Appendix A

TIME-SERIES ENERGY CONSUMPTION DATA: DEFINITIONS AND METHODOLOGY

This appendix sets out some details of the collection of the commercial energy consumption data used in Chapter 2. The data cover the years from 1960 to 1980 (inclusive), and they are plotted in Figures 2.3, 2.5, 2.7, 2.9 and 2.11.

Measuring Energy

Any analysis of energy demand begins with the conversion of the energy contents of different fuels to a common unit of measurement. There are numerous units that are widely used. Whatever the unit selected, calories or joules, tonnes of coal equivalent or kilowatt-hours, the results will be similar. The units that are often used in the national energy statistical publications of the ASEAN countries or in studies carried out by energy or related establishments in these countries are: Indonesia, barrels of oil; Malaysia, barrels per day of oil; the Philippines, barrels of oil; Singapore, tonnes of oil; and Thailand, litres of oil equivalent and calories. It can be seen that the unit favoured varies. In this study, the tonnes of oil equivalent (TOE) is adopted, and energy consumption is given in multiples of this unit. The base used for oil equivalency comprises 42 GJ (gigajoules) or 10.0 Gcal (gigacalories) per TOE.

The energy content of fuels has a dual value; a gross value and a net value. The difference between the two is the latent heat of condensation of the water vapour produced during combustion of the fuel. The difference varies with the hydrogen content of the fuel. It is of the order of 4 to 7 per cent in liquid fuels, 10 per cent in gaseous fuels, and 2 to 5 per cent in coal. In this study, the lower value, or net value, is used for all fuels.

Energy Equivalents of Fuels

The energy equivalents of fuels used in this study are summarized in Table A1. A brief description follows.

Petroleum: The energy contents of crude petroleum and petroleum products are closely related to their specific gravity. Throughout this

study the average taken for crude petroleum is 42 GJ per tonne of crude (the terminology "crude petroleum" is synonymous with crude oil). A single calorific value is also adopted for each petroleum product. The energy contents of petroleum products do not vary too much if they are measured on a weight basis. A tonne of fuel oil contains about 15 per cent less energy than a tonne of LPG. On a volume basis, however, a barrel of fuel oil contains about 70 per cent more energy than a barrel of LPG. In energy analysis, it is therefore preferable to measure petroleum products on a weight basis than on a volume basis.

Coal: Coal comprises a wide range of products which differ greatly in their energy contents. The energy content of anthracite is in the range of 0.65 TOE to 0.75 TOE per tonne, while that of bituminous coal varies greatly from 0.40 TOE to 0.70 TOE per tonne. Brown coal or lignite is young coal, and its energy content varies between 0.20 TOE to 0.40 TOE per tonne. Different types of coal are sometimes used for different purposes. For example, coking coal is needed in steel-making while generally lower quality coal is used in electricity generation. The calorific values which are representative for coal consumed in the ASEAN countries are shown in Table A1.

Gaseous fuels: A standard calorific value of 0.83 TOE per thousand cubic metres is used for natural gas. In ASEAN countries, manufactured gases are usually gas derived from petroleum products. These gases have a lower heat content than natural gas and an average of 0.39 TOE per thousand cubic metres is assumed.

Hydroelectricity: There are several ways of converting hydroelectricity (the same for nuclear and geothermal electricity) to a thermal basis. These include the following two most commonly used conventions: the conversion as if it incurred no losses and the conversion as if it incurred the same losses as fossil fuel generation. As only about one-third of the energy content of the fossil fuel burned in a fossil fuel-based power plant is transformed into electricity, the choice of convention can lead to a significant difference in the contribution of hydroelectricity to total energy consumption. In this study the second convention has been adopted. The conversion factor, or the efficiency of electricity generation, is defined here as the gross generation (including plant own use) divided by the total fuel input in a fossil fuel-fired power plant. The efficiency differs from one plant to another. The average also varies from country to country, and from one year to another in a country. For each ASEAN country, the average efficiencies for 1960 and 1980 are computed from actual data, and the efficiencies for years between 1961 and 1979 (inclusive) are interpolated linearly.

