COMPARATIVE ANALYSIS OF ENERGY INTENSITY BETWEEN THE U.S. AND JAPAN

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All errors are the author's responsibility alone.

Comparative Analysis of Energy Intensity between the U.S. and Japan

Abstract

Amidst growing concern about global warming, energy conservation has been recognized as a cost-effective way to reduce emission of carbon dioxide. It is considered that the United States has a big potential for energy conservation based on a comparison of energy intensity. Energy intensity is commonly measured by Total Primary Energy Requirement (TPER) per Gross Domestic Product (GDP). Energy intensity of the U.S. has been about 1.7 times as much as that of Japan since 1983. However, this number does not reflect the true differences in the efficiencies of energy consuming technologies; The contribution of non-technological factors such as climate, population density, life styles, or industry mix must be considered.

In this study, the structure of energy consumption in the U.S. and Japan, and the contribution of non-technological factors to the differences in energy intensity are analyzed in detail. As a result of quantitative analysis performed here, energy efficiency in Japan is superior to that in the U.S., even if the contribution of non-technological factors is removed. Adjusted TPER/GDP ratio in Japan would be about 74% of that in the U.S. in 1989. Non-technological factors are expected to contribute to about 41% of this difference with the transportation sector comprising quantitatively the largest share in the non-technological differences. It is expected that there is large potential for energy conservation by technological renovation in the U.S. manufacturing sector. On the other hand, it is supposed that the differences in life styles and living standard affect higher energy use in the U.S. residential sector significantly and it is difficult to reduce the gap between the U.S. and Japan.

Furthermore, a new standard which measures national energy intensity is proposed. Considering the production aspect of GDP, energy consumption in the residential sector and private transportation sector is excluded. Based on this standard, adjusted TPER/GDP ratio in Japan is about 81% of that in the U.S.. In other words, the lower efficiency of energy consuming technologies in the U.S. results in about 19% more energy consumption than in Japan.

Contents

1. Introduction

Amidst growing concern of global warming, the developed countries are making efforts to reduce their carbon dioxide gas (CO_2) emission that contributes to almost half of global warming. Because most of the artificial CO_2 emission depends on fossil fuel burning, the countermeasures to reduce CO_2 emissions are roughly divided into three ways: energy conservation, fuel switching, and CO_2 recovery. In particular, energy conservation is expected to be the most cost-effective way to decrease CO_2 emissions.

The U.S. has long been accused of being energy inefficient based on a comparison of energy intensities among the industrialized countries. On the other hand, Japan, the second largest industrialized country next to the U.S., has been considered to be the most energy efficient country among them. Figure 1.1 shows TPER/GDP ratio in the Group of Seven (G7) countries: the United States, Canada, Japan, France, Italy, Germany, and the United Kingdom. TPER/GDP ratio is most commonly used as national energy intensity[1], however, it is not a true measure of efficiency because it includes many non-technologically originated factors such as climate, population density, life styles, industry mix, and energy prices.

This paper tries to adjust these factors and evaluate the actual energy intensities in the U.S. and Japan through the closer examination of energy consumption. Energy end-use sectors are divided into the manufacturing, transportation, commercial, and residential sectors. Energy intensities peculiar to each sector are selected, so as to reflect the actual circumstances of energy consumption. After the sectoral analyses, an adjusted TPER/GDP ratio is computed by estimating what would happen if differences in non-technological factors were eliminated. This study is based on the previous report by S. C. McDonald (1990). Major refinements are further breakdown of energy consumption in the residential sector, better treatment of exchange rates, a more consistent treatment of energy used as feedstocks and private electricity generation, a quantitative analysis of issues involved in comparing TPER/GDP ratios, and explicit analyses of price effect.

This report contains the following sections. Section 2 outlines the way data are processed. Section 3 and 4 investigate sectoral energy intensities in both countries and evaluate the effect on TPER/GDP ratios. Section 5 includes conclusions and future work suggested by the present analysis, and an appendix contains the highway transportation energy model developed in this study.

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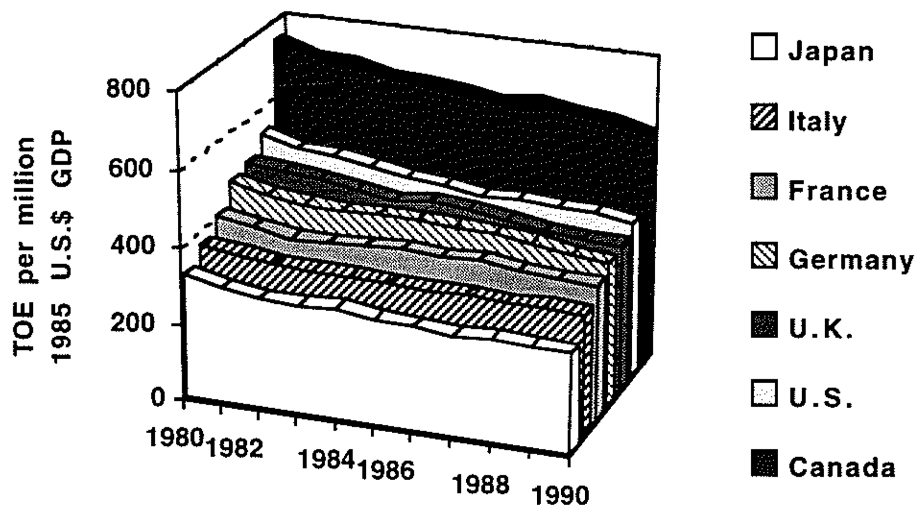
[1] Since 1991, IEA has changed the expression of primary energy consumption as TPES (Total Primary Energy Supply). Their difference is conversion factor of nuclear, hydro, geothermal, and solar power. TPES is defined from the viewpoint of accurate description of waste heat. This report adopts former TPER because of the consistency with domestic database. TPER/GDP ratio in 1990 in Figure 1.1 is estimated.

Figure 1.1 TPER / GDP in G7 Countries



Source: OECD-IEA. "Energy Balances of OECD Countries 1989-1990".

2. Methodology for Analyzing Intercountry Differences in Energy Intensity

National energy intensity is influenced by various factors. J. Darmstadter et al. (1977) summarized the non-technologically originated factors in Table 2.1. This table shows schematic ranking of each factor and qualitative relationship between these factors and energy intensities. This paper tries to analyze intercountry differences in energy intensity between the U.S. and Japan quantitatively. Underlined factors in Table 2.1 are analyzed. In addition, L. Schipper et al. (1985, 1992) quantitatively investigated the structure of energy consumption mainly in the industrialized countries, and suggest the way to disaggregate time series changes in sectoral energy use.

