>Other fields</td>
<td>175</td>
<td>375</td>
<td>700</td>
</tr>
<tr>
<td>Total</td>
<td>1000</td>
<td>1725</td>
<td>2550</td>
</tr>
</tbody>
</table>

*The estimates are for recoverable oil to 2005, and are taken from (8).*
Figure 7  Map of the offshore oil and gas fields, adapted from (19). The offshore zones marked with solid lines are the exploration blocks shown in Figure 8.

(minimum investment of US$ 50–60 million), and 20-year production intervals. Profit-sharing terms range from 67% to the national oil company, PetroVietnam, and 33% to the investor for a small find of less than 15,000 barrels per day to a 80/20 split in PetroVietnam's favor for large fields. The distribution of offshore exploration blocks is shown in Figure 8.
It is not clear whether the oil fields of Vietnam's continental shelf will be easy to recover. To date, only the Bach Ho oil field has been productive (26). The theoretically more extensive "Big Bear" field, Dai Hung, has difficult geology, and two of three wells drilled there were dry (26). Its promise is an estimated reserve of 700-800 million barrels of oil (18). A joint Soviet-Vietnamese venture called Vietsovpetro controls the exploitation of Vietnamese oil reserves. The Vietnamese government, however, has
apparently reserved several highly promising blocks currently administered by Vietsovpetro for US companies (18). These blocks are likely to be in potentially rich but technically difficult exploration areas where the water’s depth exceeds 200 meters (see Figure 7).

Despite these oil reserves, Vietnam lacks a substantial refinery and has to import liquid fuel. 1990 imports of petroleum products totalled 1.5–2 million tons (11–14 million barrels), mainly by a mechanism of exchange of crude for refined petrol with Japan and Singapore (1, 22). Consumption is about 50,000 barrels per day. Plans for an oil refinery in Dong Nai province of 3 million tons (22 million barrels) annual capacity are under way at a projected cost of US$ 500 million, including a 200 km undersea pipeline (1). Since it is believed that refineries in the region have excess capacity, the advisability of building this refinery is being questioned (1, 2). The advantages of a domestic refining capacity are currently far exceeded by the immense cost. Under current conditions, the average difference in revenue between exporting crude and refined oil is several dollars per barrel. Industry analysts argue that Vietnam should not channel scarce capital into a refinery, but rather should continue to import refined product while expanding its crude oil and gas production (25).

Oil consumption in 1990 was 1922 thousand tons, which had increased from 1713 thousand tons in 1977 (1). Commercial energy production and

![Graph of Oil Production in Vietnam](attachment:oil_production_graph.png)

**Figure 9** Oil production in Vietnam: projections to 2005. Estimates in Figures 9–11 are based on forecasts by the Resource Systems Institute, East-West Center (18, 19, X). For each plot, the base, or best estimate case, is shown as the half-filled box, while the high and low estimates are the open square and open triangle, respectively.
transportation are the principal domestic uses of oil. Projections of Vietnamese oil production are impressive, dominating foreign export earnings for at least the next decade (8, 18). The industry best estimates for median-case Vietnamese oil production peak at almost 400,000 barrels per day in the year 2000, generating revenues of about US$ 3 billion and contributing half of total Vietnamese exports (8) (Figures 9–11).

Figure 10  Value of Vietnam’s oil production: projections to 2005.

Figure 11  Projected share of oil in total Vietnamese exports to 2005.
Apart from some small-scale natural gas use around Thai Binh province in the north of Vietnam, most natural gas is at present flared at oil wells (1). Systems to make effective use of gas resources will require a large capital input (1). Discoveries of large gas fields (1–4 Tcf) seem likely, particularly in the disputed Gulf of Thailand, adjacent to currently productive Thai gas fields (18).

