DATA ON ENERGY END—USE PATTERNS AND ENERGY EFFICIENCIES IN MAJOR CO₂ EMITTING COUNTRIES

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EXECUTIVE SUMMARY

This is a report of the basic data regarding energy end-uses and efficiencies in major CO₂ emitting countries. The task is part of the multi-lab carbon dioxide energy system research program. The work is conducted by Brookhaven National Laboratory (BNL) for the U.S. Department of Energy (DOE), Office of Health and Environmental Research (OHER), Carbon Dioxide Research Program (CDRP).

Fossil energy production and use are the largest anthropogenic source of CO₂ emissions. To gain an insight into the relationship between CO₂ emission and energy use, the global energy consumption patterns and the changing energy efficiencies must be better analyzed and understood. Previous efforts to analyze global energy use patterns has been pursued on a regional basis (Edmonds and Reilly, 1985). This analysis has led to the conclusion that CO₂ emissions varied widely among regions and among countries within regions. Earlier research (Kellogg et al., 1987) has identified a set of countries responsible for significant present and anticipated future emissions of CO₂. Clearly, the energy use patterns and efficiencies of these countries are of critical importance to the analysis of future global CO₂ emissions and in any discussion of international global-change policies.

This work attempts to collect and organize the data on energy use and energy efficiency for the ten major CO₂ emitting countries: U.S.A., U.S.S.R., the People's Republic of China, Japan, the Federal Republic of Germany, the United Kingdom, France, Canada, Italy, and Australia. In 1980, these ten countries combined to account for more than 65 percent of global CO₂ emissions. Any international initiative to curtail future global CO₂ emissions would require the cooperative collective efforts of these ten key CO₂ emitting countries to improve their energy use.

A wide variety of information sources have been examined. These sources include, but are not limited to, the United Nations, the World Bank, the World Resource Institute, International Energy Agency, the U.S. Congress' Office of Technology Assessment, Department of Energy, Central Intelligence Agency, Resources for the Future, journal articles, books, and reports from various National Laboratories. For any data collection effort of this type where a great deal of data are obtained in many different forms from many different sources, crosschecking and comparing the related items are critically

important. Hence, one of the major activities in preparing the data base has been to reconcile such differences so that data in different forms from different sources become comparable.

In many instances where the data may, depend on the sources, not be consistent, the researcher's judgment was employed to ensure the accuracy of the data. In other instances, only one source for the data has been found, and in still others, the data have not yet been publicly available, especially so far for the Soviet Union and China. To fulfill the required level of detail, many data were derived by the researchers from obscured, vague information. All energy data were converted into common units of measurement (e.g., joules per year) to facilitate their use for analysis.

Since each source has different limitations and is not homogeneous in quality, every effort is made to ensure the data, which has been pieced together from many sources, as complete and accurate as possible. In order to establish the historical trend, the energy use data base was developed for the three benchmark years of 1975, 1980 and 1985. The resulting data base is a significant improvement to what presently OHER-CDRP has by way of an extensively detailed, consistent country-specific energy data base.

The data base is presented in tabular format. It is documented by three main parts, the first shows the total final energy consumption by fuel type and end-use sector for each nation. The second shows the detailed energy use by fuel type and function for each end-use sector: residential, commercial, transportation and industrial. The third part shows the country-specific energy balances for electricity generation and use. The data base is a living document and will be updated as additional information becomes available. Since the data base is to be used to accomplish the ultimate objective of improving the reliability of future CO₂-emissions estimates, many features of energy consumption were presented in detail for developing the analytical capabilities to assess the contributions of key countries to future fossil fuel consumption. Opportunities may also be developed through analyzing energy uses for markedly increasing energy efficiency to provide the options to control emissions, and assess their feasibility, efficiency and costs.

Conclusions

1. The data collection of different national energy consumptions requires an exhaustive survey of books, reports and articles published by a

wide range of organizations. Many data have to be estimated with the help of hints, allusions and vague indicators from a host of different sources, and these estimates are obviously open to distortions from a variety of causes. In any case, the resulting data base is a significant improvement to what presently OHER-CDRP has by way of an extensively detailed, consistent, country-specific energy data base. However, this data base should not, by any means, be accepted as all-inclusive. Much room remains for improvements, and especially expansions to include other key CO₂-emitting developing countries such as Brazil, India, Mexico, and Poland.

2. The data provides an insight to recent patterns of energy uses and fuel mixes in the major CO₂ emitting countries. From this insight, possible changes in fuel mixes (e.g., fuel substitutions) and potential energy savings, especially fossil fuels, can be made through intercountry comparisons and/or other means. In other words, the data base is suitable for uses such as estimation of future total energy demands, forecasting and study of conversion and fuel substitution.

3. The data can be used as a basis for energy analysis to identify the global trends and growth rates of demand for energy services in major CO₂ emitting countries, and to examine the energy efficiencies and their potential improvements through technology advancement.

4. Regarding the improvement of energy use, there is no single use which will significantly reduce the CO₂ emissions. There is no single technological fix either. Furthermore, there is no single nation that can respond unilaterally to solve the problem. However, there are many possibilities in all sectors in different countries which could collectively have a large impact in mitigating CO₂ emissions.

5. Analysis of the data will shed light on the question about efficient energy use in an international context. How will efficient energy-use programs fare in different countries. The potential for improvements in energy efficiency in all sectors remains dramatic in the future, and constitute the cornerstone of a comprehensive strategy for reducing future CO₂ emissions.

6. The data base can be used as initial conditions in the development of economic-energy models to predict future global energy use and to construct and study CO₂ emission scenarios.

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I. INTRODUCTION

This is a report of the basic data regarding energy uses and energy efficiencies in major CO₂ emitting countries. The task is part of the multi-lab carbon dioxide energy system research program. The work is conducted by Brookhaven National Lab (BNL) for the U.S. Department of Energy (DOE), Office of Health and Environmental Research (OHER), Carbon Dioxide Research Program (CDRP).

Gaining a better understanding of changing atmospheric concentrations of CO₂ and other greenhouse gases such as methane (CH₄), nitrous oxide (N₂O), Ozone (O₃) and chlorinated fluorocarbons (CFCs) and the associated environmental consequences of those changes is the major goal of ongoing OHER-CDRP research efforts. The specific concern is that such changes could lead to undesirable global changes in the environment including global warming.

Gases such as CO₂, CH₄, O₃ and CFCs are called greenhouse gases because they let radiant energy into the atmosphere more freely than they let it out. Thus, the planet's average surface temperature could increase with the atmospheric concentrations of greenhouse gases, because more heat is trapped. CO₂ is generally considered to be the most important of these gases, accounting for about half of current and anticipated greenhouse warming.

Atmospheric CO₂ concentrations have increased approximately 25% from 1860 to 1985, attributable mainly to various anthropogenic activities, first from deforestation during the massive global expansion of agriculture, and now primarily from fossil fuel combustion. Since 1860, global annual emissions of CO₂ have increased from 0.1 to 5.0×10^{15} gC. In the period 1945 to 1979, the CO₂ emission rate due to fossil energy consumption grew at 4.5 percent per year. Since 1979, annual CO₂ emissions have stabilized at 5×10^{15} gC.

Except for methane and chlorinated fluorocarbons, greenhouse gas emissions produced currently by human activity are primarily related to fossil fuel consumption. It is the overwhelming source of current and anticipated CO₂ emissions. Therefore, to gain an insight on the relationship between sources of greenhouse gas emissions, especially CO₂ emissions, and energy use, the global energy consumption patterns and the changing energy efficiencies must be better analyzed and understood. Furthermore, an understanding of what the energy is used for and how it is used, and then carefully tailors technology to these circumstances is also prerequisite to efficient energy use.

To accomplish this goal, an important first step is the collection and organization of suitable global energy use patterns.

Since CO₂ global change is an international problem, it requires an international response to mitigate global CO₂ emissions. A key to the potential global change problem is when will a problem exist; the answer to when relates directly to future global and country energy use patterns. To understand the potential future global energy use patterns, and forecast the greenhouse gas emissions, one must understand the past and present patterns of energy uses and energy efficiency development processes. Previous efforts to analysis global energy use patterns has been pursued on a regional basis (Edmonds and Reilly, 1985). This analysis has led to the conclusion that CO₂ emissions varied widely among regions, and among countries within regions. Thus, future efforts will need to focus on the more detailed country-specific energy uses and emissions of CO₂. Earlier research (Kellogg et al., 1987) has identified a set of countries responsible for significant present and anticipated future emissions of CO₂. Any international initiative to curtail future global CO₂ emissions would require the cooperative collective efforts of these major CO₂ emitting countries to improve their energy use.

Table 1. The Comparison of Thermal Efficiencies of Major Energy-Use Devices/Processes Between Developed Countries and China

	Efficiency, %	
	Developed Countries	China
Fossil power plant	35-40	28
Industrial boiler	70-80	55
Steel production	50-60	28
Synthetic ammonia	50-60	25
Rail transport	20-25	6
Cooking stove	60-70	16

The demand for energy is not a demand for energy as such, but reflects demands for heat, lighting, and mechanical work etc. In so far as energy efficiency aims at reducing the losses in the use of energy, energy use must be measured not only in terms of the energy consumed in each end-use, but also

by the nature and efficiency of its conversion to useful forms. Technological improvement can dramatically reduce the amount of energy required to provide a given level of good and service. Various studies have shown that considerable energy efficiency gains in all sectors of economy are possible in the future, and constitute the cornerstone of a comprehensive strategy for mitigating the future greenhouse gas emissions.

To assess the potential for future energy savings and reductions in CO₂ emissions, effort is required to collect and improve the quality and quantity of the data on energy efficiency for the key CO₂ emitting countries. By doing so, the evolution of existing energy efficiency and differences among countries can be better understood. Table 1, which shows the comparison of energy efficiencies for major energy-use devices/processes between the developed countries and China (Lu, 1986), demonstrates the potential for energy savings in developing nations and consequent reduction of CO₂ emissions that is possible by using the improved energy technology.

This work attempt to collect and organize the data on energy use and energy efficiency for the ten major CO₂ emitting countries: U.S.A., U.S.S.R., the People's Republic of China, Japan, the Federal Republic of Germany, the United Kingdom, France, Canada, Italy, and Australia. In 1980, these ten countries combined to account for more than 65 percent of global CO₂ emissions, approximately 85 percent of the global coal resource base, 76 percent of world GNP, 55 percent of the world's population, and 40 percent of the world's ruminant livestock which is important in methane emissions. Clearly, the energy use patterns and efficiencies of these ten countries are of critical importance to the analysis of future global greenhouse gas emissions and in any discussion of international global-change policies.

II. OBJECTIVE

The basic objective of this study is to develop a comprehensive data base of energy end-uses and efficiencies for the ten major CO₂ emitting countries than have heretofore been available to the OHER-CDRP, including the first time information on energy end-use patterns of U.S.S.R. and China. This data base is then to be used to accomplish the ultimate objective of improving the reliability of future emission estimates of CO₂ and other greenhouse gases. Many features of energy consumption were presented in detail for developing the analytical capabilities to assess the contributions of key countries to future

fossil fuel consumption. In addition, opportunities may also be developed through analyzing energy use for markedly increasing energy efficiency to provide the options to control emissions and assess their feasibility, efficiency and costs. This will help shedding light on the question: how will efficient energy-use programs fare in different countries?

III. ENERGY DATA BASE

Efforts to analysis the relationship between past and future greenhouse gas emissions and energy consumption require a comprehensive presentation of country energy use patterns and efficiencies containing end-use and fuel details beyond that currently available. Considerable effort has already been devoted to established historical data base and information on global and regional fuel uses and on energy technology efficiencies. These data have been collected independently by different researchers without cross-checking and comparing related items. Thus a fundamental problem with these data in that little attempt has been employed to place these data within an overall, integrated framework. This report attempts to meet this need. An energy end-use statistics in internally consistent balances, expressed in a common unit of joules per year, was developed for ten key fossil fuel CO₂ emitting countries: U.S.A., U.S.S.R., the People's Republic of China, Japan, the Federal Republic of Germany, the United Kingdom, France, Canada, Italy, and Australia.

Data to Collect

The energy data base is to be used as a reference data base for an enhanced global energy and carbon emission model (GECEM) which is being developed by Edmonds and his colleagues at Pacific Northwest Laboratory (PNL). Since the enhanced GECEM will model carbon emissions with emphasis on greater geographic and end-use details, the selection of specific data to include in the data base should be suitable to that level of detail. Accordingly, the country-specific energy end-use patterns were presented by breaking down the total final energy consumptions into three end-use sectors (residential and commercial, industrial and transportation) by fuel type of solid (coal, peat and biomass), liquid, gas, electricity, and heat (generated by combined heat and power plants). Final consumption is the energy delivered to the consumers, which implies that energy used in the energy production and transformation is excluded. Consumptions of different fossil fields produce different

rates of CO₂ emissions. Hence, to accurately estimate global emissions of CO₂, it is important to draw the distinction between the types and quantities of fuels being consumed.

The lack of end-use energy detail has been a significant barrier to energy/emission analysis, because types and quantities of greenhouse gases emitted from fossil fuel combustion vary not only with fuel types but also with end-use and conversion processes. To account for that complexity, final energy data is further disaggregated within each sector by end-use function, i.e., by pairing fuel type to its ultimate end-use function for the final energy needed to provide the required energy service. Energy efficiencies associated with various end-use function were also collected. With country-specific data at this level of detail, the details of the patterns of energy end uses by fuel type and sector in major greenhouse gas emitting countries can be better understood. This understanding is important to estimate how future energy demand is likely to develop for some countries and how this composite energy demand will affect future global economic growth and energy consumption patterns.

Electrification has important consequences for labor productivity, economic growth, and socio-economic development. In 1985, about 31% of global primary energy was used to generate electricity. The generation efficiencies were about 33% in the industrial countries, and 25% in the developing world. The industrial countries with about 25% of the world's population, produce approximately 75% of the world's electricity. This means that on average, per capita electricity use in the industrial countries is 9 times as much as people in the developing world. The significance of these simple ratios is that future global economic growth, particularly of the developing world will be associated with very large increases in electrification. Global electricity requirements are expected to increase, primarily because of growth of the service business and increased process automation.

Electricity generation is an energy-intensive process, even though electricity at the end use is not only convenient but also highly energy efficient. Most non-fossil energy such as nuclear, hydro, and solar which release no CO₂, is utilized in electricity generation. If the current trend toward electrification continues, significant changes in the structure of electricity generation are possible, i.e., increases in the share of non-fossil energy and generation efficiency. Such changes in efficiency and the pattern of fuel use

for electricity generation could have a significant impact in reducing future global emissions of greenhouse gases. With this in mind, the data on various fuels used in electricity generation with the associated generating efficiencies were collected.

In order to establish the historical trend, the energy use data base was developed for the three benchmark years of 1975, 1980 and 1985. The data base is organized in the form of tables which contain information on total final energy use, residential, commercial, industrial and transportation end-uses, and electricity generation. The tables can be updated as additional information becomes available.

Data Source

To collect the data on final energy consumption and efficiency, a wide variety of information sources have been examined. These sources include, but are not limited to, the United Nations, the World Bank, the World Resource Institute, International Energy Agency, the U.S. Congress' Office of Technology Assessment, Department of Energy, Central Intelligence Agency, Resources for the Future, books, journal articles and reports from various national laboratories. For any data collection efforts of this type where a great deal of data were obtained in many different forms from many different sources, crosschecking and comparing the related items are critically important. Hence, reconciliation of such differences so that data in different forms from different sources become comparable became one of the main activities in developing the data base.

In many instances where the data may, depending on the sources, not be consistent, the researcher's judgment was employed to ensure the accuracy of the data. In other instances, only one source for the data has been found and, in still others the data have not yet been publicly available, especially so far for the Soviet Union and China. To fulfill the required level of detail, many data were derived by the researcher from obscured information. All energy data were converted into common units of measurement (e.g., joules per year) to facilitate their use for analysis.

Since each source has different limitations and is not homogeneous in quality, every effort is made to ensure the data, which has been pieced together from many sources, as complete and accurate as possible. In any case, the resulting data base is a significant improvement to what present

Table 2 Final Energy Use by End-Use Sector and Fuel Type in the U.S.
in 1975, 1980 and 1985 (PJ = 10¹⁵J)

End-Use Sector	Year	Solid			Liquid	Gas	Electricity	Heat ^e	Total
		Coal	Other ^b						
Residential/Commercial	1975	217	457		4637	7459	3/13	--	16480
	1980	332	905		3302	7803	4595	--	16937
	1985	351	950		3029	7169	5339	74	16838
Transportation	1975	--	--		17209 ^c	--	14	--	17223
	1980	--	--		17987 ^c	--	11	--	17999
	1985	--	--		18759 ^c	--	13	--	18772
Industrial ^a	1975	2749	1121		6692 ^d	5942	2290	--	18794
	1980	2534	1459		8130 ^d	6145	2686	--	20957
	1985	2372	1801		6391 ^d	5396	2707	--	18113
Total	1975	2966	1579		28538	13401	6104	--	52580
	1980	2869	2364		29419	13948	7292	--	55890
	1985	2726	2751		28116	12565	8053	74	54280

^aIncludes agriculture but excludes petroleum refining industries.

^bIncludes peat, wood, industrial waste and garbage.

^cIncludes 142 PJ, 162 PJ and 138 PJ in 1975, 1980 and 1985, respectively for non-energy uses of petroleum products such as lubricants and waxes.

^dIncludes 1348 PJ, 1642 PJ and 1680 PJ in 1975, 1980, and 1985, respectively for non-energy uses (not for feedstock) of petroleum products such as white spirit, and paraffin waxes.

^eSupplies from combined heat and power plant (CHP).

Note: Totals may not equal sum of components due to independent rounding.

OHER-CDRP has by way of an extensively detailed, consistent country-specific benchmark energy data base.

Data Organization

The data base is documented by three main parts, the first shows the total final energy consumption broken down into three end-use sectors: residential/commercial, industrial and transportation. The second shows the detailed energy use for each end-use sector. The third shows the energy balance for electricity generation and use. The document is presented in tabular format. The blank spaces in the Tables mean the information is not available when the Tables were prepared. The "-" indicates the Figure is negligible.

Data Description

Total Energy Consumption

Total energy consumption is the sum of consumption by the different end-use sectors. The data base for country-specific final energy balances, expressed in a common unit of PJ (10^{15} J) per year, for the ten major CO₂ emitting countries are shown in Appendix B.

For industrialized nations such as U.S. and Japan, data have mainly been taken from IEA (IEA, 1987), while using data from national statistical publications or other reliable sources to crosscheck and fill in the necessary detail. For the Soviet Union and China, the data have been pieced together from different reliable sources. The data shown is "net" calorific value (NCV).^{*} Table 2 presents the typical data collected for total final energy consumption in the three benchmark years, using U.S. data as an example. The table presents energy data in internally consistent balance. Not all the detailed information needed to complete this data base is now available. Some data may not be publicly available or may never have been collected, especially for the U.S.S.R. and China.

Significant differences in both magnitude and the pattern of final energy consumption by fuel type exist in these countries. In the U.S., the shares of

^{*}The difference between the "net" and the "gross" calorific value is the latent heat in condensation of the water vapor produced during fuel combustion. For coal and oil, NCV is 5% less than gross. For most forms of natural and manufactured gas the difference is 9-10%, while for electricity and heat there is no difference.

energy consumption were more evenly distributed among three end-use sectors than those of the Soviet Union and China. For instance, for the U.S. in 1980, the respective shares of energy consumption are 30.3, 32.2 and 37.5 percent for residential/commercial, transportation and industrial sectors. In terms of fuel mix, the liquid fuels, of which 61 percent consumed by transportation, provides the largest share of 52.6 percent. Gas fuels provide the next largest share of 25 percent, with the remaining provided by electricity, 13% and solid fuels 9.4%. In the period 1975 to 1985, the shares of energy consumption by the three end-use sectors only varied slightly. The transportation sector increases its share from 32.8 to 34.6 percent at the expense of industrial sector, decreasing from 35.7 to 34.4 percent. For fuel mix, the electricity consumption increased from 11.6 to 14.8 percent, solid fuels (mainly due to biomass) from 8.6 to 10.0 percent, while liquid fuels decreased from 54.3 to 51.8 percent, and gas from 25.5% to 23.1%.

The largest share of the final energy consumption in the U.S.S.R. in 1980 falls to the industrial sector (67.9%), while residential/commercial (19.5%) and transportation (12.6%) accounted for much smaller shares. In terms of fuel mix, liquid fuels are the largest final energy source, account for 29.3% of the consumption, steam/hot water was the second biggest source with 23.4%, followed by solid fuels 21.4%, gaseous fuels 14.7% and electricity 11.2%. In China, while residential/commercial sector used 46.6% of the total final energy, it accounted for only 21% of the commercial energy. The industrial sector dominated commercial energy demand, accounting for 60% of the total in 1980. Due to the under-development of road transport, total energy consumption in China's transport sector accounted only for 8.8% of the total commercial energy or 6.0% of the total secondary energy use. The agriculture used 8.3% of the commercial energy or 5.0% of the total final energy. The important features of the mix of final energy sources in China are the dominance of coal in both the commercial (63%) and the total final use (44.3%), and the low share of electricity use (18% commercial, 12.7% total). In addition, biomass fuels, which are mainly used in rural households, are the second most important source of energy representing 29.6% of the total final energy consumption in 1980. Oil accounted only for 18.7% of the commercial energy demand or 12.6% of the total energy use. Gaseous fuels represented even a smaller share (3%) of the commercial energy use in 1980.

Table 3 Residential Energy Use by Fuel Type in Major CO₂ Producing Countries in 1980 (PJ=10¹⁵J)

	Coal/Coke	Liquid	Gas	Electricity	District Heat	Wood	Other	Total
U.S.A.	65.7	2015	5212	2581	-	907	-	10781
U.S.S.R.	2780		558	268	2093			
China								
Japan	23	410	236	418	-	-	-	1087
F.R. Germany	165	1101	370	308	60	13.0		2014
U.K.	283	112	816	310	-	-	-	1521
Canada ^a	-	545/433	468/507	326/260	-	15/37	-	1354/1237
France ^b	139	694	331	225	46	-	-	1420
Italy	15	522	276	146	1	26	-	986
Australia	2.5	33.5	46.9	104	-	66.1	-	253

a) 1978/1981 data. For 1980, the residential energy use, which is derived from the difference between the energy use of residential/commercial, and that of commercial sector, is coal: 135 PJ, Liquid: 753 PJ, Gas: 300 PJ, and electricity: 227 PJ with a total of 1410 PJ.

b1981 data.

Note: Totals may not equal sum of components due to independent rounding.

While U.S. GDP was about three times of that of Japan, U.S. consumes more than five times as much end-use energy as in Japan. Both countries relied heavily on liquid fuels as energy source, but the U.S. end-use energy consumption patterns also differ markedly from Japan. The largest share of the energy consumption in Japan in 1985 falls to the industrial sector (55.6%), while the remaining is about evenly shared by residential/commercial (22.5%) and transportation (21.9%). In terms of fuel mix, liquid fuels were the largest final energy source, account for 63.8% of the consumption, electricity was the second biggest share with 17.8%, followed by solid fuels 14.3% and gaseous fuels 4.0%. During the period 1975 to 1985, the shares of residential/ commercial energy use increased from 22.1 to 24.8 percent, transportation from 19.1 to 23.0 percent, while industrial dropped significantly from 60.7 to 52.2 percent. For fuel mix, electricity raised from 15.9 to 20.4 percent, gaseous fuels from 3.5 to 4.8 percent at the expense of liquid fuels, dropping from 67.2 to 60.5 percent, and coal, from 15.3 to 14.3 percent.

Detailed Sectoral Energy Consumption

A. Residential Sector

The data of detailed country-specific residential energy consumption and efficiencies is presented in Appendix C. Residential energy use in these countries ranges between extremes. In the Organization for Economic Cooperation and Development (OECD) countries, oil, gas, and electricity warm or cool air, heat water, provide light, refrigerate food and run appliances. However, in China, wood or dung is the principal fuel used mainly for cooking and heating.

Table 3 presents the residential energy consumption by fuel type and country in 1980. It shows that the fuel mixes in the residential sector varied considerably among different countries. While coal was the principal fuel in the Soviet Union and China, it was insignificant as energy source in the OECD countries, except the United Kingdom. Gaseous fuels were the largest energy source, accounted for 50% of the household energy use, in the U.S. and U.K. Liquid fuels were the main energy source (50%) in West Germany, France and Italy. In Japan, the fuel mix was more evenly shared by liquid fuels (38%), electricity (38%) and gaseous fuels (22%), with coal met the remaining need. Except in the Soviet Union, the district heat played an insignificant role as the residential energy source.

Table 4 shows the energy consumption by functional uses (e.g., space heat, water heat, cooking and appliances) and country for three benchmark years. The largest share of the household energy consumption falls to space heat, while water heat, cooking, lighting and appliances accounted for much smaller shares. The technical potential for energy savings in space heating hinges on improvements in building design and construction such as reduced air infiltration, better wall insulation, electronic indoor temperature control, and passive solar installation. Compared to Swedish homes (shown in Appendix C), the opportunities for reducing space heat demand are plenty in North America and Western Europe, where rates of energy use in this sector reflects both the climate and high income levels. More energy savings in space conditioning can be gained by replacing inefficient heating and cooling systems with improved ones.

In the Soviet Union, many people live in cities in multifamily dwellings, permitting efficient district heating. In China, where the rural households accounted for about 80% of energy use, the largest share of energy consumption is for cooking and heating. The increase in agriculture production, which has resulted in an increase of crop by-product available for fuel use, has been meeting the increasing demand for household cooking and heating fuels.

Tables 5 and 6 summarized the typical data collected to characterize the country-specific household energy use patterns, using the U.S. data as an example. In the decade 1975 to 1980, the shares of electricity and biomass as the U.S. household energy sources increased at the expense of gaseous and liquid fuels. In the same period, the energy intensity of space heat decreased by almost 30 percent, from 290 GJ/dw-dd-m² in 1975 to 210 in 1980. The information has mainly been taken from several reports of Lawrence Berkeley Laboratory (Schipper and Ketoff, 1981; 1983; 1985). The energy intensities in different functional uses can be used to analysis, assess and estimate the potential changes of fuel mixes and efficiencies in the residential energy use in these countries. The information on technology improvement in building, furnace, and boiler, lighting, and appliances was also collected and can be found in Appendix C.

B. Commercial Sector

The data of detailed country-specific commercial energy consumption is presented in Appendix D. The typical 1985 data collected by fuel type and

Table 4 Residential Energy Use by End Use in Major CO₂ Producing Countries in 1975, 1980, and 1985

	Space Heating			Water heat			Cooking			Appliances			Total		
	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985
U.S.A.	6708	6401		1740	1962		630	659		1420	1759		10498	10781	10500
U.S.S.R. ^d	2706			660			256			193			3815		
China															
Japan	328	301 ^a		356	422 ^a		160	163 ^a		172	246 ^a		1016	1132 ^a	1246
F.R. Germany	1453	1579		208	238		58.1	51.0		91.4	145		1811	2014	2116
U.K.	950	1074		296	284		141	146		126	128		1512	1668	1611
Canada	982	1011/859 ^b		181	201/218 ^b		26.1	25/33 ^b		114	119/127 ^b		1302	1354/1237 ^b	1059
France	1228/1061 ^c			143/192 ^c	210		112/145 ^c	110		70/99 ^c	106		1517/1496 ^c	1420	798
Italy	765	716		100	87.7		75.0	80.7		65.0	98.5		1005	986	776
Australia													239	253	273

^a 1979 data

^b 1978/1981 data

^c 1973/1978 data

^d 2973 PJ space heat and 325 PJ lighting and appliances with a total of 3118 PJ for commercial sector in 1975.

Note: Totals may not equal sum of components due to independent rounding.

Table 5 Characterization of and Final Energy Use in the Residential Sector in the U.S. in 1975, 1980, and 1985

	1975	1980	1985
Occupied dwellings (dw), 10 ⁶	72.5	80.1	88.4
Single-family dw (SFD), % of occupied dw	69.3	67.0	
Average dw size, m ²	125.0	128.0	
People per dw	2.91	2.78	
Central heating, % of dw	83.0	86.0	
Central heating SFD, %			
Dwelling stock vintage			
% built before 1950		40.0 ^a	
% built between 1950-1975		45.0	
% built after 1975		15.0	
Insulation of dw, W/m ² /°C			
Wall	0.49 ^b	0.5 ^c	
Roof	0.3	0.23	
Ground floor		0.82	
Final Energy Use, PJ			
Coal/coke	88.7	65.7	73.9
Liquid	2536	2015	1878
Gas	5299	5212	4747
Electricity	2117	2595	2853
District heat	-	-	-
Wood	457	907	950
Other	-	-	-
Total	10498	10795	10500
Energy Use per dwelling, GJ/dw			
Delivered	145	135	118
Useful	107	98	84
Space heat by fuel type, % dw			
Coal/coke	0.8	0.4	0.5
Liquid	28.2	23.8	15.3
Gas	56.4	55.4	55.4
Electricity	12.6	17.7	20.8
District heat	-	-	-
Wood	1.3	1.8	7.4
None	0.6	0.8	0.6

^a 1982 data. For construction after 1975, the data run through 1982.

^b For 1976 new home.

^c For 1980 new home.

Table 6 Residential Energy Use by End Use in the U.S.
in 1975, 1980, and 1985.

	1975	1980	1985
Degree-day (DD) index ^a	0.982	0.974	
<u>Space Heat, DD adj., PJ</u>	6831	6569	
Coal and coke		67.4	
Liquid		1699	
Gas		3596	
Electricity		303	
District heat		-	
Wood		903	
Other		-	
Space heat intensity			
Energy use per dwelling			
GJ/dw	94.2	82.0	
kJ/dw-dd-m ² , final energy	290	246	210
kJ/dw-dd-m ² , fossil fuel equiv.			
Useful energy, kJ/dw-dd-m ²	189	157	
<u>Water Heat, PJ</u>	1740	1962	
Coal and coke		-	
Liquid		327	
Gas		1038	
Electricity		327	
Wood		-	
Other		-	
Water heat intensity			
Energy use per dwelling			
GJ/dw, final energy	24.0	24.5	
GJ/dw, fossil fuel equiv.			
Useful energy, GJ/dw		17.0	
<u>Cooking, PJ</u>	630	659	
Coal and coke			
Liquid			
Gas		327	
Electricity		332	
Wood			
Other			
Cooking intensity, GJ/dw	8.7	8.2	
<u>Appliance energy use, PJ</u>	1420	1759 ^c	
Gas		118	
Electricity		1641 ^c	
Appliance intensity, GJ/dw	19.6	22.0	

^a Based on the adjusted yearly average heating degree-days of 2600 with base temperature of 18°C.

^b Includes coal and coke.

^c Includes 338 PJ of electricity used for air conditioning.

Table 7 Final Energy Use by Fuel Type in Commercial Sector in Major CO₂
Producing Countries in 1985 (PJ = 10¹⁵J)

	Coal	Liquid	Gas	Electricity	District Heat	Total	Total Floor Area Mm
U.S.A.	278	1151	2422	2486	74.1	6411	
U.S.S.R.							
China							
Japan	-	967	77.8	281	-	1326	
F.R. Germany	49.0	512	249	249	57	1117	
U.K.	56.1	219	257	224	-	756	
Canada	0.8	177	402	305	-	885	
France	-	729	250	204	-	1183	
Italy	-	52.3	491	99.6	-	643	
Australia	6.7	10.0	25.1	69.9	-	111	

Note: Totals may not equal sum of components due to independent rounding.

Table 8 Commercial Final Energy Use by Building and Fuel Type in the U.S.
in 1975 (PJ = 10¹⁵J)

	Coal	Liquid ^a	Gas	Electricity	Total	Floor Area Mm ²
Retail-wholesale	25.6	405	566	397	1394	486.7
Education	26.6	434	408	301	1170	609.5
Office	25.6	416	393	332	1167	496.5
Health Care	15.1	269	248	183	716	185.2
Lodging	11.0	178	165	70.6	424	134.2
Warehouses	5.0	77.1	73.1	54.0	209	212.7
Religious	4.5	70.0	66.1	39.8	180	130.4
Garage and service stations	1.4	20.8	19.8	15.8	57.7	57.4
Other	14.3	231	220	203	668	314.2
Total	128	2101	2159	1596	5984	2627

^a Includes liquefied natural gas.

Note: Totals may not equal sum of components due to independent rounding.

Table 9 Final Energy Use by Mode and Fuel Type in the Transportation Sector in U.S. in 1975, 1980 and 1985 (PJ = 10^{15} J)

Mode	Year	Solid	Liquid	Gas	Electricity	Total
Road	1975	--	14095	--	--	14095
	1980	--	14624	--	--	14624
	1985	--	15362	--	--	15362
Rail	1975	--	545	--	14	559
	1980	--	597	--	11	608
	1985	--	472	--	13	485
Air	1975	--	2144	--	--	2144
	1980	--	2340	--	--	2340
	1985	--	2648	--	--	2648
Water ^a	1975	--	282	--	--	282
	1980	--	265	--	--	265
	1985	--	138	--	--	138
Non-specified	1975	--				
	1980	--				
	1985	--				
Total	1975	--	17066	--	14	17080
	1980	--	17826	--	11	17837
	1985	--	18620			

^a Internal navigation.

Notes: Totals may not equal sum of components due to independent rounding.

country is shown in Table 7. Most data for the Soviet Union and China are not available so far. In the U.S., U.K., Canada, and Italy, gaseous fuels and electricity were the two major energy sources for commercial sector, while the largest share of the energy source falls to liquid fuels followed by electricity or gaseous fuels in Japan, West Germany, and France. Electricity is playing an increasingly important role as an energy source for commercial sector.

The typical country-specific commercial energy use by building (e.g., education, lodging, health care, office, etc.) and fuel type is shown in Table 8. In general, the retail-wholesale, office and education were the major energy users in this sector. Most of the opportunities for reducing energy consumption involve the use of more energy-efficient equipment and a better matching of energy supplies to energy service requirements via better control technology. Commercial buildings shell improvements other than for daylighting and sun control are less important. Lighting represented the major electricity requirement for commercial buildings. Hence, peak loads on utilities could be cut sharply with lighting energy conservation. In fact, air conditioning is often employed in these buildings in cold weather to remove the heat generated by excess lighting.

C. Transportation Sector

The transportation sector covers transport through road, railway, air, and internal navigation (e.g., small craft, fishing vessel and coastal shipping), except international marine bunkers. Its two main activities are passenger and freight movements. The data of detailed country-specific energy consumption in transportation sector is presented in Appendix E. Although the transportation sector uses less energy than industry, and residential and commercial, it uses oil almost exclusively. Automobiles use by far the most transportation liquid fuel, followed by trucks, buses, air transport, and rail in approximately that order. Thus, automobile fuel economy, mass transit, and efficient freight hauling offer the largest potential for oil savings.

The typical energy data collected by fuel type and mode (i.e., road, rail, air and water) in transportation sector is presented in Table 9, using the U.S. data as an example. Except in China, the transport energy is almost entirely derived from liquid fuels. In China, the liquid fuels and coal played an almost equal role as energy sources in transportation, where coal is

Table 10 Traffic and Energy Efficiency by Mode of Transport in the U.S.

	Freight Transport				Passenger Transport					
	Traffic, bn tkm		Efficiency, MJ/tkm		Traffic, bn pkm		Efficiency, MJ/pkm			
	1975	1980	1985	1975	1980	1985	1975	1980	1985	
Road	745	910	992			4330 ^g				
Automobile	-	-	-			3412 ^{b, g}	3.12	3.06	2.86	
Bus	-	-	-			199 ^g	0.65 ⁱ	0.77 ⁱ	0.82	
Truck	745	910	992	6.0	2.0	719 ^g			3.54	
Rail	1123	1350	1286	0.5	0.47	16	23 ^g	2.43 ⁱ	2.10 ⁱ	2.07 ⁱ
Air	8.6 ^e	10.4 ^e	11.4 ^e			262 ^f	505 ^f	5.2	3.82	3.18
Water	265 ^a	334 ^a	335 ^a	0.36	0.24	-	-			
Pipeline	740 ^h	858 ^h	817 ^h			-	-			
Total	2882	3462	3441				4858			

^aInternal, intraport and local water traffic, excluding Great Lake traffic.

^bThe total vehicle miles of automobiles were 1028 bn, 1112 bn and 1298 bn miles for 1975, 1980 and 1985 respectively.

^cThe average on-road fuel efficiency of automobiles were 13.5 mpg, 15.5 mpg, and 18.2 mpg in 1975, 1980 and 1985, respectively. The fuel efficiency for all motor vehicles which includes passenger cars, motorcycles, buses, and trucks were 12.2 mpg, 13.3 mpg, and 14.6 mpg in 1975, 1980, 1985 respectively.