Approach for analyzing energy intensity can be roughly classified into two ways: bottom-up approach and top-down approach. The former compares the intensities of energy consuming technologies directly. Typical example is energy requirement for the production of tons of energy intensive goods or kW of electric appliances. This approach is powerful for each technology, but it is not appropriate for analyzing non-technological factors mentioned above. The latter includes mathematical modeling and disaggregation. It fits for analyzing non-technological factors, but it also has many limits. In this study, except for price effect, non-technological factors are analyzed by disaggregating energy consumption into energy consuming sectors. The limits of approach are discussed in following sections. Price effect is analyzed by modeling approach shown later. Overall procedure is shown in Figure 2.1.

2.1 Difficulties in Intercountry Comparison

In comparing intercountry statistics on energy consumption, attentions should be paid to some points summarized in Table 2.2.

Heat contents of fossil fuels are different by database: except for IEA data which is based on net calorific value, most of energy data are based on gross calorific value[2]. For the consistency of heat contents between national and sectoral database, gross calorific value is used in this study. Also there are two measures of heat content of electricity: input (primary) base and output (secondary) base[3]. As this study focuses on energy intensity, output base is adopted so as not to include the differences in generation efficiencies between the U.S. and Japan. From the same point of view, energy used as raw material inputs is excluded.

In usual, national data are based on the sales of each type of energy and leakage is quite small. On the other hand, sectoral data are based on the sampling survey and quantity of energy consumption may not be equal with the sales data. These data are checked with each other in Section 3.

The choice of exchange rate is quite difficult and the use of market exchange rate has obvious disadvantage. It is derived from internationally traded component of national output and is therefore not well adopted to the conversion of the quantitatively much larger nontrade component. To overcome this problem, purchasing power parities (PPP) of 1989 average (203.77 ¥/$) was used in this analysis[4]. On the other hand, current exchange rate (137.97 ¥/$, 1989 average) was used to evaluate the real energy intensity in the manufacturing sector because most of the manufactured goods are internationally traded. Appropriateness of this method was confirmed by checking with some physical intensities of energy intensive goods in Section 3.

This study does not include the factors concerning on the standard of living and lifestyles. It is very difficult to analyze the relationship between energy consumption and them. For example, how people choose the size of car or how people spend their free time depend greatly on the individual sense of value and cultures in each country.

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2 Heat contents of fossil fuels are defined as gross calorific value and net calorific value. The difference between them is heat quantity used for the evaporation of water and gross calorific value is generally greater than net calorific value by 5% for coal, and by 10% for oil and gas (OECD-IEA, 1991a).

3 Conversion factors for non-fossil power plants are different between the U.S. and Japan; Electricity generated by nuclear and geothermal plants are converted by their substantial thermal efficiencies in the U.S., while by average efficiency of thermal power plants in Japan. This difference increases TPER/GDP ratio of the U.S. by 1-2 TOE per million 1989 U.S. dollars.

4 PPP is an ideal exchange rate for international and intertemporal money price measured by commodity prices. In particular, exchange rate has been greatly deviating from actual situation of economy that is measured by PPP since 1986 (see Figure 2.2). The cause of this gap is considered to be the difference of interest rate, so called "Twin Deficit" in the U.S. economy, speculation reflecting future expectation, etc..

Table 2.1 A Schematic Ranking of Factors Affecting Comparative Energy Consumption/GDP Ratios, by Country, 1972

Factors	United States	Canada	France	West Germany	Italy	Nether-lands	United Kingdom	Sweden	Japan
Energy Prices (lowest prices=1)	1	2	4	5	9	6	8	3	7
Passenger-miles per unit GDP	1	5	9	3	2	6	4	6	8
Percentage of passenger-miles accounted for by cars	1	2	8	4	7	5	6	3	9
Energy consumption per car-passenger-mile	2	1	4	8	5	7	9	6	3
Cold climate	7	2	5	4	9	3	5	1	8
Size of house & percentage single family	1	1	6	6	8	5	4	3	8
Extractive industry GDP as percent of total GDP	2	1	n.a.	4	6	n.a.	3	5	7
Industrial GDP as percent of total GDP	7	8	2	1	6	4	5	9	3
Ratio of industrial energy consumption to industrial GDP	2	1	9	8	6	5	4	3	7
Degree of energy self-sufficiency	2	1	7	5	8	3	4	6	9
For reference:									
Energy/GDP Ratio	2	1	9	6	7	3	4	5	8
Energy per capita	2	1	7	5	9	4	6	3	8
GDP per capita	1	3	4	5	9	6	8	2	7

Note: The effects of underlined factors on energy consumprion are covered in this study.
Source: J. Darmstadter et al. "How Industrisl Society Use Energy" The Johns Hopkins University Press 1977