Electricity

The electricity distribution system is divided between the north and the south, though as discussed earlier, plans to link the two with a high-tension power line are under way (2, I–IV, IX; Figure 2). Small isolated networks exist in the central region that is not served by the two major grids, and many areas remain disconnected altogether from a commercial power delivery system. In practice, this means that 30% of rural people, or about one quarter of the total population, do not have access to electricity (II). From 1976 to 1990, electricity production grew by 8% annually (3), but demand has not been met. The proportion of this production that is hydro-derived was 27% in 1976, and has increased to 58% in 1990, reflecting the Soviet-backed emphasis on the development of hydro-electric generating capacity. It is Vietnamese policy to increase the proportion of total generated electricity that is derived from hydropower to 70% of total national capacity by the year 2000 (22). International assistance will now be required to maintain or increase current capacity. Vietnam’s decision to favor hydro-electric power development complements the concerns of the developed world to limit greenhouse gas emissions. These projects are mentioned as highly appropriate targets for international assistance, although only if the environmental costs are carefully considered.

The prices of electricity, petroleum for industry, and transport appear to lie outside the realm of the Doi Moi reforms and are determined by the government. The policy for electricity pricing that was set in early 1990 applied equally to all three state electricity companies (2). The rate was first set at 250 Dong per kWh but has since risen to 450 Dong/kWh. Foreign industry paid US$ 0.06, and foreigners living in Vietnam paid a household rate of US$ 0.09. A special rate of 48 Dong per kWh applied to agricultural irrigation systems in the off-peak period. (In late 1992, US$ 1.00 was worth about 11,000 Dong.) Except for this special case, prices did not vary with peak periods, with the season, with the geographical area, with the voltage supplied, or with the dependability of the supply.

In Vietnam, consumers agree to a contract that specifies maximum levels of consumption. If these levels are exceeded by 10% or more, the amount in excess is billed at 1.5 times the regular rate. The basic rate is calculated to reflect the cost of production by the following formula:
Selling Price = Production Cost + 10% profit + tax,

with tax set at 12% of the total production cost (2). In reality, however, to cover costs in the production of electricity while keeping the price within affordable limits, the electricity companies are temporarily reducing their “on paper” production expenses. They are reducing the devaluation of their machinery by extending its theoretical lifespan (2). Investment in improved technology would increase production efficiencies and decrease losses in transmission, thereby reducing long-term costs.

A comparison of the installed capacities of electricity-generating systems shows that the total in 1990 was 2525 MW, up from 1165 in 1986. Of this 1990 installed capacity, 36% was thermal, 46% was hydro-electric, 11% was diesel, and 7% was from gas turbines. Projections of electricity demand increase from 16,550 million kWh in 1995, to 24,280 million kWh in the year 2000, to 33,100 million kWh in 2005 (3). It is probable that these estimates have not taken full account of the effects of the new market mechanisms. It is not clear at present how Vietnam will meet these demands.

**Hydro-electricity**

Vietnam has 2860 rivers with lengths of more than 10 km (1), which endow it with a large hydro-electric resource (7). About 570 hydro-electricity generating sites have been recognized. Of these, 10 have capacities of more than 300 MW, 200 of between 5 and 300 MW, and 360 of between 0.3 and 5 MW (1). The three most important river systems as a resource for hydropower generation are the Da river in the north, the Sesan in the central region, and the Dong Nai in the south. The generating potentials of these rivers are 6258 MW/31,600 GWh for the Da, 1485 MW/7990 GWh for the Sesan, and 2500 MW/11,600 GWh for the Dong Nai (7). Roughly 60% of the nation’s electricity supply is provided by hydropower, with growth of the two sectors closely linked (Figure 12).

The economically viable supply of energy available from hydropower is estimated at about 82 TWh (2). To put this in context, projections place electricity demand at 40 TWh by the year 2010 (2). It is not clear, however, what effects market changes will have on energy demand, and this projection is likely an underestimate. The potential installed capacity is 20,000 MW (2), of which 90% would be recoverable from large stations. The asymmetric distribution of these stations, with 65% in the north, 25% in the central region, and 10% in the south (28), has contributed to an imbalance in the supply of electricity between the north and south.