^dThe average on-road fuel efficiency of bus was 2.3 miles/gal or 53 liters of diesel/100 km for urban travels and 6 miles/gal or 39 liters/100 km for intercity travels.

^eRevenue ton-kilometers flown on scheduled service of certified route air carriers.

^fRevenue passenger-kilometers flown on scheduled service of certified route air carriers.

^g1984 data.

^hPetroleum pipelines.

ⁱIntercity buses and rail.

Note: Totals may not equal sum of components due to independent rounding.

the dominant fuel for rail transport. Road travel which includes freight and passenger transport is the major transportation energy user in the developed countries.

Table 10 shows the country-specific traffic and energy efficiency for each mode of transport, using the U.S.A. data as an example. In the developed countries, the truck contributed the largest share of freight transport in terms of ton-kilometer, followed by rail. However, in the Soviet Union and China, freight is mostly carried by rail. Freight transport over the road has increased over the last decade, and is expected to grow in most major countries, so the importance of increased efficiency of transport truck is essential. Road transport with automobiles and buses dominates the passenger transport in passenger-kilometer in most developed countries. While train provided about 37% of the passenger transport, road travel was the largest form (44%) of passenger transport in the Soviet Union. In China, rail provided about 60% of the passenger transport. The fuel consumption by passenger sedans is negligible in China. The passenger transportation by automobile is not expected to increase dramatically in China in the future.

Energy efficiencies for different modes of transport vary widely. Water transport uses far less energy per ton-km than rail or road. Traveling by train is inherently more efficient than using private car. In West Germany, for instance, railroads use only one quarter as much energy as cars to move people an equal distance. Evolution of automobile fuel economy for different countries can be found in Appendix E. Efficiency legislation in the U.S. enacted in the 1970s mandating corporate average fuel economy for automobile has led to dramatic gains in transportation energy performance. The fuel economy of new cars today is almost double that of past decade. The world averaged fuel economy is about 21 miles per gallon (8.9 kilometer per liter) though it varies widely. The potential improvement of automobile fuel economy can better be seen by contrasting current efficiency levels with those of prototype cars, produced by several major manufacturers, that achieve more than 70 miles per gallon (Appendix E).

D. Industrial Sector

Industrial energy use is complex and varied: fuels are consumed in the form of heat (for producing process steam and for raising the temperatures of materials), electricity (for operating electrical processes and machinery), or

Table 11 Final Energy Use by Industry and Fuel Type in the Industrial Sector in Japan (PJ = 10¹⁵ J)

	Solid			Liquid			Gas			Electricity			Total		
	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985
Chemical	16.3	12.5	34.3	1200 ^a	1147 ^a	1060 ^a	41.4	29.3	25.1	177	161	166	1435	1350	1286
Iron & Steel	1324	1272	1163	364	206	66.1	30.1	29.3		244	264	254	1933	1773	1512
Non-ferrous Metals	7.9	8.8	7.9	41.0	49.8	21.8	-	-	-	94.2	95.4	54.4	143	154	84.1
Non-metallic Minerals	19.7	126	203	327	264	65.3	-	-	-	44.8	61.9	59.4	392	452	329
Transport Equipment	-	-	-	-	-	-	-	-	-	35.2	49.8	61.5	35.2	49.8	61.5
Machinery	-	-	-	-	-	-	-	-	-	28.0	42.7	75.3	28.0	42.7	75.3
Food and Tobacco	-	-	-	135	120	98.8	-	-	-	18.0	23.9	29.3	153	144	128
Pulp, Paper & Printing	2.9	3.8	18.0	133	96.3	40.6	-	-	-	72.8	83.3	86.2	209	183	145
Wood & Wood Products	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Textile & Leather	-	-	-	207	137	110	-	-	-	23.0	23.0	23.0	230	160	133
Mining	-	-	-	16.3	12.1	4.6	-	-	-	5.9	5.9	5.9	22.6	18.0	10.5
Construction	-	-	-	118	148	167	-	-	-	-	-	-	118	148	167
Agriculture	-	-	-	94.2	142	156	-	-	-	4.6	4.2	5.4	98.8	147	162
Other	48.1	41.9	59.0	398	369	450	48.5	56.9	90	264	368	458	758	836	1058
Total	1420	1466	1486	3035 ^b	2692 ^b	2242 ^b	90.0	116	145	1010	1184	1278	5555 ^b	5459 ^b	5151 ^b

a. Includes 921 PJ in 1975, 899 PJ in 1980, and 879 PJ in 1985 as feedstock.

b. Excludes 249 PJ in 1975, 310 PJ in 1980, and 322 PJ in 1985 of non-energy uses of petroleum products such as lubricants and paraffin waxes.

Note: Totals may not equal sum of components due to independent rounding.

feedstocks (for making petrochemical products). The data for detailed country-specific industrial energy use and efficiency is shown in the Appendix F. Energy Consumption of the industrial sector covers the following industries: iron and steel, chemical, non-ferrous metals, non-metallic mineral products, transport equipment, machinery, mining (excluding fuels) and quarrying, food, beverages and tobacco, paper and pulp, textiles and leather, construction, agriculture. Industrial sector consumes more commercial energy than either residential/commercial or transportation sector. Only in OECD countries does the residential and commercial energy consumption sometimes bigger than that of industry. In the centrally planned economies of the Soviet Union and China, the share allocated to industry approached two thirds of all energy consumed.

Table 11 shows the typical energy use data collected by industry and fuel type, using the Japan data as an example. Production of basic materials, especially iron and steel, aluminum, paper, chemicals and concrete consumed the most. About eighty percent of U.S. industry energy in 1980, for example, was used in the manufacture of these goods. In contrast, agriculture, which is included under the industrial heading, accounted for only 6 percent of sectoral demand. In China, about 65 percent of the industrial energy consumption in 1980 took place in metallurgy, chemicals and building materials industries. The energy consumption in iron and steel making amounted to 87 percent of the total consumed in the metallurgical industries. The lack of full production integration, which resulted in large energy requirements for reheating pig iron and cold steel, caused high unit energy consumption in China's iron and steel industry. In general, one of the most important reasons for high unit energy consumption in the Chinese industry, at an aggregate level, is the preponderance of small-scale enterprises in these energy-intensive production. Due primarily to both the inability to capture economics of scale and the use of less advanced technology, unit energy consumptions in these plants tend to be well above those in large plants. In the Soviet Union, the largest portion (28.4%) of industrial energy consumption in 1980 derived from steam and hot water produced from cogeneration plants or local district heating schemes.

Electricity is used in industry for what is known as captive or specific electricity uses: lighting, motors, electrolysis, and a few well-defined thermal uses such as scrap iron smelting, high quality glass fusion. Rough

estimates for the total U.S. manufacturing sector in early 1980s indicate around 70% of electricity was consumed in motor drives, 15% in electrolysis, 10% in process heating, and 5% in lighting and other uses. The basic materials industries are the most energy intensive.

Energy efficiency, when applied to a machine, is defined as the ratio of output energy to input energy. For an industrial process, however, there is no energy output of such. Thus, energy consumption per unit product, such as GJ/tonne was used. Using this ratio to measure the efficiency of energy use is analogous to measuring the energy efficiency of a motor vehicle in terms of miles per gallons. Since mid-1970s, industrial nations have cut industrial energy intensity, even while energy prices declined. The iron and steel industry exemplifies the global progress made and the potential remaining by improving existing facilities, switching to more efficient furnaces and better using secondary energy resources such as combustible wastes: blast-furnace gas, and elective ferro alloy gas. The detailed country-specific of energy use and efficiency in iron and steel industry can be found in the Appendix F.

Cement, an intermediate product in the manufacture of concrete, is the worlds' most widely used construction materials. Its production, requiring much heating and grinding, is an energy intensive process. The diversity in products and processes, and the associated efficiencies in this industry varied widely around the world. As shown in Appendix F, large energy savings in general can be obtained by grinding and mixing the silicates, calcium, and aluminates in a new dry process rather than in a slurry. Pulp and paper, and fertilizer production are other energy-intensive industries. Their production processes and the associated energy need can also be found in the Appendix F.

Generally, the diversity in the relationship between industrial production and energy consumption results from two principal factors. The first is the structure of industry, especially the importance of industries with a high energy intensity per unit product. The second is the technologies employed, whether in the production processes or in the installations using energy. On the whole, through the relative importance of the various production processes, technology plays an important role in the determinations of useful energy required. On the other hand, through the energy efficiency of industrial thermal and mechanical installations (engines, pumps, boilers), it affects the final energy needs.

Table 12 Primary Energy Use in Electricity Generation by Fuel Type
in Japan in 1980 (PJ = 10¹⁵J)

	Solid	Liquid	Gas	Nuclear ^a	Solar ^{a,b}	Total
Energy use	441	2538	665	741	835	5219
Public utility	336	2092	665	736	772	4600
Industrial	105	446	---	5	63	619
Gross elec. generated	180	971	292	297	335	2075
Public utility	140	809	292	295	310	1846
Industrial	40	162	---	2	25	229
In-house plant use						(116)
Transmission and distribution losses						(91)
Import						---
Export						---
Petro. refining uses						(20)
Total electricity for end use						1848

^aThe weighted average annual thermal efficiency of 40.0% for fossil-fuel steam-electric plants was used to calculate the fossil-fuel energy equivalent of nuclear and solar energy used to produce electricity.

^bIncludes hydro, geothermal, and solar energy.

Note: Totals may not equal sum of components due to independent rounding.

Energy Balance for Electricity Generation and Use

The data of detailed country-specific electricity generation and use are shown in Appendix G. For the industrialized countries, the data have mainly been taken from IEA (IEA, 1987), while using other reliable sources to cross-check and fill in the necessary detail. For the Soviet Union and China, the data have been pieced together from different sources.

Table 12 shows the typical collected data of country-specific energy balance for electricity generation and use, using the 1980 Japan data as an example. Electricity can be generated through conversion of heat from fossil or nuclear fuel (as in a steam plant), of chemical energy (as in fuel cell), and of solar energy (as in hydro plant or solar cell). The fossil-fuel uses as energy input for electricity generation is expressed in terms of primary energy. Nuclear and solar energy used for electricity generation are expressed in terms of primary energy (fossil-fuel) equivalent needed to produce the same amount of electricity in existing fossil-fuel thermal power plants. The solar energy includes hydro, geothermal and other renewable solar energy. Electricity is generated both by public utilities and industries. The average efficiency of electricity generation for fossil fuel thermal power plants can be obtained by dividing the gross electricity generated by the corresponding fossil-fuel use. By taking into account of electricity used by power plants themselves, transmission and distribution losses, electricity importation and exportation, the total electricity consumed by end-users can be obtained. Thus, the data shows the country-specific energy balances in electricity production and end-use.

The fuel mix in electricity generation varies widely among countries. Coal is still the dominant source for power plants in the U.S., China, West Germany, and United Kingdom. In Japan, gaseous fuel and nuclear energy became the major sources for power at the expense of liquid fuel since mid-1970s. In France, the nuclear energy plays an increasingly important role in electricity generation, while the roles of liquid and gaseous fuels diminished. Hydro power is the dominated source in Canada. In the Soviet Union, a significant portion of electricity is generated from the combined heat and power plants. Cost and performance estimates for new electric power technologies can also be found in Appendix G.

IV. CONCLUSION

An energy end-use data base for 1975, 1980 and 1985 was developed for ten major fossil fuel CO₂ emitting countries: U.S.A., U.S.S.R., China, Japan, the Federal Republic of Germany, the United Kingdom, Canada, France, Italy and Australia. The data base contains information on energy use patterns for these countries by showing what, when, where, which, why, how and how much energy is needed for residential, commercial, industrial, and transportation sectors. Energy data is also disaggregated within sectors by end-use function and fuel type. The country-specific energy balances for electricity generation and use are also developed. In the course of the development of this data base, several conclusions became clear. The most important of these conclusions are as follows:

1. The data collection of different national energy consumptions requires an exhaustive survey of books, reports, journal articles published by a wide range of organizations. Many data have to be estimated with the help of hints, allusions and vague indicators from a host of different sources, and these estimates are obviously open to distortions from a variety of causes. In any case, the resulting data base is a significant improvement to what presently OHER-CDRP has by way of an extensively detailed, consistent, country-specific energy data base. However, this data base should not, by any means, be accepted as all-inclusive. Much room remains for improvements, and especially expansions to include other key CO₂-emitting developing countries such as Brazil, India, Mexico, and Poland.

2. The data provides the insight of recent patterns of energy uses and fuel mixes in the major CO₂ emitting countries. From this insight, possible changes in fuel mixes (e.g., fuel substitutions) and potential energy savings, especially fossil fuels, can be made through intercountry comparisons and/or other means. In other words, the data base is suitable for uses such as estimation of future total energy demands, forecasting and the study of conservation and fuel substitution.

3. The data can be used as a basis for energy analysis to identify the global trends and growth rates of demand for energy services in major CO₂ emitting countries, and to examine the energy efficiencies and their potential improvements through technology advancement.

4. Regarding to the improvement of energy use, there is no single use which will significantly reduce the CO₂ emissions. There is no single techno-

logical fix either. However, there are many possibilities in all sectors which could collectively have a large impact on mitigating CO₂ emissions.

5. Analysis of this data base will help shedding light on the question about efficient energy use in an international context: How will efficient energy-use programs fare in different countries. The potential for improvements in energy efficiency in all sectors remains dramatic in the future and constitute the cornerstone of a comprehensive strategy for reducing the future CO₂ emissions.

6. The data can be employed as initial conditions in the development of economic-energy models to predict future global energy use and to construct and study CO₂ emission scenarios.

REFERENCES

- Edmonds, J.A. and J. Reilly, 1985. Global Energy: Assessing the Future, Oxford University Press, New York.
- International Energy Agency, 1987. Energy Balances of OECD Countries. 1970/1985, OECD/IEA, Paris.
- Kellogg, M.A., J.A. Edmonds, and M.J. Scott, 1987. Key Statistics Related to CO₂ Emissions: Significant Contributing Countries, PNL-6238, Pacific Northwest Laboratory, Richland, Washington.
- Lu, Y.Z., 1986. Economic Growth and Energy Use in the People's Republic of China (Revised Draft), Working Paper at IEA/ORAU, Oak Ridge, TN.
- Schipper, L., A. Ketoff, and S. Meyers, 1981. International Comparison of Residential Energy Use, LBL-11703, Lawrence Berkeley Lab, CA.
- Schipper, L., A. Ketoff, 1983. Home Energy Use in Nine OECD Countries, 1960-1980, Energy Policy, p. 131, June 1983.
- Schipper, L., A. Ketoff, 1985. Residential Energy Use in the OECD, the Energy Journal, 6, p. 65, 1985.

APPENDIX A
TABLE OF CONVERSION FOR COMMON ENERGY UNITS

1 kJ - 103J - 239 cal - 278 Wh - 0.948 Btu

1 MJ - 10⁶J - 239 kcal - 0.278 kWh

1 GJ - 10⁹J - 278 kWh

1 TJ - 10¹²J - 0.278 GWh

1 PJ - 10¹⁵J - 0.278 TWh - 0.0239 Mtoe

1 EJ - 10¹⁸J - 278 TWh - 23.9 Mtoe

1 Quad - 1.055 EJ - 10¹⁵Btu - 25.2 Mtoe

1 kcal - 4186J - 3.969 Btu - 0.001163 kWh

1 kWh - 3600kJ - 860 kcal - 3412 Btu

1 Btu - 1055J - 0.252 kcal

1 Mboe - 38.7 Mtoe - 1620 PJ

1 Mtco - 29.308 PJ - 8.14 TWh - 7 Pcal - 27.78 TBtu

1 Mtoe - 41.86 PJ - 11.628 TWh - 10 Pcal - 39.68 TBtu

1 toe - 7.20 barrels oil (30° API)

1 tsf - 27.8 MBtu - 7 Gcal

Appendix B

TOTAL FINAL ENERGY USE DATA

Table B.1 Final Energy Use by End-Use Sector and Fuel Type in the U.S.
in 1975, 1980 and 1985 (PJ = 10¹⁵J)

End-Use Sector	Year	Solid		Liquid	Gas	Electricity	Heat ^e	Total
		Coal	Other ^b					
Residential/Commercial	1975	217	457	4637	7459	3713	--	16480
	1980	332	905	3302	7803	4595	--	16937
	1985	351	950	3029	7169	5339	74	16838
Transportation	1975	--	--	17209 ^c	--	14	--	17223
	1980	--	--	17987 ^c	--	11	--	17999
	1985	--	--	18759 ^c	--	13	--	18772
Industrial ^a	1975	2749	1121	6692 ^d	5942	2290	--	18794
	1980	2534	1459	8130 ^d	6145	2686	--	20957
	1985	2372	1801	6391 ^d	5396	2707	--	18113
Total	1975	2966	1579	28538	13401	6104	--	52580
	1980	2869	2364	29419	13948	7292	--	55890
	1985	2726	2751	28116	12565	8053	74	54280

^aIncludes agriculture but excludes petroleum refining industries.

^bIncludes peat, wood, industrial waste and garbage.

^cIncludes 142 PJ, 162 PJ and 138 PJ in 1975, 1980 and 1985, respectively for non-energy uses of petroleum products such as lubricants and waxes.

^dIncludes 1348 PJ, 1642 PJ and 1680 PJ in 1975, 1980, and 1985, respectively for non-energy uses (not for feedstock) of petroleum products such as white spirit, and paraffin waxes.

^eSupplies from combined heat and power plant (CHP).

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [2], [11], [17], [18].

Table B.2 Final Energy Use by End-Use Sector and Fuel Type in the U.S.S.R.
in 1975, 1980 and 1985 (PJ = 10¹⁵J)

End-Use Sector	Year	Solid		Liquid	Gas	Electricity	Heat ^c	Total
		Coal	Other ^b					
Residential/Commercial	1975						1455	
	1980	2780	590	295	1622	656	2130	8073
	1985						2700	
Transportation	1975					267 ^d		
	1980	--	--	4424	442	370 ^d	---	5236
	1985							
Industrial ^a	1975						5945	22868
	1980	4285	1209	7414	4011	3634	7550	28103
	1985						8400	
Total	1975					3737	7400	
	1980	7065	1799	12133	6076	4660	9680	41412
	1985						11100	

^aIncludes agriculture.

^bWood and other biomass.

^cSteam and hot water supplied by combined heat and power plants (CHP) and district heating and local boilers.

^dIncludes 49 PJ and 115 PJ of pipeline freight transport.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [2], [3], [4], [5], [11], [18].

Table B.3 Final Energy Use by End-Use Sector and Fuel Type in China
in 1975, 1980 and 1985 (PJ = 10¹⁵J)

End-Use Sector	Year	Solid		Liquid	Gas	Electricity	Heat	Total
		Coal	Other ^b					
Residential/Commercial	1975							
	1980	2642	6417	56	9	91	--	9215
	1985							
Transportation	1975							
	1980	557	--	615	--	6	--	1177
	1985							
Industrial ^a	1975							
	1980	6441	--	1831	407	720	--	9399
	1985							
Total	1975							
	1980	9639	6417	2501	416	817	--	19791
	1985							

^aIncludes agriculture, but excludes petroleum refining industries. The fuels used by agriculture in 1980 were 629.7 PJ of coal, 383.7 PJ of liquid, 93.7 PJ of electricity with a total of 1107.2 PJ.

^bWood and other biomass; non-commercial energy.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [7], [8], [12], [13], [14], [15], [16], [18].

Table B.4 Final Energy Use by End-Use Sector and Fuel Type in Japan
in 1975, 1980 and 1985 (PJ = 10¹⁵J)

End-Use Sector	Year	Solid		Liquid	Gas	Electricity	Heat ^c	Total
		Coal	Other ^b					
Residential/Commercial	1975	44	--	1375 ^c	242	455	--	2120
	1980	23	--	1404 ^c	298	609	--	2333
	1985	17	--	1425 ^c	360	797	--	2598
Transportation	1975	2	--	1773 ^d	--	50	--	1825
	1980	--	--	2222 ^d	--	55	--	2276
	1985	--	--	2359 ^d	--	59	--	2417
Industrial ^a	1975	1420	--	3284 ^e	90	1013	--	5807
	1980	1466	--	3002 ^e	116	1184	--	5769
	1985	1856	--	2564 ^e	145	1278	--	5473
Total	1975	1469	--	6433	332	1518	--	9572
	1980	1489	--	6627	414	1848	--	10379
	1985	1503	--	6347	504	2134	--	10488

^aIncludes agriculture, but excludes petroleum refining industries.

^bIncludes peat, wood, industrial waste and garbage.

^cIncludes 31 PJ, 25 PJ and 25 PJ in 1975, 1980 and 1985 respectively, of petroleum products such as lubricants and paraffin waxes for non-energy uses.

^dIncludes 13 PJ, 10 PJ and 9 PJ in 1975, 1980 and 1985 respectively, of petroleum products such as lubricants and waxes for non-energy uses.

^eIncludes 250 PJ, 310 PJ and 322 PJ in 1975, 1980, and 1985 respectively, for non-energy uses (not for feedstock) of petroleum products such as white spirit and paraffin waxes.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [9], [11], [18].

Table B.5 Final Energy Use by End-Use Sector and Fuel Type in F. R. Germany
in 1975, 1980 and 1985 (PJ = 10¹⁵J)

End-Use Sector	Year	Solid		Liquid	Gas	Electricity	Heat ^e	Total
		Coal	Other ^b					
Residential/Commercial	1975	318	13	1801	355	404	100	2990
	1980	227	13	1740	616	518	125	3239
	1985	186	37	1577	787	599	115	3300
Transportation	1975	12	--	1412 ^c	--	32	--	1455
	1980	3	--	1741 ^c	--	39	--	1783
	1985	--	--	1772 ^c	--	40	--	1812
Industrial ^a	1975	686	1	1469 ^d	475	499	--	3130
	1980	774	1	1378 ^d	633	591	--	3378
	1985	792	6	1068 ^d	616	620	--	3165
Total	1975	1016	14	4682	830	935	100	7614
	1980	1004	14	4860	1249	1147	125	8399
	1985	978	43	4417	1404	1259	115	8215

^aIncludes agriculture, but excludes petroleum refining industries.

^bIncludes peat, wood, industrial waste and garbage.

^cIncludes 41 PJ, 46 PJ and 11 PJ in 1975, 1980, and 1985, respectively for non-energy uses of petroleum products such as lubricants and waxes.

^dIncludes 288 PJ, 183 PJ and 165 PJ in 1975, 1980, and 1985, respectively for non-energy uses (not for feedstock) of petroleum products such as white spirit, paraffin waxes and lubricants.

^eSupplied by combined heat and power plants (CHP).

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [2], [9], [11], [18].

Table B.6 Final Energy Use by End-Use Sector and Fuel Type in the United Kingdom
in 1975, 1980 and 1985 (PJ = 10¹⁵J)

End-Use Sector	Year	Solid		Liquid	Gas	Electricity	Heat ^f	Total
		Coal	Other ^b					
Residential/Commercial	1975	442	--	433 ^c	700	479	--	2056
	1980	337	--	391 ^c	1015	504	--	2250
	1985	316	--	316 ^c	1193	504	--	2367
Transportation	1975	2	--	1340 ^d	--	10	--	1352
	1980	2	--	1424 ^d	--	11	--	1437
	1985	--	--	1530 ^d	--	10	--	1541
Industrial ^a	1975	512	4	1394 ^e	491	318	--	2619
	1980	281	1	930 ^e	576	329	5	2081
	1985	347	0.4	696 ^e	562	321	0.4	1927
Total	1975	955	4	2969	1191	808	--	5927
	1980	620	1	2705	1592	844	5	5767
	1985	664	0.4	2555	1755	873	0.4	5849

^aIncludes agriculture, but excludes petroleum refining industries.

^bIncludes peat, wood, industrial waste and garbage.

^cIncludes 2 PJ of petroleum products such as lubricants, waxes for non-energy uses.

^dIncludes 17 PJ, 16 PJ and 14 PJ in 1975, 1980, and 1985, respectively for non-energy uses of petroleum products such as lubricants and waxes.

^eIncludes 162 PJ, 114 PJ and 123 PJ in 1975, 1980 and 1985, respectively for non-energy uses (not for feedstock) of petroleum products such as white spirit, waxes and lubricants.

^fSupplied from combined heat and power plants (CHP).

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [2], [11], [18].

Table B.7 Final Energy Use by End-Use Sector and Fuel Type in Canada
in 1975, 1980 and 1985 (PJ = 10¹⁵J)

End-Use Sector	Year	Solid		Liquid	Gas	Electricity	Heat	Total
		Coal	Other ^b					
Residential/Commercial	1975	13	--	805	572	444	--	1833
	1980	4	--	645	673	567	--	1890
	1985	5	--	412 ^c	858	678	--	1953
Transportation	1975	3	--	1547	--	--	--	1550
	1980	--	--	1803	--	8	--	1811
	1985	--	--	1584 ^d	0.4	10	--	1594
Industrial ^a	1975	228	--	842 ^e	537	392	--	1999
	1980	245	317	944 ^e	703	508	--	2716
	1985	232	350	754 ^e	758	624	--	2718
Total	1975	244	--	3193	1108	836	--	5381
	1980	249	317	3392	1376	1083	--	6417
	1985	236	350	2749	1616	1312	--	6265

^aIncludes agriculture, but excludes petroleum refining industries.

^bIncludes peat, wood, industrial waste and garbage.

^cIncludes 9 PJ for non-energy uses of petroleum products such as lubricants and waxes.

^dIncludes 8 PJ for non-energy uses of petroleum products such as lubricants and waxes.

^eIncludes 209 PJ, 233 PJ and 180 PJ in 1975, 1980, and 1985, respectively for non-energy uses (not for feedstock) of petroleum products such as white spirit and paraffin waxes.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [11], [18].

Table B.8 Final Energy Use by End-Use Sector and Fuel Type in France
in 1975, 1980 and 1985 (PJ = 10¹⁵J)

End-Use Sector	Year	Solid		Liquid	Gas	Electricity	Heat	Total
		Coal	Other ^b					
Residential/Commercial	1975	194	--	1153	258	247	--	1850
	1980	135	--	1038	414	378	--	1966
	1985	113	--	824	534	513	--	1984
Transportation	1975	2.1	--	1189 ^c	0.4	22	--	1213
	1980	0.8	--	1405 ^c	0.4	25	--	1431
	1985	--	--	1484 ^c	--	29	--	1514
Industrial ^a	1975	414	--	1377 ^d	265	298	--	2354
	1980	394	--	1410 ^d	409	349	--	2562
	1985	392	--	941 ^d	459	357	--	2149
Total	1975	610	--	3718	524	568	--	5420
	1980	530	--	3853	824	752	--	5960
	1985	506	--	3249	993	897	--	5644

^aIncludes agriculture but excludes petroleum refining industries.

^bincludes peat, wood, industrial waste and garbage.

^cIncludes 16.7 PJ, 16.3 PJ and 15.9 PJ in 1975, 1980 and 1985, respectively for non-energy uses of petroleum products such as lubricants and waxes.

^dIncludes 241.5 PJ, 166.6 PJ and 142.3 PJ in 1975, 1980 and 1985, respectively for non-energy uses (not for feedstock) of petroleum products such as white spirit, paraffin waxes.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [2], [18].

Table B.9 Final Energy Use by End-Use Sector and Fuel Type in Italy
in 1975, 1980 and 1985 (PJ = 10¹⁵J)

End-Use Sector	Year	Solid		Liquid	Gas	Electricity	Heat	Total
		Coal	Other ^b					
Residential/Commercial	1975	15	26	818	493	147	--	1499
	1980	15	26	729 ^c	533	210	--	1513
	1985	8	25	619 ^c	506	260	--	1432
Transportation	1975	3	--	803	11	15	--	832
	1980	--	--	1037	11	17	--	1065
	1985	--	--	1156	10	19	--	1185
Industrial ^a	1975	177	20	1064 ^d	425	289	--	1976
	1980	189	15	1024 ^d	474	348	--	2051
	1985	248	16	791 ^d	417	346	--	1818
Total	1975	195	46	2686	686	451	--	4307
	1980	204	41	2791	860	575	--	4629
	1985	257	41	2578	933	625	--	4435

^aIncludes agriculture, but excludes petroleum refining industries.

^bIncludes peat, wood, industrial waste, and garbage.

^cIncludes 3 PJ and 13 PJ in 1980 and 1985, respectively for non-energy uses of petroleum products such as lubricants and waxes.

^dIncludes 140 PJ, 136 PJ and 118 PJ in 1975, 1980 and 1985 respectively for non-energy uses of petroleum products such as white spirit and paraffin waxes.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [2], [18].

Table B.10 Final Energy Use by End-Use Sector and Fuel Type in Australia
in 1975, 1980 and 1985 (PJ = 10¹⁵J)

End-Use Sector	Year	Solid		Liquid	Gas	Electricity	Heat	Total
		Coal	Other ^b					
Residential/Commercial	1975	15	72	100 ^c	42	121	--	324
	1980	9	67	80 ^c	64	160	--	380
	1985	7	69	48 ^c	89	193	--	385
Transportation	1975	0.4	--	605	--	2	--	608
	1980	--	--	738	--	3	--	741
	1985	3	--	813	--	4	--	820
Industrial ^a	1975	289	76	335 ^d	92	101	--	893
	1980	254	80	341 ^d	164	122	--	961
	1985	224	91	249 ^d	222	161	--	947
Total	1975	305	149	1041	134	221	--	1850
	1980	263	146	1159	228	285	--	2082
	1985	233	159	1111	311	357	--	2172

^aIncludes agriculture, but excludes petroleum refining industries.

^bIncludes peat, wood, industrial waste and garbage.

^cIncludes 24 PJ, 25 PJ and 20 PJ in 1975, 1980, and 1985, respectively for non-energy uses of petroleum products such as lubricants and waxes.

^dIncludes 22 PJ, 29 PJ and 36 PJ in 1975, 1980 and 1985, respectively for non-energy uses (not for feedstock) of petroleum products such as white spirit and paraffin waxes.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [18].

Table B.11 Heat Consumption from Centralized Sources by End-Use Sector
in the U.S.S.R. (PJ = 10^{15} J)

	1975	<u>Heat Consumption</u> 1980 ^b	1985
Residential/and public services	1455 (19.7) ^a	2130 (22.5)	2700 (24.3)
Industrial	<u>5945 (80.3)</u>	<u>7350 (77.5)</u>	<u>8400 (75.7)</u>
Total	7400 (100)	9480 (100)	1110 (100)

^aThe figure inside the bracket represents precentage.

^bThe total production of heat by centralized scources and local boilers is 13100 PJ, (Ref. [14]).

Sources: Adapted from Refs. [19[, Table 1.

REFERENCES

1. International Energy Agency, Energy Balances of OECD Countries 1970/1985, OECD/IEA, Paris, 1987.
2. United Nations Economic Commission for Europe, An Efficient Energy Future, Butterworths, London, 1983.
3. United Nations Economic Commission for Europe, Energy Transition in the ECE Region, E/ECE/1063, Butterworths, London, 1983.
4. Wilson, D. The Demand for Energy in the Soviet Union, Rowman & Allanheld, Croom Helm, Australia, 1983.
5. Kelly, W.J., Shaffer, H.L., and Thompson, T.K. Energy Research and Development in the U.S.S.R., Duke University Press, Durham, NC, 1986.
6. Joint Economic Committee, Soviet Economy in 1980's: Problems and Prospects, Part 1, Selected papers submitted to the Joint Economic Committee, Congress of the U.S., GPO, Washington DC, 1983.
7. World Bank, China: The Energy Sector, Annex 3 to China Long-Term Development Issues and Options, Washington DC, 1985.
8. Statistical Year Book of China, 1985, compiled by the State Statistical Bureau, PRC, Oxford University Press, New York, 1985.
9. International Energy Agency, World Energy Outlook, IEA/OECD, Paris, France, 1982.
10. International Energy Agency, Energy Balances of Developing Countries, 1971-1982, IEA/OECD, Paris, France, 1984.
11. Hedley, D. World Energy: The Facts and the Future, Euromonitor Publications Limited, 1986.
12. Jablonski, D.M. [Ed.]. McGraw-Hills International Energy Outlook, Vol. 1:Mid-East, Far East and Africa, McGraw-Hill, New York 1982.
13. Zhu, Y.J. The Present Status of Energy Use in China and Its Development Prospectives, Energy 8, 73-77, 1983.
14. Lu, Y.Z. Economic Growth and Energy Use in People's Republic of China, Revised Draft, Working paper at IEA/ORAU, Oak Ridge, TN, 1986.
15. Lu, Y.Z. Long-Term Energy Forecasting of PRC and Strategies in the Development of Nuclear Energy, Working paper at IEA/ORAU, Oak Ridge, TN, 1986.

16. Lu, Y.Z. Some Comments on CO₂ Issues in PRC, Working paper at IEA/ORAU, Oak Ridge, TN, 1987.
17. U.S. Department of Energy, Energy Information Administration, Annual Energy Review 1985, DOE/EIA-0384(85), Washington, DC, 1986.
18. U.S. CENTRAL Intelligence Agency, Handbook of Economic Statistics, 1986, CPAS 86-10002, 1986.
19. Tarnizhervsky, M.V. Energy Consumption in the Residential and Public Services Sector. Energy 12, p.1009, 1987.

Appendix C

RESIDENTIAL SECTOR ENERGY USE DATA

General Conventions for Tables C.9-C.28

All energy use data refer to final (secondary) energy (i.e. 1 kwh = 3600 kJ), unless otherwise stated. To obtain the primary energy use, average conversion efficiencies of 34.6% and 75% were used for electricity generation and district heat, respectively. To obtain the useful energy (i.e. energy requirement) for space heat and water heat, average conversion efficiency of 0.66 is used for oil and gas, and 0.55 for solid fuels.

Energy use for space heat are adjusted to average yearly degree-days with a common 18°C base temperature, unless otherwise noted. Thus, the space heat values in the Tables are not actual energy use in a particular year. To obtain the actual space heat values, multiply the figures given by the degree-day index.

To compare the energy intensities of space and water heat in different countries, with various fuel form mixes, the electricity and district heat were converted into fossil-fuel equivalent values by dividing them by a hypothetical fuel conversion efficiency of 65%.

Single family dwelling (SFD) refers to detached one- and two-family houses, row houses, terraced houses and farm dwellings. However, in Canada and Italy, row and terraced houses are counted as mutli-family dwelling. In every country, dwellings counted for energy use purposes exclude residences in institutions, commercial establishments, and other non-residential buildings. These usually account for 203% of all residences.

Central heat refers to heat produced in most or all rooms of a house by a single heating device, or heat produced in most or all rooms by modern electric or gas heaters. Small wood, oil gas or coal stoves are not counted as central heat.

Appliances include lighting.

Table C.1 Residential Energy Use by Fuel Type in Major CO₂ Producing Countries in 1975 (PJ=10¹⁵J)

	Coal/Coke	Liquid	Gas	Electricity	District			Total
					Heat	Wood	Other	
U.S.A.	88.7	2536	5299	2117	-	457	-	10498
U.S.S.R. ^a	2901	381	1401	204	1402	352	97	6738
China								
Japan	43.8	471	242	259	-	-	-	1016
F.R. Germany	229	1041	246	244	58.3	12.5	-	1831
U.K.	444	146	605	317	-	-	-	1512
Canada	-	575	422	290	-	15.0	-	1302
France ^b	177/132	921/826	208/298	109/193	19.3/45	22.5/2.5	-	1517/1496
Italy	15	619	258	100	-	26	-	1018
Australia	7.1	48.5	32.6	79.5	-	71.6	-	239

^aIncluded energy used by public building.

b)1973/1978 data. For 1975, the residential energy use, which is derived from the difference between the energy use of residential/commercial (Ref. [1]), and that of commercial sector (Ref. [18]), is coal: 180 PJ, Liquid: 814 PJ, Gas: 191 PJ, and Electricity: 140 PJ with a total of 1325 PJ.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1]–[6], [18].

Table C.2 Residential Energy Use by Fuel Type in Major CO₂ Producing Countries in 1980 (PJ=10¹⁵J)

	Coal/Coke	Liquid	Gas	Electricity	District Heat	Wood	Other	Total
U.S.A.	65.7	2015	5212	2581	-	907	-	10781
U.S.S.R.	2780		558	268	2093			
China								
Japan	23	410	236	418	-	-	-	1087
F.R. Germany	165	1101	370	308	60	13.0		2014
U.K.	283	112	816	310	-	-	-	1521
Canada ^a	-	545/433	468/507	326/260	-	15/37	-	1354/1237
France ^b	139	694	331	225	46	-	-	1420
Italy	15	522	276	146	1	26	-	986
Australia	2.5	33.5	46.9	104	-	66.1	-	253

^a1978/1981 data. For 1980, the residential energy use, which is derived from the difference between the energy use of residential/commercial (Ref. [11]), and that of commercial sector (Ref. [18]), is coal: 135 PJ, Liquid: 753 PJ, Gas: 300 PJ, and electricity: 227 PJ with a total of 1410 PJ.