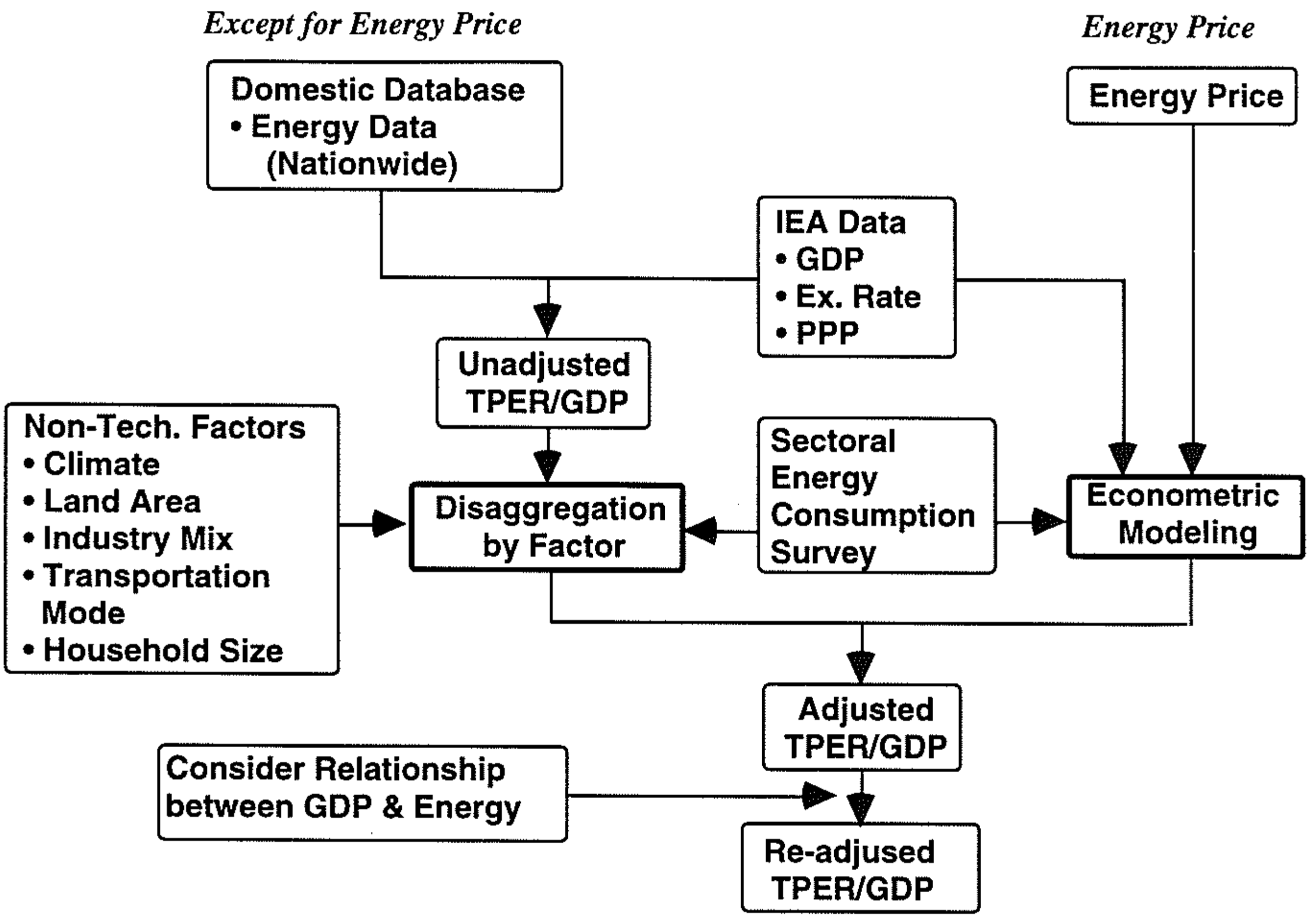
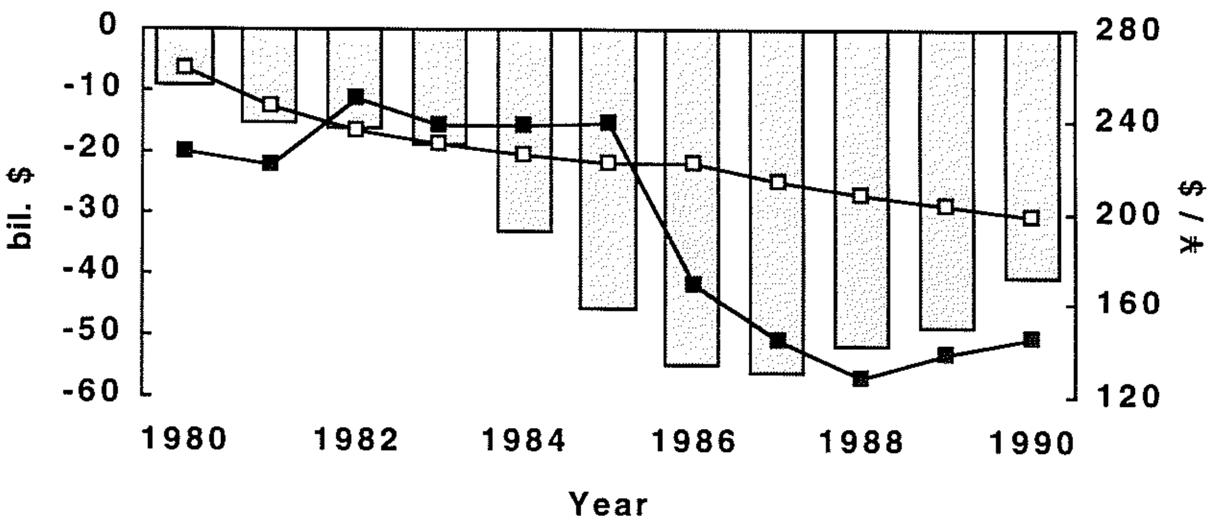


Figure 2.1 Procedure for Analyzing Intercountry Differences in E/GDP

Table 2.2 Problems in Intercountry Comparison of Energy Consumption and Treatment in This Study

Problem	Treatment in This Study
Energy Data	
• Heat Contents	
Fossil Fuels: Gross or Net	Unified as Gross Measure
Electricity: Input or Output Base	Unified as Output Base
• Sales Data / Consumption Survey	Check Before Use
• Energy Used as Raw Material Inputs	Excluded
Monetary Value	
• Current Exchange Rate (CER) / Purchasing Power Parities (PPP)	Manufacturing: CER Other: PPP
• Intertemporal Evaluation	GNP Deflator
Energy Prices and Taxes	Partly Analyzed
Standard of Living and Life Styles	
• Diffusion Ratio and Average Size of Appliances and Vehicles	Not Analyzed
• Operating Time of Appliances	Not Analyzed

Figure 2.2 US Merchandise Trade Balance to Japan, Exchange Rate, and PPP



Source: OECD-IEA. "Energy Prices and Taxes: Second Quater 1991".
U.S. DOC. "Statictical Abstract of the United States".

2.2 Industrial Sector

It is true for most economies that the bulk of industrial energy is consumed by a small group of industries called as "heavy industries". Heavy industries include primary metal, petroleum refining, chemicals, paper, and stone, clay, and glass. Therefore industry mix affects aggregate energy intensity greatly. If we adjust the difference in industry mix, energy mix changes simultaneously. Changes in energy mix vary primary energy requirement through conversion efficiency. This effect is most important for electricity because of low conversion efficiency. The difference in product mix is another important factor. Product mix is measured by Output/VA ratio and if manufactures produce high VA goods, energy intensity per VA will decrease.

Energy consumption is disaggregated according to the following equations. Aggregate energy intensity is divided into energy mix, intensity in each industry, industry mix, and product mix. Delta (Δ) means percentage deviation from initial values.

i: Industry
j: Energy Type
PE: Primary Energy Requirement
SE: Secondary Energy Consumption
X: Output
V: Value Added
η_{ij}: Conversion Efficiency of Energy Type j
ES_{ij}: Share of Energy Type j
I_i: Energy Intensity of i Industry
XS_i: Output Share of i Industry

$$PE = \sum PE_{ij} = \sum_i \left(\sum_j \left(\frac{PE_{ij}}{SE_{ij}} \cdot \frac{SE_{ij}}{\sum_j SE_{ij}} \cdot \frac{\sum_j SE_{ij}}{X_i} \cdot \frac{X_i}{X} \right) \cdot \frac{X}{V} \cdot V \right.$$

$$= \sum (1/\eta_{ij} \cdot ES_{ij} \cdot I_i \cdot XS_i) \cdot (X/V) \cdot V$$

$$\Delta(PE/V) = \sum (\Delta(1/\eta_{ij}) + \Delta ES_{ij} + \Delta I_i + \Delta XS_i) + \Delta(X/V)$$

2.3 Transportation Sector

In the transportation sector, energy intensity is broken down into energy mix, intensities of mode, modal structure, and demand of transportation relative to economic size. T/GDP is substitutable variable for land area.