The largest hydropower plant is Hoa Binh in the north, with a planned
capacity of 1920 MW (3). Five of the eight planned generators have been completed to date. When this plant is fully operational, estimates are that it will satisfy the electricity demands of the Hanoi region up to the year 2000 (2). It is from this generating station that the proposed north-south power line will run (Figure 2). The completion of Hoa Binh is projected for 1995 (3). Other large hydropower stations include Da Nhim in Lam Dong province in the south, with an installed capacity of 160 MW. Tri An, the largest hydro station in the south with an installed capacity of 400 MW, is located in the province of Dong Nai, about 30 km from Ho Chi Minh City (3). Thac Ba in Hoang Lien Son province is another of the large hydro-electricity generating stations with an installed capacity of 120 MW (3).

Since 1989, the government has followed a policy of cutting subsidies on commercial fuels, which has coincided with increases in hydro-electricity generation from the Hoa Binh and Tri An plants, rapidly changing the energy structure of the country (14). New hydro-electricity plants at Thac Mo, 150 MW, and Vinh Son, 68 MW, are planned (28). Hydro plants of 700 MW at Yali in the central region and of 360 MW at Ham Thuan in the south are likely future projects (32). A massive hydropower plant at Son La in the north, with an installed capacity of 3000–3500 MW, has been proposed (22). This huge plant would accentuate the disparity in energy

Figure 12  Total energy production and hydropower-generated electricity in Vietnam, 1976–1990.
supply between the north and the south. The Son La and Yali plants would be connected to the 500 kV high-tension power line between the currently operational Hoa Binh plant and consumers in the south (Figure 2).

The completion of all these plants would give Vietnam a total capacity of more than 6000 MW, with an annual electricity output of 30 TWh (22). No environmental impact study has been performed for the Son La development to date, with the possible exception of an Asian Development Bank (ADB) survey in 1990 reviewing the general environmental impacts of energy development in Vietnam (29). At the very least, reforesting of the watersheds associated with the large hydro projects must be integrated into construction plans.

The technological know-how for the construction of these plants is available in Vietnam; however, research facilities and funding are lacking for the development of new hydro-electricity technology (17). Research on micro-hydro has been carried out, especially in the range from 100 W to 10 kW (28). Micro-hydro apparatus have been designed and manufactured by Vietnamese scientists, and are being disseminated principally in mountainous regions that are not serviced by the commercial network (11, III, VI). Interestingly, the Vietnamese have also established micro-hydro plants in Laos that have met with considerable success, particularly in the mountainous areas (28).

**Thermal Electricity Generation**

Since hydro-electricity is climate sensitive, the annual dry season can impair electricity production. For this reason, and to take advantage of Vietnam’s coal reserves, two new thermal electricity plants are planned with total capacities of 600–1000 MW in the north and of 400–800 MW in the south (22). It is hoped that improved technology will reduce the environmental impact of these plants. However, at present, pollution control is minimal. Pollution-related disease is prevalent in communities near thermal generators, and in the past, workers in the areas were given a 10% bonus by the government as compensation (1). Existing thermal plants include Soviet-equipped Phai Lai with a capacity of 440 MW, Chinese-equipped Ninh Binh with a capacity of 100 MW, Soviet-type Uong Bi with a capacity of 148 MW, and Thu Duc with a capacity of 160 MW (22). Three oil-fired thermal plants in the south, together with gas turbine generators principally in the central region, have a combined capacity of 400 MW (32). No evaluation of emissions from these plants has been undertaken nor is there at present any requirement for environmental impact studies of proposed generating plants. Many of the generating plants are old, and their average efficiency is 70%. Currently, no waste-treatment or emission-reducing equipment is used.
The Present and the Potential: Renewable Energy

Vietnam has a national program for the development and dissemination of new and renewable sources of energy. It is run by the Ministry of Education and Training, and includes several research centers including one that operates under the Ministry of Energy. This program emphasizes improved cooking stoves, micro-hydro power, solar energy, biogas production, and wind energy (30, 31). Progress has been limited by financial constraints, with the total annual governmental contribution totaling only US$ 33,000 (30). In addition, the very low annual incomes of the potential users, mostly rural, precludes the possibility of full costs being carried by them. The situation is of course exacerbated by the lack of international development funds for Vietnam. As a result, new and renewable sources of energy are currently restricted to use by relatively wealthy people in the countryside who lack access to the national power grid. The contribution of these sources to energy production in Vietnam is negligible, and current policy does not emphasize their development.