^b1981 data.

Note: Totals may not equal sum of components due to independent rounding.

Source: Adapted and/or derived from Refs. [1], [6], [11], [18], [20], [21].

Table C.3 Residential Energy Use by Fuel Type in Major CO₂-Producing Countries in 1985 (PJ=10¹⁵J)

	Coal/Coke	Liquid	Gas	Electricity	District		Other	Total
					Heat	Wood		
U.S.A.	73.9	1878	4747	2853	-	950	-	10500
U.S.S.R.								
China								
Japan	17.2	432	282	515	-	-	-	1246
F.R. Germany	137	1055	537	350	58	36.8	-	2174
U.K.	260	97.1	936	318	-	-	-	1611
Canada	3.8	226	456	373	-	-	-	1059
France	113	92.1	284	309	-	-	-	798
Italy	8.4	567	15.1	160	-	25.5	-	776
Australia	6.8	18.4	63.6	122	-	67.8	-	273

Note: Totals may not equal sum of components due to independent rounding.

Source: Adapted and/or derived from Refs. [1], [11], [20], [21].

Table C.4 Residential Energy Use by End Use in Major CO₂ Producing Countries in 1975, 1980, and 1985

	Space Heating			Water heat			Cooking			Appliances			Total		
	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985
U.S.A.	6708	6401		1740	1962		630	659		1420	1759		10498	10781	10500
U.S.S.R. ^d	2706			660			256			193			3815		
China															
Japan	328	301 ^a		356	422 ^a		160	163 ^a		172	246 ^a		1016	1132 ^a	1246
F.R. Germany	1453	1579		208	238		58.1	51.0		91.4	145		1811	2014	2116
U.K.	950	1074		295	284		141	146		126	128		1512	1668	1611
Canada	982	1011/859 ^b		181	201/218 ^b		26.1	25/33 ^b		114	119/127 ^b		1302	1354/1237 ^b	1059
France	1228/1061 ^c			143/192 ^c	210		112/145 ^c	110		70/99 ^c	106		1517/1496 ^c	1420	798
Italy	765	716		100	87.7		75.0	80.7		65.0	98.5		1005	986	776
Australia													239	253	273

^a 1979 data^b 1978/1981 data^c 1973/1978 data^d 2973 PJ space heat and 325 PJ lighting and appliances with a total of 3118 PJ for commercial sector in 19.5.

Note: Totals may not equal sum of components due to independent rounding.

Source: Adapted and/or derived from Refs. [11]-[6], [11], [19].

Table C.5 Energy Use in Residential Space Heating by Fuel Type in Major Co₂ producing countries in 1975
(PJ=10¹⁵J)

	Coal/Coke	Liquid	Gas	Electricity	District			Total
					Heat	Wood	Other	
U.S.A.								6708
U.S.S.R.								
China								
Japan	25.1	255	26.3	21.2	-	-	-	328
F.R. Germany	161	973	195	59.3	52.2	12.5	-	1453
U.K.	322	126	410	92.5	-	-	-	950
Canada	-	544	343	81.1	-	13.5	-	982
France ^a	169/85	873/689	133/207	11.8/43.4	19.3/36.1	22.5/0.8	-	1228/1061
Italy	27	585	149	4.0	-	-	-	765
Australia								

^a1973/1978 data

Note: Totals may not equal sum of components due to independent rounding.

Source: Adapted and/or derived from Refs. [2] - [5]

Table C.6 Energy Use in Residential Space Heating by Fuel Type in Major Co₂ producing countries in 1980
(PJ=10¹⁵J)

	Coal/Coke	Liquid	Gas	Electricity	District			Total
					Heat	Wood	Other	
U.S.A.	65.7	1656	3503	295	-	880		6400
U.S.S.R.								
China								
Japan ^a	15.7	246	19.5	19.7	-	-	-	301
F.R. Germany	138	943	367	58.5	58.5	13.0	-	1579
U.K. ^b	327	115	525	71.5				1039/1074 ^c
Canada ^b	-	514	380	103	-	13.0	-	1010/859 ^e
France ^d	134	554	232	64	33	-	-	1018
Italy ^b	24.3	591	180	3.2	-	-	-	794/709 ^c
Australia								

a|1979 data

b|1978 data

c|1978/1980 data

d|1981 data

e|1978/1981 data

Note: Totals may not equal sum of components due to independent rounding.

Source: Adapted and/or derived from Refs. [2] - [5], [19].

Table C.7 Energy Use in Residential Space Heating by Fuel Type in Major Co₂ Producing Countries in 1985

	Coal/Coke	Liquid	Gas	Electricity	District		Other	Total
					Heat	Wood		
U.S.A. ^a		1382	3703	316				
U.S.S.R.								
China								
Japan								
F.R. Germany								
U.K.								
Canada								
France								
Italy								
Australia								

^a1984 data

Sources: Adapted and/or derived from Ref. [21].

Table C.8 Energy Intensity for Residential Space Heating in Major CO₂ producing countries in 1975, 1980, and 1985

	Final Energy Use per dwelling ^a						Useful energy		
	GJ/dwelling			kJ/dwelling/m ² /degree-day			kJ/dwelling/m ² /degree-day		
	1975	1980	1985	1975	1980	1985	1975	1980	1985
U.S.A.	94.2	82.0		290	246		189		157
U.S.S.R.									
China									
Japan	9.3	10.6 ^b		65.4	73.2 ^b				
F.R. Germany	67.0	63.3		282	247		195	169	
U.K.	51.8	53.0		214	226		135		
Canada	132	125/104 ^c		291	274/228 ^c		194	178/148 ^c	
France	68.4/58.2 ^d	51.0		388/308 ^d	263		232/204 ^d	176	
Italy	48.8	41.3		335	248			159	
Australia									

^a The yearly degree-days for each country have been adjusted to a common 18°C base to allow comparison.

^b 1979 data

^c 1978/1981 data

^d 1973/1978 data

Sources: Adapted and/or derived from Refs. [2]-[5]

Table C.9 Characterization of and Final Energy Use in the Residential Sector in the U.S. in 1975, 1980, and 1985

	1975	1980	1985
Occupied dwellings (dw), 10 ⁶	72.5	80.1	88.4
Single-family dw (SFD), % of occupied dw	69.3	67.0	
Average dw size, m ²	125.0	128.0	
People per dw	2.91	2.78	
Central heating, % of dw	83.0	86.0	
Central heating SFD, %			
Dwelling stock vintage			
% built before 1950		40.0 ^a	
% built between 1950-1975		45.0	
% built after 1975		15.0	
Insulation of dw, W/m ² /°C			
Wall	0.49 ^b	0.5 ^c	
Roof	0.3	0.23	
Ground floor		0.82	
Final Energy Use, PJ			
Coal/coke	88.7	65.7	73.9
Liquid	2536	2015	1876
Gas	5299	5212	4747
Electricity	2117	2595	2853
District heat	-	-	-
Wood	457	907	950
Other	-	-	-
Total	10498	10795	10500
Energy Use per dwelling, GJ/dw			
Delivered	145	135	118
Useful	107	98	84
Space heat by fuel type, % dw			
Coal/coke	0.8	0.4	0.5
Liquid	28.2	23.8	15.3
Gas	56.4	55.4	55.4
Electricity	12.6	17.7	20.8
District heat	-	-	-
Wood	1.3	1.8	7.4
None	0.6	0.8	0.6

^a 1982 data. For construction after 1975, the data run through 1982.

^b For 1976 new home.

^c For 1980 new home.

Source: Adapted and/or derived from Refs. [1] - [4], [6], [11], [20].

Table C.10 Residential Energy Use by End Use in the U.S.
in 1975, 1980, and 1985.

	1975	1980	1985
Degree-day (DD) index ^a	0.982	0.974	
<u>Space Heat</u> , DD adj., PJ	6831	6569	
Coal and coke		67.4	
Liquid		1699	
Gas		3596	
Electricity		303	
District heat		-	
Wood		903	
Other		-	
Space heat intensity			
Energy use per dwelling			
GJ/dw	94.2	82.0	
kJ/dw-dd-m ² , final energy	290	246	210
kJ/dw-dd-m ² , fossil fuel equiv.			
Useful energy, kJ/dw-dd-m ²	189	157	
<u>Water Heat</u> , PJ	1740	1962	
Coal and coke		-	
Liquid		327	
Gas		1038	
Electricity		327	
Wood		-	
Other		-	
Water heat intensity			
Energy use per dwelling			
GJ/dw, final energy	24.0	24.5	
GJ/dw, fossil fuel equiv.			
Useful energy, GJ/dw		17.0	
<u>Cooking</u> , PJ	630	659	
Coal and coke			
Liquid			
Gas		327	
Electricity		332	
Wood			
Other			
Cooking intensity, GJ/dw	8.7	8.2	
<u>Appliance</u> energy use, PJ	1420	1759 ^c	
Gas		118	
Electricity		1641 ^c	
Appliance intensity, GJ/dw	19.6	22.0	

^a Based on the adjusted yearly average heating degree-days of 2600 with base temperature of 18°C.

^b Includes coal and coke.

^c Includes 338 PJ of electricity used for air conditioning.

Source: Adapted and/or derived from Refs. [2], [3], [4], [11].

Table C.11 Characterization of Final Energy Uses in the Residential Sector in U.S.S.R. in 1975, 1980, and 1985.

	1975	1980	1985
Occupied dwellings (dw), 10 ⁶	55.9		
Single-family dw (SFD), % of occupied dw			
Average dw size, m ²			
People per dw	4.5		
Central heating, % of dw			
Central heating SFD, %			
Dwelling stock vintage			
% built before 1950			
% built between 1950-1975			
% built after 1975			
Insulation of dw, W/m ² /°C			
Wall			
Roof			
Ground floor			
Final Energy Use, PJ			
Coal/coke	2901 ^a	2780	
Liquid	381 ^a		
Gas	1401 ^a	558	
Electricity	204	268	
District heat	1042 ^a	2093	
Wood	352 ^a	590	
Other	97 ^a		
Total			
Energy Use per dwelling, GJ/dw			
Useful energy, GJ/dw			
Space heat by fuel type, % dw			
Coal/coke			
Liquid			
Gas			
Electricity			
District heat			
Wood			
None			

^aIncluded energy used by public building.

Sources: Adapted and/or derived from Refs. [2], [8], [10].

Table C.12 Residential Energy Use by End Use in the U.S.S.R.
in 1975, 1980, and 1985.

	1975	1980	1985
Degree-day (DD) index			
<u>Space Heat, DD adj., PJ</u>	2706		
Coal and coke			
Liquid			
Gas			
Electricity			
District heat			
Wood			
Other			
Space heat intensity			
Energy use per dwelling			
GJ/dw			
kJ/dw-dd-m ² , final energy			
kJ/dw-dd-m ² , fossil fuel equiv.			
Useful energy, kJ/dw-dd-m ²			
<u>Water Heat, PJ</u>	660		
Coal and coke			
Liquid			
Gas			
Electricity		18.4 ^a	
Wood			
Other			
Water heat intensity			
Energy use per dwelling			
GJ/dw, final energy	11.8		
GJ/dw, fossil fuel equiv.			
Useful energy, GJ/dw	8.0		
<u>Cooking, PJ</u>	256		
Coal and coke			
Liquid			
Gas			
Electricity		23.8	
Wood			
Other			
Cooking intensity, GJ/dw	4.6		
<u>Appliance energy use, PJ</u>	193		
Gas			
Electricity		239	
Appliance intensity, GJ/dw	3.45		

^aIncluded space heating.

Source: 1975 data adapted and/or derived from Fig. 3.15 in Ref. [10], and
1980 data from Ref. [8].

Table C.13 Characterization of Final Energy Uses in the Residential Sector in China in 1975, 1980, and 1985.

	1975	1980	1985
Occupied dwellings (dw), 10 ⁶			
Single-family dw (SFD), % of occupied dw			
Average dw size, m ²			
People per dw			
Central heating, % of dw			
Central heating SFD, %			
Dwelling stock vintage			
% built before 1950			
% built between 1950-1975			
% built after 1975			
Insulation of dw, W/m ² /°C			
Wall			
Roof			
Ground floor			
Final Energy Use, PJ			
Coal/coke			
Liquid			
Gas			
Electricity			
District heat			
Wood			
Other			
Total			
Energy Use per dwelling, GJ/dw			
Useful energy, GJ/dw			
Space heat by fuel type, % dw			
Coal/coke			
Liquid			
Gas			
Electricity			
District heat			
Wood			
None			

Table C.14 Residential Energy Use by End Use in China
in 1975, 1980, and 1985.

	1975	1980	1985
Degree-day (DD) index			
<u>Space Heat, DD adj., PJ</u>			
Coal and coke			
Liquid			
Gas			
Electricity			
District heat			
Wood			
Other			
Space heat intensity			
Energy use per dwelling			
GJ/dw			
kJ/dw-dd-m ² , final energy			
kJ/dw-dd-m ² , fossil fuel equiv.			
Useful energy, kJ/dw-dd-m ²			
<u>Water Heat, PJ</u>			
Coal and coke			
Liquid			
Gas			
Electricity			
Wood			
Other			
Water heat intensity			
Energy use per dwelling			
GJ/dw, final energy			
GJ/dw, fossil fuel equiv.			
Useful energy, GJ/dw			
<u>Cooking, PJ</u>			
Coal and coke			
Liquid			
Gas			
Electricity			
Wood			
Other			
Cooking intensity, GJ/dw			
<u>Appliance energy use, PJ</u>			
Gas			
Electricity			
Appliance intensity, GJ/dw			

Table C.15 Characterization of Final Energy Use in the Residential Sector in Japan in 1975, 1980, and 1985.

	1975	1980 ^a	1985
Occupied dwellings (dw), 10 ⁶	33.04	33.2	
Single-family dw (SFD), % of occupied dw	65	65	
Average dw size, m ²	78.7	80.2	
People per dw	3.4	3.2	
Central heating, % of dw		4	
Central heating SFD, %			
Dwelling stock vintage			
% built before 1950			
% built between 1950-1975			
% built after 1975			
Insulation of dw, W/m ² /°C			
Wall			
Roof			
Ground floor			
Final Energy Use, PJ			
Coal/coke	43.8	23.8	17.2
Liquid	471	539	432
Gas	242	244	282
Electricity	259	325	515
District heat	-	-	-
Wood	-	-	-
Other	-	-	-
Total	1016	1132	1246
Energy use per dwelling, GJ/dw	30.8	34.1	
Useful energy, GJ/dw		27.0	
Space heat by fuel type, % dw			
Coal/coke		4.0	
Liquid		78.0	
Gas		7.0	
Electricity		11.0	
District heat		-	
Wood		-	
None		-	

^a1979 data.

Sources: Adapted and/or derived from Refs. [1], [3], [4], [5].

Table C.16 Residential Energy Use by End Use in Japan in
1975, 1980 and 1985.

	1975	1980 ^a	1985
Degree-day (DD) index ^b	1.071	0.857	
<u>Space Heat</u> , DD adj., PJ	306	351	
Coal and coke	23.4	18.3	
Liquid	238	287	
Gas	24.6	22.8	
Electricity	19.8	23.0	
District heat	-	-	
Wood	-	-	
Other	-	-	
Space heat intensity			
Energy use per dwelling			
GJ/dw	9.3	10.6	
kJ/dw-dd-m ² , final energy	65.4	73.2	
kJ/dw-dd-m ² , fossil fuel equiv.			
Useful energy, kJ/dw-dd-m ²			
<u>Water heat</u> , PJ	356	422	
Coal and coke	10.4	5.4	
Liquid	170	211	
Gas	147	161	
Electricity	29.0	44.6	
Wood	-	-	-
Other	-	-	-
Water heat intensity			
Energy use per dwelling			
GJ/dw, final energy	10.8	13.4	
GJ/dw, fossil fuel equiv.		14.2	
Useful energy, GJ/dw	6.9	8.3	
<u>Cooking</u> , PJ	160	163	
Coal and coke	8.3	2.8	
Liquid	45.9	82.3	
Gas	68.8	63.5	
Electricity	37.2	14.1	
Wood	-	-	
Other	-	-	
Cooking intensity, GJ/dw	4.8	4.9	
<u>Appliance energy use</u> , PJ	172 (11.8) ^c	246 (17.5) ^c	
Gas	-	-	
Electricity	172	246	
Appliance intensity, GJ/dw	5.2	7.4	

^a1979 data.

^bBased on the adjusted yearly average heating degree-days of 1800 with base temperature 18°C. The official base temperature is 14°C.

^cThe figures inside the bracket represent the electricity use by air conditioner.

Sources: Refs. [3], [4], [5].

Table C.17 Characterization of Final Energy Use in the Residential Sector in F.R. Germany, in 1975, 1980, and 1985.

	1975	1980	1985
Occupied dwellings (dw), 10 ⁶	22.6	24.3	
Single-family dw (SFD), % of occupied dw	48.0	49.0	
Average dw size, m ²	75.1	81.0	
People per dw	2.73	2.53	
Central heating, % of dw	57.0	70.0	
Central heating SFD, %	28.0	39.0	
Dwelling stock vintage			
% built before 1950		25.0 ^a	
% built between 1950-1975		63.0	
% built after 1975		12.0	
Insulation of dw, W/m ² /°C			
Wall	0.81 ^b	0.57-0.9 ^c	
Roof	0.69	0.45	
Ground floor	0.83	0.80	
Final Energy Use, PJ			
Coal/coke	209	165	137
Liquid	1041	1101	1055
Gas	246	370	537
Electricity	244	308	350
District heat	58.3	58	58
Wood	12.5	13.0	36.8
Other	-		
Total	1811	2014	2174
Energy use per dwelling, GJ/dw	80.1	82.9	
Useful energy, GJ/dw	56.5	59.5	
Space heat by fuel type, % dw			
Coal/coke	23	9	
Liquid	51	50	
Gas	15	25	
Electricity	6	7	
District heat	5	8	
Wood	-	1	
None	-	-	

^aBased on samples taken in 1982. For construction after 1975, the data run through 1982.

^bGenerally values required or used in the mid-1970s.

^cValues required by codes issued in 1977-1979.

Sources: Adapted and/or derived from Refs. [2]-[5], [7], [10].

Table C.18 Residential Energy Use by End Use in F.R. Germany in
1975, 1980 and 1985.

	1975	1980	1985
Degree-day (DD) index ^a	0.958	1.026	
<u>Space Heat</u> , DD adj., PJ	1517	1539	
Coal and coke	168	135	
Liquid	1016	919	
Gas	204	358	
Electricity	61.9	57.0	
District heat	54.5	57.0	
Wood	13.0	12.7	
Other	-	-	
Space heat intensity			
Energy use per dwelling			
GJ/dw	67.0	63.3	
kJ/dw-dd-m ² , final energy	282	247	
kJ/dw-dd-m ² , fossil fuel equiv.			
Useful energy, kJ/dw-dd-m ²	195	169	
<u>Water heat</u> , PJ	208	238	
Coal and coke	28.4		
Liquid	67.3		
Gas	38.0		
Electricity	68.4		
Wood	-		
District heat	6.1		
Water heat intensity			
Energy use per dwelling			
GJ/dw, final energy	9.2	9.8	
GJ/dw, fossil fuel equiv.	12.3		
Useful energy, GJ/dw	6.8	7.6	
<u>Cooking</u> , PJ	58.1	51.0	
Coal and coke	20.2		
Liquid	-		
Gas	12.9		
Electricity	25.0		
Wood	-		
Other	-		
Cooking intensity, GJ/dw	2.6	2.1	
<u>Appliance energy use</u> , PJ	91.4	145	
Gas	-	-	
Electricity	91.4	145	
Appliance intensity, GJ/dw	4.0	5.9	

^aBased on the adjusted yearly average heating degree-days of 3163 with base temperature of 18°C. The official base temperature is 20°C.

Sources: Adapted and/or derived from Refs. [2] - [5], [7], [10].

Table C.19 Characterization of Final Energy Use in the Residential Sector in the United Kingdom in 1975, 1980, and 1985.

	1975	1980	1985
Occupied dwellings (dw), 10 ⁶	19.1	20.3	
Single-family dw (SFD), % of occupied dw	75	82	
Average dw size, m ²	83	82	
People per dw	2.9	2.7	
Central heating, % of dw	47.0	58.3	
Central heating SFD, %			
Dwelling stock vintage			
% built before 1950			
% built between 1950-1975			
% built after 1975			
Insulation of dw, W/m ² /°C			
Wall	1.0 ^a	1.0 ^b	
Roof	0.6	0.6	
Ground floor			
Final Energy Use, PJ			
Coal/coke	444	309	260
Liquid	146	123	97.1
Gas	605	895	936
Electricity	317	341	318
District heat	-		-
Wood	-		-
Other	-		-
Total	1512	1668	1611
Energy use per dwelling, GJ/dw	79.1	82.1	
Useful energy, GJ/dw	53		
Space heat by fuel type, % dw			
Coal/coke		24	
Liquid		10	
Gas		55	
Electricity		11	
District heat		-	
Wood		-	
None		-	

^aGenerally values required or used in the mid-1970s.

^bValues required by codes issued in 1977-1979.

Sources: Adapted and/or derived from Refs. [2] - [5], [10].

Table C.20 Residential Energy Use by End Use in the United Kingdom in 1975, 1980 and 1985.

	1975	1980	1985
Degree-day (DD) index ^a	0.96	0.998	
<u>Space Heat</u> , DD adj., PJ	990	1076	
Coal and coke	336	332 ^b	
Liquid	131	117 ^b	
Gas	427	532 ^b	
Electricity	96.4	72.5 ^b	
District heat		-	
Wood		-	
Other		-	
Space heat intensity			
Energy use per dwelling			
GJ/dw	51.8	53.0	
kJ/dw-dd-m ² , final energy	214	226	
kJ/dw-dd-m ² , fossil fuel equiv.			
Useful energy, kJ/dw-dd-m ²	135		
<u>Water heat</u> , PJ	296	284	
Coal and coke	122	59.2 ^b	
Liquid	20.0	29.8 ^b	
Gas	82.0	124 ^b	
Electricity	72.3	62.4 ^b	
Wood	-	-	
Other	-	-	
Water heat intensity			
Energy use per dwelling			
GJ/dw, final energy	15.5	14.0	
GJ/dw, fossil fuel equiv.			
Useful energy, GJ/dw			
<u>Cooking</u> , PJ	141	146	
Coal and coke	-	3.0 ^b	
Liquid	-	3.1 ^b	
Gas	106	109 ^b	
Electricity	34.5	32.3 ^b	
Wood	-	-	
Other	-	-	
Cooking intensity, GJ/dw	7.4	7.2	
<u>Appliance</u> energy use, PJ	126	158	
Gas	7.6	1.5 ^b	
Electricity	118	142 ^b	
Appliance intensity, GJ/dw	6.6	7.8	

^aBased on the adjusted yearly average heating degree-days of 2917 with base temperature of 18°C. The official base temperature is 17°C.

^b1978 data with the degree-day index of 0.986.

Sources: Adapted and/or derived from Refs. [2] - [5], [7].

Table C.21 Characterization of Final Energy Use in the Residential Sector in Canada in 1975, 1980, and 1985.

	1975	1980 ^a	1985
Occupied dwellings (dw), 10 ⁶	7.16	7.62/8.0	
Single-family dw (SFD), % of occupied dw	64	64/67	
Average dw size, m ²	98.7	99.4/100	
People per dw	3.23	3.09/2.95	
Central heating, % of dw	92	93/95	
Central heating SFD, %	62	62/	
Dwelling stock vintage			
% built before 1950		/23.4	
% built between 1950-1975		/58.6	
% built after 1975		/18.0	
Insulation of dw, W/m ² /°C			
Wall			
Roof			
Ground floor			
Final Energy Use, PJ			
Coal/coke	-	-	3.8
Liquid	575	545/443	226
Gas	422	468/507	456
Electricity	290	326/260	373
District heat	-	-	-
Wood	15.0	15.0/37.1	-
Other	-	-	-
Total	1302	1354/1237	1059
Energy use per dwelling, GJ/dw	182	178/155	
Useful energy, GJ/dw			
Space heat by fuel type, % dw			
Coal/coke	-	-	
Liquid	49	45/35	
Gas	36	38/41	
Electricity	13	15/21	
District heat			
Wood	2	2/3	
None	-	-	

^a1978/1981 data.

Sources: Adapted and/or derived from Refs. [3], [4], [5], [10].

Table C.22 Residential Energy Use by End Use in Canada in
1975, 1980 and 1985.

	1975	1980 ^a	1985
Degree-day (DD) index ^b	1.04	1.064/1.074	
<u>Space Heat</u> , DD adj., PJ	944	950/800	
Coal and coke	-	-	
Liquid	523	483	
Gas	330	357	
Electricity	78.0	96.8	
District heat	-	-	
Wood	13.0	12.3	
Other	-	-	
Space heat intensity			
Energy use per dwelling			
GJ/dw	132	125/104	
kJ/dw-dd-m ² , final energy	291	274/228	
kJ/dw-dd-m ² , fossil fuel equiv.			
Useful energy, kJ/dw-dd-m ²	194	178/148	
<u>Water heat</u> , PJ	181	201/218	
Coal and coke	-	-	
Liquid	29.9	30.4	
Gas	74.2	83.8	
Electricity	76.1	85.3	
Wood	1.0	1.0	
Other	-	-	
Water heat intensity			
Energy use per dwelling			
GJ/dw, final energy	25.3	26.4/27.3	
GJ/dw, fossil fuel equiv.			
Useful energy, GJ/dw		21.2/22	
<u>Cooking</u> , PJ	26.1	24.7/33.0	
Coal and coke	-	-	
Liquid	1.0	0.7	
Gas	5.0	4.4	
Electricity	19.3	18.7	
Wood	0.8	0.7	
Other	-	-	
Cooking intensity, GJ/dw	3.6	3.2/4.1	
<u>Appliance energy use</u> , PJ	114	119/127	
Gas	-	-	
Electricity	114	119/127	
Appliance intensity, GJ/dw	15.9	15.6/15.9	

^a1978/1981 data.

^bBased on the adjusted yearly average heating degree-days of 4581 with base temperature of 18°C.

Sources: Adapted and/or derived from Refs. [3], [4], [5].

Table C.23 Characterization of Final Energy Use in the Residential Sector in France in 1975, 1980, and 1985.

	1975	1980	1985
Occupied dwellings (dw), 10 ⁶	17.8	19.1	
Single-family dw (SFD), % of occupied dw	48	50	
Average dw size, m ²	74	79	
People per dw	3.0	2.8	
Central heating, % of dw	53.0	67.0	
Central heating SFD, %	43.0		
Dwelling stock vintage			
% built before 1950		56.0 ^a	
% built between 1950-1975		33.0 ^a	
% built after 1975		11.0 ^a	
Insulation of dw, W/m ² /°C			
Wall	0.7 ^b	0.7 ^c	
Roof	0.55 ^b	0.55 ^c	
Ground floor			
Final Energy Use, PJ			
Coal/coke	177/132 ^d	139 ^e	
Liquid	981/826 ^d	694 ^e	
Gas	208/298 ^d	331 ^e	
Electricity	109/193 ^d	225 ^e	
District heat	19.3/45 ^d	46 ^e	
Wood	22.5/2.5 ^a	-	
Other		-	
Total	1517/1496	1420	
Energy use per dwelling, GJ/dw	73	74.2	
Useful energy, GJ/dw		53	
Space heat by fuel type, % dw			
Coal/coke	26/18 ^d	16	
Liquid	53/48 ^d	45	
Gas	12/18 ^d	22	
Electricity	4/10 ^d	12	
District heat	1.6/3 ^d	3	
Wood	-	-	
None	3/3 ^d	2	

^aBased on the sample taken in 1982. For construction after 1975, the data run through 1982.

^bGenerally values required or used in the mid-1970s.

^cValues required by codes issued in 1977-1979.

^d1973/1978 data.

^e1981 data.

Sources: Adapted and/or derived from Refs. [2] - [5], [7], [10].

Table C.24 Residential Energy Use by End Use in France in
1975, 1980 and 1985.

	1975 ^a	1980	1985
Degree-day (DD) index ^b	1.07/1.01	1.04	
<u>Space Heat</u> , DD adj., PJ	1.48/1051	955	
Coal and coke	158/84	122 ^c	
Liquid	816/682	504 ^c	
Gas	124/205	210 ^c	
Electricity	11/43	58.2 ^c	
District heat	18/35.7	30.0 ^c	
Wood	21/0.8	-	
Other	-	-	
Space heat intensity			
Energy use per dwelling			
GJ/dw	68.4/58.2 ^d	51.0 ^d	
kJ/dw-dd-m ² , final energy	388/308	263	
kJ/dw-dd-m ² , fossil fuel equiv.			
Useful energy, kJ/dw-dd-m ²	232/204	176	
<u>Water heat</u> , PJ	143/192	210	
Coal and coke	4.2/3.3	3 ^c	
Liquid	75/85	99 ^c	
Gas	42/58	62 ^c	
Electricity	21/36	37 ^c	
Wood	-/0.4	-	
District heat	-/8.9	12 ^c	
Water heat intensity			
Energy use per dwelling			
GJ/dw, final energy	8.3/10.3	11.0	
GJ/dw, fossil fuel equiv.			
Useful energy, GJ/dw			
<u>Cooking</u> , PJ	112/145	110	
Coal and coke	40/44	2.0 ^c	
Liquid	33/52	40.5 ^c	
Gas	33/33	37.0 ^c	
Electricity	6.5/14.8	17.0 ^c	
Wood	- /1.3	-	
Other	- / -	-	
Cooking intensity, GJ/dw	6.5/7.8	5.7	
<u>Appliance</u> energy use, PJ	70/99	106	
Gas	-	-	
Electricity	70/99	106	
Appliance intensity, GJ/dw	4.0/5.3	5.5	

Table C.24 (continued)

^a1973/1978 data.

^bBased on the adjusted yearly average heating degree-days of 2450 with base temperature of 18°C. The official base temperature is 18°C.

^c1981 data with the degree-day index of 1.1.

^dCalculated based on 97% and 98% of dwelling with space heat in 1973 (1978) and 1980, respectively.

Sources: Adapted and/or derived from Refs. [2] - [5], [7].

Table C.25 Characterization of Final Energy Use in the Residential Sector in Italy in 1975, 1980, and 1985.

	1975	1980	1985
Occupied dwellings (dw), 10 ⁶	16.15	17.5	
Single-family dw (SFD), % of occupied dw	25.0	40.0	
Average dw size, m ²	68.0	78.0	
People per dw	3.4	3.27	
Central heating, % of dw	50.0	58.0	
Central heating SFD, %	9.0		
Dwelling stock vintage			
% built before 1950		43	
% built between 1950-1975		48	
% built after 1975		9	
Insulation of dw, W/m ² /°C			
Wall	1.39 ^a	0.68 ^b	
Roof	2.03 ^a	0.87 ^b	
Ground floor			
Final Energy Use, PJ			
Coal/coke	15	15	
Liquid	619	522	
Gas	258	276	
Electricity	100	146	
District heat	-	1	
Wood	26	26	
Other	-	-	
Total	1018	986	
Energy use per dwelling, GJ/dw	63.0	56.3	
Useful energy, GJ/dw			
Space heat by fuel type, % dw			
Coal/coke		11.8	
Liquid		51.9	
Gas		27.4	
Electricity	6	6.9	
District heat		0.1	
Wood		-	
None	3.0	2.0	

^aGenerally values required or used in the mid-1970's.

^bValues required by codes issued in 1977-1979.

Sources: Adapted and/or derived from Refs. [3] - [5], [7], [10].

Table C.26 Residential Energy Use by End Use in Italy in
1975, 1980 and 1985.

	1975 ^a	1980	1985
Degree-day (DD) index ^a	1.00	1.01	
<u>Space Heat</u> , DD adj., PJ	765	709	
Coal and coke	27	24.2 ^b	
Liquid	585	588 ^b	
Gas	149	179 ^b	
Electricity	4.0	3.2 ^b	
District heat	-	-	
Wood	-	-	
Other	-	-	
Space heat intensity			
Energy use per dwelling			
GJ/dw	48.8 ^c	41.3 ^c	
kJ/dw-dd-m ² , final energy	335 ^c	248 ^c	
kJ/dw-dd-m ² , fossil fuel equiv.			
Useful energy, kJ/dw-dd-m ²		159	
<u>Water heat</u> , PJ	100	87.7	
Coal and coke	-	16.6 ^b	
Liquid	34	28.2 ^b	
Gas	36	27.2 ^b	
Electricity	30	31.9 ^b	
Wood	-	-	
Other	-	-	
Water heat intensity			
Energy use per dwelling			
GJ/dw, final energy	6.2	5.0	
GJ/dw, fossil fuel equiv.			
Useful energy, GJ/dw		4.8	
<u>Cooking</u> , PJ	75.0	80.7	
Coal and coke	1	1.7 ^b	
Liquid	-	47.0 ^b	
Gas	73	27.6 ^b	
Electricity	1	0.7 ^b	
Wood	-	-	
Other	-	-	
Cooking intensity, GJ/dw	4.6	4.6	
<u>Appliance energy use</u> , PJ	65.0	98.5	
Gas	-	-	
Electricity	65.0	98.5	
Appliance intensity, GJ/dw	4.0	5.6	

Table C.26 (continued)

^aBased on the adjusted yearly average heating degree-days of 2140 with base temperature of 18°C. The official base temperature is 18°C.

^b1978 data with the degree-day index of 1.005.

^cCalculated based on the number of dwellings with the facility, i.e. 98% for space heat in 1980, and 97% in 1975.

Sources: Adapted and/or derived from Refs. [3] - [5], [7].

Table C.27 Characterization of Final Energy Use in the Residential Sector in Australia

	1975	1980	1985
Occupied dwellings (dw), 10 ⁶			
Single-family dw (SFD), % of occupied dw			
Average dw size, m ²			
People per dw			
Central heating, % of dw		3.2	
Central heating SFD, %			
Dwelling stock vintage			
% built before 1950			
% built between 1950-1975			
% built after 1975			
Insulation of dw, W/m ² /°C ^a			
Wall			
Roof			
Ground floor			
Final Energy Use, PJ			
Coal/coke	7.1	2.5	0.8
Liquid	48.5	33.5	18.4
Gas	32.6	46.9	63.6
Electricity	79.5	104	122
District heat	-	-	-
Wood	71.6	66.1	67.8
Other	-	-	-
Total	239	253	273
Energy use per dwelling, GJ/dw			
Useful energy, GJ/dw			
Space heat by fuel type, % dw			
Coal/coke			
Liquid			
Gas			
Electricity			
District heat			
Wood			
None			

^a There is no building insulation standard in force in Australia.

Sources: Adapted and/or derived from Refs. [1]

Table C.28 Residential Energy Use by End Use in Australia in
1975, 1980 and 1985.

	1975	1980	1985
Degree-day (DD) index			
<u>Space Heat</u> , DD adj., PJ			
Coal and coke			
Liquid			
Gas			
Electricity			
District heat			
Wood			
Other			
Space heat intensity			
Energy use per dwelling			
GJ/dw			
kJ/dw-dd-m ² , final energy			
kJ/dw-dd-m ² , fossil fuel equiv.			
Useful energy, kJ/dw-dd-m ²			
<u>Water heat</u> , PJ			
Coal and coke			
Liquid			
Gas			
Electricity			
Wood			
Other			
Water heat intensity			
Energy use per dwelling			
GJ/dw, final energy			
GJ/dw, fossil fuel equiv.			
Useful energy, GJ/dw			
<u>Cooking</u> , PJ			
Coal and coke			
Liquid			
Gas			
Electricity			
Wood			
Other			
Cooking intensity, GJ/dw			
<u>Appliance</u> energy use, PJ			
Gas			
Electricity			
Appliance intensity, GJ/dw			

Table C.29 Electricity Intensity by End Use for Residential Sector in 1983.

	Space heating ^a		Water heating	Cooking	Appliances ^b
	KJ/m ² /DD	SFD share	GJ/dw	GJ/dw	GJ/dw
U.S.A.	81	56	14.4	2.5	15.5
U.S.S.R.					
China					
Japan			14.4	-	6.8
Germany	144	44	40	1.8	5.8
U.K.	102	35	3.6	3.2	7.9
Canada	150	55	18.4	4.7	14.0
France	122	56	5.4	3.2	6.1
Italy					5.8
Austral					
Sweden	69	91	12.6	1.8	10.4

^aLong-term heating degree-day values, with base 18C, are as follows:
Canada-4580, France-2450, Germany-3113, Italy-2140, Japan-1975, UK-2823,
US-2172.

^bIncluding lighting.

Source: Adapted from Ref. [22].