i: Mode
T: Passenger Travel or Freight Movement
S_i: Share of i Mode

$$PE = \sum PE_{ij} = \sum_i \left(\sum_j \left(\frac{PE_{ij}}{SE_{ij}} \cdot \frac{SE_{ij}}{\sum_j SE_{ij}} \cdot \frac{\sum_j SE_{ij}}{T_i} \cdot \frac{T_i}{T} \right) \cdot \frac{T}{GDP} \cdot GDP \right.$$

$$= \sum (1/\eta_{ij} \cdot ES_{ij} \cdot I_i \cdot S_i) \cdot (T/GDP) \cdot GDP$$

$$\Delta(PE/GDP) = \sum (\Delta(1/\eta_{ij}) + \Delta ES_{ij} + \Delta I_i + \Delta S_i) + \Delta(T/GDP)$$

2.4 Residential Sector

For the residential sector, the effects of climate and floor space per home are analyzed for heating and air conditioning, and the effect of size of family is analyzed for water heating. Since it is known energy demand for water heating greatly changes by the number of persons per household, it is important to consider the structure of household size (see Figure 2.3). It should be noted that the former adjustment accompanies second order term because floor space and degree days are directly multiplied. The effect of second order term is expressed as interactive effect in the result.

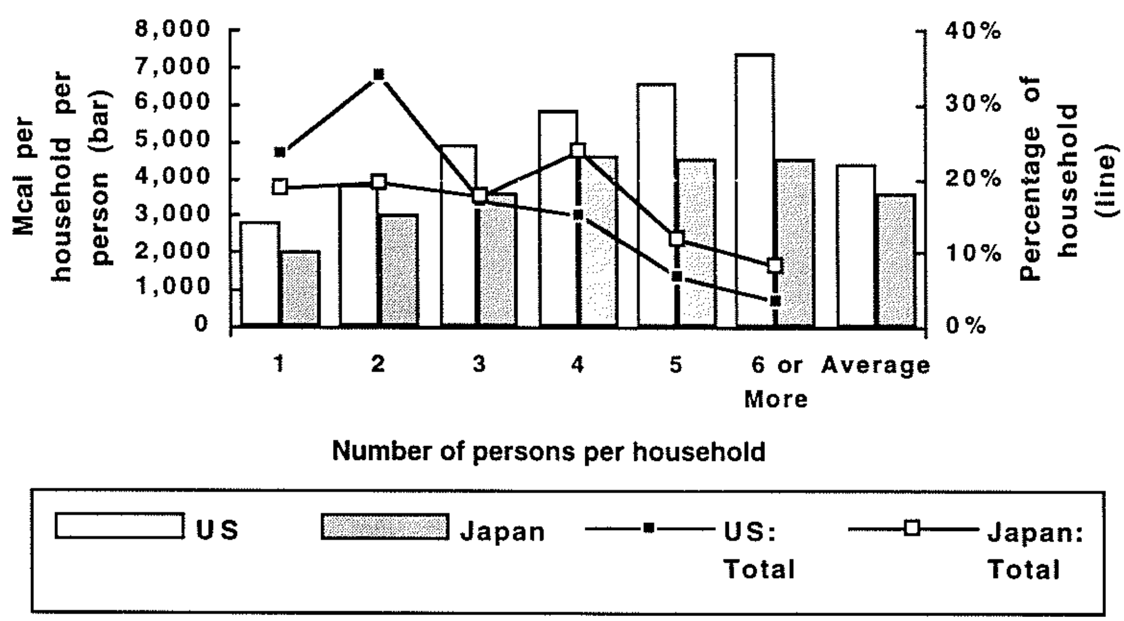
For Heating and Air Conditioning:

- i: Use
- F: Floor Space per Home
- DD: Degree Day
- H: Number of Households

$$PE = \sum PE_{ij} = \sum_i \left(\sum_j \left(\frac{PE_{ij}}{SE_{ij}} \bullet \frac{SE_{ij}}{\sum_j SE_{ij}} \bullet \frac{\sum_j SE_{ij}}{F \bullet DD} \right) \bullet \frac{F \bullet DD}{H} \bullet H \right)$$

$$\Delta(PE/H) = \sum (\Delta(1/\eta_{ij}) + \Delta ES_{ij} + \Delta I_i) + \Delta(F \bullet DD/H)$$

Figure 2.3 Energy Consumption for Water Heating by Household Size



Source: JIEE. "Survey based on a Questionnaire and Interviews on Energy Consumption in the Commercial Sector".
U.S. DOE-EIA. "Hosehold Energy Consumption and Expenditures 1987 Part1: National Data".

For Water Heating:

[i: Household Size
H_i: Number of Households by Household Size
S_i: Share of i Household]

$$PE = \sum PE_{ij} = \sum_i \left(\sum_j \left(\frac{PE_{ij}}{SE_{ij}} \bullet \frac{SE_{ij}}{\sum_j SE_{ij}} \bullet \frac{\sum_j SE_{ij}}{H_i} \bullet \frac{H_i}{H} \right) \bullet H \right.$$

$$\Delta(PE/H) = \sum(\Delta(1/\eta_{ij}) + \Delta ES_{ij} + \Delta I_i + \Delta S_i)$$

2.5 Commercial Sector

Like industry sector, energy intensity greatly differs between activities. In the commercial sector, energy intensity is measured by floor space. Difference in floor space relative to economic size is also accounted.

[i: Activity
F: Floor Space
S_i: Share of i Activity]

$$PE = \sum PE_{ij} = \sum_i \left(\sum_j \left(\frac{PE_{ij}}{SE_{ij}} \bullet \frac{SE_{ij}}{\sum_j SE_{ij}} \bullet \frac{\sum_j SE_{ij}}{F_i} \bullet \frac{F_i}{F} \right) \bullet \frac{F}{GDP} \bullet GDP \right.$$

$$\Delta(PE/GDP) = \sum(\Delta ES_{ij} + \Delta I_i + \Delta S_i) + \Delta(F/GDP)$$

Adjustment of TPER/GDP ratio is attempted by these non-technological factors. It is a rough estimate because national and sectoral databases are not coincide with each other as mentioned before and sectoral databases are not available every year[5]. Therefore following two points are assumed.

1 . Non-technological factors are fundamental differences which affect energy consumption between the U.S. and Japan, and the changes in energy intensity over time are relatively small compared with the intercountry differences.

2 . Although national and sectoral data are based on different samples, these data can be directly combined in case the difference between them is small.

Based on these assumptions, TPER/GDP ratio is adjusted in the following manner. At first the effects on energy consumption in Japan is evaluated if non-technological factors are same between the U.S. and Japan, by using the equations shown before. It means that ΔXS_i and $\Delta(X/V)$ for industry, ΔS_i and $\Delta(T/GDP)$ for transportation, $\Delta(F \bullet DD/H)$ for heating and air conditioning, ΔS_i for water heating, and ΔS_i and $\Delta(F/GDP)$ for the commercial sector are equalized. The contribution of each factor is evaluated if all other factors remain unchanged. At the same time the changes in energy conversion losses caused by these adjustments are evaluated.