Solar energy is used principally in the traditional form of biomass. Total radiation for Vietnam is 100–180 kcal cm\(^{-2}\) year\(^{-1}\), with 1000–2500 hours of sunshine per year (30, 32). However, unpredictable cloudy weather, especially in the north, thwarts the adoption of solar energy systems (32). The most popular applications for solar energy are dryers for agricultural products and water heaters, but again, the cost of these systems prevents wider dissemination. Wind energy resources are marginal in Vietnam, with a mean velocity of 3 m/s (32). The use of waste for the production of biogas is a promising and appropriate technology for Vietnam, but the capital costs are too high for the average rural user (14, 15, 30), and additional research is necessary to determine the impact on competing agricultural uses of biomass. In rural areas, the cost of a family-sized biogas digester of 2–3 m\(^3\) can equal the annual income of a typical user, excluding labor, which in pilot projects has been contributed by the user, and technological assistance, which is provided by the government (16, 21). To encourage the diffusion of this relatively expensive technology, the government has provided a “stimulating fund,” which provides one-third of the cost of construction of a digester to the first user in a district. The digester then serves as the pilot for that area, advertising the benefits of the technology.

The biogas dissemination program is considered a success, with 1200 families and collectives benefiting from biogas technology. These users do not need woodfuel or other sources of energy for cooking and lighting, have lower levels of air pollution in their homes, and can use the digester liquid as an effective and disease-free fertilizer (30). However, without
subsidies, rural users cannot afford to build digesters. Greater diffusion of the technology therefore awaits the development of a less expensive model (8, 30). Micro-hydro resources are plentiful, as described in the hydro-electricity section above. Subsidized micro-hydro units are being successfully disseminated in the highland regions (32, 33, III, VI). The main thrust of rural energy planning is to encourage sustainable use of forest resources and to increase the efficiency of biomass use through the dissemination of improved stoves. Biogas digesters are often seen less as a means of producing energy than as a way to dispose of waste. Biogas, improved stoves, micro-hydro power, and windmills in some areas of southern Vietnam and on the coast, have been adopted successfully.

However, many failures have also been associated with the dissemination of these systems. Problems have included a lack of information, a shortage of capital, and the high cost of operation and maintenance for some systems. The Chinese new and renewable energy program has been relatively successful, and may provide a model for Vietnam, which, like China, has a high population density, a large and poor rural sector, and a broad energy resource base to exploit (34). China has made efforts to bolster economic development through energy conservation and the dissemination of small-scale renewable energy technologies, most notably improved biomass cookstoves (35). The improved cookstove dissemination project in China was a phenomenal success, and reached more than 100 million families at a cost of about US$ 2 per stove. A similar program is under way in Vietnam (see the Biomass section, above). With a progressive new and renewable energy program already in place, it is evident that an investment of seed money by international donors would catalyze the development and dissemination of more efficient small-scale renewable energy technologies. This strategy has become increasingly popular, with good results, for similar small-scale energy technologies (36).