Commercial Energy Consumption: Definitions and Coverage

The various types of fuels in the time-series consumption data are:

(a) Petroleum
    - Liquefied petroleum gases (LPG)
    - Gasolines (aviation and motor gasolines)
    - Kerosenes
    - Jet fuels
    - Diesel fuels (distillate fuel oils)
    - Fuel oils (residual fuel oils)
    - Refinery use

(b) Coal

(c) Natural gas

(d) Primary electricity

In addition to these fuels, time-series data on total electricity generation and GDP were also collected and plotted on a per capita basis in Figures 2.14 and 2.18 respectively.

Petroleum products: To carry out a detailed analysis of the energy demand patterns in a country it is impractical to measure total petroleum consumption in terms of the crude petroleum available for consumption (that is, production plus imports less exports). Firstly, petroleum products are widely traded. The crude petroleum available for consumption after refining may be exported. Similarly petroleum products may be imported to supplement those produced locally for domestic needs. Secondly, it is sometimes necessary to treat bunkers, petroleum for non-energy uses and aviation fuels separately (bunkers are fuel supplied to ships in international transportation, irrespective of flag of the carrier). Crude oil consumption series does not provide a breakdown of these categories of consumption. In this study petroleum consumption is taken as the total internal consumption of energy petroleum products (excluding petroleum products for non-energy use) plus refinery use. The petroleum products included are the six categories listed above. Gasolines include aviation gasoline and motor gasoline. In ASEAN the consumption of aviation gasoline was insignificant compared to motor gasoline and jet fuel, especially in more recent years. Jet fuel and aviation gasoline consumptions include that part supplied to overseas bound aircraft. It is difficult, particularly in time-series covering 21 years, to separate the amount of these fuels which were used locally from that used by aircraft on international service. Since jet fuel consumption is treated separately it could easily be excluded from the total petroleum product consumption if necessary. The series on diesel fuel and fuel oil consumption do not include bunkers.

Refinery use: The main problems involved in including refinery fuel use (petroleum or gas used as refinery fuel, and processing losses) are the high fluctuations of consumption from year to year, particularly in Indonesia and Singapore. This raises the question of whether

there is a need to include refinery use in the energy consumption series. For Malaysia, the Philippines and Thailand, the inclusion or exclusion of refinery use does not significantly alter the trend of commercial energy consumption between 1960 and 1980. In these three countries the annual refinery throughput roughly equalled the annual domestic demand for petroleum products, and hence fuel use in refineries increased more or less in line with domestic petroleum product consumption. In Singapore, and in Indonesia in the earlier years, petroleum refining has been an important industry and has made important contribution to their economies. In the identification of the relationship between energy demand and economic growth, it appears relevant to include the energy used in this industry. The first refinery was not in operation until 1964 in Thailand and until 1961 in Singapore; refinery use was nil prior to these years in the respective countries. Because of year to year fluctuations, it is thought useful to have a series which shows the trend of refinery consumption rather than the actual consumption in each year. One possible way of doing this is to average the ratios of refinery use to the total refinery output for all years between 1960 and 1980, and multiplied to the average by the refinery output for all years to give a series. This method has been adopted in this study. If the total refinery output increases at the same rate as the total inland petroleum product consumption, the refinery consumption series would follow the same trend as the total inland petroleum product consumption. However, in Indonesia and Singapore, trade of petroleum products was significant. Refinery output therefore did not follow closely internal consumption. Adjustments were therefore made on their computed series to reduce the year to year fluctuations with the application of the simple moving average method.

Coal: The consumption series on coal represents total coal consumption, including coal used in mines wherever possible. Imports and exports of coal were taken into account, and different calorific values were used for different types of coal.