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[5] In the U.S., large scale survey of energy consumption in the manufacturing, commercial buildings, and residential sector is carried out every year in turn. Therefore data are available every three years in each sector.

Table 2.3 Energy Prices (1989)

	Unit	U.S.	Japan	Japan/U.S.
Industrial Sector (Converted by Current Exchange Rate)				
Steam Coal	$/ton	36.4	68.3	1.9
Coking Coal	$/ton	52.4	61.0	1.2
Light Fuel Oil	$/1000L	171.2	194.1	1.1
Heavy Fuel Oil	$/1000L	95.0	178.1	1.9
Natural Gas	$/Gcal	11.3	45.0	4.0
Electricity	$/MWh	47.0	133.0	2.8
Household Sector (Converted by Purchasing Power Parities)				
Gasoline	$/1000L	270.0	584.0	2.2
Light Fuel Oil	$/1000L	245.7	177.0	0.7
Natural Gas	$/10Gcal	216.9	670.1	3.1
Electricity	$/MWh	76.0	130.0	1.7

Source: Energy Prices and Taxes (1991).

2.6 Price Effect

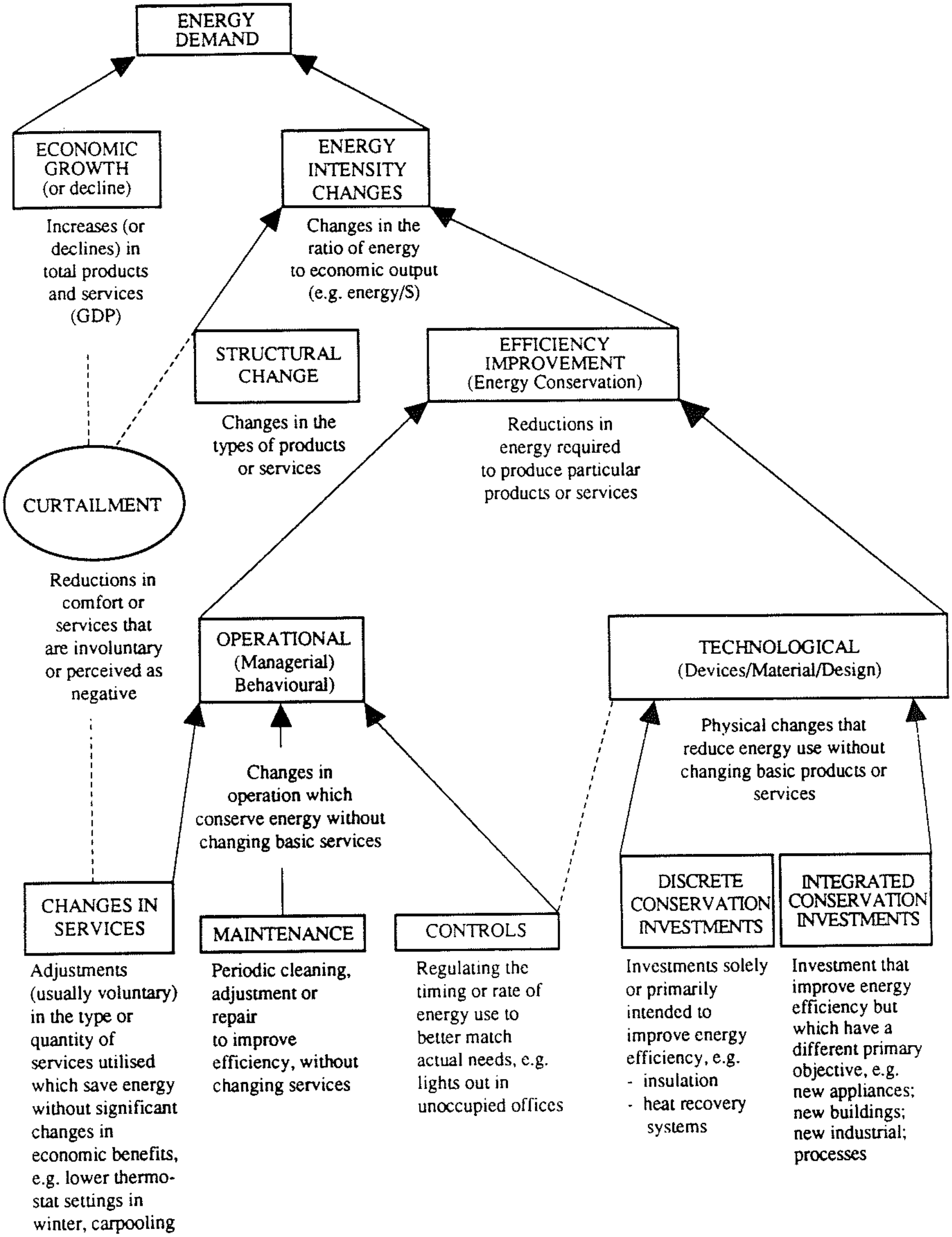
Differences in energy price are supposed to have a biggest effect on higher energy use in the U.S.. Table 2.3 shows energy prices in the U.S. and Japan in 1989. Except for light fuel oil (kerosene)[6], energy prices in Japan are expensive than those in the U.S..

Energy price has a various effect on energy consumption. They are roughly divided into technological, operational, and macro economic impacts (see Figure 2.4). Technological impact is caused by the investments for energy efficient appliances and it affects stock level efficiency. Operational impact includes the changes in maintenance, control, and pattern of energy use. Macro economic impact has various effects: changes in demand of total products and services, substitution between production factors, and producer/consumer prices. For example, in the highway transportation sector, increase in energy price brings about decrease in new car sale, increase in demand of efficient cars, less drive, modal substitution, and macro economic impacts (see Figure 2.5).

It is difficult to analyze the price effects in all energy consuming sectors because of lack of sufficient data. In this paper, econometric energy model in the highway transportation sector is built. This sector consumes about 20% of TPER and 50% of oil in the U.S. in 1989. The structure of model is described in appendix. By using this model, price effects shown by thick line in Figure 2.5 are analyzed.

[6] Kerosene price in Japan has been kept low politically because it is considered to be necessaries of life. Besides of taxes, it is one of the reason of higher price of other petroleum products in Japan through cross-subsidization.