Table C.30 Trends in the Energy Efficiency of New Residential Electric Appliances in the U.S.^a

Efficiency Parameter		1972	1975	1978	1980	1983	Top-rated Model Sold in 1984/1985 ^b
Central Space Heat							
Furnace and Boiler	Oil		73.6		78.5		
	Gas		62.7-63.2 ^b	63.6 ^b	63.3 ^b -65.9	68.4	94.0-97.0
Water Heat ^d	Gas	47.4					64.0
	Electricity	79.8		48.2	48 ^b -51.2	83.0	
Electric heat pump	Overall eff., %			80.7	78.3 ^b -81.0	1.90	2.6
	COP			1.7			
Air Conditioner	EERE (COP)	6.7 ^b (1.96)		7.0(2.05)	7.6(2.23)	8.4 ^b	15.0
	Central Room	6.0(1.82)		6.7(1.98)	7.0(2.06)	7.3 ^b	12.0
Refrigerator ^f	ft ³ /kWh/day	3.8		5.0	5.6	6.4	
Freezer ^g	ft ³ /kWh/day	7.3-7.5 ^b		9.9	10.8	11.4	
Cooking Top	Gas	19.0		30.8			
	Electricity	73.4		75.0			
Oven	Overall eff., %	3.8		4.6			
	Gas	12.6 ^h -12.7		12.6 ^h -13.0			
Clothes Washer ⁱ	ft ³ /kWh/cycle	0.6			0.9 ^l	0.99	
	lb/kWh	2.59		2.76 ^j	2.79		
Dishwasher ^k	cycle/kWh	0.24			0.31 ^l	0.37	
Lighting	lumens/watt				80 ^m	100 ⁿ	

Table C.30 (continued)

^aThe efficiencies are weighted by manufacturers' shipment, unless noted otherwise.

^bFrom Refs. [13], [14].

CAFUE (annual fuel utilization efficiency) is the ratio of the annual useful heat output to the annual energy input of a furnace or boiler. In early 1980's, the range of available efficiencies were 52.1-97.0% for gas-fueled central furnaces, 63.7-87.8% for oil-fueled, 62.9-90.8% for gas-fueled indoor boilers, and 74.3-87.4% for oil-fueled.

^dThe range of available water heat efficiencies in early 1980's were 40-64% for gas-fueled, 68-97% for electric, 50-63% for oil, 220-290% for heat pump without tank, and 240-350% for heat pump with tank.

^eEER (Energy Efficiency Ratio) is the ratio of cooling delivered (Btu) to electric power input (watt-hr).

^fThe average size and energy consumption per unit in 1972 were 18.16 ft³ and 1726 kWh/yr, 19.73 ft³ and 1453 kWh/yr in 1978, 19.7 ft³ and 1278 kWh/yr in 1980, 20.31 ft³ and 1160 kWh/yr in 1983.

^gThe average size and energy consumer per unit in 1972 were 29.18 ft³ and 1460 kWh/yr, 28.64 ft³ and 9.86 kWh/yr in 1978, 26.26 ft³ and 883 kWh in 1980, 25.32 ft³ and 813 kWh in 1983.

^hFor self-clean types.

ⁱThe average size and energy consumption per unit in 1972 were 2.44 ft³ and 1585 kWh/yr in 1972, 2.56 ft³ and 1165 kWh/yr in 1979.

^jThe average energy factor for existing clothes dryer stock in 1980 was 2.41 lb/kWh.

^kThe energy consumption was 1343 kWh/unit/yr in 1972, 1040 kWh/unit/yr in 1979, and 869 kWh/unit/yr in '983.
1979 data.

^mThe typical fluorescent lamp in 1981. The energy efficiency of the fluorescent lamp operated at 30,000 cycles in 1982 is 90 lumens/watt.

ⁿThe narrow fluorescent lamp with tuned phosphors.

Source: Adapted from Refs. [12], [13], [14].

Table C.31 Averaged Annual Energy Consumption for Existing and New Household Appliance Stocks in the U.S. in 1980 (GJ/yr)

	Existing Stock ^a	New Stock ^b
Refrigerator	6.1	4.6 ^c
Freezer	4.7	3.2 ^d
Washing Machine		4.2 ^e
Clothes Dryer		
Gas	5.3	
Electricity	3.6	
Dishwasher		3.7
Cooking Range		
Gas	9.5	
Electricity	2.9	
Lighting	3.6	
Television		
Monochrome		0.3
Color		0.9

^aThe consumption values correspond to the amount of energy used in households where the product is present.

^bThe shipment-weighted average.

^cUnit size = 19.60 ft³/unit.

^dUnit size = 26.26 ft³/unit.

^eUnit size = 2.56 ft³/unit.

Sources: Adapted from Refs. [12] - [14].

Table C.32 Comparison of Residential Final Energy Use by End Use
in the U.S. and Sweden (GJ/capital)

End Use	Average households	
	U.S. (1980) ^a	Sweden (1978-1982) ^b
Space heat	28.1	28.4
Air conditioning	1.5	-
Hot water	8.8	5.7
Refrigerator	2.5	0.5
Freezer	0.7	0.8
Stove	2.0	0.8
Lighting	1.3	0.9
Other	<u>2.5</u>	<u>2.0</u>
Total	47.3	39.2

^aThe total consists of 24% electricity and 76% fuel.

^bThe total consists of 28% electricity and 72% fuel. 50% of the electricity is for appliances and 50% is for heating purposes.

Note: Totals may not equal sum of components due to independent rounding.

Source: Adapted and/or derived from Refs. [19], Table 3.

Table C.33 Comparison of Space Heat Requirements in Single Family Dwellings in the U.S. and Sweden (KJ per m² per degree day)^a

United States	
Average, housing stock	160
New construction, 1980	100
Mean measured values for 97 houses in Minnesota's Energy Efficient Housing Demonstration Program	51
Mean measured value for 9 houses built in Eugene, Oregon	48
Calculated value for a Northern Energy Home in N.Y. City area ^b	15
Sweden	
Average, housing stock ^c	135
Home built to conform to the 1975 Swedish Building Code ^d	65
Mean measured value for 39 houses built in Skane, Sweden ^e	36
Measured value, house of Mats Wolgast, in Sweden ^f	18
Calculated value for alternative version of the prefabricated house sold by Fabuhus ^g	
Version #1	83
Version #2	17

^aThe required output of the space heating system; heating day, base 18°C.

^bThe Northern Energy Home is a super-insulated home design based on modular construction techniques with factory-built wall and ceiling sections mounted on a post and beam frame. The house has 120 m² of floor area; triple-glazed windows with night shutter; 20 cm (23cm) of polystyrene insulation in the walls (ceiling); 0.15 ACH natural ventilation plus 0.35 ACH forced ventilation via 70% efficient air-to-air heat exchanger; and an internal heat load of 0.65 kW. The indoor temperature is assumed to be 21°C in the daytime, set back to 18°C at night.

^cIn 1980 the average values for fuel consumption, floor area, and heating degree days were 98.5 G.J., 120m², and 4474 DD respectively, for oil heating single family dwellings. To convert fuel use to net heating requirements, a furnace efficiency of 66% is assumed.

^dFor a single story house with 130 m² floor area, no basement, electric resistance heat, an indoor temperature of 21°C and 4010 DD.

^eThe average for 39 identical, 4 bedroom, semi-detached houses, 112 m² of floor area; 3300 DD.

^fThe Wolgast house has 130 m² of heated floor space, 27 cm (45 cm) of mineral wool insulation in the walls (ceiling), quadruple glazing, low natural ventilation plus forced ventilation via air preheated in ground channels. Heat from the exhaust air is recovered via a heat exchanger. for 3800 DD.

^gThe Fabuhus has a floor area of 112 m². The more energy-efficient version #2 has extra insulation and heat recuperation.

Source: Adapted from Ref. [19], Table 2.

Table C.34 Electricity Consumption for Household and Public Services
in the U.S.S.R. (TWh/yr)

	1975			1980			1985	
	Urban	Rural	Total	Urban	Rural	Total	Urban	Urban
Population (10 ⁶)	155	100	255	167	99	266		
Household								
Lighting	13.6	4.2	17.8	16.0	5.9	21.9		21
Appliance	20.8	6.9	27.7	31.0	7.8	38.8		40
Cooking	4.2	1.6	5.8	5.1	2.0	7.1		6
Refrigerator	4.2	0.9	5.3	5.0	1.7	6.7		7
Subtotal	40.3	13.6	56.6	57.1	17.6	74.5		74
Public Service								
Lighting & auxiliaries of buildings	51.7	4.6	56.3	58.4(30.0)	7.1(3.0)	65.5(33.0)		68
Lighting of streets	3.8	0.4	4.2	4.3(5.2)	0.7(0.3)	5.0(5.5)		6
Water supply & waste water disposal	14.3	0.2	14.5	19.7	0.4	20.1		23
urban transport	5.8	1.0	6.8	12.0	1.2	13.2		14
Electric Motor				(47.9)	(3.0)	(50.9)		
Food preparation				(10.7)	(0.6)	(11.3)		
Heating of hot water				(3.2)	(0.3)	(3.5)		
Other	0.5	0.1	0.6	3.5	0.5	4.0		5
Subtotal	76.1	6.3	82.4	97.9(97.0)	9.9(7.2)	108(104)		117
total	119	19.9	139	155	27.3	182		191

Note: Totals may not equal sum of components due to independent rounding.

Sources: The figure in the brackets is from Ref. [8], Table 2.23. The rest is adapted from Ref. [23], Table 2.

Table C.35 Thermal Efficiencies of Space Heating Systems in China

System	Efficiency, %
Urban	
Steam boiler space heat	$\leq 30^a$
Residential heating system (Beijing apartment buildings)	40 ^b
Hand stoked boilers	50 ^b
Modern chain-grid boilers	80 ^b
Small stoves (charcoal or wood)	15-18 ^c
Rural	
Kang (northern rural areas)	10 ^c
Open Fire	5 ^c
Kitchen stove without chimney	5 ^c
Braziers	10 ^c

^aFrom [15].

^bFrom [16].

^cFrom [17].

Sources: Adapted from Refs. [15], [16], [17].

Table C.36 Thermal Efficiencies and Annual Fuel Demand of Cookstoves Used in China in 1980

	Heating Value MJ/kg	Type of Cookstove	Averaged Thermal Efficiency, %	Fuel Demand	
				Mt	PJ
Non Commercial Fuels					
Crop by-products	14.65	agricultural residue cookstove	12-20	235	3441.6
Corn stalk	13.31		9-10		
Fuelwood	15.70	wood cookstove	10-19	180	2823.6
Leaves	12.77		14		
Dung					
Biogas	20.93	biogas cookstove	50-59	3.1	64.4
Dung cakes ^a	8.92		10		
Commercial Fuels					
Bituminous coal	29.30	coal cookstove	16-18	14	269.5
Comb-shape coal		cast-iron type	25-28 ^c		
Coal briquettes		cast-iron type	21 ^c	6	105.4
Natural gas	38.93 MJ/m ³		50	0.6 x 10 ⁹ m ³	23.4
Liquefied petroleum gas	45.21		50	0.3	11.4
Kerosene	43.11				
Charcoal	29.03				

^aDried dung is not widely used as direct fuel in China.

^bMost of the gas is manufactured, including coke-oven gas, low-Btu water gas made from coal, medium-Btu gas made from coal using the Lurgi process, and gas made from heavy oil.

^cAn efficiency of 28%, when comb-shaped coal is used, but it may be as low as 10% when inferior fuels (e.g., coke ball and cake) are used as is frequently the case [15].

Source: Adapted and/or derived from Refs. [9], [15].

Table C.37 Efficiencies of Space Heat and Water Heat by Fuel Type in
F.R. Germany in 1975 (%)

	Solid	Liquid	Gas	Electricity	District Heating
Space Heat ^{a, b}					
Room Heating	41-61(15)	45-66(14)	60-70(5)	90-95(6) ^d	---
Central Heating	45-66(3)	51-73(38)	53-75(11)	---	71-95(8)
Average	42-66	49-70	55-70	90-95	71-95
Water Heat ^c	30-45	50-58	63-70	90-94 ^e	---

^aHigher figure: the boiler or stove efficiency only; lower figure: the successive efficiencies from the boiler to the dwelling (i.e., boiler, distribution and regulation efficiencies).

^bFigures in the brackets are the market share (in %) of space heating equipment by heating and source of energy in 1975. The average end-use conversion efficiency was 55-73% for all heating systems and 49-70% for direct-fuel systems.

^cThe efficiency represents the ratio between the useful energy delivered at the tap and the secondary energy demand.

^dExcludes electric storage heating.

^eProbably excludes the tank and pipe losses. The electricity needs were 1.09 and 1.08 kWh/kWh of hot water in 1975 and 1980, respectively.

Source: Adapted from Ref. [7].

REFERENCES

1. International Energy Agency, Energy Balances of OECD Countries, 1970/1985, OECD/IEA, Paris, 1987.
2. Schipper, L., Ketoff, A., and Kahane, A., Explaining Residential Energy Use by International Bottom-up Comparison, *Ann. Rev. Energy*, 10, p 341, 1985.
3. Schipper, L. and Ketoff, A., Residential Energy Use in the OECD, *The Energy Journal*, 6, p. 65, 1985.
4. Schipper, L. and Ketoff, A., Home Energy Use in Nine OECD Countries, 1960-1980, *Energy Policy*, p. 131, June 1983.
5. Schipper, L. Ketoff, A., and Meyers, S., International Comparison of Residential Energy Use, LBL11703, Lawrence Berkeley Lab. CA., 1981.
6. U.S. Dept. of Energy, Energy Information Administration, Annual Energy Review, DOE/EIA-0384(85).
7. Chateau, B., and Lapillonne, B., Energy Demand: Facts and Trends, Springer-Verlag, New York, 1982.
8. Wilson, D., The Demand for Energy in the Soviet Union, Rowman and Allanheld, Croom Helm, Australia, 1983.
9. World Bank, China: The Energy Sector, Washington, D.C., 1985.
10. United Nations, Economic Commission for Europe, An Efficient Energy Future, Butterworths, London, 1983.
11. Meyers, S., Energy Consumption and Structure of the U.S. Residential Sector: Changes between 1970 and 1985, *Ann. Rev. Energy*, 12, p. 81, 1987.
12. Geller, H.S., Energy Efficient Appliances, American Council for an Energy-Efficient Economy, Washington D.C., 1983.
13. Geller, H.S., Progress in the Energy Efficiency of Residential Appliances and Space Conditioning Equipment, Chapter 15 in Energy Sources: Conservation and Renewables, Hafemeister, D., Kelly, H., and Levi, B., Eds., Am. Inst. of Physics, No. 135, New York 1985.
14. Blatt, M.H., Trends in the Energy Efficiency of Residential Electric Appliances, EPRI EM-4539, Electric Power Research Institute, Palo Alto, CA, 1986.

15. Zhu, Y.J., The Present Status of Energy Use in China and Its Development Prospectives, Energy 8, p. 73, 1983.
16. Huang, Y.J., Rosenfeld, A.H., de Piedade, A.C., and Tseng, D., Energy Efficiency in Chinese Apartment Building, Energy 9, p. 979, 1984.
17. Taylor, R.P., Rural Energy Development in China, Resources for the Future Inc., Washington, D.C., 1981.
18. Schipper, L. Meyers, S., and Ketoff, A.N., Energy Use in the Service Sector: An International Perspective, LBL-19443, Lawrence Berkeley Lab., Berkeley, CA. 1985.
19. Goldemberg, J., Johansson, T.B., Reddy, A.K.N., and William, R.H., An End-Use Oriented Global Energy Strategy, Am Rev. Energy, 10 p. 613, 1985.
20. U.S. Dept. of Energy, Office of Conservation, Energy Conservation, Multi-Year Plan, FY 1989-93, 1987.
21. U.S. Dept. of Energy, Energy Information Administration, Annual Energy Review, DOE/EIA-0384 (88), 1989.
22. Schipper, L., Ketoff, S., Meyers, S., and Hawk, D. Electricity and the Home: An International Overview of Trends, LBL-21187, Lawrence Berkeley Laboratory, 1986.
23. Tarnizhevsky, M.V., Energy Consumption in the Residential and Public Services Sector, Energy, 12, p.1009, 1987.

Appendix D

COMMERICAL SECTOR ENERGY USE DATA

Table D.1 Final Energy Use by Fuel Type in Commercial Sector in Major CO₂ Producing Countries in 1975 (PJ = 10¹⁵J)^a

	Coal	Liquid	Gas	Electricity	District Heat	Total	Total Floor Area Mm ²
U.S.A. ^b	132/128	1288/2101	2698/2160	1686/1596	-	5803/5985	3776/2627
U.S.S.R.						3118	
China							
Japan	-	/873	-	/197	-	/1070	
F.R. Germany	44/90.0	636/760	147/109	182/160	38/41	1047/1160	
U.K.	73/64	291/291	142/130	150/158		656/643	381
Canada ^c	-	/287	/283	/213	-	/782	
France	14/	366/	67/	107/	-	524/	663
Italy	-	/199	/235	/47.3	-	/481	
Australia ^d	9.2	27.6	9.6	38.1	-	84.5	

^a The first number is adapted from Ref. [3], and the second number is derived from Refs. [1] and [4-6], unless otherwise noted.

^b The first number is adapted from Ref. [3]; and the second number is from Ref. [2].

^c In Ref. [3], Liquid: 209 PJ, Gas: 308/238 PJ, Electricity: 237/208 PJ with a total of 754/655 PJ. For gas, electricity and total, the first number is as reported by Statistics Canada; the second number is after residential consumption (mass-metered apartments) as estimated by Shell Canada has been removed.

^d Adapted from Ref. [1].

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1] - [6].

Table D.2 Final Energy Use by Fuel Type in Commercial Sector in Major CO₂ Producing Countries in 1980 (PJ = 10¹⁵J)^a

	Coal	Liquid	Gas	Electricity	District Heat	Total	Total Floor Area Mm ²
U.S.A. ^b	93/266	1245/1287	2816/2591	2012/2012	-	6166/6156	4159
U.S.S.R.							
China							
Japan	-	/968	/62.0	/190	-	/1220	
F.R. Germany	35/61.5	551/639	202/248	234/210	62/65	1084/1224	1030
U.K.	62/54.8	263/279	271/199	185/194	-	727/727	590
Canada ^c	/1.3	/209	/300	/261	-	/772	
France ^d	5.6/	282/306	114/125	151/121	-	553/552	663
Italy	-	/205	/257	/64	-	/526	
Australia ^e	7.1	21.3	16.3	55.7	-	101	

^aThe first number is adapted from Ref. [3], and the second number is derived from Refs. [1] and [4-6], unless otherwise noted.

^bIn Ref. [7], Table 17, the final energy use in commercial sector is 2030 PJ of electricity and 4340 PJ of fuel, with a total of 6370 PJ. The total commercial floor area is 4230 million square meters.

^cIn Ref. [3], coal: 1 PJ, Liquid: 199 PJ, Gas: 333/292 PJ, Electricity: 261/232 PJ, District Heat: 1 PJ, with a total of 795/725. For gas, electricity and total, the first number is as reported by Statistics Canada; the second number is after residential consumption (mass-metered apartments) as estimated by Shell Canada has been removed.

^dAdapted from Ref. [3]. The first number is from Table A3, and the second number is from Table B2.

^eAdapted from Ref. [1].

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1] - [6].

Table D.3 Final Energy Use by Fuel Type in Commercial Sector in Major CO₂
Producing Countries in 1985 (PJ = 10¹⁵J)

	Coal	Liquid	Gas	Electricity	District Heat	Total	Total Floor Area Mm
U.S.A.	278	1151	2422	2486	74.1	6411	
U.S.S.R.							
China							
Japan	-	967	77.8	281	-	1326	
F.R. Germany	49.0	512	249	249	57	1117	
U.K.	56.1	219	257	224	-	756	
Canada	0.8	177	402	305	-	885	
France	-	729	250	204	-	1183	
Italy	-	52.3	491	99.6	-	643	
Australia	6.7	10.0	25.1	69.9	-	111	

Note: Totals may not equal sum of components due to independent rounding.

Source: Adapted and/or derived from Ref. [1]

Table D.4 Commercial Final Energy Use by Fuel Type and End Use in the US (PJ = 10¹⁵J)

	Coal/Coke			Liquid			Gas			Electricity			Total		
	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985
Space heating	128			1904 ^b			1751			105			3966		
Space cooling	-			-			148			579			727		
Water heating	-			106			84.4			12.7			203		
Lighting	-			-			-			662			662		
Other ^a	-			-			179			241			420		
Total	128	266	278	2010	1287	1151	2160	2591	2422	1596	2012	2486	5978	6156	6337

^a Includes cooking and electromechanical uses.

^b Includes liquefied natural gas.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1]-[6].

Table D.5 Commercial Final Energy Use by Building and Fuel Type in the U.S.
in 1975 (PJ = 10¹⁵J)

	Coal	Liquida ^a	Gas	Electricity	Total	Floor Area Mm ²
Retail-wholesale	25.6	405	566	397	1394	486.7
Education	26.6	434	408	301	1170	609.5
Office	25.6	416	393	332	1167	496.6
Health Care	15.1	269	248	183	716	185.2
Lodging	11.0	178	165	70.6	424	134.2
Warehouses	5.0	77.1	73.1	54.0	209	212.7
Religious	4.5	70.0	66.1	39.8	180	130.4
Garage and service stations	1.4	20.8	19.8	15.8	57.7	57.4
Other	14.3	231	220	203	668	314.2
Total	128	2101	2159	1596	5984	2627

^a Includes liquefied natural gas.

Note: Totals may not equal sum of components due to independent rounding.

Source: Adapted from Ref. [2]

Table D.6 Commercial Final Energy Use by Building and Fuel Type in the U.S.
in 1979 (PJ = 10^{15} J)

	Coal	Liquid	Gas	Electricity	Steam	Total	Floor Area Mm ²
Retail-Services	-	63.4	320	308	-	698	708.8
Education	-	114	223	171	-	537	544.9
Office	-	133	373	513	-	1070	762.0
Health Care	-	100	195	122	-	465	155.1
Lodging	-	20	115	122	-	284	186.0
Warehouses	-	108	318	276	-	684	562.6
Auto Sales/Service	-	47	116	63	-	234	168.3
Food sales	-	23.4	145	195	-	367	172.8
Assembly	-	68.4	218	129	-	435	465.1
Vacant	-	15	31	36	-	86	119.6
Other	-	82.1	300	206	-	606	292.4
Total	-	800	2349	2105	215	5467	4138

Note: Totals may not equal sum of components due to independent rounding.

Source: Adapted from Ref. [3]

Table D.7 Commercial Final Energy Use by Building and Fuel Type in Japan
in 1976 (PJ = 10^{15} J)

	Coal	Liquid	Gas	Electricity	Total	Floor Area Mm ²
Retail-wholesale ^a	-	28.0	11.2	72.9	125	
Education	-	63.3	14.4	18.2	96.0	269.6
Office	-	72.7	15.7	108	208	234.5
Health Care	-	77.2	11.0	22.1	110	58.6
Hotels	-	76.4	7.3	20.9	105	50.0
Restaurants	-	18.6	32.7	21.8	72.6	
Laundry, Barber, Bath	-	34.5	20.7	13.6	69.9	
Dept. Stores, Supermarkets	-	6.5	4.8	21.0	32.3	25.9
Entertainment	-	3.4	1.0	4.4	8.8	
Theaters, movie ^b	-	7.9	1.0	7.5	16.4	16.6
Total	-	388	119	311	818	

^a Refers mainly to small establishments, and particularly stores. Many of these are in malls.

^b Probably includes assembly such as sports, worship, etc.

Note: Totals may not equal sum of components due to independent rounding.

Source: Adapted from Ref. [3]

Table D.8 Commercial Final Energy Use by Building and Fuel Type in Japan
in 1979 (PJ = 10^{15} J)

	Coal	Liquid	Gas	Electricity	Total	Floor Space Mm ²
Retail-wholesale ^a					124	
Education					103	
Offices					224	
Hospitals					117	
Hotels					115	
Restaurants					82.4	
Laundry, Barber, Bath					72.6	
Dept. Stores, Supermarkets					38.9	
Entertainment					10.2	
Theaters, movie ^b					16.6	
Total					904	

^a Refers mainly to small establishments, and particularly stores. Many of these are in malls.

^b Probably includes assembly such as sports, worship, etc.

Note: Totals may not equal sum of components due to independent rounding.

Source: Adapted from Ref. [3]

Table D.9 Commercial Final Energy Use by Building and Fuel Type in
F.R. Germany in 1980 (PJ = 10^{15} J)

	Coal	Liquid	Gas	Electricity	District Heat	Total	Floor Space Mm ²
Retail	3.2	70.1	43.9	38.0	8.6	164	
School	3.1	39.5	24.1	5.6	26.3	102	
Health Care	0.4	33.3	15.4	19.0	25.4	93.6	
Lodging/Restaurants	0.5	36.0	29.9	17.8	1.4	85.6	
Govt. Buildings	4.1	20.6	20.5	49.0	2.1	96.5	
Banks/Insurance	-	7.4	10.8	6.6	1.0	25.8	
Laundries	-	23.4	1.7	5.6	-	30.8	
Pools/Baths	-	6.6	88.0	6.6	5.1	27.1	
Work Shops	4.2	39.4	7.9	17.4	0.2	69.2	
Other	-	41.6	8.5	25.1	1.2	76.7	
Total	15.6	318	172	191	71.4	771	1030

Note: Totals may not equal sum of components due to independent rounding.

Source: Adapted from Ref. [3], Table B3.

Table D.10 Commercial Final Energy Use by Building and Fuel Type in the United Kingdom in 1980 (PJ = 10^{15} J)

	Coal	Liquid	Gas	Electricity	District Heat	Total	Floor Space Mm ²
Education	17.2	44.8	42.4	15.2	-	120	110
Government	9.8	74.4	28.7	20.0	-	133	
Health Care	21.6	49.5	28.9	13.1	-	113	40
Commercial Office ^a	3.9	20.8	32.0	34.5	-	91.2	
Shops ^b	3.4	24.3	19.2	52.7	-	99.6	
Other Premises ^c	5.6	28.3	66.2	41.0	-	141	
Total	61.5	242 ^d	217	185	-	706 ^d	590

^a Includes wholesale warehouses.

^b Includes public houses and clubs.

^c Includes restaurants and hotels.

^d The liquid energy use shown in Table A7 of Ref. [3] is 263 PJ with a total of 727 PJ final energy used by commercial sector.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted from Ref. [3], Table B7.

Table D.11 Commercial Final Energy Use by Building and Fuel Type in France in 1980 (PJ = 10^{15} J)

	Coal	Liquid	Gas	Electricity	District Heat	Total	Floor Space Mm ²
Retail, Artisans ^a	-	69.1	8.3	25.5	-	103	106.1
Education	-	56.9	17.8	6.5	-	81.3	152.5
Office	-	23.5	9.7	25.8	-	58.9	99.5
Health	-	32.2	19.0	6.3	-	57.5	66.3
Hotels/Restaurants	-	34.8	12.7	10.3	-	57.7	92.8
Large commerce ^b	-	46.1	42.2	18.3	-	106	33.1
Group facilities ^c	-	15.9	1.8	5.9	-	23.6	39.8
Sports, Culture ^d	-	11.7	8.6	15.5	-	35.8	66.3
Transport ^e	-	15.5 ^f	5.1 ^f	6.9	-	27.5	13.3
Total	-	306	125	121	-	552	663

^aIncludes small commerce and garages.

^bIncludes supermarkets, large stores and markets, and wholesale commerce.

^cIncludes army barracks, prisons, religious communities, vacation resorts, union halls.

^dIncludes museums, libraries, zoos, assembly buildings, churches, entertainment and some vacation centers.

^eIncludes air, rail, and other buildings.

^fHeating only.

Note: Totals may not equal sum of components due to independent rounding.

Source: Adapted from Ref. [3].

Table D.12 Energy Intensity Factors for Commercial Buildings in the U.S.
and Sweden (GJ per m² per year)

	Fuel-use	Electricity-use	Total
United States			
Average 1979 building stock ^a	0.82	0.49	1.31
1980 U.S. practice	0.16	0.57	0.73
Am. Inst. Architects (AIA) Res. Corp. redesigns	0.07	0.40	0.47
AIA life-cycle cost minimum design	0.04	0.28	0.32
Enerplex South, Princeton, NJ		0.31	0.31
Sweden			
Average 1982 building stock ^b	0.66	0.38	1.04
Swedish norm for new construction	0.57	0.19	0.76
Folksam Building, Farsta ^c	0.07	0.39	0.46
Harnosand Building, Harnosand ^d	0.12	0.13	0.25

^aFor an average of 2700 heating degree-C-days.

^bFor 4010 heating degree-C-days.

^cMeasured values for the representative period Dec. 1978 to Dec. 1979 (3810 heating-degree-C-days).

^dMeasured values for 4600 heating degree-C-days.

Source: Adapted from Ref. [7]

References

1. International Energy Agency. Energy Balances of OECD Countries, 1970/1985, OECD/IEA, Paris, 1987.
2. Jackson, J.R. and Johnson, W.S. Commercial Energy Use: A Disaggregation by Fuel, Building Type, and End Use. ORNL/CON-14, Oak Ridge National Lab., Oak Ridge, TN, 1978.
3. Schipper, L., Meyers, S., and Ketoff, A.N. Energy Use in the Service Sector: An International Perspective, LBL-19443, Lawrence Berkeley Lab., Berkeley, CA, 1985.
4. Schipper, L., Ketoff, A., and Kahane, A., Explaining Residential Energy Use by International Bottom-up Comparison, Ann. Rev. Energy, 10, p 341, 1985.
5. Schipper, L. and Ketoff, A., Residential Energy Use in the OECD, The Energy Journal, 6, p. 65, 1985.
6. Schipper, L., Ketoff, A., and Meyers, S., International Comparison of Residential Energy Use, LBL11703, Lawrence Berkeley Lab. CA., 1981.
7. Goldemberg, J., Johansson, T.B., Reddy, A.K.N., and Williams, R.H., Energy for a Sustainable World. World Resources Institute, Washington, DC, 1987.

Appendix E

TRANSPORTATION SECTOR ENERGY USE DATA

Table E.1 Final Energy Use by Mode and Fuel Type in the Transportation Sector in U.S. in 1975, 1980 and 1985 (PJ = 10^{15} J)

Mode	Year	Solid	Liquid	Gas	Electricity	Total ^a
Road	1975	--	14095	--	--	14095
	1980	--	14624	--	--	14624
	1985	--	15362	--	--	15362
Rail	1975	--	545	--	14	559
	1980	--	597	--	11	608
	1985	--	472	--	13	485
Air	1975	--	2144	--	--	2144
	1980	--	2340	--	--	2340
	1985	--	2648	--	--	2648
Water ^b	1975	--	282	--	--	282
	1980	--	265	--	--	265
	1985	--	138	--	--	138
Non-specified ^c	1975	--				
	1980	--				
	1985	--				
Total	1975	--	17066	--	14	17080
	1980	--	17826	--	11	17837
	1985	--	18620			^d

^a In Ref. [9], the respective transportation energy uses by mode in 1975 and 1980, were: Road, 14480 & 15348 PJ; Rail, 629 & 701 PJ; Air, 1343 & 1612 PJ; Water, 898 & 1769 PJ; Pipeline, 881 & 937 PJ, with the total of 18236 and 20347 PJ.

^b Internal navigation.

^c In 1984, 250 PJ of natural gas and 253 PJ of electricity were used in pipeline transport [9].

^d In Ref. [9] the total transportation energy use in 1985 was 21110 PJ.

Notes: Totals may not equal sum of components due to independent rounding.

Sources: Refs. [1], [2], [3], [7], [9].

Table E.2 Traffic and Energy Efficiency by Mode of Transport in the U.S.

	Freight Transport				Passenger Transport				
	Traffic, bn tkm		Efficiency, MJ/tkm		Traffic, bn pkm		Efficiency, MJ/pkm		
	1975	1980	1985	1975	1980	1985	1975	1980	1985
Road	745	910	992			4330 ^g	c	c	c
Automobile	-	-	-			3412 ^{b,g}	3.12	3.06	2.86
Bus	-	-	-			199 ^g	0.65 ⁱ	0.77 ⁱ	0.82
Truck	745	910	992	6.0	2.0	719 ^g			3.54
Rail	1123	1350	1286	0.5	0.47	16	2.43 ⁱ	2.10 ⁱ	2.07 ⁱ
Air	8.6 ^e	10.4 ^e	11.4 ^e			262 ^f	5.2	3.82	3.18
Water	265 ^a	334 ^a	335 ^a	0.36	0.24	-	-	-	-
Pipeline	740 ^h	858 ^h	817 ^h			-	-	-	-
Total	2882	3462	3441						4858

E. 3

^aInternal, intraport and local water traffic, excluding Great Lake traffic [7]. In Ref. [4], water freight which might include inland and coastal transport are 909 bn tkm in 1975 and 1480 bn tkm in 1980.

^bThe total vehicle miles of automobiles were 1028 bn, 1112 bn and 1298 bn miles for 1975, 1980 and 1985 respectively.

^cThe average on-road fuel efficiency of automobiles were 13.5 mpg, 15.5 mpg, and 18.2 mpg in 1975, 1980 and 1985, respectively. The fuel efficiency for all motor vehicles which includes passenger cars, motorcycles, buses, and trucks were 12.2 mpg, 13.3 mpg, and 14.6 mpg in 1975, 1980, 1985 respectively.

^dThe average on-road fuel efficiency of bus was 2.3 miles/gal or 53 liters of diesel/100 km for urban travels and 6 miles/gal or 39 liters/100 km for intercity travels [6].

^eRevenue ton-kilometers flown on scheduled service of certified route air carriers.

^fRevenue passenger-kilometers flown on scheduled service of certified route air carriers [7], In Ref. [9], 561 bn pkm and 3.18 MJ/pkm in 1985.

^g1984 data, Ref [9].

^hPetroleum pipelines. In Ref. [4], 816 and 946 bn tkm in 1975 and 1980, respectively might include the natural gas pipelines.

ⁱIntercity buses and rail.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and derived from Refs. [2], [3], [4], [6], [7], [9].

Table E.3 Final Energy Use by Mode and Fuel Type in the Transportation Sector in U.S.S.R. in 1975, 1980 and 1985 (PJ = 10^{15} J)

Mode	Year	Solid	Liquid	Gas	Electricity	Total
Road	1975				24	913
	1980				30	
	1985					
Rail	1975				155	2818
	1980				175	
	1985				205	
Air	1975					452 ^a
	1980					
	1985					
Water	1975					33
	1980					
	1985					
Non-specified	1975				88 ^b	
	1980				165 ^c	
	1985					
Total	1975				267	4216
	1980		4424	442	370	5236
	1985					

^aIncludes 9 PJ of international flight.

^bIncludes 49PJ for pipeline freight transport.

^cIncludes 115 PJ for pipeline freight transport.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and derived from Refs. [3], [4], [7], [8].

Table E.4 Traffic and Energy Efficiency by Mode of Transport in the U.S.S.R.

	Freight Transport				Passenger Transport			
	Traffic, bn tkm		Efficiency, MJ/tkm		Traffic, bn pkm		Efficiency, MJ/pkm	
	1975	1980	1985	1975	1980	1985	1975	1980 1985
Road	338	432	477		304	390		
Automobile	-	-	-				1.2 ^d	
Bus	-	-	-				0.6	
Truck	338	432	477	1.76 ^a				
Rail	3236	3440	3719	0.88 ^a	313	332	0.48 ^a	
Air	2.6	3.1	3.4		123	161	4.52 ^a	
Water	222 ^b	245 ^b	262 ^b	0.15 ^a	8	9		
Pipeline	666 ^c	1216 ^c	1313		-	-		
Total	3555	5336	5774		747	891		

^aFrom Ref [3].

^bInland water freight.

^cPetroleum pipelines. In Ref. [4], the pipeline Freight traffics were 945 and 1824 bn tkm in 1975 and 1980, respectively which might include natural gas pipelines.

^dThe average on-road fuel efficiency was 23.5 mpg or 10.1 liters of gasoline/100 km.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and derived from Refs. [3], [4], [7], [8].

Table E.5 Final Energy Use by Mode and Fuel Type in the Transportation Sector in China in 1975, 1980 and 1985 (PJ = 10¹⁵J)

Mode	Year	Solid	Liquid	Gas	Electricity	Total
Road	1975					
	1980	--	445 ^c	--	--	445
	1985					
Rail	1975					
	1980 ^a	556	50	--	6	612 ^d
	1985					
Air	1975					
	1980	--	12	--	--	12 ^e
	1985					
Water ^b	1975					
	1980	--	108	--	--	108 ^f
	1985					
Non-specified	1975					
	1980	--	--	--	--	--
	1985					
Total	1975					
	1980	556	615	--	6	1178
	1985					

^aIncludes 14.6 PJ of liquid fuels, 123 PJ of solid fuels, and 5.3 PJ of electricity consumed by stations, housing, construction, etc.