Natural gas: Natural gas was produced and consumed in Indonesia and Malaysia. It is difficult to obtain a reliable time-series on the actual consumption as gas produced was not only used for energy and non-energy purposes, but was also flared, lost or re-injected into the oil fields. For simplicity, in Indonesia, we treated that part of gas produced which was not flared, lost or re-injected as the gas consumed. Between 1960 and 1980 most of the gas produced in Malaysia was flared, and the actual inland consumption of indigenously produced gas was insignificant. A small amount of natural gas was, however, used in Sarawak, mainly in brickworks. The United Nations' *Yearbook of World Energy Statistics* (WES) gives data on the gas that was imported from Brunei to Sarawak for this use. With no further information, the gas imports between 1960 and 1980 were taken as the consumption series for Malaysia.

Primary electricity: Hydroelectricity was the only important primary electricity source in the ASEAN countries. There was no nuclear generation between 1960 and 1980, but generation by geothermal energy at a commercial scale began in 1979 in the Philippines. The series on electricity include both the public generation and generation by self-generating industries wherever possible. Electricity was traded between countries, between Laos and Thailand, and between Malaysia and Singapore. They were mostly done in a small scale. It is therefore not taken into account in the series except imports by Thailand from Laos in 1980 which were more substantial. The imports, measured in primary energy equivalent, were included under hydroelectricity consumption.

Energy Consumption Series for the ASEAN Countries

The main difficulty involved in studying the energy demand of the ASEAN countries is the problem of data availability. There is as yet no one single central source which gives reliable time-series on energy consumption for the five ASEAN countries. For individual countries data are available in certain publications such as national statistical yearbooks, annual reports of energy utilities, and research papers or reports. However these data are highly scattered, usually uncoordinated and not sufficiently comprehensive; they either cover short time spans or are for only certain types of fuels. It is also not uncommon that different consumption figures are given in different sources. This is usually due to variations in coverage, fuel classifications, or in conversion factors for converting different fuel consumption into a common unit of measurement. Unfortunately the definitions and conventions used are usually not specified in these sources.

The consumption series used in this study are based on the database built up by the author. The data were collected from many sources, including national and international publications, and unpublished data provided by a number of energy companies (oil companies and electricity utilities). They have been converted or adjusted to conform to the definitions and conventions described in the preceding sections. A list of the principal data sources is shown in the section, Data Sources. A brief description of data collection and of the time-series for individual countries follows.

Indonesia: Consumption data on petroleum products are available in two separate sources, and there are marked differences between the data given in these two sources. In WES the apparent consumption of energy petroleum products in 1960 is given as 8.0 million tonnes of coal equivalent, or 5.3 MTOE according to the conversion factor used by the United Nations. The consumption remained at about the same level, or even declined in certain years, during the early and mid-1960s. Consumption in 1970 is put at 6.7 MTOE. Data given in the national statistical sources, however, show the con-

sumption of energy petroleum products (excluding bunkers and refinery fuel) increased fairly consistently from 3.9 MTOE in 1960 to 5.6 MTOE in 1970. There are three possible explanations why the data given in WES show highly irregular series and are so different from the national statistics. Firstly, Indonesia was an important petroleum refinery centre in the region prior to the mid-1960s. The apparent consumption series in WES was derived by using the formula "production + imports − exports − bunkers" and this gives the consumption a small residue element derived from calculation between large aggregate series. The apparent consumption figures are therefore sensitive to a small variation in the data on production and trade (the same applies to the data for Singapore in WES). Secondly, in WES refinery fuel use is included in energy consumption which are omitted by the national sources. Refinery fuel consumption in the 1960s was high compared to total petroleum product consumption and changes in refinery fuel use might have been substantial from year to year. Thirdly, the mid-1960s was a period of political unrest in Indonesia. Most statistics for the period, including energy statistics, were poor in quality. The consumption series used in this study were based largely on those given in the national statistical sources. These with estimates of refinery fuel use give the total petroleum consumption. Data on natural gas include only that used as fuel and for non-energy use purposes, as already mentioned. Coal consumption data for Indonesia are well-documented though data on hydroelectricity production are less so. Our hydroelectricity consumption series is largely based on that given in the WES.