Figure 2.4 Energy Demand and Efficiency Terms and Definitions



Source: OECD/IEA "Energy Conservation in IEA Countries" (1987)

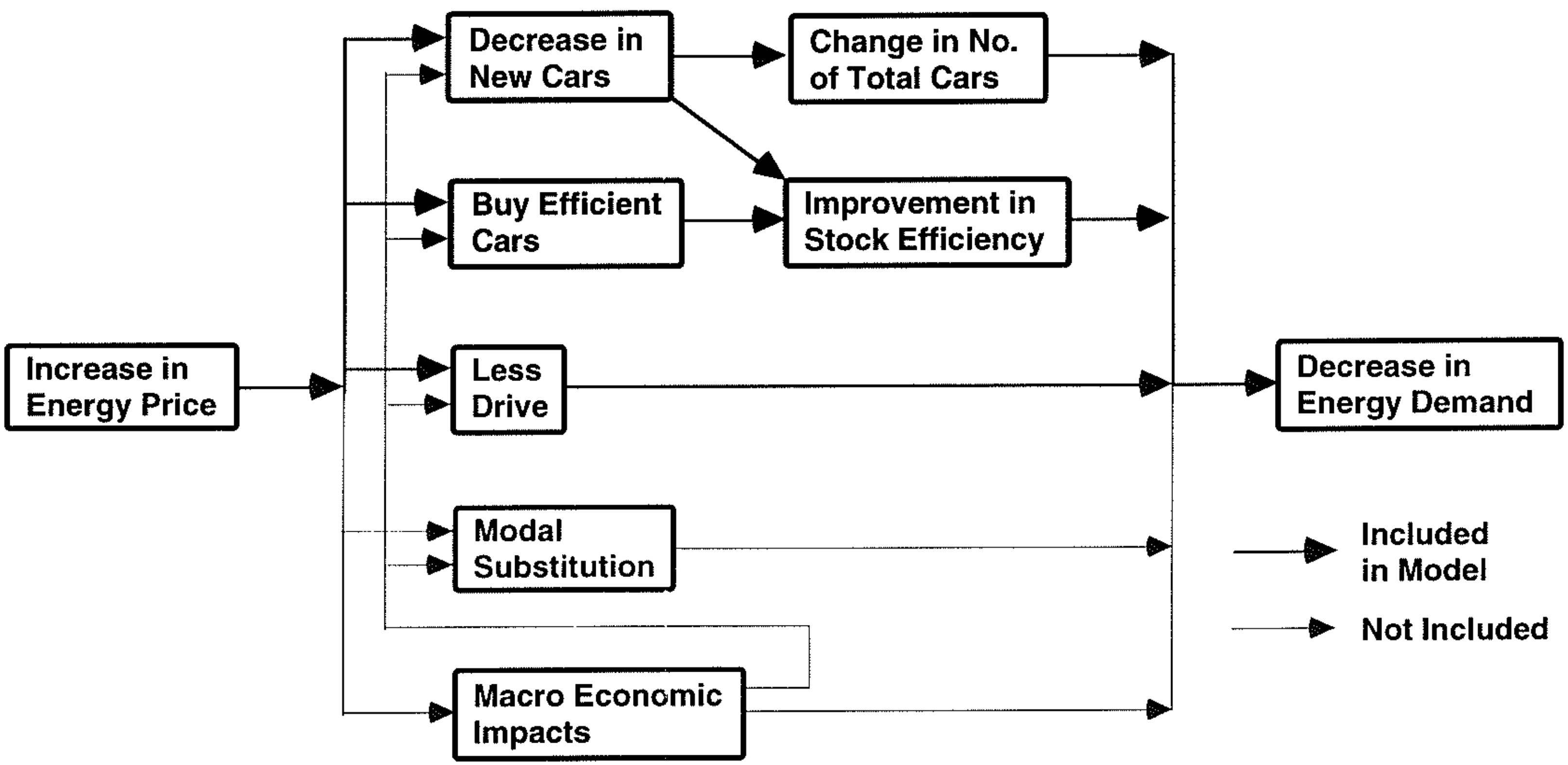


Figure 2.5 Repercussion Effect of Increasing Energy Price in Highway Transportation

2.7 The Relationship between GDP and Energy Consumption

Considering the principle of three aspects of GDP (production, distribution and expenditure), the relationship between GDP and energy consumption is shown in Figure 2.6.

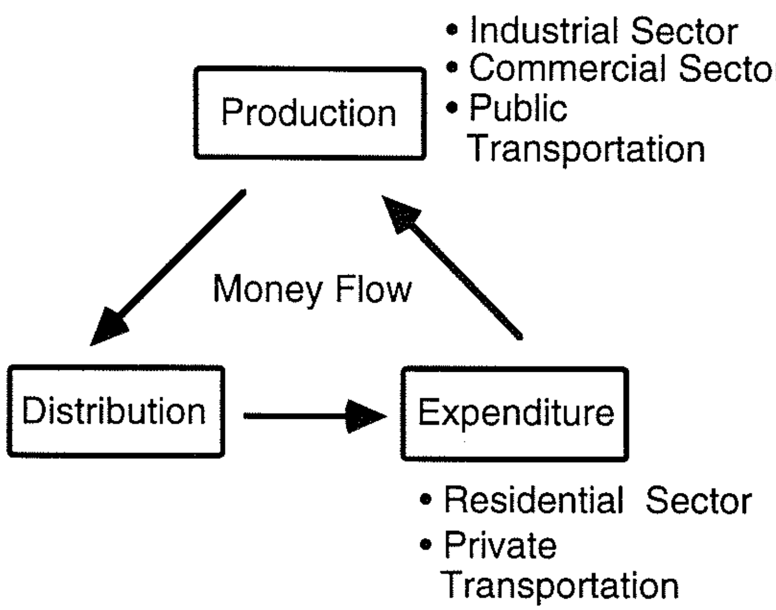


Figure 2.6 GDP Component and Energy Consuming Sectors

In the aspect of production, energy is consumed in the industrial, commercial and public transportation sectors to contribute to the production of value added. On the other hand, in the residential and private transportation sectors, energy consumption doesn't directly contribute to the production of value added. The expenditures on energy consumption in these sectors are added up in the aspect of expenditure. Therefore, if we adopt TPER/GDP ratio as an indicator of nationwide energy intensity, energy consumption in the residential and private transportation sectors is double counted. It is more appropriate to exclude energy consumption in these sectors for the calculation of TPER/GDP. This attempt is carried out for the final adjustment in this study.

3. SECTORAL ANALYSIS OF ENERGY INTENSITIES

3.1 Energy consumption and intensity

Table 3.1 shows final energy consumption in 1989 in both countries. Domestic and IEA database are available, however, there is 5-10% discrepancy between them. As mentioned earlier, main reason of this discrepancy comes from the treatment of heat content. Heat contents of fossil fuels are converted by gross calorific value in domestic database, while by net calorific value in IEA database. Other reason is the classification of the energy consuming sectors, especially the treatment of non-specified. The U.S. domestic data accounts onsite electricity generation as input base. This is another reason that domestic data in the U.S. particularly in industry is larger than IEA data. As mentioned earlier, domestic database is used for this analysis, considering the consistency of heat contents with sectoral database.