^bInland water and coastal transport.

^cAutomobiles, 5.9 PJ, buses, 79 PJ, and freight transport (trucks), 360 PJ.

^d119 PJ for passenger transport and 493 PJ for freight transport.

^e11.4 PJ for passenger transport and 0.3 PJ for freight transport.

^f8.4 PJ for passenger transport and 100 PJ for freight transport.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and derived from Refs. [4], [5], [7].

Table E.6 Traffic and Energy Efficiency by Mode of Transport in China

	Freight Transport				Passenger Transport			
	Traffic, bn tkm		Efficiency, MJ/tkm		Traffic, bn pkm		Efficiency, MJ/pkm	
	1975	1980	1985	1975	1980	1985	1975	1980 1985
Road	20.3 ^a	76.4	178.2 ^b		37	73	129 ^d	1.1
Automobile	-	-	-					
Bus	-	-	-					
Truck	20.3	76.4	178.2	4.7				
Rail	426	572	812	0.51	96	138	205 ^d	0.51
Air	0.06	0.14			1.54	4.0	8.4 ^d	2.8
Water	82	152 ^c		0.7	9	13	4 ^d	0.7
Pipeline	26	49			-	-	-	
Total	554	850			144	228	358	

^aFrom Ref. [7]. In Ref. [4], the road freight was 60 bn tkm in 1975.

^bIncludes freight carried in vehicles by all sectors [7].

^cIncludes 95.1 bn tkm for coastal shipping and 57.2 bn tkm for inland water. Ocean shipping was 353.2 bn tkm.

^d1984 data.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and derived from Refs. [4], [6], [7].

Table E.7 Final Energy Use by Mode and Fuel Type in the Transportation Sector in Japan in 1975, 1980 and 1985 (PJ = 10^{15} J)

Mode	Year	Solid	Liquid	Gas	Electricity	Total
Road						
	1975	--	1406	--	--	1406
	1980	--	1824	--	--	1824
	1985	--	2028	--	--	2028
Rail						
	1975	1.3	48	--	50	99
	1980	--	53	--	54	107
	1985	--	39	--	59	98
Air						
	1975	--	73	--	--	73
	1980	--	105	--	--	105
	1985	--	104	--	--	104
Water ^a						
	1975	--	230	--	--	230
	1980	--	228	--	--	228
	1985	--	175	--	--	175
Non-specified						
	1975	--	4	--	--	4
	1980	--	2	--	--	2
	1985	--	2	--	--	2
Total						
	1975	1.3	1761	--	50	1812
	1980	--	2212	--	54	2266
	1985	--	2350	--	59	2408

^aInternal navigation.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and derived from Refs. [1], [2], [7].

Table E.8 Traffic and Energy Efficiency by Mode of Transport in Japan

	Freight Transport				Passenger Transport				
	Traffic, bn tkm		Efficiency, MJ/tkm		Traffic, bn pkm		Efficiency, MJ/pkm		
	1975	1980	1985	1975	1980	1985	1975	1980	1985
Road	130	179	201		361	432	489		
Automobile	-	-	-				384		
Bus	-	-	-				105		
Truck	130	179	201						
Rail	47.1	39.3	21.3		172	167	176		
Air	0.9 ^a	2.0 ^b			30.1 ^c	50.9 ^c	33.1		
Water	184	222			6.6	6.1	5.7		
Pipeline	-	-			-	-	-		
Total	362	442			570	656	704		

^aJapan Air Lines data only [7].

^bJapan Air Lines and Japan-Asia airways [7].

^cIn Ref. [4], the air passenger traffics which might include domestic traffic only were 19.1 bn and 29.7 bn pkm in 1975 and 1980, respectively.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and derived from Refs. [4], [6], [7].

Table E.9 Final Energy Use by Mode and Fuel Type in the Transportation Sector in F. R. Germany 1975, 1980 and 1985 (PJ = 10¹⁵J)

Mode	Year	Solid	Liquid	Gas	Electricity	Total
Road						
	1975	--	1202	--	--	1202
	1980	--	1501	--	--	1501
	1985	--	1555	--	--	1555
Rail						
	1975	12	27	--	32	71
	1980	3	30	--	39	72
	1985	--	20	--	40	60
Air						
	1975	--	103	--	--	103
	1980	--	127	--	--	127
	1985	--	156	--	--	156
Water ^a						
	1975	--	38	--	--	38
	1980	--	37	--	--	37
	1985	--	30	--	--	30
Non-specified						
	1975	--	--	--	--	--
	1980	--	--	--	--	--
	1985	--	--	--	--	--
Total						
	1975	12	1370	--	32	1414
	1980	3	1695	--	39	1737
	1985	--	1741	--	40	1801

^aInternal navigation.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and derived from Refs. [1], [2], [3], [7].

Table E.10 Traffic and Energy Efficiency by Mode of Transport in F. R. Germany

	Freight Transport				Passenger Transport				
	Traffic, bn tkm		Efficiency, MJ/tkm		Traffic, bn pkm		Efficiency, MJ/pkm		
	1975	1980	1985	1975	1980	1985	1975	1980	1985
Road	86 ^a						538		
Automobile	-						469		
Bus	-						69		
Truck	86			3.0	2.63				
								b	2.3
								0.5	0.5
Rail	55.1	65.3	62.8		0.32		38	0.61	0.61
Air	1.0	1.6	2.5				1.6		2.2
Water ^c	47.6	51.4		0.81			-		0.7
Pipeline	14						-		
Total	204						577		

^aThe average of 79 bn tkm [3] and 93 bn tkm [6].

^bThe average on-road fuel efficiency of automobiles was 23.4 mpg or 10.2 liters of gasoline/100 km.

^cInland water freight.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and derived from Refs. [2], [3], [6], [7], [10].

Table E.11 Final Energy Use by Mode and Fuel Type in the Transportation Sector in the United Kingdom in 1975, 1980 and 1985
(PJ = 10¹⁵J)

Mode	Year	Solid	Liquid	Gas	Electricity	Total
Road	1975	--	957	--	--	957
	1980	--	1111	--	--	1111
	1985	--	1222	--	--	1222
Rail	1975	1.3	40	--	10	52
	1980	1.3	36	--	11	49
	1985	--	32	--	10	42
Air	1975	--	175	--	--	175
	1980	--	211	--	--	211
	1985	--	224	--	--	224
Water ^a	1975	0.4	52	--	--	52
	1980	0.4	50	--	--	50
	1985	--	50	--	--	50
Non-specified	1975	--	--	--	--	--
	1980	--	--	--	--	--
	1985	--	--	--	--	--
Total	1975	1.7	1223	--	10	1235
	1980	1.7	1409	--	11	1421
	1985	--	1528	--	10	1538

^aInternal navigation.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and derived from Refs. [1], [2], [3], [7].

Table E.12 Traffic and Energy Efficiency by Mode of Transport in the United Kingdom

	Freight Transport				Passenger Transport			
	Traffic, bn tkm		Efficiency, MJ/tkm		Traffic, bn pkm		Efficiency, MJ/pkm	
	1975	1980	1985	1975	1980	1985	1975	1980 1985
Road	86.8						402	
Automobile	-						343	
Bus	-						54	
Truck	86.8						-	
Rail	20.9-23.4 ^a	17.6					30.3	
Air	0.9	1.5	1.9				30.2 ^b	56.1 58.9
Water	-							
Pipeline								
Total	109						435	

^aThe lower figure from Ref. [7] excluding data for Northern Ireland Ref. [3].

^bIncludes 2.1 bn pkm of domestic flight [3].

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and derived from Refs. [3], [7].

Table E.13 Final Energy Use by Mode and Fuel Type in the Transportation Sector in Canada in 1975, 1980 and 1985 (PJ = 10^{15} J)

Mode	Year	Solid	Liquid	Ga	Electricity	Total
Road						
	1975	--	1226	--	--	1226
	1980	--	1466	--	--	1466
	1985	--	1279	--	--	1279
Rail						
	1975	1.3	92	--	--	93
	1980	--	91	--	8	99
	1985	--	82	--	10	92
Air						
	1975	--	143	--	--	143
	1980	--	166	--	--	166
	1985	--	159	--	--	159
Water ^a						
	1975	1.7	85	--	--	87
	1980	--	73	--	--	73
	1985	--	54	--	--	54
Non-specified						
	1975	--	--	--	--	--
	1980	--	1.3	--	--	1.3
	1985	--	1.3	--	--	1.3
Total						
	1975	3	1547	--	--	1550
	1980	--	1803	--	8	1811
	1985	--	1576	--	10	1586

^aInternal navigation.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and derived from Refs. [1], [2], [7].

Table E. 14 Traffic and Energy Efficiency by Mode of Transport in Canada

	Freight Transport			Passenger Transport		
	Traffic, bn tkm		Efficiency, MJ/tkm	Traffic, bn pkm		Efficiency, MJ/pkm
	1975	1980	1985	1975	1980	1985
Road						
Automobile						
Bus						
Truck						
Rail	197	228	230			
Air	0.6	0.8	1.2	25	36.2	39.9
Water						
Pipeline						
Total						

Sources: Adapted from Ref. [7].

Table E.15 Final Energy Use by Mode and Fuel Type in the Transportation Sector in France in 1975, 1980 and 1985 (PJ = 10^{15} J)

Mode	Year	Solid	Liquid	Gas	Electricity	Total
Road						
	1975	--	992	--	--	992
	1980	--	1178	--	--	1178
	1985	--	1255	--	--	1255
Rail						
	1975	2	28	--	22	52
	1980	1	25	--	25	51
	1985	--	21	--	27	48
Air						
	1975	--	122	--	--	122
	1980	--	150	--	--	150
	1985	--	163	--	--	163
Water ^a						
	1975	--	30	--	--	30
	1980	--	15	--	--	15
	1985	--	13	--	--	13
Non-specified						
	1975	--	--	--	--	--
	1980	--	19	--	--	19
	1985	--	17	--	--	17
Total						
	1975	2	1172	--	22	1196
	1980	1	1388	--	25	1414
	1985	--	1468	--	27	1495

^aInternal navigation.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and derived from Refs. [1], [2], [3], [6], [7].

Table E.16 Traffic and Energy Efficiency by Mode of Transport in France

	Freight Transport			Passenger Transport		
	Traffic, bn tkm		Efficiency, MJ/tkm	Traffic, bn pkm		Efficiency, MJ/pkm
	1975	1980		1975	1980	
Road	78.5			401		
Automobile	-			377		
Bus	-			24		
Truck	78.5			-		
Rail	64.0	69.5	58.4	50.7		
Air	1.1	2.1	2.9	23.3 ^a	34.1	39.4
Water	11.9	12.2		-		
Pipeline				-		
Total	155			475		

^aIncludes 6.0 bn pkm of domestic flight.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and derived from Refs. [3], [7].

Table E.17 Final Energy Use by Mode and Fuel Type in the Transportation Sector in Italy in 1975, 1980 and 1985 (PJ = 10^{15} J)

Mode	Year	Solid	Liquid	Gas	Electricity	Total
Road						
	1975	--	696	11	--	707
	1980	--	923	11	--	934
	1985	--	1038	10	--	1048
Rail						
	1975	3	5	--	15	23
	1980	--	7	--	17	24
	1985	--	9	--	19	28
Air						
	1975	--	78	--	--	78
	1980	--	82	--	--	82
	1985	--	85	--	--	85
Water ^a						
	1975	--	24	--	--	24
	1980	--	25	--	--	25
	1985	--	23	--	--	23
Non-specified						
	1975	--	--	--	--	--
	1980	--	--	--	--	--
	1985	--	--	--	--	--
Total						
	1975	3	803	11	15	833
	1980	--	1037	11	17	1065
	1985	--	1156	10	19	1185

^aInternal navigation.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and derived from Refs. [1], [2], [3], [7].

Table E.18 Traffic and Energy Efficiency by Mode of Transport in Italy

	Freight Transport			Passenger Transport		
	Traffic, bn tkm		Efficiency, MJ/tkm	Traffic, bn pkm		Efficiency, MJ/pkm
	1975	1980	1975 1980 1985	1975 1980 1985	1975 1980 1985	1975 1980 1985
Road	62.8			349		
Automobile	-			279		
Bus	-			42.3		
Truck	62.8			-		
Rail	15.0 ^a	18.4 ^a	17.4 ^a	36.3		
Air				2.2 ^b		
Water				-		
Pipeline				-		
Total				387		

^aExcluding livestock.

^bDomestic flight.

^cThe average fuel efficiencies in 1980 and 1985 were 8.1 and 7.8 liters of gasoline/100 km.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and derived from Refs. [3], [7].

Table E.19 Final Energy Use by Mode and Fuel Type in the Transportation Sector in Australia in 1975, 1980 and 1985 (PJ = 10^{15} J)

Mode	Year	Solid	Liquid	Gas	Electricity	Total
Road						
	1975	--	475	--	--	475
	1980	--	588	--	--	588
	1985	--	673	--	--	673
Rail						
	1975	0.4	25	--	2.5	28
	1980	--	27	--	3.3	30
	1985	--	27	-	4.2	31
Air						
	1975	--	67	--	--	67
	1980	--	77	--	--	77
	1985	--	84	--	--	84
Water ^a						
	1975	--	38	--	--	38
	1980	--	46	--	--	46
	1985	3	29	--	--	31
Non-specified						
	1975	--	--	--	--	--
	1980	--	--	--	--	--
	1985	--	--	--	--	--
Total						
	1975	0.4	605	--	2.5	608
	1980	--	737	--	3.3	741
	1985	3	813	--	4.2	820

^aInternal navigation.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and derived from Refs. [1], [2].

Table F.20 Traffic and Energy Efficiency by Mode of Transport in Australia

	Freight Transport			Passage Transport		
	Traffic, bn tkm		Efficiency, MJ/tkm	Traffic, bn pkm		Efficiency, MJ/pkm
	1975	1980	1975 1980	1975	1980	1975 1980
Road						
Automobile						
Bus						
Truck						
Rail						
Air						
Water						
Pipeline						
Total						
Sources:						

Table E.21 Actual Average Fuel Efficiency of New Passenger Automobiles
(liters of gasoline per 100 km)

	1973	1978	1980	1985
U.S.A.	16.6	11.8	10.0	8.7
U.S.S.R.				
China				
Japan	10.4	8.8	8.3	7.8
W. Germany	10.3	9.6	9.0	7.5
U.K.	11.0	9.1	8.7	7.6
Canada		11.5	10.3	8.2
France		8.2	7.6	
Italy ^a	8.4	8.3	8.1	7.8
Australia		11.8	10.1	

^aThe figures represent average efficiency of the total car fleet.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and derived from Refs. [10], Table 4 and [13], Table 3.28.

Table E.22 Sales-Weighted Automobile Fuel Efficiency (mpg) by Interia
Weight Class in the U.S., model years 1975, 1980 and 1985

Model Year	Weight Class (pounds)								Average fleet fuel efficiency
	under 2250	2250	2500	2750	3000	3500	4000	over 4000	
1975	31.4	28.3	24.4	21.7	21.4	18.2	15.6	13.3	15.8
1980	33.0	32.4	28.0	26.1	23.6	20.7	18.8	18.9	23.5 ^a
1985	48.4	37.5	33.0	30.7	26.9	23.5	21.8	21.2	27.0 ^a

^aThe corporate average fuel economy (CAFE) standards for automobiles are 20.0 and 27.5 mpg for 1980 and 1985 respectively.

Sources: Adapted from Ref. [9].

Table E.23 Model Year Sales and Sales-Weighted Fuel Efficiencies
of Light Trucks^a in the U.S. 1975, 1980 and 1985

Year	Sales, Million	Light trucks of light-duty vehicle ^b sales, %	Fuel efficiency, mpg	CAFE ^c mpg
1975	2.281	20.1		
1980	2.440	19.8	18.1	
1985	4.458	28.7	20.4	19.5

^aTrucks of 10,000 lbs gross vehicle weight and less.

^bLight-duty vehicles include cars and light trucks.

^cCorporate average fuel economy standards.

Sources: Adapted from Ref. [9].

Table E.24 High Fuel Efficiency for Commercial and Prototype Passenger Automobiles

Car	Fuel	Passenger capacity	Curb wt., kg	Maximum power, kW	Fuel Effic. l/100 km (mpg) ^a	Development Status
Commercial						
1885 VW Golf, Jetta	diesel	5	1029	39	5.0(47)	
1985 Nissan Sentra	diesel	5	850	41	4.2(55)	
1985 Ford Escort/ Mercury Linx	diesel	5	945	39	4.3(55)	
1986 Honda CRX	gasoline	2	779	45	4.3(54)	
1986 Chevrolet Sprint	gasoline	4	676	36	4.1(57)	
Prototype						
GM TPC ^b	gasoline	2	472	28	3.5(67)	Prototype complete, no production plans.
VW Auto 2000 ^c	diesel	4-5	780	39	3.6(66)	Prototype complete.
VW VW-E80 ^d	diesel	4	700	38	2.8(85)	On-going research, possibility of production.
Volvo LCP 2000 ^e	diesel	2-4	705	39/66	3.4(69)	Prototype complete, adaptable to production.
Renault EVE ^h	diesel	4-5	855	37	3.4(70)	Prototype complete.
Renault VESTA2 ^g	gasoline	2-4	475	20	2.6(91)	Program complete.
Peugeot VERA ^h	diesel	4-5	790	37	3.4(69)	On-going development.
Peugeot ECO2000 ⁱ	gasoline	4	450	21	3.2(73)	On-going development.
Ford J	diesel	4-5	850	30	3.2(73)	Research.
Toyota AXV ^k	diesel	4-5	650	42	2.4(98)	On-going development.

^aThe combined fuel efficiency consists of a weighted average of 55% urban driving and 45% highway driving.

^bAluminium body and engine.

^cThree-cylinder, direct-injection, turbocharged diesel engine, use of plastic and aluminum parts, flywheel stop-start.

Table E.24 (continued)

dModified 3-cylinder, direct-injection, flywheel stop-start, supercharger.

eThe 39 kW car has a 3-cylinder, direct-injection, turbo charged diesel engine. The 66kW car has a 3-cylinder, heat-insulated, turbo charged, intercooled diesel engine with multi-fuel capability. Extensive use of aluminium, magnesium, and plastics.

fSupercharged, direct-injection diesel engine with stop-start.

gHigh use of light material.

hDirect-injection engine, high use of light material.

i2-cylinder engine, high use of light material.

jDirect-injection engine.

kDirect-injection diesel engine, continuously variable transmission (CVT), weight is 15% plastic, 6% aluminium.

Sources: Adapted from Refs. [11], [12].

REFERENCES

1. International Energy Agency Energy Balances of OECD Countries 1970/1985, OECD/IEA, Paris, 1987.
2. United Nations, 1984 Energy Statistics Yearbook, New York, 1986.
3. United Nations Economic Commission for Europe: An Efficient Energy Future, Butterworths, London, 1983.
4. World Bank, China: The Transport Sector, Annex 6 to China Long-Term Development Issues and Options, Washington, D.C., 1985.
5. Chateau, B., and Lapillonne, B. Energy Demand: Facts and Trends, Springer-Verlag, New York, 1982.
6. World Bank, China: The Energy Sector, Annex 3 to China Long-Term Development Issues and Options, Washington, D.C., 1985.
7. U.S. Central Intelligence Agency, Handbook of Economic Statistics, 1986, CPAS 86-10002, 1986.
8. Wilson, D. The Demand for Energy in the Soviet Union, Rowman & Allanheld, Croom Helm, Australia, 1983.
9. Holcomb, M.C., Floyd, S.D., Cagle, S.L. Transportation Energy Data Book: Ed. 9, ORNL-6325, Oak Ridge National Lab. TN, 1987.
10. International Energy Agency Energy Conservation in IEA Countries, OECD/IEA, Paris, 1987.
11. Bleviss, D.L. Testimony Before the Senate Committee on Environment and Public Works, On S. 2666 "The Global Environmental Protection Act of 1988", Sept. 16, 1988.
12. Johansson, T.B., and Williams, R.H. "Energy Conservation in the Global Context", Energy, 12, p.907, 1987.
13. International Energy Agency, World Energy Outlook, OECD/IEA, Paris, 1982.

Appendix F

INDUSTRIAL SECTOR ENERGY USE DATA

Table F.1 Final Energy Use by Industry and Fuel Type in the Industrial Sector in the U.S. (PJ = 10¹⁵ J)

	Solid			Liquid			Gas			Electricity			Total	
	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985	1980	1985
Chemical	299	327	463				1592			521	544			
Iron & Steel	1878	1570	906	243	240		530	630		123	203	233	2778	2510
Non-ferrous Metals	23.4	52.3	91.7				334				436			
Non-metallic Minerals	174	292	356				556				110			
Transport Equipment	41.4	59.8	48.6				152				108			
Machinery	27.6	53.2	56.5				140				208			
Food and Tobacco	62.4	92.9	118				468				153			
Pulp, Paper & Printing	175	208	280				450				214			
Wood & Wood Products	4.6	5.9	8.8				60.7				67.0			
Textile & Leather	23.0	37.3	41.4				109				119			
Mining	6.7	-	-				-				77.4			
Construction	-	-	-				-							
Agriculture	-	-	-	580	578	553	-							
Other	111	23.9	0.8				1654				403			
Total	2749 ^a	2534 ^a	2372 ^a	5345 ^b	6488 ^b	4711 ^b	5941	6145	5396	2290	2686	2707	16325 ^{a,b}	15186 ^{a,b}

a. Excludes 1121 PJ in 1975, 1459 PJ in 1980, and 1801 PJ in 1985 of wood, peat, and solid waste.

b. Excludes 1347 PJ in 1975, 1642 in 1980, and 1680 PJ in 1985 of non-energy uses of petroleum products such as lubricants and paraffin waxes.

Note: Totals may not equal sum of components due to independent rounding.

Source: Adapted and derived from Ref. [1].

Table F.2 Final Energy Use by Industry and Fuel Type in the Industrial Sector in the U.S.S.R. (PJ = 10 ¹⁵ J)									
	Solid			Liquid			Gas		
	1975	1980	1985	1975	1980	1985	1975	1980	1985
							Electricity		
							1975	1980	1985
							Total		
							1975	1980	1985
Chemical									
Iron & Steel							4748	4585	3952
Non-ferrous Metals									
Non-metallic Minerals									
Transport Equipment									
Machinery									
Food and Tobacco									
Pulp, Paper & Printing									
Wood & Wood Products									
Textile & Leather									
Mining									
Construction									
Agriculture									
Other									
Total									

Source: Adapted and derived from Ref. [8]

Table F.3 Final Energy Use by Industry and Fuel Type in the Industrial Sector in China (PJ = 10¹⁵ J)

	Solid			Liquid			Gas			Electricity			Total		
	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985
Chemical		1005			363			223			187			1778	
Iron & Steel		1473			176			38.1			114			1801	
Non-ferrous Metals		114			18			-			53			185	
Building Materials ^a		1239			58.5			2.9			41			1341	
Transport Equipment															
Machinery		422			103			20.5			82.0			627	
Food and Tobacco		284			17.6			8.8			20.5			331	
Pulp & Paper		158			17.6			2.9			20.5			199	
Wood & Wood Products															
Textile & Leather		293			176			11.7			46.9			527	
Mining															
Construction															
Agriculture		630			384			-			93.7			1107	
Other ^b		272			87.9			2.9			43.9			407	
Unallocated ^c		287			226			96.7			-			609	
Total		6178			1626			407			703			8913	

a. Includes cement, brick, tile and plate glass.

b. Includes forestry, clothing, leather goods and cultural articles (including printing) industries.

c. Includes utility steam and hot water supply and any not specified uses.

Note: Totals may not equal sum of components due to independent rounding.

Source: Adapted and derived from Ref. [10]

Table F.4 Final Energy Use by Industry and Fuel Type in the Industrial Sector in Japan (PJ = 10¹⁵ J)

	Solid			Liquid			Gas			Electricity			Total		
	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985
Chemical	16.3	12.5	34.3	1200 ^a	1147 ^a	1060 ^a	41.4	29.3	25.1	177	161	166	1435	1350	1286
Iron & Steel	1324	1272	1163	364	206	66.1	30.1	29.3		244	264	254	1933	1773	1512
Non-ferrous Metals	7.9	8.8	7.9	41.0	49.8	21.8	-	-	-	94.2	95.4	54.4	143	154	84.1
Non-metallic Minerals	19.7	126	203	327	264	65.3	-	-	-	44.8	61.2	59.4	392	452	329
Transport Equipment	-	-	-	-	-	-	-	-	-	35.2	49.8	61.5	35.2	49.8	61.5
Machinery	-	-	-	-	-	-	-	-	-	28.0	42.7	75.3	28.0	42.7	75.3
Food and Tobacco	-	-	-	135	120	98.8	-	-	-	18.0	23.9	29.3	153	144	128
Pulp, Paper & Printing	2.9	3.8	18.0	133	96.3	40.6	-	-	-	72.8	83.3	86.2	209	183	145
Wood & Wood Products	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Textile & Leather	-	-	-	207	137	110	-	-	-	23.0	23.0	23.0	230	160	133
Mining	-	-	-	16.3	12.1	4.6	-	-	-	5.9	5.9	5.9	22.6	18.0	10.5
Construction	-	-	-	118	148	167	-	-	-	-	-	-	118	148	167
Agriculture	-	-	-	94.2	142	156	-	-	-	4.6	4.2	5.4	98.8	147	162
Other	48.1	41.9	59.0	398	369	450	48.5	56.9	90	264	368	458	758	836	1058
Total	1420	1466	1486	3035 ^b	2692 ^b	2242 ^b	90.0	116	145	1010	1184	1278	5555 ^b	5459 ^b	5151 ^b

a. Includes 921 PJ in 1975, 899 PJ in 1980, and 879 PJ in 1985 as feedstock.

b. Excludes 249 PJ in 1975, 310 PJ in 1980, and 322 PJ in 1985 of non-energy uses of petroleum products such as lubricants and paraffin waxes.

Note: Totals may not equal sum of components due to independent rounding.

Source: Adapted and derived from Ref. [1]

Table F.5 Final Energy Use by Industry and Fuel Type in the Industrial Sector in F.R. Germany (PJ = 10¹⁵ J)

	Solid		Liquid		Gas		Electricity		Total						
	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985			
Chemical	75.3	92.5	119	372 ^a	560 ^b	520 ^c	128	192 ^b	206 ^c	149	172	183	724	1015	1029
Iron & Steel	506	539	506	116	53.6	23.4	137	137	95.8	77.8	89.2	83.3	837	818	708
Non-ferrous Metals	15.1	14.2	15.9	15.9	15.1	9.6	12.5	22.2	21.8	55.7	65.3	67.8	99.2	117	115
Non-metallic Minerals	25.5	67.0	83.7	150	113	60.7	85.0	98.0	74.1	30.5	35.6	31.8	291	313	250
Transport Equipment	11.3	13.8	8.8	30.5	36.4	25.9	14.2	20.2	31.8	24.7	31.8	38.5	80.8	103	105
Machinery	16.3	13.8	8.8	35.2	33.5	56.5	33.5	51.5	52.3	16.7	20.5	22.2	102	119	139
Food and Tobacco	13.8	10.9	12.5	114	102	59.9	18.4	36.4	49.8	22.6	28.0	30.5	169	117	153
Pulp, Paper & Printing	8.0	10.9	19.6	42.7	41.4	33.9	10.9	20.5	26.4	28.5	39.8	45.2	90.0	113	126
Wood & Wood Products	2.4 ^d	2.4 ^d	2.5 ^d	18.8	19.7	9.2	0.8	1.7	1.7	8.4	10.0	9.6	31.0	33.9	22.6
Textile & Leather	5.0	4.2	5.4	38.5	32.6	24.3	13.4	23.4	22.6	17.6	18.4	18.0	74.5	78.7	70.3
Mining	0.4	-	3.3	5.0	2.9	5.0	13.4	14.6	11.7	7.5	7.9	9.2	26.4	25.9	29.3
Construction	-	-	-	-	-	-	-	-	-	2.1	2.5	2.5	2.1	2.5	2.5
Agriculture	7.5	6.3	12.1	57.3	53.2	54.4	0.4	0.4	5.0	22.6	25.5	27.2	87.5	85.8	99.2
Other	-	-	-	185	133	20.9	7.9	15.5	17.6	35.6	44.8	50.6	228	192	89.2
Total	687	776	798	1181 ^e	1195 ^e	903 ^e	475	633	616	499	591	620	2842 ^e	3195 ^e	2938 ^e

a. Includes 258 PJ as feedstock.

b. Includes 462 PJ of liquid and 57 PJ of gas as feedstock.

c. Includes 443 PJ of liquid and 79 PJ of gas as feedstock.

d. Includes 1.2 PJ of wood in both 1975 and 1980, and 1.7 PJ in 1985.

e. Excludes 288 PJ in 1975, 183 PJ in 1980 and 164 PJ in 1985 of non-energy uses of petroleum products such as lubricants and paraffin waxes.

Note: Totals may not equal sum of components due to independent rounding.

Source: Adapted and derived from Ref. [1]

Table F.6 Final Energy Use by Industry and Fuel Type in the United Kingdom (PJ = 10¹⁵ J)

	Solid			Liquid			Gas			Electricity			Total		
	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985
Chemical	6.6	5.4	16.3	347 ^a	235 ^b	244 ^c	188	221	213	67.0	68.6	64.0	608	532	538
Iron & Steel	278	137	191	134	54.8	27.6	36.0	43.1	44.4	41.9	36.0	32.2	490	272	295
Non-ferrous Metals	25.1	3.3	10.0	14.6	10.9	3.8	16.7	16.7	16.7	26.4	30.5	22.6	83.3	61.5	53.6
Non-metallic Minerals	88.7	74.5	50.2	54.8	38.1	21.8	49.0	45.2	56.1	16.7	18.8	24.3	209	177	153
Transport Equipment	20.9	15.9	5.9	32.2	23.4	15.1	-	-	28.5	20.1	21.2	20.5	73.7	61.5	69.9
Machinery	1.7	1.7	3.8	88.3	61.1	29.3	94.6	108	64.5	39.8	41.4	45.6	224	212	143
Food and Tobacco	23.9	15.9	9.6	94.2	78.3	41.4	38.1	51.5	58.6	23.9	25.5	30.5	180	171	140
Pulp, Paper & Printing	26.0	4.2	5.9	50.2	38.9	12.1	26.4	30.5	33.1	18.8	20.5	20.1	122	94.6	71.6
Wood & Wood Products	-	-	-	4.6	3.8	2.1	-	-	3.3	2.9	3.3	-	7.5	7.1	5.4
Textile & Leather	19.2	9.6	5.0	54.0	40.6	16.3	-	19.2	15.9	19.7	17.6	12.1	92.9	87.1	49.8
Mining	-	-	-	18.0	16.3	15.1	3.4	3.3	-	5.9	7.1	7.1	27.2	26.8	22.2
Construction	-	-	-	38.1	38.9	33.5	-	-	-	2.9	2.9	3.3	41.0	41.9	36.8
Agriculture	1.7	0.8	0.8	59.0	44.8	39.8	-	-	2.1	13.0	14.2	14.6	74.1	60.3	57.3
Other	23.4	13.0	49.4	142	89.2	71.6	38.5	36.0	24.7	18.4	23.8	23.0	223	162	169
Total	515	282	348	1131 ^d	774 ^d	573 ^d	490.6	576	562	318	334	321	2456	1967	1804

a. Includes 323 PJ as feedstock.

b. Includes 169 PJ as feedstock.

c. Includes 228 PJ as feedstock.

d. Excludes 162 PJ in 1975, 114 PJ in 1980, and 123 PJ in 1985 of non-energy uses of petroleum products such as lubricants and paraffin waxes.

Note: Totals may not equal sum of components due to independent rounding.

Source: Adapted and derived from Ref. [1]

Table F.7 Final Energy Use by Industry and Fuel Type in the Industrial Sector in Canada (PJ = 10¹⁵ J)

	Solid			Liquid			Gas			Electricity			Total		
	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985
Chemical	-	6.3	7.1	115 ^a	182 ^b	225 ^c	202 ^b	266 ^c	35.2	50.6	62.8	150	440	561	
Iron & Steel	169	184	166	18.8	33.9	11.7	62.4	53.6	24.3	34.3	31.4	212	315	262	
Non-ferrous Metals	5.9	13.8	13.4	27.6	24.7	7.5	28.0	25.1	92.1	93.3	118	126	160	165	
Non-metallic Minerals	7.1	10.0	20.9	37.2	23.0	13.4	21.3	14.6	13.4	16.7	17.2	57.3	71.2	66.1	
Transport Equipment	1.2	-	-	10.0	7.1	2.9	-	-	9.2	10.9	15.5	20.9	18.0	18.4	
Machinery	-	-	-	2.1	2.1	0.8	-	-	15.1	16.3	8.4	17.2	18.4	9.2	
Food and Tobacco	0.4	-	-	30.5	26.8	15.1	-	-	13.4	17.6	21.3	44.4	44.4	36.8	
Pulp, Paper & Printing	12.5	8.8	5.9	139	138	73.7	73.2	74.1	91	130	174	242	351	328	
Wood & Wood Products	-	-	-	7.5	28.0	13.8	-	-	9.2	14.6	15.5	16.7	42.7	29.3	
Textile & Leather	-	-	-	-	10.9	5.0	-	-	9.2	9.2	10.0	9.2	20.1	15.1	
Mining	5.4	2.9	2.9	59.4	84.1	65.3	43.5	67.0	32.6	61.5	87.1	98.0	193	223	
Construction	-	-	-	-	48.5	34.7	-	-	-	-	-	-	48.5	34.7	
Agriculture	-	-	-	41.4	63.2	68.2	11.7	17.2	23.9	28.0	31.8	65.7	103	117	
Other	25.9	336 ^d	366 ^d	145	38.1	37.2	537	260	240	23.4	23.9	30.1	731	658	674
Total	228	562	582	633 ^e	711 ^e	574 ^e	537	703	758	392	508	624	1790 ^e	2484 ^e	2539 ^e

a. Includes 78.3 PJ as feedstock.

b. Includes 159 PJ of liquid and 99.6 PJ of gas as feedstock.

c. Includes 218 PJ of liquid and 160 PJ of gas as feedstock.

d. Includes 317 PJ in 1980 and 350 PJ in 1985 of wood, peat and solid waste.

e. Excludes 209 PJ in 1975, 233 PJ in 1980, and 180 PJ in 1985 of non-energy uses of petroleum products such as lubricants and paraffin waxes.

Note: Totals may not equal sum of components due to independent rounding.

Source: Adapted and derived from Ref. [1]

Table F.8 Final Energy Use by Industry and Fuel Type in the Industrial Sector in France (PJ = 10¹⁵ J)

	Solid			Liquid			Gas			Electricity			Total		
	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985
Chemical	25.1	24.7	35.2	277 ^a	388 ^b	377 ^c	92.9	161	194	66.5	77.0	79.1	462	651	686
Iron & Steel	330	303	249	88.7	54.0	17.2	33.5	42.7	32.6	49.4	54.8	47.7	501	455	346
Non-ferrous Metals	14.6	3.8	32.6	24.3	14.6	25.5	12.1	14.2	23.4	38.5	44.4	34.7	89.6	77.4	116
Non-metallic Minerals	10.0	17.2	51.1	46.5	23.9	31.4	56.9	67.4	54.8	19.7	22.2	20.9	133	131	158
Transport Equipment	-	-	5.0	17.6	11.7	12.1	-	-	-	16.3	19.7	21.8	33.9	31.4	38.9
Machinery	11.7	11.3	0.8	-	-	18.0	33.9	59.4	57.8	27.2	33.1	35.2	73.2	104	111
Food and Tobacco	5.4	5.9	10.9	102	105	61.5	9.2	18.0	38.5	18.8	25.5	36.0	136	154	146
Pulp, Paper & Printing	2.1	1.7	3.8	51.9	54.0	28.0	8.4	13.0	19.2	18.0	21.3	24.7	80.8	90.0	76.2
Wood & Wood Products	-	-	-	4.6	-	2.1	-	-	-	4.6	5.9	5.9	9.2	5.9	8.0
Textile & Leather	4.2	2.9	2.9	43.1	20.1	16.3	3.3	6.3	10.0	21.8	25.1	27.6	72.4	54.4	56.5
Mining	2.9	2.1	0.0	15.9	9.6	2.5	8.4	9.6	5.4	6.3	7.5	7.5	33.1	28.5	15.9
Construction	-	-	-	121	82.5	81.2	-	-	-	3.3	2.9	2.5	124	85.8	83.7
Agriculture	-	-	-	110	125	116	-	-	-	4.6	5.4	7.5	115	131	123
Other	8.0	21.3	0.8	231	354	10.0	6.3	17.2	23.0	2.9	4.2	5.4	248	397	39
Total	414	394	391	1135 ^d	1243 ^d	799 ^d	265	409	459	298	349	467	2113 ^d	2396 ^d	2006 ^d

a. Includes 175 PJ of liquid as feedstock.

b. Includes 284 PJ of as feedstock.

c. Includes 326 PJ as feedstock.

d. Excludes 241 PJ in 1975, 167 PJ in 1980, and 142 PJ in 1985 of non-energy uses of petroleum products such as lubricants and paraffin waxes.