A DYNAMIC ENERGY SECTOR

Both the past and future trends in Vietnamese energy production and consumption demonstrate a most dynamic energy sector. A number of energy planning lessons can be learned from the Vietnamese example. The evolution of energy elasticity (Table 5) in Vietnam is quite remarkable. The post-war (1976–1980) values for the consumption elasticity, defined as the percentage change in consumption divided by the change in GDP, in the oil sector, $e_{oil} = -6.8$ and for all energy, $e_{total} = 9.1$, indicate a volatile situation. Initial Soviet-style emphasis of the industrial sector were ill suited to the agricultural and family business–oriented Vietnamese economy. During the 1980s, $e_{oil}$ remained stagnant owing to poor national management, lack of free-market incentives (instituted only in 1988), and lack of domestic
Table 5 Oil and total energy elasticity, 1976–1990

<table>
<thead>
<tr>
<th>Period</th>
<th>Average annual growth</th>
<th>Elasticities</th>
<th></th>
<th></th>
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<tr>
<td></td>
<td>Income</td>
<td>Oil</td>
<td>Energy</td>
<td>$e_{\text{Oil}}$</td>
</tr>
<tr>
<td>1976–1980</td>
<td>0.4</td>
<td>-2.7</td>
<td>3.7</td>
<td>-6.8</td>
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<tr>
<td>1980–1985</td>
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<td>7.4</td>
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<tr>
<td>1985–1990</td>
<td>3.1</td>
<td>1.4</td>
<td>7.5</td>
<td>0.4</td>
</tr>
</tbody>
</table>

The elasticity is defined as the annual percentage change in the consumption of the commodity (here, oil or total domestic energy consumption), divided by the corresponding change in domestic product, or income. For some years energy consumption figures were based on production tables, which is a reasonable proxy in Vietnam where demand has exceeded harvested (biomass) or refined (fossil-fuel) supply up to the present. The value of $e_{\text{Total}}$ for 1976–1980 is anomalous: while economic growth appears nominal, there was significant demobilization and reconstruction of the basic infrastructure and social service networks. Post-1985 values are more comparable with those of other nations (36). The gray economy, however, constitutes roughly 50% of total economic activity.

The prospects for future growth, particularly in the oil and gas sectors, are also interesting. The forecasts for oil production over the next decade (Figures 9–11) suggest that Vietnam can triple or quintuple oil revenues. Vietnam would become one of the largest Asian oil producers, with Japan a ready market. The importance of this supply in light of declining US and Russian reserves is substantial even in the face of a weak petroleum market.

NATIONAL PLAN FOR ENVIRONMENTALLY SUSTAINABLE DEVELOPMENT

“If we shoot a pistol at the environment, it will fire a cannon back at us.” These words of the Vietnamese Vice-Minister of Transport exemplify the high status of environment issues in the eyes of a new generation of policy-makers (VII). Whether words will be translated into action remains to be seen, but Vietnam has laid the groundwork for environmentally
responsible development with the formulation of a comprehensive National Plan for Environment and Sustainable Development 1991–2000 Framework for Action (13). This document follows on the heels of a 1985 publication, the Vietnam National Conservation Strategy (12). Although few of the recommendations of the earlier work were carried out (VII, IX), it is a thorough review of the environmental resources of the country, and provided the background for the 1991 package. A summary of the specific recommendations for the energy sector are listed below as they appear in the Framework for Action plan:

* All energy projects should undergo an environmental impact assessment during their planning stage, in order to integrate environmental considerations into the engineering designs of the project and to ensure that mitigating measures are employed.

* The efficient use of energy should be established through the development of energy-efficiency standards for all end-uses of energy.

* Maximization of energy use efficiency, and planning for expansion of electricity supply, should be conducted through integrated planning and policy development in all sectors (41). Energy-efficiency and conservation can help to reduce the need to expand energy supplies, a desirable objective as increases in energy consumption can be accompanied by significant environmental costs.

* To the extent feasible, the country should rely on clean, renewable, and decentralized energy sources. When comparing the costs and benefits of these energy sources with the traditional, nonrenewable, and/or centralized sources, the latter's full environmental and social costs should be given the weight they deserve.

* All development projects, including buildings, tourism, road building, industrial facilities, and land use planning, should also be reviewed with an energy-efficiency assessment.

Hard evidence of concern over the environmental ramifications of development projects is slowly beginning to appear. The Hoa Binh dam/reservoir project, one of the largest in the world, has been the subject of at least two preliminary environmental impact assessments (37, 38), with the hope that these will spur more comprehensive reviews of Hoa Binh and other projects.