The U.S. consumes about 5 times more energy measured by final energy consumption. As for primary consumption, this ratio slightly decreases mainly because the share of electricity in final energy consumption is smaller in the U.S. (U.S. 16%, Japan 21% by IEA data). It is noticeable that the share of industrial energy consumption in Japan is extremely high among G7 countries (see Figure 3.1).

Table 3.2 shows some intensity measures that represent the relative size of each country and energy intensities. The U.S. consumes 1.7 times more energy measured by TPER/GDP, 2.3 times more by TPER/Pop., and 5 times less by TPER/Area ratio. Among these intensity measures, TPER/GDP is supposed to be most appropriate for international comparison because TPER/Pop. greatly varies reflecting the degree of economic development. For example, TPER/Pop. in China is over 10 times smaller than that in the U.S., but it doesn't mean China is more than 10 times energy efficient than the U.S.. Likewise, it is hard to believe that former Soviet Union is more energy efficient than the U.S. and Japan that is indicated by TPER/Area ratio.

Before going into sectoral analysis, national and sectoral database must be checked. Table 3.3 compares them and they are almost congruent with each other except for the U.S. commercial sector[7].

[7] Main reason is shorter natural gas consumption in sectoral database (Commercial Buildings Energy Consumption Survey, CBECS). Energy Information Administration estimates the discrepancy comes from the difference in data coverage. CBECS excludes energy consumed by central physical plants providing district heating or cooling to commercial complexes. It also excludes direct purchase of natural gas.

Table 3.1 Final Energy Consumption (1989)

	U.S.				Japan***			
	Quad Btu*		MTOE**		Quad Btu*		MTOE**	
	Dom.	IEA	Dom.	IEA	Dom.	IEA	Dom.	IEA
Industry	22.4	19.4	564.0	488.7	6.5	6.0	164.4	150.2
Transportation	22.4	19.4	563.3	488.9	2.8	2.6	71.2	66.3
Residential	9.7	9.9	244.4	250.6	1.7	1.4	42.5	34.0
Commercial	6.7	6.4	167.7	161.0	1.3	1.0	33.1	25.6
Non-specified	---	0.2	---	4.1	---	0.4	---	10.7
Total	61.1	55.3	1,539.3	1,393.4	12.3	11.4	311.3	286.9
TPER	81.3	77.6	2,049.8	1,955.0	17.8	16.3	447.6	411.6

Source: Annual Energy Review (1991)
State Energy Data Report: Consumption Estimates 1960-1989 (1991)
Energy Balances of OECD Countries (1992)
Sougou Enerugii Toukei (1991)

*1 Quad Btu = 1,000,000,000,000,000 Btu = 252 Trillion kcal = 25.2 MTOE.

**1 TOE is defined as 10,000,000kcal according to IEA Conversion.

***All energy data in Japan are based on fiscal year (April to March).

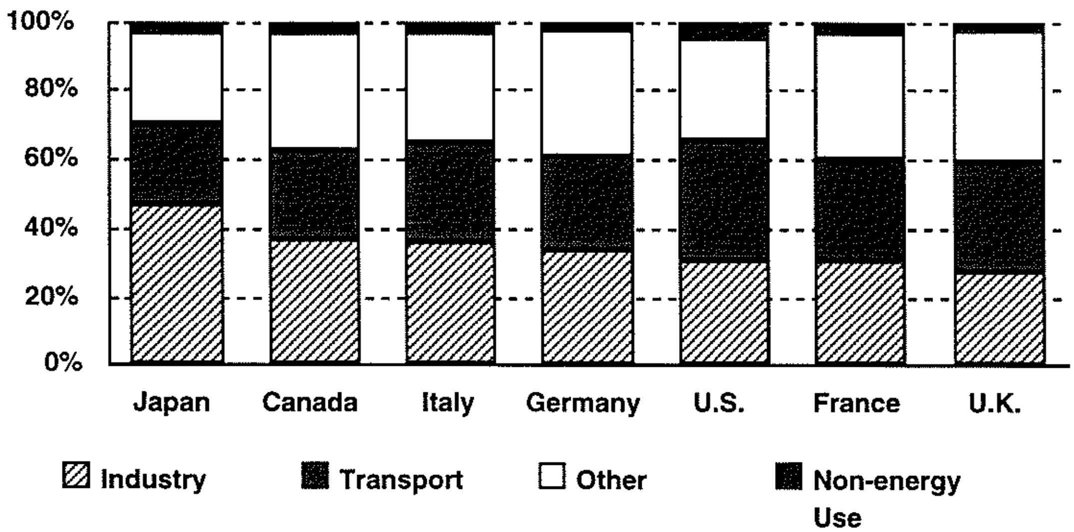
Table 3.2 Aggregate Energy Intensity Measures (1989)

	U.S.	Japan	U.S./Japan
GDP (bil. 1989$)*	5,163.2	1,944.3	2.7
Population (mil.)	248.8	123.1	2.0
Land Area (mil. ha)	923.3	37.8	24.4
TPER (MTOE)	2,049.8	447.6	4.6
GDP/Pop. (1000$/person)	20.8	15.8	1.3
TPER/GDP (TOE/mil. $)	397.0	230.2	1.7
TPER/Pop. (TOE/person)	8.2	3.6	2.3
TPER/Area (TOE/ha)	2.2	11.8	0.2

Source: Nihon no Toukei (1992)
Keizai Yoran (1992)
Statistical Abstract of the United States 1991 (1991)
Survey of Current Business April 1991 (1991)
Energy Prices and Taxes (1991)

*Japanese GDP is converted by PPP (203.77¥/$, 1989 average).

Figure 3.1 Sectoral Energy Consumption in G7 Countries (1990)



Source: OECD-IEA. "Energy Balances of OECD Countries 1989-1990".

Table 3.3 Comparison between National and Sectoral Database (MTOE)

	U.S.			Japan		
	Year	National	Sectoral	Year	National	Sectoral
Manufacturing	1988	n.a.	517.5	1989	139.5	140.8
Transportation	1989	563.3	538.2	1989	71.2	71.9
Residential	1987	225.4	230.2	1988	41.6	39.9
Commercial	1989	167.7	145.9	1989	33.1	32.6

n.a. = Not Available.

3.2 Industrial Sector

In the industrial sector, detailed data of manufacturing industries are available. Classification of manufacturing industries is almost similar between both countries and these data are directly comparable[8]. For both countries, specific energy intensive industries are classified in detail and physical energy intensities in these industries are also evaluated.

[8] In this study, Japanese manufacturing industries are re-classified according to the U.S. 2-digit SIC code 20 through 39.

Industrial Structure and Product Mix

Energy intensities are measured by energy requirement per value of output and value added (VA) in each industry. Table 3.4 shows the values of industrial output. Industrial structure particularly for energy consumption is quite similar in both countries because percentage of heavy industries is almost same. With respect to VA/Output ratio, the U.S. industries have higher value than Japanese industries except for few industries. It means product mix of the U.S. industries generally has higher VA.