Note: Totals may not equal sum of components due to independent rounding.

Source: Adapted and derived from Ref. [1]

Table F.9 Final Energy Use by Industry and Fuel Type in the Industrial Sector in Italy (PJ = 10¹⁵ J)

	Solid			Liquid			Gas			Electricity			Total		
	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985
Chemical	18.0 ^a	27.2 ^a	17.2 ^a	333 ^b	335 ^c	271 ^d	141	129 ^c	156 ^d	74.5	79.1	79.1	566	560	523
Iron & Steel	151	150	173	53.6	44.4	23.9	69.1	85.8	60.7	57.8	71.6	65.7	331	352	323
Non-ferrous Metals	3.8	3.8	1.7	17.2	1.7	1.2	3.8	5.4	5.9	19.2	24.7	20.5	43.5	35.6	29.3
Non-metallic Minerals	12.3 ^e	20.5	69.1	178	171	121	116	140	86.2	27.2	35.2	33.9	333	367	310
Transport Equipment	-	-	-	-	-	-	-	-	-	9.6	11.3	10.5	9.6	11.3	10.5
Machinery	9.6	9.2	2.1	79.1	67.4	50.6	31.0	37.2	32.2	26.0	36.4	38.9	146	150	124
Food and Tobacco	1.7	1.7	0.8	58.6	51.5	25.5	25.1	31.4	31.0	13.8	18.0	20.9	99.2	103	78.3
Pulp, Paper & Printing	-	0.8	-	40.6	31.0	21.8	13.4	16.3	19.7	15.5	20.5	20.1	69.5	68.6	61.5
Wood & Wood Products	-	-	-	-	-	-	-	-	-	5.0	7.5	7.5	5.0	7.5	7.5
Textile & Leather	-	-	-	47.3	47.7	28.0	15.9	16.7	15.9	17.6	24.7	27.2	81.2	89.6	71.2
Mining	-	-	-	-	-	-	2.5	1.7	0.8	4.2	4.6	4.2	7.1	6.3	5.0
Construction	-	-	-	-	-	-	-	-	-	2.5	3.3	3.3	2.5	3.3	3.3
Agriculture	-	-	-	79.5	83.7	86.6	-	0.4	0.4	5.9	9.2	11.7	85.4	93.8	98.8
Other	0.4	-	0.4	38.5	54.0	43.1	8.0	10.5	8.0	9.2	1.7	1.7	56.1	66.1	53.2
Total	197	204	264	924 ^f	889 ^f	673 ^f	425	474	416	289	348	346	1836 ^f	1915 ^f	1700 ^f

a. Includes 12.1 PJ in 1975, 10.5 PJ in 1980, and 11.3 PJ in 1985 of wood, peat and solid waste.

b. Includes 114 PJ as feedstock.

c. Includes 143 PJ of liquid and 87.9 PJ of gas as feedstock, respectively.

d. Includes 154 PJ of liquid and 82.5 PJ of gas as feedstock, respectively.

e. Includes 7.9 PJ in 1975, 4.6 PJ in 1980, and 4.2 PJ in 1985 of wood, peat and solid waste.

f. Excludes 140 PJ in 1975, 136 PJ in 1980 and 118 PJ in 1985 of non-energy uses of petroleum products such as lubricants and paraffin waxes.

Note: Totals may not equal sum of components due to independent rounding.

Source: Adapted and derived from Ref. [1]

Table F.10 Final Energy Use by Industry and Fuel Type in the Industrial Sector in Australia (PJ = 10¹⁵ J)

	Solid			Liquid			Gas			Electricity			Total		
	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985
Chemical	16.3 ^a	17.2 ^a	15.9 ^a	72.8 ^b	66.5 ^b	58.6 ^b	16.7 ^c	38.1 ^c	50.6 ^c	7.1	9.6	10.9	113	131	136
Iron & Steel	196	175	119	28.5	17.2	1.7	1.2	8.4	18.4	15.9	16.3	13.8	240	216	153
Non-ferrous Metals	30.1	28.9	45.2	49.4	77.4	45.6	22.2	26.0	54.4	25.1	34.3	66.1	127	167	212
Non-metallic Minerals	27.2	22.6	25.1	31.4	10.5	4.6	27.2	45.2	47.7	6.7	7.5	8.4	92.5	86.2	85.8
Transport Equipment	0.4	0.4	-	2.1	1.2	0.4	3.8	4.2	4.6	2.9	3.3	0.4	9.2	9.6	9.6
Machinery	0.8	0.4	0.4	3.8	2.5	0.8	3.3	6.3	6.3	5.4	7.1	7.4	13.8	16.3	15.1
Food and Tobacco	67.0 ^d	67.0 ^d	80.4 ^d	26.8	18.8	7.1	6.3	15.1	18.4	8.4	11.3	12.5	109	112	119
Pulp, Paper & Printing	16.3 ^e	11.2 ^e	15.5 ^e	7.9	7.5	1.2	7.1	14.6	15.5	7.1	9.2	11.7	38.9	43.1	44.0
Wood & Wood Products	8.3 ^f	8.3 ^f	7.5 ^f	2.5	2.9	2.1	-	-	0.4	1.7	2.5	2.9	12.5	14.2	12.5
Textile & Leather	3.3	2.1	1.7	4.6	2.5	1.2	2.5	5.4	5.4	4.6	4.6	5.4	14.6	14.6	13.8
Mining	0.8	0.8	2.5	23.4	29.7	14.6	0.4	0.4	-	11.7	10.9	11.3	36.4	41.9	28.5
Construction	-	-	-	27.2	36.4	29.0	-	-	-	-	-	-	27.2	36.4	29.0
Agriculture	-	-	-	33.5	39.8	46.0	-	-	-	3.8	5.0	6.3	37.3	44.8	52.3
Other	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	365	334	314	314	313	213	91.7	164	222	101	121	161	872	933	911

a. Includes 5.4 PJ in 1975, 8.4 PJ in both 1980, and 1985 of wood, peat and solid waste.

b. Includes 41.4 PJ in 1975, 53.6 PJ in both 1980 and 1985 as feedstock.

c. Includes 7.1 PJ in 1975, 12.1 PJ in 1980 and 19.2 PJ in 1985 as feedstock.

d. Includes 56.5 PJ in 1975, 57.8 PJ in 1980, and 69.9 PJ in 1985 of wood, peat, and solid waste.

e. Includes 3.8 PJ in 1975, 3.3 PJ in 1980, and 4.6 PJ in 1985 of wood, peat and solid waste.

f. Includes 7.5 PJ in both 1975 and 1980, and 6.7 PJ in 1985 of wood and waste.

g. Excludes 21.8 in 1975, 28.5 PJ in 1980, and 35.6 PJ in 1985 of non-energy uses of petroleum products such as lubricants and paraffin waxes.

Note: Totals may not equal sum of components due to independent rounding.

Source: Adapted and derived from Ref. [1]

Table F.11 Final Energy Use in Manufacturing in the U.S. in 1980 (PJ = 10^{15} J)

	Coal & Coke	Liquid	Gas	Electricity	Other	Total
Food	137	127	549	148	31.6	1002
Tobacco	10.6	0.0	0.0	5.3	0.0	15.9
Textiles	42.2	52.7	116	92.8	10.5	314
Apparel	0.0	10.5	21.1	22.1	-	53.7
Lumber	0.0	52.7	73.8	52.7	31.6	211
Furniture	0.0	10.5	21.1	13.8	0.0	45.4
Paper	253	400	454	179	63.2	1349
Publishing	-	10.5	42.2	34.8	0.0	87.5
Chemicals	369	2437 ^a	2300 ^a	479	127	5712
Petroleum	10.5	1836	1023	116	31.6	3017
Rubber	21.1	31.6	95.0	78.1	0.0	226
Leather	-	0.0	10.5	5.3	0.0	15.8
Stone, clay & glass	390	73.8	601	110	10.5	1185
Steel	1530	116	633	204	42.2	2525
Aluminum	-	84.4	179	280	10.5	554
Fabricated Metal prod.	10.5	42.2	232	90.7	10.5	386
Non-electrical machinery	31.6	31.6	169	110	10.5	353
Electrical equip.	10.5	21.1	116	98	10.5	256
Transportation equip.	52.7	42.2	148	108	21.1	372
Instruments	-	10.5	31.6	21.1	0.0	63.2
Misc. Mfr.	<u>0.0</u>	<u>10.5</u>	<u>10.5</u>	<u>12.7</u>	<u>0.0</u>	<u>33.7</u>
Total	2869	5401	6826	2261	411	17770

^a Includes 2226 PJ of liquid and 622 PJ of gas as feedstock.

Note: Totals may not equal sum of components due to independent rounding.

Source: Adapted and derived from Ref. [12]

Table F.12 Energy Used for Heat and Power in Manufacturing in the U.S., 1985

Industry	SIC ^a	<u>Electricity^b</u>	<u>Fuel^c</u>	<u>Total^d</u>
		(TWh)	(TWh)	(TWh)
Food processing, tobacco	20,21	50.0	236	403
Textiles, Apparel	22,23,31	31.6	55	162
Lumber, Furniture	24,25	20.6	96	166
Pulp and paper, printing	26,27	69.2	650	884
Chemicals	28	130.5	590	1031
Petroleum refining	29	35.5	676	795
Rubber & plastic products	30	26.6	38	128
Cement, clay, glass	32	34.1	238	353
Primary metals	33	134.4	558	1012
Metal products & machines	34-39	<u>138.0</u>	<u>223</u>	<u>689</u>
Total		670.1	3359	5624

a. Standard Industrial classification.

b. Does not include electricity generated from fuel at the site because the fuels are included in the next column.

c. Includes biomass fuels (about 0.5 TWh in SICs 20,24 and 26), but it does not include fuel used as feedstock, about 0.9 TWh in SIC 28. Includes petroleum process by-products used as fuels, especially in 28 and 29.

d. Primary energy. This includes losses in generation and transmission of electricity, using a typical fossil fuel heat rate: losses = $2.34 \times$ delivered energy. Thus, to obtain the total for chemicals = $3.34 \times 130.5 + 590 = 1031$.

Note: Totals may not equal sum of components due to independent rounding.

Source: Adapted and derived from Ref. [20]

Table F.13 Energy Intensities for Selected Basic Materials Industries in the U.S., 1980

Industry	Energy Intensity (GJ/tonne of product)			Reduction in Energy Intensity ^g (1972-1983)%
	Primary Energy ^a	Final Energy ^b	Thermodynamic Minimum	
Paper	30.6 ^c	23.4 ^c		26 ^c
Steel	39.3	33.1	7.1 ^c	18
Chemicals (Polyethylene)		71		31 ^h
Aluminum	193 ^d	88 ^d	29.3 ^f	17
Petroleum rfg	4.9	4.5	0.4	10 ⁱ
Cement	7.1	5.9	0.8	

a. Electricity evaluated at 11500 BTU/KWh

b. Electricity evaluated at 3412 BTU/KWh, or 3600 KJ/KWh(i.e. losses in generation, transmission, and distribution are not included).

c. Excludes wood-derived fuels.

d. The energy intensities are per tonne of shipped product. If the base is taken to be tonnes of primary plus secondary metal the energy intensities are 17% higher, and if the base is tonnes of primary metal it is 37% higher.

e. If the mix of iron ore and scrape feedstocks is assumed to be 50/50, which is approximately the present average for the U.S., the theoretical minimum energy required to produce a tonne of steel with this mix is 3.9 GJ.

f. Per tonne of primary metal.

g. Purchased electricity evaluated at 10,000 BTU/KWh.

h. Excludes fuels used as feedstock.

i. Changes in the mixes of inputs and outputs and in environmental regulations have had a particularly strong impact on petroleum-refining energy. Adjusted for such changes, energy intensity was reduced 26%.

Source: Adapted from Ref. [15], tables 2 and 3.

Table F.14 Energy Required to Manufacture Automobiles and Vans in the U.S.^a, 19

Vehicle	Powerplant type	Curb Weight (lbs)	Energy to produce ^b (10 ⁹ J)	Energy required per unit (10 ⁶ J)	Energy use per type vehicle's Lifetime(10 ⁹ J)
Automobile	Otto(uniform charge)				
	small ^d	2369	70.7	29.8	471.0
	medium ^e	3111	92.8	29.8	558.8
	Large	3703	110.7	29.9	637.1
Van	Otto(uniform charge)	3688	110.2	29.9	720.7

a. These estimates assume material recycling for specific materials and exclude energy required outside the U.S. to produce materials imported to the U.S.

b. Energy required for materials fabrication and vehicle manufacture.

c. Assumes an average lifetime of 100,000 miles for each vehicle.

d. Minicompact and subcompact automobiles.

e. Compact automobiles.

Source: Adapted from Ref. [21].

Table F.15 Final Energy Use by Main Uses in Industrial Sector in
U.S.S.R. in 1975

Usage	Energy consumption, PJ	Efficiency, GJ/ton
Iron making	2153 (10.3%)	25.0
Steel production	2595 (12.4%)	33.6
Process heat	13423 (64.1%)	
Electricity (electrolysis, electric drive, lighting)	2766 (13.2%)	
Total	20937 (100%)	

Source: Adapted from Ref. [5]

Table F.16 Industrial Energy Efficiency in Small and Large Plants
in China in 1980

Industrial Product	Small Plant Share of Total Production, %	Energy Efficiency, GJ/ton		
		Small Plants	Large Plants	Average
Crude steel	24 ^a	46.0 ^b	35.1 ^b	38.1 ^b
Cement ^c	68	5.3	6.2	5.6
Plate glass	n.a.	25.5 ^d	8.8 ^d	n.a.
Coke	n.a.	76.2	57.4	n.a.

^a. Estimate for small- and medium-sized iron and steel plants.

^b. Includes only energy used for the production of iron and steel, not energy used in mining and equipment manufacturing.

^c. The quality of cement made in small plants is far lower than that in large plants.

^d. Refer to PJ per standard case.

Source: Adapted and derived from Ref. [10]

Table F.17 Energy Efficiency in Synthetic Ammonia Production in China in 1980

Plant Size	Share of Production, %	Feedstocks	Efficiency	
			tce/ton	GT/ton
Large plant (>1000 tpd)	21	Natural gas/naphtha	1.44	42.2
Medium size	24	Coal/fuel oil/natural gas	2.50	73.2
Small plant (30-100 tpd)	55	Coke/anthracite ^a	3.00	87.9
Average			2.55	74.7

^a. Referring to coke/anthracite with 84% of carbon content.

Source: adapted and derived from Ref. [10]

Table F.18 Impact of New Technologies on Industrial Electricity Intensity

Application	Estimated 1983 consumption %	Technologies that will impact by 2000	Probable to trend in elec. intensity	Largest industrial users
Electromechanical drives	70	High-efficiency motors Adjustable speed drives Cogeneration	Down	Textiles, paper, chemicals petroleum rfg, rubber products primary metals
Electrolysis	15	Improved cell efficiency Chloride process Membrane separation Electrochemical synthesis	Down	Chemicals, primary metals
Electroheat	10	Plasma reduction Plasma melting Induction heating Laser heating Electron beam heating Electroslag casting Plasma chemistry Microwave and radio frequency heating Infrared heating Ultraviolet curving	Up	Food processing, textiles chemicals, primary metals, fabricated metals
Other	5	Robotics Improvements in HVAC	Down	All

Source: Adapted and derived from Ref. [17], Table 2.

Table F.19 Primary Industrial Energy Consumption in Selected Developing Countries in 1980 (PJ = 10 ¹⁵ J)									
Country	Total Energy Consumption			Industrial Energy Consumption ^d					
	Commercial ^a	Non-Commercial ^b	Total	Coal	Oil	Gas	Elec. ^c	Non-Commercial	Total
Brazil	2954	1834	4788	164	604	14	743	422	1947
India	4434			966	360	56.8	1003		2385
Indonesia	2031			3.1	244	49.5	20		317
S. Korea	1862	106	1964	226	425	0	287	0	939
Mexico	4229	558	4787	88	211	378	254	0	931
Turkey	1106	307	1413	154	184	0	171	0	508

a Commercial energy includes petroleum products, natural gas and solid fuels such as coal and cokes.

b Non-commercial energy includes wood, charcoal, bagasse, and other agroindustrial residuls.

c Electricity is accounted for in primary energy equivalent.

d Includes energy used by petroleum refining.

Source: Adapted from Ref. [18], Table 2

Table F.20 Primary Energy Consumption of Selected Energy-Intensive Industrial Processes in Developing Countries in 1980

Industry	Estimated Production, Mtonne		Percent	Estimated Commercial Energy Use, PJ	Potential Energy Saving, PJ		
	World	Developing Countries			Group A ^a	Group B ^b	Total
Iron & Steel	713	101	14.1	3373-3800	214-299	214-555	428-854
Aluminum	16.1	2.4	14.9	470-512	0-43	43-86	64-128
Petroleum Rfg.	2920	692	23.7	1708-1921	128-213	256-470	128-683
Fertilizer (ammonia)	71.3	15.4	21.6	662-790	21-43	128-214	149-257
Glass	99.3	38.7	39.0	576-820	43-85	43-171	128-256
Construction Material (bricks)	97.4	22.8	23.4	107-149	21-43	21-43	42-86
Cement	868	319	36.8	1793-2434	171-299	256-598	427-897
Pulp and Paper	166	21	12.7	897-1349	83-214	83-214	171-428
Food (sugar)	55.6	48	86.3	619-1025	83-171	83-299	171-470
Textile	18.9	3.2	16.9	162-243	21-43	21-43	42-86
Total				10368-13045	790-1452	1153-2690	1750-4142

^a Short term, low-cost measures (that is, housekeeping and minor modifications).

^b Long-term, more expensive measures (that is, retrofitting and process modifications).

Source: Adapted from Ref. [18], Tables 12 and 14.

Table F.21 Potential Energy Savings and Typical Energy-Saving Measures in Selected Energy-Intensive Industries in Developing Countries in 1980

Industry	Process or Product (Efficiency ^a , GJ/t)	Energy-Savings Measures (potential saving Rat ^e , %)	
		Group A ^b	Group b ^c
Iron & Steel	Raw and Finished steel (25-29)	Improved combustion controls and insulation, use iron ore pellet (5-7)	Recover waste heat, replace inefficient equipment (5-13)
Aluminum	Hall-Heroult smelting (188-226)	Improve combustion controls in remelting furnaces, insulation and power factors (2-4)	Install process controls, increase waste heat recovery and aluminum recycling (10-15)
Petroleum Rfg.	Refining (1.5-4.2) ^d	Improve combustion controls, increase steam condensate return (7-12)	Recover waste heat, replace inefficient equipments (15-25)
Fertilizer (ammonia)	Steam refining (33.5-54.4) ^e	Insulate primary reformer, do various housekeeping measures (2-5)	Recover waste heat in reformer, recover H ₂ and CO, and replace compressor (20-25)
Glass	Flat and Containers (8.4-25.1)	Improve combustion controls and insulation (10-12)	Install efficient recuperators and waste heat boilers, increase boosting (15-20)
Construction materials	Bricks (3.8-25.1)	Improve flue gas recirculation, combustion controls and kiln insulation. Replace burner (10-15)	Increase stack gas recuperation, rebuild kiln (15-20)
Cement	Dry (3.4-5.0) Wet (5.4-8.8)	Improve combustion, insulation etc. (10-20)	Convert from wet to dry process. Install high-efficiency heat exchanger systems and process controls
Pulp and Paper	All grades (6.3-96.3) ^f	Improve boiler and steam system, recondition insulation (10-15)	Increase use of waste fuels, blank liquor, cogeneration, and waste-heat recovery from dryers (10-16)
Food	Cane sugar (08-8.2)	Improve boiler combustion efficiency, steam systems and insulation, and evaporator management (16-18)	Increase use of waste fuels (e.g. bagasse), waste-heat recovery, and add-up effects on evaporators (15-30)
Textile	Finishing (39.8-105)	Improve boiler combustion and steam distribution efficiency (12-15)	Install waste-heat recovery devices, replace old inefficient boilers, improve water and liquor systems

a. Energy intensity, primary energy equivalent.

b. Short-term, low-cost measures (that is, housekeeping and minor modifications).

c. Long term, more expensive measures (that is, retrofitting and process modifications).

d. 4.2 GJ/t of refined product is an extreme encountered only in China; 2.7 GJ/t is generally considered high consumption.

e. Some small plants in China use up to 83.7 GJ/t.

f. Depends on the level of black liquor recovery. The upper bound refers to small mills in India and Bangladesh.

g. In cases where only bagasse is used.

Source: Ref. [18].

Table F.22 Industrial Energy Intensity Indicators in Selected Developed and Developing Countries

Country	Annual Growth Rates (%)						% of Ind. in EDP. 1983		
	National GDP		Industrial Output		Average Commercial				
	1965-1973 1973-1983		1965-1973 1973-1983		Energy Use 1965-1973 1973-1983				
	1965-1973 1973-1983		1965-1973 1973-1983		Energy Intensity ^a 1965-1973 1973-1983				
<u>Developed</u>									
U.S.	3.2	2.3	2.8	1.2	4.1	-0.4	0.7	-3.5	32
Japan	9.8	4.3	13.5	5.5	11.9	0.4	-3.8	-6.7	42
F.R. Germany	4.6	2.1	4.9	1.6	4.9		-0.7	-1.1	46
U.K.	2.8	1.1	2.1	-0.3	2.6	-1.4	-2.8	-6.0	32
Canada	5.2	2.3	5.2	0.9	6.1	2.0	4.2	3.0	29
France	5.5	2.5	6.7		6.0	0.5	-2.1	-0.3	
Italy	5.2	2.2	6.2	1.9	7.1		-3.3	-0.1	40
Sweden	3.6	1.3	3.9	0.2	4.5	0.4	-1.0	-0.6	31
<u>Developing</u>									
Argentina	4.3	0.4	5.1	-0.7	5.9	2.7	-3.4	-1.5	39
Brazil	9.8	4.8	11.0	4.7	11.5	4.9	0.8	0.2	35
India	3.9	4.0	3.7	4.3	5.1	6.6	4.5	-0.2	26
S. Korea	10.0	7.3	18.4	11.2	15.8	8.8	-5.0	-4.8	39
Mexico	7.9	5.6	8.6	6.2	7.2	8.7	-2.7	0.4	40
Turkey	6.5	4.1	7.9	4.2	10.0	4.6	1.5	3.5	33

a. Energy consumption per unit of industrial output; growth rates correspond to commercial energy consumption for the stated periods.

Source: Ref. [18], Tables 15 and 16.

Table F.23 Efficiencies of Cogeneration Technologies

Technology	Power/heat generation ratio	Efficiency %
Cogeneration		
Boiler/steam turbine	0.05-0.2	65-80
Combustion turbine/ heat recovery boiler	0.5-0.8	65-80
Diesel engine/heat recovery boiler	1.0-3.0	50-75
Conventional		
Central steam power plant	N.A.	32-35

N.A. Not applicable.

Source: Adapted from Ref. [18]. Table 11.

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Table F.24 Final Energy Use in the Steel Manufacturing in Major CO₂ Producing Countries in 1975 (PJ = 10¹⁵J)

	Crude Steel Production 10 ⁶ tonne	Final Energy Use, PJ					Share of Steel Ind. in Energy Use, %	
		Solid	Liquid	Gas	Elec.	Total	Ind. Sector Energy Use	Total Final Energy Use
U.S.A.	105.8	1878	243	530	123	2778 ^a	14.8	5.3
U.S.S.R.	141.3					4748	20.8	
China	24.0							
Japan	102.3	1324	364	-	244	1933	34.8	19.8
F.R. Germany	40.4	506	116	137	77.8	837	30.4	11.1
U.K.	20.2	278	134	36.0	41.9	490	20.0	8.3
Canada	12.9	169	18.8	-	24.3	212	10.6	3.9
France	21.5	330	88.7	33.5	49.4	501	23.7	9.3
Italy	21.8	151	53.6	69.1	57.8	331	18.1	8.2
Australia	7.8	194	28.5	1.2	15.9	240	27.5	13.0

^a 2547 PJ in Ref. [5]

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [2], [4], [7]

Table F.25 Final Energy Use in the Steel Manufacturing in Major CO₂ Producing Countries in 1980 (PJ = 10¹⁵J)

	Crude Steel Production 10 ⁶ tonne	Final Energy Use, PJ					Share of Steel Ind. in Energy Use, %	
		Solid	Liquid	Gas	Elec.	Total	Ind. Sector Energy Use	Total Final Energy Use
U.S.A.	101.5	1570	240	630	203	2510	11.4	4.4
U.S.S.R.	147.9					5128 ^a	18.2	11.7
China	37.1	1473	176	38	114	1801 ^b	20.2	9.1
Japan	111.4	1272	206	30.1	265	1773	32.5	17.1
F.R. Germany	43.8	539	53.6	136	89.2	818	25.6	9.7
U.K.	11.3	137	54.8	43.1	36.0	272 ^c	13.8	4.7
Canada	15.9	184	33.9	62.4	34.3	315	12.7	4.9
France	23.2	303	54.0	42.7	54.8	455	19.0	7.6
Italy	26.5	150	44.4	85.8	71.6	352	18.4	7.9
Australia	7.6	174	17.2	8.4	16.3	216	23.1	10.3

^a Includes 1937 PJ of coke, 771 PJ of blast furnace gas, 519 PJ of coking gas, 1365 PJ of natural gas, 302 PJ of oil and 234 PJ of coal.

^b Referred to in Chinese sources as "comprehensive" consumption, and included mining and beneficiation of ore, refractory production, alloy production, workers' residences, some equipment manufacturing, and any sideline activities pursued by iron and steel companies.

^c In Ref. [11], energy uses in Iron & Steel industry in 1980 were 126 PJ of coal and coke, 51.5 PJ of liquid fuels, 61 PJ of gas and 27.6 PJ of electricity for the total of 266 PJ.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [2], [5], [8], [10], [12]

Table F.26 Final Energy Use in the Steel Manufacturing in Major CO₂ Producing Countries in 1985 (PJ = 10¹⁵J)

	Crude Steel Production 10 ⁶ tonne	Final Energy Use, PJ					Share of Steel Ind. in Energy Use, %	
		Solid	Liquid	Gas	Elec.	Total	Ind. Sector Energy Use	Total Final Energy Use
U.S.A.	80.1	906			233			
U.S.S.R.	155.0							
China	46.6							
Japan	105.3	1163	66.1	29.3	254	1512	29.4	14.4
F.R. Germany	40.5	507	23.4	95.8	83.3	708	24.1	8.6
U.K.	15.7	191	27.6	44.4	32.2	295	16.4	5.0
Canada	15.0	166	11.7	53.6	31.4	262	10.8	4.2
France	18.8	249	17.2	32.6	47.7	346	17.3	6.1
Italy	23.7	173	23.9	60.7	65.7	323	19.2	7.3
Australia	6.6	119	1.7	18.4	13.8	153	16.8	7.0

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [2], [6], [8]

Table F.27 Comparison of Energy Efficiency in Steelmaking in Major CO₂ Producing Countries in 1975

	Blast furnace coke rate, kg/ ton of pig iron	Share of Steelmaking process, %			Continuous casting ratio, % of crude steel production	Energy Effi- ciency, GJ/ton crude steela
		Hearth	Oxygen	Electric	Other	
U.S.A.	612	19.0	62.0	19.0	-	26.4 (29.3)
U.S.S.R.		64.8	24.6	9.9	0.8	33.6 (38.1)
China						
Japan	444	-	80.0	20.0	-	18.9 (21.4)
F.R. Germany	498	18.0	13.0	69.0	-	20.7 (23.4)
U.K.	609	23.0	50.0	26.0	1.0	24.3
Canada	471					16.4
France	532	23.0	63.0	14.0	-	23.3
Italy		11.0	46.0	43.0	-	15.2
Australia						30.8

a The figures inside the brackets represent the primary energy use.

Sources: Adapted and/or derived from Refs. [1], [3], [4], [5], [7], [8], [9], [10]

Table F.28 Comparison of Energy Efficiency in Steelmaking in Major
CO₂ Producing Countries in 1980

	Blast furnace coke rate, kg/ ton of pig iron	Share of Steelmaking process, %				Continuous casting ratio, % of crude steel production	Energy Effi- ciency, GJ/ton crude steel ^a
		Open Hearth	Oxygen	Electric	Other		
U.S.A.	583	12.0	60.0	28.0	-	20.3	24.7 (29.0)
U.S.S.R.	532	60.2	28.5	10.8	0.5	12.0	31.0 (34.7)
China	585 ^b	32.0	48.8	19.2	-	6.6	38.1 ^c
Japan	423	-	75.5	24.5	-	59.5	15.9 (18.8)
F.R. Germany	515	6.7	78.4	19.9	-	46.0	18.7 (21.8)
U.K.	588	-	66.6	34.4	-	27.0	23.8
Canada	462	14.0	61.0	25.0	-	-	19.8
France	520	1.1	81.9	17.0	-	41.3	19.6 (23.9)
Italy	463	1.7	45.3	53.1	-	50.1	13.3 (17.6)
Australia							28.4 (36.1)

^a The figures inside the brackets represent the primary energy use.

^b Based on large steel plants which account for over 75% of steel production

^c Includes only energy used for the production of iron and steel, not energy used in workers' residences, equipment manufacturing and other sideline activities pursued by iron and steel companies.

Sources: Adapted and/or derived from Refs. [1], [3], [4], [5], [7], [8], [10], [12]

Table F.29 Comparison of Energy Efficiency in Steelmaking in Major
CO₂ Producing Countries in 1985

	Blast furnace coke rate, kg/ ton of pig iron	Share of Steelmaking process, %			Continuous casting Energy Effi- ratio, % of crude ciency, GJ/ton steel production crude steel
		Hearth	Oxygen	Electric Other	
U.S.A.	540				
U.S.S.R.	514				25.4 (27.7) ^a
China					
Japan					14.4
F.R. Germany					17.5
U.K.					18.8
Canada					17.5
France					18.4
Italy					13.6
Australia					23.2

^a The figure inside the brackets is evaluated at 8.35 MJ/kWh. From the mining of ore to the manufacture of rolled steel, direct uses of fuel account for 23.7 GJ and fuel converted to electricity accounts for 4.0 GJ. The net energy efficiency, taking a credit for blast-furnace gas, is 23.4 (24.7) PJ.

Sources: Adapted from Refs. [6], [14]

Table F.30 Characteristics of Energy Use in Steel Production in the U.S.

	1975	1980	1985
Total Pig iron production, 10 ⁶ tonne	72.3	62.3	45.3
Total steel production, 10 ⁶ tonne	105.8	101.5	80.1
Average coke rate to blast furnace, kg coke/t of pig iron	612	580	540
Total coke use for iron production, PJ	1294	1040	740
Energy use for iron production			17.7
Fossil Fuel, GJ/t pig iron		19.6	
Electricity, kWh/t pig iron		25.0	
Total final energy use for iron making, PJ	1790	1246	800
Shares of steel production by proces, %			
Open hearth	19.0	12.0	
Basic oxygen	62.0	60.0	
Electric arc	19.0	28.0	
Other	-	-	
Continuous casting, % of crude steel	9.1	20.3	
Electricity used in electric furnace, kWh/t steel	550.0	594.5	
Energy use for casting and rolling			
Fossil fuel, GJ/t crude steel			
Electricity, kWh/t crude steel			
Total elec. use in iron & steel prod., 10 ¹² Wh	34.2	56.4	64.7
Total final energy use in iron & steel prod., PJ	2778	2510	
Energy efficiency in steel production, GJ/t crude steel	26.4	24.7	

Sources: Adapted and/or derived from Refs. [1], [2], [3], [4], [5], [15]

Table F.31 Characteristics of Energy Use in Steel Production
in the U.S.S.R.

	1975	1980	1985
Total Pig iron production, 10 ⁶ tonne	102.9	107.3	116.2
Total steel production, 10 ⁶ tonne	141.3	147.9	155.0
Average coke rate to blast furnace, kg coke/t of pig iron	547	532	514
Total coke use for iron production, PJ	1630	1653	1732
Energy use for iron production	25.2	22.4	18.5
Fossil Fuel, GJ/t pig iron			
Electricity, kWh/t pig iron			
Total final energy use for iron making, PJ	2595	2408	2155
Shares of steel production by proces, %			
Open hearth	64.8	60.2	
Basic oxygen	24.6	28.5	
Electric arc	9.9	10.8	
Other	0.8	0.5	
Continuous casting, % of crude steel		12.0	
Electricity used in electric furnace, kWh/t steel	300		
Energy use for casting and rolling			
Fossil fuel, GJ/t crude steel			
Electricity, kWh/t crude steel			
Total elec. use in iron & steel prod., 10 ¹² Wh			
Total final energy use in iron & steel prod., PJ	4748	4585	3952
Energy efficiency in steel production, GJ/t crude steel	33.6	31.0	25.4

Sources: Adapted and derived from Refs. [2], [3], [5], [8], [9], [14]

Table F.32 Characteristics of and Energy Use in Steel Production in China

	1975	1980	1985
Total Pig iron production, 10 ⁶ tonne	33.8	38.0	43.5
Total steel production, 10 ⁶ tonne	24.0	37.1	46.6
Average coke rate to blast furnace, kg coke/t of pig iron		585	
Total coke use for iron production, PJ		667	
Energy use for iron production			
Fossil Fuel, GJ/t pig iron			
Electricity, kWh/t pig iron			
Total final energy use for iron making, PJ			
Shares of steel production by proces, %			
Open hearth		32.0	
Basic oxygen		48.8	
Electric arc		19.2	
Other		-	
Continuous casting, % of crude steel		6.6	
Electricity used in electric furnace, kWh/t steel			
Energy use for casting and rolling			
Fossil fuel, GJ/t crude steel			
Electricity, kWh/t crude steel			
Total elec. use in iron & steel prod., 10 ¹² Wh		31.7	
Total final energy use in iron & steel prod., PJ		1801 ^a	
Energy efficiency in steel production, GJ/t crude steel		38.1 ^b	

^a Referred to in Chinese sources as "comprehensive" consumption, and included mining and beneficiation of ore, refractory production, alloy production, workers' residence, some equipment manufacturing, and any sideline activities pursued by iron and steel companies.

^b Includes only energy used for the production of iron and steel, not energy used in workers' residences, equipment manufacturing and other sideline activities pursued by iron and steel companies.