RESOURCES FOR DEVELOPMENT: CAPITAL

Vietnam hopes that substantial funding for the development of its energy infrastructure will come from external grants or concessional funding (1). The role of foreign aid in long-term development, however, can easily be overstated. Sustained economic growth will likely depend on domestic
savings and guarantees of reasonable rates of return, particularly in the energy sector.

Aid levels reached US$ 2 per capita in 1987 according to the United Nations Development Programme (UNDP). By contrast, Bangladesh received aid of US$ 15 per capita (1). This disparity may be attributed to the political isolation of Vietnam that occurred after its invasion of Cambodia in late 1978, and to the policies of some donor nations, Canada for example, to link aid with the status of human rights in recipient nations. Now that the US veto on International Monetary Fund (IMF), ADB, and World Bank funds is being lifted, they will become significant sources of capital (39). Since the dissolution of the Soviet Union, Russian consultants for engineering projects such as hydropower plants have been paid in hard currency, whereas previously they had been paid for with exports of Vietnamese goods (IV). Vietnam has now to find sources of capital and affordable consultants and a market for its products.

CONCLUSIONS: OUTLOOK FOR DEVELOPMENT

Vietnam’s combination of diverse energy resources, large population, low labor costs, and proximity to the dynamic Asian economic community suggests that Vietnam could rapidly make the transition from a poor developing nation to a rapidly industrializing one. Paramount in determining the direction of development over the next decade is the change in US-Vietnamese relations. Allowing Vietnam access to international credit institutions such as the World Bank, the Asian Development Bank, and the International Monetary Fund will improve its chances of economic recovery. Current levels of foreign investment are about US$ 150 million annually, which is not enough to ensure the success of the Doi Moi economic reforms (40–42) or to substantially spur development.

Evidently, Vietnam must work to convince investors of its stability and of its determination to limit corruption. According to the UNDP, Vietnam needs capital infusions of US$ 4 billion per year over the next five years if it is to develop its infrastructure and re-equip its industries (41, 42). Without these funds, Vietnam’s near-term development outlook is dim. To achieve its development goals, Vietnam must renovate its energy production and delivery system, as detailed above. Planning and policy-making in this sector will be aided by an energy data bank for Indochina, called Enerdata, now being compiled at the Hanoi Institute of Technology in collaboration with the Asian Institute of Technology (I).

Important target projects for foreign investment or aid include concessional funding of the major hydropower projects, the exploitation of coal reserves, transmission facilities, and the development of the power grid. Planning of an integrated national power system will require technical assistance and
the training of Vietnamese experts. Specific issues such as energy pricing policy need examination and would benefit from input from foreign experts.

Biomass is still the predominant form of energy used in Vietnam, and its consumption is leading to widespread deforestation. Restructuring the energy supply must therefore involve forest management and the development and dissemination of alternatives to biomass for cooking, all of which require outside sources of funds. Strategies for the modernization of existing facilities is another matter for consultation with foreign experts (1).

Vietnam represents a good investment for foreign aid and commercial ventures. The country has extraordinary human resources: the population is highly educated, hard working, and endowed with ingenuity. The nation’s natural riches, including the oil reserves, are irresistible to foreign investors (43–45). Vietnam’s economic growth rate has doubled in the past year (40), in spite of low levels of foreign investment and development aid and the denial of credit. With access to capital and with the continuation of support for the Doi Moi reforms, Vietnam could well become another Asian success story.

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INTERVIEWS

The lack of published literature necessitates partial reliance on oral interviews: the following individuals are thanked for their helpful contributions to this study. Interviews were conducted in November, 1991 and from June to August, 1992 in Hanoi, Vietnam, and in Bangkok, Thailand, and in September, 1992 in Hawaii. Interviews are cited in the text with Roman numerals.

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XIII. South China Sea Project, University of British Columbia. Professor I. Townsend-Gault.
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