Malaysia: National statistical publications do not give any energy consumption data apart from data on electricity generation and consumption. The petroleum product consumption series given in this study are based largely on data provided by energy companies or given in WES. The coal consumption series is based on that given in WES. Time-series on hydroelectricity production is well-documented. The natural gas consumption series used has already been noted earlier. All consumption figures prior to 1964 are the aggregates for Peninsular Malaysia, Sabah and Sarawak.

Philippines: Complete consumption series on petroleum products from 1960 to 1980 are not available from any one source except WES. Our series consist of data collected from many sources, including various national statistical publications and data provided by energy companies. Consumption for missing years was estimated from the data given in WES. As the data for the other ASEAN countries, the data for the 1970s are of better quality than for the preceding decade. Hydroelectricity and total electricity production in the earlier years may not be as good as those for the other ASEAN countries as the electricity sector in the Philippines, unlike in these countries, consisted of more than 400 public and private utilities. Coal

consumption data were collected from WES and various national statistical publications, but a different calorific value from that used in the original sources was adopted.

Singapore: No comprehensive energy data are available from any national statistical source except those on the production and consumption of electricity and manufactured gas. The consumption series on petroleum products were based on data provided by oil companies and data given in various conference papers presented by the Public Utilities Board of Singapore. The gasoline consumption series includes the consumption of naphtha which was used mainly in gas production. The coal consumption series was taken from WES. Singapore exported electricity to Malaysia between 1960 and 1963, and after 1978. The exports amounted to 7.3 per cent of total production in 1963 but less than 2 per cent in 1980. As mentioned earlier, fuel oil that was needed for the production of these electricity was not excluded from the consumption series.

Thailand: Energy statistics are published annually by the National Energy Administration, and Thailand is the only ASEAN country where this has been carried out by the government in a systematic way. Petroleum product consumption estimates in these publications are taken as refinery production plus imports less exports, and do not take into account stock changes. Bunkers are also not treated separately. Notwithstanding this the data are relatively good, and the petroleum product consumption series used in this study were largely based on the data given in these statistical publications. Coal consumption and hydroelectricity generation are readily available. Different calorific values were used for coal produced in different mines, and a different calorific value was also used for the imported coal which was of better quality than that produced locally.

Table A1

Energy Equivalents of Fuels (Net Values)

Fuels	TOE per tonne	TOE per barrel
Liquid fuels		
Crude petroleum	1.00	0.137
Liquefied petroleum gases	1.11	0.086
Gasolines	1.06	0.124
Kerosenes and jet fuels	1.04	0.134
Diesel fuels	1.02	0.141
Fuel oils	0.96	0.145
Chemical feedstocks	1.06	0.121
Naphtha	1.06	0.121
Lubricants	1.01	0.145
Bitumen	0.93	0.153
Other non-energy oils	0.94	0.134
Solid fuels		
Anthracite and bituminous		
Indonesia	0.60	—
Philippines	0.50	—
Other ASEAN countries	0.65	—
Lignite and brown coal		
Thailand (average)	0.38	—
Non-commercial fuels		
Fuelwood (0.72 gm/cubic cm)	0.38	—
Charcoal (0.40 gm/cubic cm)	0.67	—
Crop residues	0.30	—
Bagasse	0.20	—
Gaseous fuels (TOE per thousand cubic metres)		
Natural gas	0.83	—
Manufactured gas	0.39	—

Hydroelectricity in primary energy terms

	MTOE per TWh		Generation efficiency (%)	
	1960	1980	1960	1980
Indonesia	0.44	0.32	19.6	27.0
Malaysia	0.36	0.25	24.0	34.7
Philippines	0.34	0.26	25.0	33.3
Singapore	0.32	0.24	27.0	35.4
Thailand	0.41	0.24	21.1	35.0

Note: The base for oil equivalency is 42 GJ (gigajoules), or 10.0 Gcal (gigacalories) per TOE.