Sources: Adapted and/or derived from Refs. [2], [3], [10]

Table F.33 Characteristics of Energy Use in Steel Production in Japan

	1975	1980	1985
Total Pig iron production, 10 ⁶ tonne	86.9	87.0	80.6
Total steel production, 10 ⁶ tonne	102.3	111.4	105.3
Average coke rate to blast furnace, kg coke/t of pig iron	444	423	
Total coke use for iron production, PJ	1157	1104	
Energy use for iron production			
Fossil Fuel, GJ/t pig iron			
Electricity, kWh/ton pig iron			
Total final energy use for iron making, PJ			
Shares of steel production by proces, %			
Open hearth	-	-	
Basic oxygen	80.0	75.5	
Electric arc	20.0	24.5	
Other	-	-	
Continuous casting, % of crude steel	25.0	59.5	
Electricity used in electric furnace, kWh/t steel			
Energy use for casting and rolling			
Fossil fuel, GJ/t crude steel			
Electricity, kWh/t crude steel			
Total elec. use in iron & steel prod., 10 ¹² Wh	67.8	73.6	70.5
Total final energy use in iron & steel prod., PJ	1933	1773	1512
Energy efficiency in steel production, GJ/t crude steel	18.9	15.9	14.4

Sources: Adapted and/or derived from Refs. [1], [2], [6], [10]

Table F.34 Characteristics of Energy Use in Steel Production in F.R. Germany

	1975	1980	1985
Total Pig iron production, 10 ⁶ tonne	30.1	33.9	31.5
Total steel production, 10 ⁶ tonne	40.4	43.8	40.5
Average coke rate to blast furnace, kg coke/t of pig iron	498	515	
Total coke use for iron production, PJ	450	524	
Energy use for iron production			
Fossil Fuel, GJ/t pig iron	16		
Electricity, kWh/t pig iron	77		
Total final energy use for iron making, PJ			
Shares of steel production by proces, %			
Open hearth	18.0	6.7	
Basic oxygen	13.0	78.4	
Electric arc	69.0	19.9	
Other	-	-	
Continuous casting, % of crude steel		46.0	
Electricity used in electric furnace, kWh/t steel	545	527	
Energy use for casting and rolling			
Fossil fuel, GJ/t crude steel	5.4		
Electricity, kWh/t crude steel	230		
Total elec. use in iron & steel prod., 10 ¹² Wh	21.6	24.8	23.1
Total final energy use in iron & steel prod., PJ	837	818	708
Energy efficiency in steel production, GJ/t crude steel	20.7	18.7	17.5

Sources: Adapted and/or derived from Refs. [1], [2], [5], [6], [7]

Table F.35 Characteristics of Energy Use in Steel Production in the United Kingdom

	1975	1980	1985
Total Pig iron production, 10 ⁶ tonne	12.0	6.4	10.5
Total steel production, 10 ⁶ tonne	20.2	11.3	15.7
Average coke rate to blast furnace, kg coke/t of pig iron	609	588	
Total coke use for iron production, PJ	219	113	
Energy use for iron production			
Fossil Fuel, GJ/t pig iron	16.3		
Electricity, kWh/t pig iron	174.0		
Total final energy use for iron making, PJ			
Shares of steel production by proces, %			
Open hearth	23.0	-	
Basic oxygen	50.0	66.6	
Electric arc	26.0	34.4	
Other	1.0	-	
Continuous casting, % of crude steel		27.0	
Electricity used in electric furnace, kWh/t steel	420		
Energy use for casting and rolling			
Fossil fuel, GJ/t crude steel	7.0		
Electricity, kWh/t crude steel	209		
Total elec. use in iron & steel prod., 10 ¹² Wh	11.6	10.0	8.9
Total final energy use in iron & steel prod., PJ	490	272	295
Energy efficiency in steel production, GJ/t crude steel	24.3	23.8	18.8

Sources: Adapted and/or derived from Refs. [1], [2], [5], [6], [7], [11]

Table F.36 Characteristics of Energy Use in Steel Production in Canada

	1975	1980	1985
Total Pig iron production, 10 ⁶ tonne	9.2	11.2	10.0
Total steel production, 10 ⁶ tonne	12.9	15.9	15.0
Average coke rate to blast furnace, kg coke/t of pig iron	471	462	
Total coke use for iron production, PJ	130	155	
Energy use for iron production			
Fossil Fuel, GJ/t pig iron			
Electricity, kWh/t pig iron			
Total final energy use for iron making, PJ			
Shares of steel production by proces, %			
Open hearth			
Basic oxygen			
Electric arc			
Other			
Continuous casting, % of crude steel			
Electricity used in electric furnace, kWh/t steel			
Energy use for casting and rolling			
Fossil fuel, GJ/t crude steel			
Electricity, kWh/ton crude steel			
Total elec. use in iron & steel prod., 10 ¹² Wh	6.7	9.5	8.7
Total final energy use in iron & steel prod., PJ	212	315	262
Energy efficiency in steel production, GJ/t crude steel	16.4	19.8	17.5

Sources: Adapted and/or derived from Refs. [1], [2]

Table F.37 Characteristics of Energy Use in Steel Production in France

	1975	1980	1985
Total Pig iron production, 10 ⁶ tonne	17.5	19.2	15.4
Total steel production, 10 ⁶ tonne	21.5	23.2	18.8
Average coke rate to blast furnace, kg coke/t of pig iron	532	520	
Total coke use for iron production, PJ	280	300	
Energy use for iron production			
Fossil Fuel, GJ/t pig iron	23.4		
Electricity, kWh/t pig iron	129		
Total final energy use for iron making, PJ			
Shares of steel production by proces, %			
Open hearth	23.0	1.1	
Basic oxygen	63.0	81.9	
Electric arc	14.0	17.0	
Other	-	-	
Continuous casting, % of crude steel		41.3	
Electricity used in electric furnace, kWh/t steel			
Energy use for casting and rolling			
Fossil fuel, GJ/t crude steel	4.9		
Electricity, kWh/t crude steel	256		
Total elec. use in iron & steel prod., 10 ¹² Wh	13.7	15.2	13.3
Total final energy use in iron & steel prod., PJ	501	455	346
Energy efficiency in steel production, GJ/t crude steel	23.3	19.6	18.4

Sources: Adapted and/or derived from Refs. [1], [2], [5], [6], [7]

Table F.38 Characteristics of Energy Use in Steel Production in Italy

	1975	1980	1985
Total Pig iron production, 10 ⁶ tonne	11.4	12.1	11.7
Total steel production, 10 ⁶ tonne	21.8	26.5	23.7
Average coke rate to blast furnace, kg coke/t of pig iron	482	463	
Total coke use for iron production, PJ	165	168	
Energy use for iron production			
Fossil Fuel, GJ/t pig iron	14.0		
Electricity, kWh/t pig iron	60.0		
Total final energy use for iron making, PJ			
Shares of steel production by proces, %			
Open hearth	11.0	1.7	
Basic oxygen	46.0	45.3	
Electric arc	43.0	53.1	
Other	-	-	
Continuous casting, % of crude steel		50.1	
Electricity used in electric furnace, kWh/t steel	617	609	
Energy use for casting and rolling			
Fossil fuel, GJ/t crude steel	3.9		
Electricity, kWh/t crude steel	205		
Total elec. use in iron & steel prod., 10 ¹² Wh	16.0	19.9	18.2
Total energy final use in iron & steel prod., PJ	331	352	323
Energy efficiency in steel production, GJ/t crude steel	15.2	13.3	13.6

Sources: Adapted and/or derived from Refs. [1], [2], [5], [6], [7]

Table F.39 Characteristics of Energy Use in Steel Production in Australia

	1975	1980	1985
Total Pig iron production, 10 ⁶ tonne	7.5	7.0	5.6
Total steel production, 10 ⁶ tonne	7.8	7.6	6.6
Average coke rate to blast furnace, kg coke/t of pig iron			
Total coke use for iron production, PJ			
Energy use for iron production			
Fossil Fuel, GJ/t pig iron			
Electricity, kWh/t pig iron			
Total final energy use for iron making, PJ			
Shares of steel production by proces, %			
Open hearth			
Basic oxygen			
Electric arc			
Other			
Continuous casting, % of crude steel			
Electricity used in electric furnace, kWh/t steel			
Energy use for casting and rolling			
Fossil fuel, GJ/t crude steel			
Electricity, kWh/t crude steel			
Total elec. use in iron & steel prod., 10 ¹² Wh	4.4	4.5	3.8
Total final energy use in iron & steel prod., PJ	240	216	153
Energy efficiency in steel production, GJ/t crude steel	30.8	28.4	23.2

Sources: Adapted and/or derived from Refs. [1], [2]

Table F.40 Characteristics of Typical Steelmaking Processes and their Associated Energy Consumption in 1980 (GJ per ton of crude steel^a)

	Conventional Integrated Steel Plant		Mini Steel Plant	
	BF-OHF	BF-BOF	DR-EAF	Scrap-EAF
<u>Main Material Inputs</u>	Iron ore, scrap	Iron ore, scrap	Iron ore, scrap	Scrap
<u>Main Energy Inputs</u>	Coking coal, oil, electricity	Coking coal, oil electricity	Natural gas ^h electricity	electricity,
<u>Capacity Range^b</u> (10 ⁶ tpy)	0.5-2.0	0.5-3.7	0.2-1.0	0.2-0.8
<u>Type of Furnace</u>				
Ironmaking stage	BF	BF	DR	-
Steelmaking stage	OHF	BOF	EAF	EAF
<u>Energy Consumption^c</u> (GJ/t)				
Ironmaking				
Sinter and pellet plant	2.93	2.93	-	-
Coke ovens	1.67	1.67	-	-
BF/DR unit ^d	12.56	13.40	14.23	-
Sub-total	17.16	18.00	14.23	-
Steelmaking				
OHF/BOF/EAF ^e	4.19	0.46	6.0 ⁱ	6.0 ⁱ
continuous casting ^f	0.38	0.38	0.38	0.38
Sub-total	4.57	0.84	6.38	6.38
Total for Crude Steel production	21.73	18.84	20.61	6.38
Rolling mills ^g	4.19	4.19	4.19	4.19
Power Plant & Others	2.09	2.09	0.42	0.42
TOTAL	28.05	25.12	25.22	11.01

^a Crude steel: first solid state after the steelmaking stage which includes ingots, continuously cast semi-finished products and castings.

^b Typical range (crude steel).

^c With electricity evaluated at about 10.5 MJ/kWh (2.5 Mcal/kWh, 10.0 kBtu/kWh)

^d BF - sinter ratio: 40%; fuel ratio: 450-600 kg of fuel/ton of hot metal; DR - 100% pellets.

^e OHF - hot metal ratio: 60%; BOF - hot metal ratio: 80%; DR-EAF - DRI: 80%, scrap: 20%; Scrap-EAF - scrap: 100%.

^f Including the primary rolling stage and continuous casting to produce semi-finished steel products such as slabs, blooms and billets. For non-continuous casting, the energy consumption at this stage is about 1.26 GJ per ton of ingot.

^g The energy used for each rolling stage.

^h Coal-based DR processes are currently being developed.

ⁱ Consisting of about 570 kWh of electricity per ton of crude steel plus some fuel and oxygen.

Note: BF: Blast furnace, OHF: Open hearth furnace, BOF: Basic oxygen furnace
DR: Direct reduction furnace, EAF: Electric arc furnace

Sources: Adapted from Refs. [3], [4]

Table F.41 Possible Energy Saving Measures for the Blast Furnace - Basic Oxygen Furnace (BF-BOF) Steelmaking

	Estimated Savings/t of Crude Steel Processed	
	Amount	Equivalent in Primary Energy, MJ
<u>BF-BOF Route</u>		
Known to be practicable		
Dry coke quenching	15 kg. coke breeze	440
Sinter cooling air used for combination	30 kg. coke breeze	880
BF top-gas turbine	33 kWh	120
More speculative		
Steam generation from slag	75% of loss	460
<u>Shaping and Treating</u>		
Waste-heat boilers at slab furnaces	50% of stack loss	200
Speculative		
Ability to send, say, 75% of slabs through to mill without cooling (If successful this would reduce saving at waste-heat boiler to 50 MJ)	1000 MJ gas or oil	1000

Sources: Adapted from Ref. [16], Table 1

Table F.42 Selected Energy Saving Measures for the Electric Arc Furnace (EAF)

Energy Saving Measure	Energy Saved MJ/t Crude Steel	As % of EAF Energy Consumption ^a
1. Introduction of UHP furnace	167.4	3.1
2. Use of oxygen lancing to assist melting	104.6	1.9
3. Preheating of scrap	125.6	2.3
4. Secondary refining of steel	71.2	1.3
5. Water cooled panels	12.5	0.2
6. Bottom pouring	41.9	0.8
7. Installing electrode saver	<u>20.9</u>	<u>0.4</u>
Total	544.2	10.0

^a. Based on EAF energy consumption of 54420 MJ per tonne of crude steel

Source: Adapted from Ref. [3], Table 11

Table F.43 Average Energy Intensity by Process Stage in the Steel Industry in the U.S. in 1983

Process Stage	Mass of Input/Mass of Mill Product (t/t)	Energy Intensity ^a (GT/tonne)	
		Fuel ^b	Electricity ^c
Ironmaking	0.73 ^d	13.8	0.16 (0.47)
Sintering	0.40 x 0.73	0.6	0.05 (0.14)
Coking	0.54 x 0.73	2.9	0.06 (0.17)
Blast Furnace	0.73	10.2	0.06 (0.17)
Steelmaking	1.31 ^e	1.0	1.07 (3.15)
Shaping		8.4	1.31 (3.84)
Rough shaping	1.15 ^f	2.1	0.14 (0.42)
Finishing	1.00	6.3	1.16 (3.41)
Other		0.7	0.03 (0.1)
Internal generation of electricity		1.0	-0.34 (-1.0)
Totals		25.1	2.2 (6.7)
Total energy intensity			27.3 (31.8)

a. 1983 energy use divided by 1983 output of mill product (60.8 million tonne). The energy use is as follows: 1010 PJ of coal, 433 PJ natural gas, 75 PJ of petroleum products, 136 PJ (or equivalent to 400 PJ of fuel) of electricity and 12 PJ of other with a total of 1666 PJ.

b. Steam is evaluated in terms of fuels used at a boiler.

c. The figure inside the brackets is evaluated at 10,000 Btu/kWh.

d. Hot metal.

e. Liquid metal.

f. Slabs, blooms and continuously cast billets (rough shapes).

Source: Adapted and derived from Ref. [15], Tables 4 and 5.

Table F.44 Average Energy Intensity by Type of Steel Mill in the U.S. in 1983

Type of Mill	Energy Intensity ^a (GT/tonne)	
	Integrated Mill	Secondary Mill
Ironmaking	17	-
Steelmaking	3	8.9
Shaping and Other	<u>14</u>	<u>8.9</u>
Total	35	17
Of which electricity ^a	6	10

^a. Evaluated at 10,000 Btu/kWh.

Source: Adapted from Ref. [15], Table 6

Table F.45 Energy Intensity by Process of Steel Mill in the U.S.S.R. in 1985

Process	Fuel	Energy Intensity ^a (GJ/tonne)	
		Electricity ^b	Net ^c
Open Hearth Furnace (OHF)	23.1	1.5 (3.5)	24.6 (26.6)
Basic Oxygen Furnace (BOF)	28.1	1.8 (4.2)	29.9 (32.3)
Electric Arc Furnace (EAF)	6.0	3.7 (8.6)	9.7 (14.6)

a. All direct and indirect energy expenditures from raw materials to ingots or continuous casters.

b. The figure in the brackets is evaluated at 8.35 MJ/kWh (43% conversion efficiency).

c. Taking credit for blast furnace gas.

Source: Adapted from Ref. [14], Table 1

ENERGY DATA FOR CEMENT INDUSTRY

Table F.46 Final Energy Use in the Cement Industry in Major CO₂
Producing Countries in 1975

	Production, 10 ⁶ tonne		Final Energy Use, PJ			Share of Cement Ind. in Energy Use, %	
	Clinker	Cement	Elec.		Total	Ind. Sector Energy Use	Total Final Energy Use
			Fuel				
U.S.A. ^a	68.6	71.2	456	41.3	498	2.6	1.0
U.S.S.R.	93.9	122	625 ^c				
China		47.1					
Japan		65.5					
F.R. Germany ^a	31.0	35.6	10.1	12.8	130	4.5	1.7
U.K. ^a	17.7	18.4	10.9	6.5	115	4.4	1.9
Canada		9.7					
France ^b	27.5	31.9	121	10.6	132	5.6	2.4
Italy		34.2					
Australia							

^a 1974 data. The cement production in 1975 is 61.8, 33.5 and 16.9 Mtonne for U.S., F.R. Germany and U.K., respectively.

^b 1973 data. The cement production in 1975 is 29.7 Mtonne for France.

^c Includes 149 PJ of coal, 376 PJ of gas, 90 PJ of oil and 7 PJ of others.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Derived and/or Adapted from Refs. [2], [7], [8], [10], [13]

Table F.47 Final Energy Use in the Cement Industry in Major CO₂
Producing Countries in 1980

	Production, 10 ⁶ tonne		Final Energy Use, PJ		Share of Cement Ind. in Energy Use, %
	Clinker	Cement	Fuel	Elec. Total	
					Ind. Sector Total Final Energy Use
U.S.A.		68.2			
U.S.S.R.	96.2	125	634		
China		79.9			
Japan		88.0			
F.R. Germany		34.3			
U.K.		14.8			
Canada		10.3			
France		29.1			
Italy		41.9			
Australia					

Sources: Adapted and/or derived Refs. [2], [8], [13]

Table F.48 Final Energy Use in the Cement Industry in Major CO₂
Producing Countries in 1985

	Production, 10 ⁶ tonne		Final Energy Use, PJ			Share of Cement Ind. in Energy Use, %
	Clinker	Cement	Total		Ind. Sector Total Final Energy Use	
			Fuel	Elec.		
U.S.A.		72.6				
U.S.S.R.		131				
China		143				
Japan		71.9				
F.R. Germany		26.3				
U.K.		12.2				
Canada		9.9				
France		22.2				
Italy		37.8				
Australia						

Sources: Adapted from Refs. [2]

Table F.49 Comparison of Energy Efficiency in Cement Production
in Major CO₂ Production Countries in 1975

	Share of cement production process, %				Energy Efficiency, GJ/t	
	Wet	Dry	Semi-dry	Other	Fuel/t clinker	Elec./t cement
U.S.A. ^a	59	41	-	-	6.61	0.50
U.S.S.R.					6.68	
China						
Japan	27	73	-	-	4.0	0.45
F.R. Germany ^a	5	66	26	3	3.76	0.36
U.K. ^a	69	15	16	-	6.15	0.36
Canada						
France ^b	23	77	-	-	4.39	0.33
Italy	13	40	46	1		
Australia						

^a 1974 data

^b 1973 data

Sources: Adapted and/or derived from Refs. [7], [8], [10], [13]

Table F.50 Comparison of Energy Efficiency in Cement Production
in Major CO₂ Production Countries in 1980

	Share of cement production process, %			Energy Efficiency, GJ/t	
	Wet	Dry	Semi-dry	Other	Fuel/t clinker Elec./t cement
U.S.A.	52.0	48.0	-	-	5.4 0.51
U.S.S.R.					6.59
China					
Japan					3.4
F.R. Germany	3.0	97.0	-	-	3.4 0.39
U.K.					
Canada					
France	10.0	90.0 ^a			0.38
Italy					
Australia					

^a Includes semi-dry and semi-wet processes.

Sources: Adapted and/or derived from Refs. [8], [13]

Table F.51 Comparison of Energy Efficiency in Cement Production in Major CO ₂ Production Countries in 1985					
Share of cement production process, %					
Energy Efficiency, GJ/t					
Wet	Dry	Semi-dry	Other	Fuel/t clinker	Elec./t cement
U.S.A.					
U.S.S.R.				6.33	
China					
Japan					
F.R. Germany				3.6	
U.K.					
Canada					
France					
Italy					
Australia					

Sources: Adapted and/or derived from Refs. [6], [8]

Table F.52 Characteristics of Energy Use in Cement Production in the U.S.

	1975 ^a	1980	1985
Total clinker production, 10 ⁶ tonne	68.6		
Total cement production, 10 ⁶ tonne	71.2 ^b	68.2	72.6
Clinker production by process			
% wet process	59.0	52.0	
Thermal energy, GJ/t clinker	7.1		
Electricity, kWh/t cement	136.0		
% dry process	41.0	48.0	
Thermal energy, GJ/t clinker	5.7		
Electricity, kWh/t cement	154.0	142.0	
% Semi-dry process	-	-	
Thermal energy, GJ/t clinker			
Electricity, kWh/t cement			
% Other	-		
Total Energy Consumption			
Fossil fuel, PJ	456.3		
Electricity, TWh	11.5		
Energy intensity, GJ/t clinker	7.1	5.9	
Fossil fuel, GJ/t clinker	6.6		
Electricity, kWh/t cement	140.0	142.0	
% of blended cement	3.0		
% of additives			
Clinker/cement ratio, %	95.0		

a 1974 data

b 61.8 million tonne in 1975

Sources: Adapted and/or dervied from Refs. [2], [7], [8], [10], [13]

Table F.53 Characteristics of Energy Use in Cement Production
in the U.S.S.R.

	1975	1980	1985
Total clinker production, 10 ⁶ tonne	93.9	96.2	
Total cement production, 10 ⁶ tonne	122	125	131
Clinker production by process			
% wet process			
Thermal energy, GJ/t clinker		7.0	6.7
Electricity, kWh/t cement			
% dry process		14.6	18.0
Thermal energy, GJ/t clinker		5.3	5.2
Electricity, kWh/t cement			
% Semi-dry process			
Thermal energy, GJ/t clinker			
Electricity, kWh/t cement			
% Other			
Total Energy Consumption			
Fossil fuel, PJ			
Electricity, TWh			
Energy intensity, GJ/t clinker			
Fossil fuel, GJ/t clinker	66.8	6.59	6.33
Electricity, kWh/t cement			
% of blended cement			
% of additives			
Clinker/cement ratio, %	77	77	

Sources: Adapted and/or derived from Refs. [2], [8]

Table F.54 Characteristics of Energy Use in Cement Production in China

	1975	1980	1985
Total clinker production, 10 ⁶ tonne			
Total cement production, 10 ⁶ tonne	47.1	79.9	143
Clinker production by process			
% wet process			
Thermal energy, GJ/t clinker			
Electricity, kWh/t cement			
% dry process			
Thermal energy, GJ/t clinker			
Electricity, kWh/t cement			
% Semi-dry process			
Thermal energy, GJ/t clinker			
Electricity, kWh/t cement			
% Other			
Total Energy Consumption			
Fossil fuel, PJ			
Electricity, TWh			
Energy intensity, GJ/t clinker			
Fossil fuel, GJ/t clinker			
Electricity, kWh/t cement			
% of blended cement			
% of additives			
Clinker/cement ratio, %			

Source: Adapted from Ref. [2]

Table F.55 Characteristics of Energy Use in Cement Production in Japan

	1975	1980	1985
Total clinker production, 10 ⁶ tonne			
Total cement production, 10 ⁶ tonne	65.5	88.0	71.9
Clinker production by process			
% wet process	27		
Thermal energy, GJ/t clinker			
Electricity, kWh/t cement			
% dry process	73		
Thermal energy, GJ/t clinker			
Electricity, kWh/t cement			
% Semi-dry process			
Thermal energy, GJ/t clinker			
Electricity, kWh/t cement			
% Other	-		
Total Energy Consumption			
Fossil fuel, PJ			
Electricity, TWh			
Energy intensity, GJ/t clinker	4.5		
Fossil fuel, GJ/t clinker	4.0	3.4	
Electricity, kWh/t cement	126.0		
% of blended cement			
% of additives			
Clinker/cement ratio, %			

Sources: Adapted and/or derived from Refs. [2], [6], [7], [13]

Table F.56 Characteristics of Energy Use in Cement Production in
F.R. Germany

	1975 ^a	1980	1985
Total clinker production, 10 ⁶ tonne	31.0		
Total cement production, 10 ⁶ tonne	35.6 ^b	34.3	26.3
Clinker production by process			
% wet process	5.0	3.0	
Thermal energy, GJ/t clinker	5.0-5.9		
Electricity, kWh/t cement			
% dry process	66.0	97.0	
Thermal energy, GJ/t clinker	3.2-3.8		
Electricity, kWh/t cement	103	108	
% Semi-dry process	26.0	-	
Thermal energy, GJ/t clinker	3.3-4.6		
Electricity, kWh/t cement			
% Other	3.0	-	
Total Energy Consumption			
Fossil fuel, PJ	117.2		
Electricity, TWh	3.5		
Energy intensity, GJ/t clinker	4.2		
Fossil fuel, GJ/t clinker	3.8	3.4	
Electricity, kWh/t cement	100.0	108.0	
% of blended cement	24.0		
% of additives			
Clinker/cement ratio, %	84.0		

^a 1974 data

^b 33.5 million tonne in 1975

Sources: Adapted and/or dervied from Refs. [2], [6], [7], [13]

Table F.57 Characteristics of Energy Use in Cement Production in the U.K.

	1975 ^a	1980	1985
Total clinker production, 10 ⁶ tonne	17.7		
Total cement production, 10 ⁶ tonne	18.4 ^b	14.8	12.2
Clinker production by process			
% wet process	69.0		
Thermal energy, GJ/t clinker	6.5-6.7		
Electricity, kWh/t cement	93.0		
% dry process	15.0		
Thermal energy, GJ/t clinker	3.5-3.7		
Electricity, kWh/t cement	119.0		
% Semi-dry process	16.0		
Thermal energy, GJ/t clinker	3.8		
Electricity, kWh/t cement	109		
% Other	-		
Total Energy Consumption			
Fossil fuel, PJ	108.8		
Electricity, TWh	1.8		
Energy intensity, GJ/t clinker			
Fossil fuel, GJ/t clinker	6.2		
Electricity, kWh/t cement	99.0		
% of blended cement	2.0		
% of additives			
Clinker/cement ratio, %	94.0		

^a 1974 data

^b 16.9 million tonne in 1975

Sources: Adapted and/or derived from Refs. [2], [7], [13]

Table F.58 Characteristics of Energy Use in Cement Production in Canada			
	1975	1980	1985
Total clinker production, 10 ⁶ tonne			
Total cement production, 10 ⁶ tonne	9.7	10.3	9.9
Clinker production by process			
% wet process			
Thermal energy, GJ/t clinker			
Electricity, kWh/t cement			
% dry process			
Thermal energy, GJ/t clinker			
Electricity, kWh/t cement			
% Semi-dry process			
Thermal energy, GJ/t clinker			
Electricity, kWh/t cement			
% Other			
Total Energy Consumption			
Fossil fuel, PJ			
Electricity, TWh			
Energy intensity, GJ/t clinker			
Fossil fuel, GJ/t clinker			
Electricity, kWh/t cement			
% of blended cement			
% of additives			
Clinker/cement ratio, %			

Sources: Adapted from Refs. [2]

Table F.60 Characteristics of Energy Use in Cement Production in Italy

	1975	1980	1985
Total clinker production, 10 ⁶ tonne			
Total cement production, 10 ⁶ tonne	34.2	41.9	37.8
Clinker production by process			
% wet process	13.0		
Thermal energy, GJ/t clinker	6.2		
Electricity, kWh/t cement	94.0		
% dry process	40.0		
Thermal energy, GJ/t clinker	4.1		
Electricity, kWh/t cement	107.0		
% Semi-dry process	46.0		
Thermal energy, GJ/t clinker	4.2		
Electricity, kWh/t cement	104.0		
% Other	1.0		
Total Energy Consumption			
Fossil fuel, PJ			
Electricity, TWh			
Energy intensity, GJ/t clinker			
Fossil fuel, GJ/t clinker	4.4		
Electricity, kWh/t cement	103.0		
% of blended cement	2.0		
% of additives			
Clinker/cement ratio, %	94.0		

Sources: Adapted and/or derived from Refs. [2], [7], [10], [13]

Table F.61 Characteristics of Energy Use in Cement Production in Australia

	1975	1980	1985
Total clinker production, 10 ⁶ tonne			
Total cement production, 10 ⁶ tonne			
Clinker production by process			
% wet process			
Thermal energy, GJ/t clinker			
Electricity, kWh/t cement			
% dry process			
Thermal energy, GJ/t clinker			
Electricity, kWh/t cement			
% Semi-dry process			
Thermal energy, GJ/t clinker			
Electricity, kWh/t cement			
% Other			
Total Energy Consumption			
Fossil fuel, PJ			
Electricity, TWh			
Energy intensity, GJ/t clinker			
Fossil fuel, GJ/t clinker			
Electricity, kWh/t cement			
% of blended cement			
% of additives			
Clinker/cement ratio, %			

Table F.62 Final Energy Use by Cement Manufacturing Stage in 1980^a

	Fuel, GJ/t clinker		Electricity, kWh/t cement		Total GJ/t cement	
	Normal Range	Average	Normal Range	Average	Average	% Share
Quarrying (MJ)	20.9-62.8	41.9	2-6	4	0.06	1.1
Raw Material Grinding and preparation						
Pyroprocessing	3.1-8.8	4.6	20-40	30	0.11	2.3
Clinker grinding			15-30	22	4.86	92.4
Miscellaneous			35-64	50	0.18	3.4
			10-16	13	0.05	1.0
Total	3.2-8.9	4.6	82-156	119	5.26	100
% share in Total ^b		91(79)		9(21)		

^a Average clinker to cement conversion ratio assumed 1.0:1.04

^b The figures inside the brackets are based on the primary energy equivalent, 1 Kwh = 2500 kcals.

Note: Totals may not equal sum of components due to independent rounding.

Source: Adapted and/or derived from Ref. [13].

Table F.63 Final Energy Use and Comparative Features of Different
Kiln Processes (pyroprocess) in cement production in 1980

	Wet	Semi-wet	Semi-dry	Long dry	One stage preheater	4 stage preheater	4 stage preheater W. precalciner
Thermal energy use, GJ/t of clinker	5.86	3.35-3.77	3.93-4.44	3.68-4.19	3.6-3.98	3.14-3.56	3.14-3.56
Electricity Use kWh/t of cement	18-27	18-28	18-28	20-22	22-24	27-31	30-34
Availability of secondary heat, max. % of moisture in raw material which can be handled by recovery heat	N.A.	4	N.A.	10	9	7-8	7-8
Sensitivity to raw materials characteristics							
Desirable	-	high nodule strength	filterability	-	-	low alkalis low chloride	low alkalis low chloride
Undesirable	high plasticity	-	-	-	-	-	-
Critical area	chain system	preheater grate	filter	-	-	preheater	preheater

Sources: Adapted from Ref. [13].

Table F.64 Comparative Thermal Energy Consumption in Various Pyroprocessing Systems (MJ/tonne of clinker)

Process	Wet	Semi-wet (Grate Preheater)	Semi-dry (Grate Preheater)	Dry (Long (Rotary Kiln)	4-Stage Preheater	4-Stage Pre- heater/Precalciner
Evaporation	2093	879	544	0	0	0
Waste Kiln Gases & Dust	963	523	364	1088	712	557
Cooler exhaust Air	356	544	557	544	565	565
Wall Losses	712	293	293	670	335	293
Total Energy Consumption	5860	3977	3495	4039	3139-3558	3139-3558
Theoretical Heat of Reaction	1737	1737	1737	1737	1737	1737
Energy Efficiency ^a , %	30	44	50	43	49-55	49-55

^a Efficiency is the percentage ratio of the theoretical heat of reaction to the total energy consumption.

Source: Adapted from Ref. [13].

Table F.65 Average Energy Intensities of Building Materials in 1980

Building Materials	energy Intensities (GJ/t)
Concrete aggregates	0.17
Concrete	0.8
Brick/tile	3.7
Cement	5.9
Refractories	6.6
Ceramic tiles	20.1
Plate glass	25.1
Steel	28.0

Source: Adapted from Ref. [13].

Table F.66 Comparison of Energy Intensities in End Products of Alternative Building Materials in 1980

	Unit Energy Consumption (MJ/m ²) Using			
	Concrete	Steel	Asphalt	Brick
building Wall	377-419			544-628
Bridge	3767	7953		
Roadway	837		3140	

Source: Adapted from Ref. [13].

Table F.67 Energy Intensity in the Pulp and Paper Industry in Selected Countries in 1981

	Total Purchased Energy Use (PJ)	% of Energy Use by all Industry	Energy Intensity (GJ/t paper)
USA	1013	6.7	18.0
Japan	272	4.9	15.9
UK	80	4.3	23.4
Canada	193	8.1	14.2
France	80	3.9	15.1
Italy	71	4.1	14.2
Sweden	209	41.0	34.3
Finland	142	38.6	23.0
Turkey			41.4
India			72.0 (101.3) ^a
Pakistan			51.1 (54.0)
Indonesia			30.1 (45.6)

^a. The figures inside the brackets include the non-commercial energy used.

Source: Adapted and/or derived from Ref. [19].

Table F.68 Typical Process Energy Consumption Before and After Internal Energy-Efficiency Improvement in the Production of Selected Pulp and Paper Grades (Thermal in GT and Electricity in kWh per Tonne of Product)

	Before Energy-Efficiency Improvement ^a				After Energy-Efficiency Improvement ^b			
	Bleached Kraft Pulp Heat Power	Linerboard Heat Power	Newsprint Heat Power		Bleached Kraft Pulp Heat Power	Linerboard Heat Power	Newsprint Heat Power	
Wood Preparation	0.1 65	0.1 55	0.1 45		0.1 60	0.1 50	0.1 45	
Pulping and Washing	3.5 120	3.0 210	- 1710		2.8 115	2.4 200	- 1625	
Bleaching	5.0 190	-	-		2.2 180	-	-	
Pulp Drying	3.6 160	-	-		2.5 150	-	-	
Stock Preparation	-	- 240	- 100		-	- 230	- 95	
Paper-making	-	6.5 190	5.8 250		-	4.6 180	4.1 240	
Chemical Recovery	5.2 75	4.2 65	-		4.1 70	3.3 60	-	
Miscellaneous	1.1 130	1.2 140	1.0 100		0.8 125	0.9 135	0.8 95	
Totals	18.5 740	15.0 900	6.9 2205		12.5 700	11.3 855	5.0 2100	

^a For mills built with 1960s technology and thus no out-of-the-ordinary energy saving or heat recovery system.

^b Includes direct energy conservation at the point of use, in-process waste heat recovery, improved utilization of waste materials for fuel, in particular wood wastes and black liquor, and cogeneration of steam and electricity.

Source: Adapted and/or derived from Ref. [19].

References

1. International Energy Agency. Energy Balances of OECD Countries 1970/1985, OECD/IEA, Paris 1987.
2. U.S. Central Intelligence Agency. Handbook of Economic Statistics, 1986, CPAS 86-10002 1986.
3. Meunier, M.Y. and de Bruyn Kops, O. Energy Efficiency in the Steel Industry with Emphasis on Developing Countries. World Bank Technical Paper no. 22, World Bank, Washington, D.C. 1984.
4. Sparrow, F.T. Energy and Materials Flows in the Iron and Steel Industry. ANL/CNSV-41, Argonne National Laboratory, IL 1983.
5. United Nations Economic Commission for Europe. An Efficient Energy Future, Butterworths, London 1983.
6. International Energy Agency. Energy Conservation in IEA Countries, OECD/IEA, Paris 1987.
7. Chateau, B., and Lapillone, B. Energy Demand: Facts and Trends, Springer-Verlag, New York 1982.
8. Wilson, D. The Demand for Energy in the Soviet Union, Rowman & Allanheld, Croon Helm, Australia 1983.
9. Kelly, W.J., Shaffer, H.L., and Thompson, T.K., Energy Research and Development in the U.S.S.R., Duke University Press, Durham, NC 1986.
10. World Bank, China: The Energy Sector, Annex 3 to China Long-Term Development Issues and Options, Washington, D.C. 1985.
11. Langley, K. Industrial Energy Efficiency in the United Kingdom up to the Year 2000, Applied Energy, 26, pp. 47-65, 1987.
12. Koss, M. Industrial Energy Conservation, Chapter 18 in Energy Sources: Conservation and Renewables, Hafemeister, D., Kelly, H., and Levi, B., Eds. Am. Inst. of Physics, No. 135, New York 1985.
13. Fog, M.H., and Nadkarni, K.L. Energy Efficiency and Fuel Substitution in the Cement Industry with Emphasis on Developing Countries. World Bank, Washington, D.C. 1983.
14. Lyakishev, N.P. and Perlov, N.I. Technological Progress and Energy Conservation in the Iron and Steel Industry of the U.S.S.R, Energy, 12, p. 1169, 1987.

15. Ross, M. Industry Energy Conservation and the Steel Industry of the United States, Energy 12, p. 1135, 1987.
16. Eketorp, S. Energy Considerations of Classical and New Iron-and Steel-Making Technology, Energy 12, p. 1153, 1987.
17. Kahane, A and Squitieri, R. Electricity Use in Manufacturing, Ann. Rev. Energy 12, p. 223, 1987
18. Gamba, J.R., Caplin. D.A., and Mulckhuyse, J.J. Industrial Energy Rationalization in Deveoping Countries, World Bank, 1986.
19. Ewing, A.J. Energy Efficiency in the Pulp and Paper Industry with Emphasis on Developing Countries, World Bank Technical Paper, No. 34, Washington, DC, 1985.
20. Boyd, G.A., and Ross, M.H. The Role of Sectoral Shifts in Trends in Electricity Use in the U.S. and Swedish Manufacturing and in Comparing Forecasts, p. 461 in Electricity ed. by Johansson, T.B. et. al., Lund Univ. Press, Sweden 1989.
21. Holcomb, M.C., Floyd, S.D., Cagle, S.L. Transportation Energy Data Book, 9th ed., ORNL-6324, Oak Ridge National Lab., TN, 1987.

Appendix G

ELECTRICITY - GENERATION AND USE DATA

Table G.1 Primary Energy Use in Electricity Generation by Fuel Type
in the U.S. in 1975 (PJ = 10^{15} J)

	Solid	Liquid	Gas	Nuclear ^b	Solar ^{b,c}	Total
Energy use	9431 ^a	3065	3119	1884	3146	20645
Gross elec. generated	3208	1114	1155	607	1103	7240
In-house plant use						(430)
Transmission and distribution losses						(636)
Import						41
Export						(18)
Petro. refining uses						(90)
Total electricity for end use						6104

^aIncludes 2.1 PJ of wood and waste which produced 202 Gwh of electricity.

^bThe weighted average annual thermal efficiency of 35.07% for fossil-fuel steam electric plants was used to calculate the primary energy equivalent of nuclear and solar energy used to produce electricity.

^cIncludes hydro, geothermal, and solar energy.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [9], [10].

Table G.2 Primary Energy Use in Electricity Generation by Fuel Type
in the U.S. in 1980 (PJ = 10^{15} J)

	Solid	Liquid	Gas	Nuclear ^b	Solar ^{b,c}	Total
Energy use	12230 ^a	2536	3654	2614	2789	23822
Gross elec. generated	4476	948	1334	958	1023	8738
In-house plant use						(646)
Transmission and distribution losses						(763)
Import						107
Export						(15)
Petro. refining uses						(129)
Total electricity for end use						7292

^aIncludes 4.6 PJ of wood and waste which produced 457 Gwh of electricity.

^bThe weighted average annual thermal efficiency of 36.68% for fossil-fuel steam electric plants was used to calculate the primary energy equivalent of nuclear and solar energy used to produce electricity.

^cIncludes hydro, geothermal, and solar energy.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [9], [10].

Table G.3 Primary Energy Use in Electricity Generation by Fuel Type
in the U.S. in 1985 (PJ = 10^{15} J)

	Solid	Liquid	Gas	Nuclear ^b	Solar ^{b,c}	Total
Energy use	14859 ^a	1051	3036	4011	2912	255869
Gross elec. generated	5401	386	1125	1464	1063	9439
In-house plant use						(708)
Transmission and distribution losses						(725)
Import						165
Export						(18)
Petro. refining uses						(101)
Total electricity for end use						8053

^aIncludes 15 PJ of wood and solid waste which produced 1482 Gwh of electricity.

^bThe weighted average annual thermal efficiency of 36.5% for fossil-fuel steam electric plants was used to calculate the primary energy equivalent of nuclear and solar energy used to produce electricity.

^cIncludes hydro, geothermal, and solar energy.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [9], [10].

Table G.4 Primary Energy Use by Power Stations by Fuel Type
in the U.S.S.R. in 1975, 1980, and 1985 (PJ = 10¹⁵J)

	Solid					Nuclear ^c	Solar ^{c,d}	Total
	Coal	Other ^a	Liquid	Gas				
Total energy use								
1975	5567	565	3882	3463	198	1247	14922	
1980	5998	440	5567	3829	701	1765	18300	
1985 plan	6789	498	4439	5400	2062	2156	21345	
Energy use for heat ^b								
1975							4659	
1980							5919	
1985 plan							6768	
Energy use for electric								
1975							10263	
1980							12382	
1985							14576	
Elec. generated								
(Efficiency %)								
1975		3211 ^e			72	454	3737 (36.4%)	
1980		3737 ^e			263	662	4660 (37.5%)	
1985 plan		3978 ^e			792	828	5598 (38.4%)	

^aIncludes peat, shale and wood.

^bEnergy used by combined heat and power plants to produce steam and hot water.

^cThe average annual thermal efficiency of fossil-fuel steam electric plants was used to calculate the fossil energy equivalent of nuclear and solar energy used to produce electricity.

^dMostly hydro energy.

^eTotal electricity generated from solid, liquid and gaseous fuels.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [2], [3], [4], [5], [10].

Table G.5 Primary Energy Use for the Generation of Thermal Energy by Boiler Type
in the U.S.S.R. in 1975, 1980 and 1985 (PJ = 10^{15} J)

	Solid		Liquid	Gas	Total	Heat Generated	Efficiency %
	Coal	Other ^c					
Power stations (CHP)							
1975					4659	3830	82.3
1980					5919	4898	82.6
1985 plan					6768	5609	82.8
Central boilers ^a							
1975						3445	
1980	1011	646	1231	2989	5332	4563	75.4
1985 plan	1172	---	1465	3574	6212	4814	77.5
Local boilers ^b							
1975						2771	
1980	2754	1875 ^d	469	674	5596	3642	65.1
1985 plan	2227	1758 ^d	527	1025	5538	3684	66.5

^aLarge municipal and industrial boilers.

^bSmall factory and household boilers.

^cIncludes peat, shale and wood.

^dAlso includes energy from factories via heat exchangers, coke, and oil products other than fuel oil.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [2], [3], [4], [5].

Table G.6 Heat Rate and Efficiency for the Generation of Electricity and Thermal Energy
in the U.S.S.R. in 1975, 1980 and 1985^a

	Electricity generation		Thermal energy	
	Heat rate, kJ/kWh	Efficiency, %	Heat rate, kJ Fuel/kJ, Thera.	Efficiency, %
Fossil-fuel power plants^b				
Condensing plants				
1975	10695	33.7		
1980	10432	34.5		
1985				
CHPC				
1975	8176	44.0	1.22	82.3
1980	7970	45.2	1.21	82.6
1985			1.21	82.7
Average				
1975	9887	36.4		
1980	9597	37.5		
1985	9367	38.4		
Central boilers ^d				
1975			1.31	76.4
1980			1.33	75.4
1985			1.29	77.2
Local boilers ^e				
1975				
1980			1.54	65.0
1985			1.50	66.4

^aThe year-1985 data are forecast figures.

^bThe efficiencies of nuclear power plants are 31.3% and 32.5% in 1975 and 1980, respectively.

^cCombined heat and power plants.

^dLarge municipal and industrial boilers.

^eSmall factory and household boilers.

Sources: Adapted and/or derived from Refs. [2], [4].

Table G.7 Primary Energy Use in Electricity Generation by Fuel Type
in China in 1975 (PJ = 10^{15} J)

	Solid	Liquid	Gas	Nuclear	Solar	Total
Total energy use						
Energy use for heat ^a						
Energy use for electricity						
Gross elec. generated						705
In-house plant use						
Transmission and distribution losses						
Import						
Export						
Petro. refining uses						
Total electricity for end uses						

^aEnergy which is used to product steam and hot water for consumers outside the power industry.

Source: Ref. [10].

Table G.8 Primary Energy Use in Electricity Generation by Fuel Type
in China in 1980 (PJ = 10^{15} J)

	Solid	Liquid	Gas	Nuclear	Solar ^{b,c}	Total
Total energy use	2290	829	176	---	706	4001
Energy use for heat ^a	120	138	97	---	---	355
Energy use for electricity	2170	691	79	---	706	3646
Gross elec. generated	644	205	23	---	208	1081
In-house plant use						(70)
Transmission and distribution losses						(91)
Import						---
Export						---
Petro. refining uses						(100) ^d
Total electricity for end use						820

^aEnergy which is used to produce steam and hot water for consumers outside of the power industry.

^bThe average annual thermal efficiency of 29.6% for fossil-fuel steam electric plants was used to calculate the fossil energy equivalent of hydro energy used to generate electricity.

^cMainly hydro energy.

^dIncludes energy use by coal industries.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [6], [10].

Table G.9 Primary Energy Use in Electricity Generation by Fuel Type
in China in 1985 (PJ = 10^{15} J)

	Solid	Liquid	Gas	Nuclear	Solar	Total
Total energy use						
Energy use for heat ^a						
Energy use for electricity						
Gross elec. generated						1466
In-house plant use						
Transmission and distribution losses						
Import						
Export						
Petro. refining uses						
Total electricity for end use						

^aEnergy which is used to produce steam and hot water for consumers outside of the power industry.

Source: Ref. [10].

Table G.10 Primary Energy Use in Electricity Generation by Fuel Type
in Japan in 1975 (PJ = 10^{15} J)

	Solid	Liquid	Gas	Nuclear ^a	Solar ^{a,b}	Total
Total energy use	519	2672	189	230	789	4401
Public utility	347	2301	189	230	728	3797
Industrial	172	371	---	---	61	604
Gross elec. generated	152	1087	73	90	310	1712
Public utility	108	932	73	90	286	1490
Industrial	44	155	---	---	24	222
In-house plant use						(87)
Transmission and distribution losses						(89)
Import						---
Export						---
Petro. refining uses						(18)
Total electricity for end use						1518

^aThe weighted average annual thermal efficiency of 39.2% for fossil-fuel steam-electric plants was used to calculate the fossil-fuel energy equivalent of nuclear and solar energy used to produce electricity.

^bIncludes hydro, geothermal, and solar energy.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [8].

Table G.11 Primary Energy Use in Electricity Generation by Fuel Type
in Japan in 1980 (PJ = 10^{15} J)

	Solid	Liquid	Gas	Nuclear ^a	Solar ^{a,b}	Total
Energy use	441	2538	665	741	835	5219
Public utility	336	2092	665	736	772	4600
Industrial	105	446	---	5	63	619
Gross elec. generated	180	971	292	297	335	2075
Public utility	140	809	292	295	310	1846
Industrial	40	162	---	2	25	229
In-house plant use						(116)
Transmission and distribution losses						(91)
Import						---
Export						---
Petro. refining uses						(20)
Total electricity for end use						1848

^aThe weighted average annual thermal efficiency of 40.0% for fossil-fuel steam-electric plants was used to calculate the fossil-fuel energy equivalent of nuclear and solar energy used to produce electricity.

^bIncludes hydro, geothermal, and solar energy.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [8], [10].

Table G.12 Primary Energy Use in Electricity Generation by Fuel Type
in Japan in 1985 (PJ = 10^{15} J)

	Solid	Liquid	Gas	Nuclear ^a	Solar ^{a,b}	Total
Energy use	874	1703	1122	1402	784	5885
Public utility	734	1318	1122	1397	723	5294
Industrial	141	385	---	5	61	592
Gross elec. generated	360	702	462	574	322	2420
Public utility	294	550	462	572	297	2174
Industrial	66	153	---	2	25	246
In-house plant use						(163)
Transmission and distribution losses						(104)
Import						---
Export						---
Petro. refining uses						(18)
Total electricity for end use						2135

^aThe weighted average annual thermal efficiency of 41.1% for fossil-fuel steam-electric plants was used to calculate the fossil-fuel energy equivalent of nuclear and solar energy used to produce electricity.

^bIncludes hydro, geothermal, and solar energy.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [2], [10].

Table G.13 Primary Energy Use in Electricity Generation by Fuel Type
in F. R. Germany in 1975 (PJ = 10^{15} J)

	Solid	Liquid	Gas	Nuclear ^a	Solar ^{a,b}	Total
Energy use	1908	270	546	222	177	3125
Public utility	1422 ^a	199	474	222	154	2472
Industrial	486 ^b	71	72	---	23	653
Gross elec. generated	618	108	217	77	62	1082
Public utility ^c	474	65	186	77	54	856
Industrial	144	43	31	---	8	226
In-house plant use						(106)
Transmission and distribution losses						(53)
Import						63
Export						(36)
Petro. refining uses						(16)
Total electricity for end use						936

^aIncludes 16.7 PJ of wood and waste which produced 1.1 Twh of electricity.

^bIncludes 19.7 PJ of wood and waste which produced 2.0 Twh of electricity.

^cPublic electricity also produced 99.6 PJ of heat for end uses from combined heat and power plants (CHP). This heat does not include heat produced in pure district heating plants.

^dThe weighted average annual thermal efficiency of 34.6% for fossil-fuel steam-electric plants was used to calculate the primary energy equivalent of inputs for nuclear and solar energy used to produce electricity.

^eIncludes hydro, geothermal, and solar energy.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [2], [7], [10].

Table G.14 Primary Energy Use in Electricity Generation by Fuel Type
in F. R. Germany in 1980 (PJ = 10^{15} J)

	Solid	Liquid	Gas	Nuclear ^d	Solar ^{d,e}	Total
Energy use	2334	236	560	454	194	3777
Public utility	1816 ^a	155	488	443	170	3073
Industrial	518 ^b	80	72	11	24	705
Gross elec. generated	791	93	220	157	67	1328
Public utility ^c	617	51	184	153	59	1074
Industrial	155	42	36	4	8	254
In-house plant use						(129)
Transmission and distribution losses						(51)
Import						69
Export						(49)
Petro. refining uses						(21)
Total electricity for end use						1147

^aIncludes 15.9 PJ of wood and waste which produced 2.85 Twh of electricity.

^bIncludes 25.9 PJ of wood and waste which produced 2.58 Twh of electricity.

^cPublic electricity also produced 124.7 PJ of heat for end uses, from combined heat and power plants (CHP). This heat does not include heat produced in pure district heating plants.

^dThe weighted average annual thermal efficiency of 34.7% for fossil-fuel steam-electric plants was used to calculate the primary energy equivalent of inputs for nuclear and solar energy used to produce electricity.

^eIncludes hydro, geothermal, and solar energy.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [2], [7], [8], [10].

Table G.15 Primary Energy Use in Electricity Generation by Fuel Type
in F. R. Germany in 1985 (PJ = 10^{15} J)

	Solid	Liquid	Gas	Nuclear ^d	Solar ^{d,e}	Total
Energy use	2332	95	243	1178	166	4014
Public utility	1881 ^a	59	177	1166	144	3427
Industrial	451 ^b	36	66	12	22	587
Gross elec. generated	832	34	89	453	63	1471
Public utility ^c	669	17	57	449	56	1247
Industrial	162	17	32	4	8	224
In-house plant use						(143)
Transmission and distribution losses						(59)
Import						68
Export						(59)
Petro. refining uses						(19)
Total electricity for end use						1259

^aIncludes 31.8 PJ of wood and waste which produced 4.5 Twh of electricity.

^bIncludes 8.4 PJ of wood and waste which produced 2.8 Twh of electricity.

^cPublic electricity also produced 115 PJ of heat for end uses from combined heat and power plants (CHP). This heat does not include heat produced in pure district heating plants.

^dThe weighted average annual thermal efficiency of 35.1% for fossil-fuel steam-electric plants was used to calculate the primary-energy equivalent of nuclear and solar energy use to produce electricity.

^eIncludes hydro, geothermal, and solar energy.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [10].

Table G.16 Primary Energy Use in Electricity Generation by Fuel Type
in the United Kingdom in 1975 (PJ = 10^{15} J)

	Solid	Liquid	Gas	Nuclear ^a	Solar ^{a,b}	Total
Energy use	1839	524	83	319	52	2817
Public utility	1796	448	73	279	46	2641
Industrial	43	76	10	40	6	176
Gross elec. generated	610	209	33	109	18	979
Public utility	583	180	30	95	16	904
Industrial	27	29	3	14	2	75
In-house plant use						90
Transmission and distribution losses						(70)
Import						0.8
Export						(0.4)
Petro. refining uses						(11)
Total electricity for end use						809

^aThe weighted average annual thermal efficiency of 34.3% for fossil-fuel steam-electric plants was used to calculate the fossil-fuel energy equivalent of nuclear and solar energy used to produce electricity.

^bIncludes hydro, geothermal, and solar energy.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [2] [7], [10].

Table G.17 Primary Energy Use in Electricity Generation by Fuel Type
in the United Kingdom in 1980 (PJ = 10^{15} J)

	Solid	Liquid	Gas	Nuclear ^a	Solar ^{a,b}	Total
Energy use	2165	341	24	386	53	2967
Public utility	2098	265	5	347	47	2762
Industrial	67	77	18	37	6	205
Gross elec. generated	748	119	8	133	18	1027
Public utility	726	94	2	120	16	959
Industrial	22	25	6	13	2	68
In-house plant use						(95)
Transmission and distribution losses						(77)
Import						0
Export						(0)
Petro. refining uses						(11)
Total electricity for end use						844

^aThe weighted average annual thermal efficiency of 34.7% for fossil-fuel steam-electric plants was used to calculate the fossil-fuel energy equivalent of nuclear and solar energy used to produce electricity.

^bIncludes hydro, geothermal, and solar energy.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [2], [8], [10].

Table G.18 Primary Energy Use in Electricity Generation by Fuel Type
in the United Kingdom in 1985 (PJ = 10^{15} J)

	Solid	Liquid	Gas	Nuclear ^a	Solar ^{a,b}	Total
Energy use	1767	464	33	571	65	2900
Public utility	1708	404	12	527	59	2710
Industrial	59	60	21	44	6	190
Gross elec. generated	642	174	10	220	25	1071
Public utility	623	155	5	203	23	1008
Industrial	19	19	6	17	2	63
In-house plant use						(105)
Transmission and distribution losses						(82)
Import						---
Export						---
Petro. refining uses						(11)
Total electricity for end use						873

^aThe average annual thermal efficiency of 38.5% for fossil-fuel steam-electric plants was used to calculate the primary energy equivalent of nuclear and solar energy used to produce electricity.

^bIncludes hydro, geothermal, and solar energy.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [10].

Table G.19 Primary Energy Use in Electricity Generation by Fuel Type
in Canada in 1975 (PJ = 10^{15} J)

	Solid	Liquid	Gas	Nuclear ^a	Solar ^{a,b}	Total
Energy use	372	115	179	133	2145	2944
Public utility	370	87	138	133	1833	2561
Industrial	2	28	41	---	312	383
Gross elec. generated	131	37	56	45	729	998
Public utility	130	26	46	45	623	871
Industrial	1	10	10	---	106	128
In-house plant use						(25)
Transmission and distribution losses						(100)
Import						14
Export						(41)
Petro. refining uses						(10)
Total electricity for end use						836

^aThe average annual thermal efficiency of 34.0% for fossil-fuel steam-electric plants was used to calculate the primary energy equivalent of nuclear and solar energy used to produce electricity.

^bIncludes hydro, geothermal, and solar energy.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [8], [10].

Table G.20 Primary Energy Use in Electricity Generation by Fuel Type
in Canada in 1980 (PJ = 10^{15} J)

	Solid	Liquid	Gas	Nuclear ^b	Solar ^{b,c}	Total
Energy use	630	122	75	393	2599	3819
Public utility	620	111	55	393	2282	3461
Industrial	10 ^a	11	20	---	317	358
Gross elec. generated	220	50	33	137	904	1344
Public utility	215	41	18	137	794	1205
Industrial	5	9	15	---	110	139
In-house plant use						(33)
Transmission and dis- tribution losses						(117)
Import						10
Export						(109)
Petro. refining uses						(13)
Total electricity for end use						1083

^aWood and solid waste.

^bThe average annual thermal efficiency of 34.8% for fossil-fuel steam-electric plants was used to calculate the fossil energy equivalent of nuclear and solar energy used to produce electricity.

^cIncludes hydro, geothermal, and solar energy.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [8], [10].

Table G.21 Primary Energy Use in Electricity Generation by Fuel Type
in Canada in 1985 (PJ = 10^{15} J)

	Solid	Liquid	Gas	Nuclear ^b	Solar ^{b,c}	Total
Energy use	843	63	56	634	3180	4776
Public utility	825	55	22	634	2868	4404
Industrial	18 ^a	8	34	---	312	372
Gross elec. generated	292	24	25	218	1093	1653
Public utility	284	20	6	218	986	1514
Industrial	8	4	19	---	108	139
In-house plant use						(52)
Transmission and distribution losses						(126)
Import						10
Export						(155)
Petro. refining uses						(17)
Total electricity for end use						1312

^aIncludes 15 PJ of wood and waste which produced 6 Gwh of electricity.

^bThe weighted average annual thermal efficiency of 34.7% for fossil-fuel steam-electric plants was used to calculate the fossil energy equivalent of nuclear and solar energy used to produce electricity.

^cIncludes hydro, geothermal, and solar energy.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Ref. [1], [10].

Table G.22 Primary Energy Use in Electricity Generation by Fuel Type
in France in 1975 (PJ = 10^{15} J)

	Solid	Liquid	Gas	Nuclear ^b	Solar ^{b,c}	Total
Energy use	426	492	110	173	574	1774
Public utility	231	436	102	173	549	1491
Industrial	195 ^a	56	8	---	25	284
Gross elec. generated	136	203	44	66	218	667
Public utility	78	175	39	66	209	567
Industrial	58	28	5	---	10	100
In-house plant use						(53)
Transmission and distribution losses						(45)
Import						31
Export						(23)
Petro. refining uses						(11)
Total electricity for end use						567

^aIncludes 7.1 PJ of non-coal solid fuels such as wood, peat and solid wastes.

^bThe weighted average annual thermal efficiency of 38.0% for fossil-fuel steam-electric plants was used to calculate the fossil-fuel energy equivalent of nuclear and solar energy used to produce electricity.

^cIncludes hydro, geothermal, and solar energy.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [2], [8], [10].

Table G.23 Primary Energy Use in Electricity Generation by Fuel Type
in France in 1980 (PJ = 10^{15} J)

	Solid	Liquid	Gas	Nuclear ^b	Solar ^{b,c}	Total
Energy use	722	427	56	570	658	2435
Public utility	496	383	41	570	618	2108
Industrial	226 ^a	44	15	---	40	326
Gross elec. generated	254	174	25	221	255	929
Public utility	179	152	15	221	239	805
Industrial	75	22	10	---	16	123
In-house plant use						(109)
Transmission and distribution losses						(62)
Import						56
Export						(45)
Petro. refining uses						(17)
Total electricity for end use						752

^aIncludes 7.1 PJ from non-coal solid fuels such as wood, peat and solid wastes.

^bThe weighted average annual thermal efficiency of 38.7% for fossil-fuel steam-electric plants was used to calculate the fossil-fuel energy equivalent of nuclear and solar energy used to produce electricity.

^cIncludes hydro, geothermal, and solar energy.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [2], [8], [10].

Table G.24 Primary Energy Use in Electricity Generation by Fuel Type
in France in 1985 (PJ = 10^{15} J)

	Solid	Liquid	Gas	Nuclear ^b	Solar ^{b,c}	Total
Energy use	444	67	23	2095	601	3230
Public utility	242	36	9	2095	553	2935
Industrial	202 ^a	31	13	---	48	294
Gross elec. generated	165	25	11	807	231	1240
Public utility	97	15	3	807	213	1135
Industrial	68	10	8	---	18	105
In-house plant use						(158)
Transmission and distribution losses						(84)
Import						20
Export						(104)
Petro. refining uses						(16)
Total electricity for end use						897

^aIncludes 6.7 PJ of wood and waste which produced 792 Gwh of electricity.

^bThe weighted average annual thermal efficiency of 38.5% for fossil-fuel steam-electric plants was used to calculate the fossil-fuel energy equivalent of nuclear and solar energy used to produce electricity.

^cIncludes hydro, geothermal, and solar energy.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [10].

Table G.25 Primary Energy Use in Electricity Generation by Fuel Type
in Italy in 1975 (PJ = 10^{15} J)

	Solid	Liquid	Gas	Nuclear ^c	Solar ^{c,d}	Total
Energy use	75	752	72	35	416	1349
Public utility	35 ^a	623	47	35	338	1078
Industrial	40 ^b	129	25	---	78	272
Gross elec. generated	27	300	28	14	162	530
Public utility	12	245	18	14	132	420
Industrial	15	55	10	---	31	110
In-house plant use						(36)
Transmission and dis- tribution losses						(45)
Import						18
Export						(9)
Petro. refining uses						(7)
Total electricity for end use						452

^aIncludes 0.8 PJ of non-coal solid fuels such as wood, peat and wastes which produces 92 Gwh of electricity.

^bIncludes 10.5 PJ of non-coal solid fuels such as wood, peat and wastes which produces 1.4 Twh of electricity.

^cThe weighted average annual thermal efficiency of 39% for fossil-fuel steam-electric plants was used to calculate the fossil-fuel energy equivalent of nuclear and solar energy used to produce electricity.

^dIncludes hydro, geothermal, and solar energy.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [2], [7], [8], [10].

Table G.26 Primary Energy Use in Electricity Generation by Fuel Type
in Italy in 1980 (PJ = 10^{15} J)

	Solid	Liquid	Gas	Nuclear ^c	Solar ^{c,d}	Total
Energy use	181	951	85	20	454	1692
Public utility	143 ^a	782	64	20	382	1392
Industrial	38 ^b	169	21	---	72	300
Gross elec. generated	70	377	33	8	181	669
Public utility	52	317	24	8	152	553
Industrial	18	60	9	---	29	116
In-house plant use						(47)
Transmission and distribution losses						(60)
Import						29
Export						(7)
Petro. refining uses						(9)
Total electricity for end use						575

^aInclude 0.4 PJ of non-coal solid fuels such as wood, peat and wastes which produces 89 Gwh of electricity.

^bIncludes 5.86 PJ of non-coal solid fuels such as wood, peat and wastes which produces 1.2 Twh of electricity.

^cThe weighted average annual thermal efficiency of 39.7% for fossil-fuel steam-electric plants was used to calculate the fossil-fuel energy equivalent of nuclear and solar energy

^dIncludes hydro, geothermal, and solar energy.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [2], [8], [10].

Table G.27 Primary Energy Use in Electricity Generation by Fuel Type
in Italy in 1985 (PJ = 10^{15} J)

	Solid	Liquid	Gas	Nuclear ^c	Solar ^{c,d}	Total
Energy use	293	677	215	66	442	1693
Public utility	255 ^a	584	195	66	370	1460
Industrial	38 ^b	93	20	---	72	223
Gross elec. generated	110	274	89	25	170	669
Public utility	97	239	79	25	142	583
Industrial	13	35	10	---	28	86
In-house plant use						(57)
Transmission and distribution losses						(63)
Import						90
Export						(5)
Petro. refining uses						(8)
Total electricity for end use						625

^aIncludes 0.8 PJ of wood and waste which produced 64 Gwh of electricity.

^bIncludes 9 PJ of wood and waste which produced 467 Gwh of electricity.

^cThe weighted average annual thermal efficiency of 38.4% for fossil-fuel steam-electric plants was used to calculate the fossil-fuel energy equivalent of nuclear and solar energy used to produce electricity.

^dIncludes hydro, geothermal, and solar energy.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [10].

Table G.28 Primary Energy Use in Electricity Generation by Fuel Type
in Australia in 1975 (PJ = 10^{15} J)

	Solid	Liquid	Gas	Nuclear ^c	Solar ^{c,d}	Total
Energy use	670	46	31	---	205	952
Public utility	643 ^a	24	29	---	204	900
Industrial	27 ^b	22	2	---	0.7	52
Gross elec. generated	184	17	10	---	54	266
Public utility	171	6	8	---	54	240
Industrial	13	11	2	---	---	27
In-house plant use						(15)
Transmission and distribution losses						(27)
Import						---
Export						---
Petro. refining uses						(3)
Total electricity for end use						(222)

^aIncludes 1.3 PJ of non-coal solid fuels such as wood, peat and wastes which produces 94 Gwh of electricity.

^bIncludes 4.6 PJ of non-coal solid fuels such as wood, peat and wastes which produces 395 Gwh of electricity.

^cThe weighted average annual thermal efficiency of 26.6% for fossil-fuel steam-electric plants was used to calculate the fossil-fuel energy equivalent of nuclear and solar energy used to produce electricity.

^dIncludes hydro, geothermal, and solar energy.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [10].

Table G.29 Primary Energy Use in Electricity Generation by Fuel Type
in Australia in 1980 (PJ = 10^{15} J)

	Solid	Liquid	Gas	Nuclear ^b	Solar ^{b,c}	Total
Energy use	849	47	70	---	169	1135
Public utility	823	26	65	---	168	1082
Industrial	26 ^a	21	5	---	0.7	53
Gross elec. generated	252	19	25	---	50	346
Public utility	239	6	23	---	49.4	317
Industrial	12	13	2	---	0.2	29
In-house plant use						(24)
Transmission and distribution losses						(33)
Import						---
Export						---
Petro. refining uses						(3)
Total electricity for end use						285

^aIncludes 4.6 PJ of non-coal solid fuels such as wood, peat and wastes which produces 0.4 Twh of electricity.

^bThe weighted average annual thermal efficiency of 29.3% for fossil-fuel steam-electric plants was used to calculate the fossil-fuel energy equivalent of nuclear and solar energy used to produce electricity.

^cIncludes hydro, geothermal, and solar energy.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [10].

Table G.30 Primary Energy Use in Electricity Generation by Fuel Type
in Australia in 1985 (PJ = 10^{15} J)

	Solid	Liquid	Gas	Nuclear	Solar ^{b,c}	Total
Energy use	980	38	102	---	164	1284
Public utility	954	21	93	---	164	1232
Industrial	26 ^a	17	9	---	---	52
Gross elec. generated	322	17	41	---	54	434
Public utility	308	7	34	---	54	403
Industrial	14	10	7	---	---	31
In-house plant use						(41)
Transmission and distribution losses						(31)
Import						---
Export						---
Petro. refining uses						(4)
Total electricity for end use						357

^aIncludes 5 PJ of wood and waste which produced 456 Gwh of electricity.

^bThe weighted average annual thermal efficiency of 32.7% for fossil-fuel steam-electric plants was used to calculate the fossil-fuel energy equivalent of nuclear and solar energy used to produce electricity.

^cIncludes hydro, geothermal, and solar energy.

Note: Totals may not equal sum of components due to independent rounding.

Sources: Adapted and/or derived from Refs. [1], [10].

Table G.31 Cost and Performance Estimates for New Electric Power Technologies,
based on May 1985 Technology Status

Technology	Duty Cycle	Op. Avail- ability, %	Capacity Factor ^a , %	Reference Plant Size, MWe	Plant Effl- ciency ^b , %	Capital \$/kWh	Costs ^c		Development ^g Status
							O&M \$/kWh	Fuel Mills/kWh	
AFBC ^d	base/interm.	85-87	20-70	150	35	1260-1580	7.66	17	Demo. under
IGCCe	base	85	70	500	35-40	1200-1350	6-12	15-17	Demo.
Fuel cells									
large	variable	80-90	40-75	11	40-44	700-3000	4.2-11.5	4.2-11.5	Demos planned
small	variable	80-90	40-75	0.4	36-40	950-3000	27-30	30-33	Demos operating
CAES ^f									
maxi	peak/inter.	90-98	10-20	220	51	565-600	3.6	42-63	Demo ^h
mini	peak/inter.	90-98	10-20	50	51	487-833	3.6	42-63	No Demo.
Batteries									
lead-acid	peaking	90	10	20	70-75	600-500	6-20	27-50	Demo.
zinc-chlor	peaking	90	10	20	60-70	500-3000	3-11	29-58	Demo.
Solar Photovoltaic									
Flat plate	interm.	90-100	20-40	10	8-14	1000-11000	4-28	0	Commercial
concen.	interm.	90-100	20-35	10	12-20	1000-8000	4-23	0	Commercial
Solar, parabolic dish	interm.	95	20-35	10	20-25	2000-3000	15-23	0	Demo ⁱ
Wind	interm.	95-98	20-35	20		900-1200	6-14	0	Commercial
Geothermal									
Dual-flash	base	85-90	70	50	7.0-8.0	1300-1600	1500-1800	1500-2000	Commercial
Large binary	base	85-90	70	50	9.5-12.0	10-15	10-15	10-15	Commercial
small binary	base	85-90	70	7	7.0-9.0	20-70	20-70	20-70	Commercial

^aThe ratio of actual energy produced by the plant in a year to the energy the plant could have generated if it operated continuously at its rated power.

Table G.31 (continued)

^bThe annual average plant efficiency, defined as the ratio of total net energy produced to total available energy contained in the fuel or resource. The conversion factor for electricity is 3412 Btu/kWh.

^cAll capital and O&M costs are reported in Mid-1983 dollars. Electricity and fuel costs are first year annual average costs based on a typical plant in the reference year, which is 1995, except 1990 for AFBC, IGCC and CAES mini. Fuel prices are based on 1983 fuel prices, \$/MBtu (coal: 1.66, gas: 3.47, oil residual: 4.58 and oil distillate: 6.09) with assumed real escalation rate of 1% per annum for coal and 2% per annum for oil and gas. Electricity for CAES and batteries is assumed to be generated by a base load plant, at prices expected to range from 20 to 35 mill/kWh.

^dAtmospheric fluidized-bed combination.

^eIntegrated gasification combined cycle.

^fCompressed air energy storage plants.

^gThe technology may be commercially deployed, or it may be operating as a demonstration unit or pilot plant; or plans may be underway to deploy such units.

^hA 290 MWe salt dome based CAES plant is operating in Huntorf, W. Germany. Another smaller 25 MWe plant is operating in Italy. No demonstration plant is operating in the U.S.

ⁱOnly individuals modules are being demonstrated.

Sources: Adapted from Ref. [11].

Table G.32 Cost and Performance Characteristics for U.S. Central-Station Power Plants^a

Type	Unit Size, MW	Unit Cost, \$/kW	Efficiency ^c , %	Levelized Capital ^d	Busbar Fuel	Cost (cents/kWh) O&M	Total
Coal steam-electric ^b							
	200	1880	34.6	2.25	1.86	1.37	5.48
	500	1410	34.6	1.69	1.86	0.99	4.54
	2 x 500	1340	34.6	1.61	1.86	0.89	4.36
Nuclear, light water reactor ^e							
current	1100	3060	33.4	3.66	0.91	1.11	5.68
target	1100	1670	33.4	2.00	0.91	1.11	4.02
Natural gas-fired plants ^f							
steam ^g	2 x 500	760	36.3	0.9	2.08	0.49	3.48
ACCH ^h	205	520	45.0	0.63	1.68	0.29	2.60
STIG ⁱ	4 x 51	410	40.0	0.49	1.89	0.29	2.67
ISTIG ^j	114	400	47.0	0.48	1.61	0.29	2.38
Coal-gas-fired gas turbine system							
current combined cycles (CCC) ^k							
	100	2720	34.3	3.26	1.88	2.11	7.25
	250	2000	35.7	2.39	1.81	1.19	5.39
	500	1680	36.0	2.01	1.79	0.89	4.69
Advanced combined cycles (ACC)							
l	600	1550	37.9	1.85	1.70	0.80	4.35
m	520	1160	37.6	1.39	1.71	0.45	3.55
STIG ^m	2 x 50	1300	35.6	1.56	1.81	0.71	4.08
ISTIG ^m	110	1030	42.1	1.23	1.53	0.60	3.36

^aAll costs are 1987 U.S. dollars.

^bThe Electric Power Research Institute (EPRI) estimates, for a bituminous coal-fired subcritical steam plant with flue gas desulfurization. The assumed coal price is \$1.79/GJ, the average U.S. utility price projected for 2000 by the U.S. Department of Energy.

^cBased on the fuel's higher heating value and for operation at 100% load.

^dFor a 6.1% real discount rate, a 30-year plant life, and a 70% capacity factor. No taxes or tax incentives are included.

^eEPRI estimates. The target figures are for improved conditions resulting from shorter construction period, streamlined licensing process, etc. The assumed fuel cycle cost is \$0.84/GJ, EPRI's projection for the period 1990-2000. The assumed O&M cost is the 1985 U.S. average for nuclear power plants, twice as large as the EPRI estimate for new plants.

^fThe average gas price for U.S. electric utilities was \$2.10/GJ in 1987.

^gThe steam plant involves 165 bar, 540°C steam driving a conventional turbine/electric generator. The costs are EPRI estimates.

^hThe advanced combined cycle (ACC) is a commercialized 135 MW GE Frame 7F gas turbine plus a 70 MW steam turbine, the indicated performance is a General Electric estimate. The costs are EPRI estimates.

Table G.32 (continued)

ⁱThe steam-injected gas turbine (STIG) unit is a commercial steam-injected gas turbine based on the GE LM 5000. The costs are Bechtel estimates.

^jThe ISTIG unit is a proposed intercooled steam-injected gas turbine, based on GE LM 8000. The unit capital is based on estimates made by GE and the California Energy Commission. The O&M cost is an EPRI estimate for combined cycles.

^kTexaco oxygen-blown gasifier and cold gas clean-up. EPRI estimates.

^lTexaco oxygen-blown gasifier and cold gas clean-up. EPRI estimates.

^mLurgi fixed bed air-blown gasifier and hot gas clean-up. GE estimates.

Sources: Adapted from Ref. [12].

REFERENCES

1. International Energy Agency Energy Balances of OECD Countries 1970/1985, OECD/IEA, Paris, 1987.
2. United Nations, 1984 Energy Statistics Yearbook, New York, 1986.
3. United Nations Economic Commission for Europe: An Efficient Energy Future, Butterworths, London, 1983.
4. Wilson, D. The Demand for Energy in the Soviet Union, Rowman & Allanheld, Croom Helm, Australia, 1983.
5. Kelly, W.J., Shaffer, H.L., and Thompson, T.K. Energy Research and Development in the U.S.S.R., Duke University Press, Durham, NC 1986.
6. World Bank, China: The Energy Sector, Annex 3 to China Long-Term Development Issues and Options, Washington, D.C., 1985.
7. Hedley, D. World Energy: The Facts and the Future, Euromonitor Publications Limited, 1986.
8. Jablonski, D.M. [Ed.]. McGraw-Hills International Energy Outlook, Vol. 1, Mid-East, Far East and Africa, McGraw-Hill, New York 1982.
9. U.S. Department of Energy, Energy Information Administration, Annual Energy Review 1985, DOE/EIA-0384(85), Washington, DC, 1986.
10. U.S. Central Intelligence Agency, Handbook of Economic Statistics, 1986, CPAS 86-10002, 1986.
11. U.S. Congress, Office of Technology Assessment, New Electric Power Technologies: Problems and Prospects for the 1990's OTA-E-246, 1985.
12. Williams, R.H. and Larson, E.D., "Expanding Roles for Gas Turbines in Power Generation, in Electricity, ed. by Johansson, T.B. et. al., p.503, Lund Univ. Press, Sweden 1989.

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