Energy Consumption and Intensities

Energy consumption of manufacturing industries is shown in Table 3.5. Although onsite electricity generation is treated as input base in original data, it is accounted as output base for intercountry comparison as mentioned earlier[9]. Also energy used as raw material inputs and feedstocks is subtracted from Japanese data for consistency with the U.S. data.

Table 3.6 shows energy intensities of manufacturing industries. All Japanese manufactures except for tobacco are more energy efficient by either measure. The U.S. average energy intensity is 1.9 times higher than Japan measured by value of output, and 1.5 times by VA. Physical intensity of some energy intensive goods is shown in Table 3.7. Except for aluminum, U.S./Japan ratio of physical intensity is close to that measured by value of output using current exchange rate (see Table 3.8)[10]. It confirms the appropriateness of evaluating method. Therefore energy intensity measured by value of output is used for the further analysis. In fact, according to industry survey, the U.S. heavy industries have been losing international competitiveness and import substitution is remarkable. Producers lose their will to invest in the construction of new plants and therefore many inefficient plants are still operating in the U.S.[11].

It must be noted that even physical energy intensities shown in Table 3.8 are not equal to the technological intensities. Remaining factor is recyciing which can reduce energy intensity drastically. For example, the U.S. iron and steel industry consumed higher rate of scrap than Japanese industry (U.S. 37%, Japan 31%[12]). while U.S. paper industry has lower rate of paper recycling.

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9 Onsite electricity generation as a percent of total electricity use is 14% in the U.S. and 24% in Japan respectively. In this study, generating efficiency of onsite electricity generation is assumed to be 35%.

10 Primary aluminum production in Japan has rapidly decreased in 1980's losing competitiveness because of high energy price. We can imagine that the value of output in Japanese primary aluminum industry includes values of imported aluminum ingot or other products.

11 For instance, total capability of the U.S. raw steel production that was 154.3 million short tons in 1981 continued to reduce to 112 in 1988 (AISI, 1991). Similarly, import reliance of cement jumped up from 4% in 1981 to 19% in 1988 (DOC, 1987).

12 These numbers are the share of raw steel produced by electric furnace. Energy intensity of electric furnace is evaluated to be about 1/6 of blast furnace (electricity is accounted as input level (M. Ishikawa et al., 1992)).

Table 3.4 Value of Industrial Output (billion of 1988 U.S. dollars)

	U.S. (1988)		Japan (1989)		U.S./Japan	
	Output	VA	Output	VA	Output	VA
Food and Kindred Products	351.5	128.8	161.0	53.7	2.2	2.4
Tobacco Manufactures	23.8	17.2	16.6	1.9	1.4	9.2
Textile Mill Products	64.8	26.3	35.4	13.0	1.8	2.0
Apparel and Other Textile Products	65.0	32.5	16.3	7.6	4.0	4.3
Lumber and Wood Products	72.1	29.0	13.1	4.3	5.5	6.8
Furniture and Fixtures	39.2	20.9	15.2	6.2	2.6	3.4
Paper and Allied Products	122.6	57.4	49.0	17.0	2.5	3.4
Papar Mills	33.1	16.8	18.0	6.1	1.8	2.8
Paparboard Mills	16.7	9.1	5.3	1.7	3.1	5.4
Printing and Publishing	143.9	94.1	59.7	29.3	2.4	3.2
Chemicals and Allied Products	259.7	137.9	144.6	72.4	1.8	1.9
Industrial Inorganic Chemicals, nec	13.9	8.2	4.5	2.0	3.1	4.1
Plastics Materials and Resins	29.3	11.9	24.9	11.2	1.2	1.1
Industrial organic Chemicals, nec	51.5	24.0	12.4	5.1	4.1	4.7
Nitrogenous Fertilizers	2.4	1.0	0.2	0.1	9.6	12.4
Petroleum and Coal Products	131.4	25.3	46.1	5.6	2.8	4.6
Petroleum Refining	121.1	21.3	42.9	4.9	2.8	4.4
Rubber and Miscellaneous Plastics Products	94.2	46.6	69.6	26.1	1.4	1.8
Leather and Leather Products	9.6	4.5	3.6	1.3	2.7	3.4
Stone, Clay and Glass Pruducts	63.1	34.2	44.8	22.7	1.4	1.5
Cenent, Hydraulic	4.3	2.2	4.8	2.4	0.9	1.0
Primary Metal Industries	149.1	56.5	152.2	50.3	1.0	1.1
Blast Furnaces and Steel Mills	46.6	19.3	63.5	26.0	0.7	0.7
Primary Aluminun	8.0	3.8	0.9	0.4	9.3	10.4
Fablicated Metal Industries	158.8	79.9	75.7	29.7	2.1	2.7
Machinery, except Electrical	243.3	129.3	168.3	61.9	1.4	2.1
Electronic and Electronic Equipment	187.0	103.5	336.8	121.1	0.6	0.9
Transportation Equipment	354.0	143.5	283.6	73.2	1.2	2.0
Instruments and Related Products	114.5	76.1	28.4	10.9	4.0	7.0
Miscellaneous Manufacturing Establishments	34.9	19.0	21.2	8.2	1.6	2.3
Total Manufacturing	2,682.5	1,262.3	1,741.5	616.3	1.5	2.0
Percent of Heavy Industries*	27.1%	24.7%	25.1%	27.3%		

Sources: Manufacturing Energy Consumption Survey: Consumption of Energy, 1988 (1991)
Statistical Abstract of the United States 1991 (1991)
The Structural Survey of Energy Consumption in Commerce, Mining and Manufacturing, 1989 (1991)
Census of Manufactures 1989: Report by Industries (1991)

* Paper, Chemicals, Petroleum and Coal Products, Stone, Clay and Glass Pruducts, and Primary Metals.

Table 3.5 Manufacturing Energy Consumption (1000TOE)*

	U.S. (1988)	Japan (1989)	U.S./Japan
Food and Kindred Products	24,432	4,909	5.0
Tobacco Manufactures	605	73	8.3
Textile Mill Products	6,864	2,572	2.7
Apparel and Other Textile Products	1,361	169	8.1
Lumber and Wood Products	9,791	227	43.2
Furniture and Fixtures	1,583	132	12.0
Paper and Allied Products	52,078	9,713	5.4
Papar Mills	23,238	6,912	3.4
Paparboard Mills	19,669	1,765	11.1
Printing and Publishing	2,898	472	6.1
Chemicals and Allied Products	66,034	17,308	3.8
Industrial Inorganic Chemicals, nec	6,545	1,287	5.1
Plastics Materials and Resins	6,636	4,126	1.6
Industrial organic Chemicals, nec	24,412	4,294	5.7
Nitrogenous Fertilizers	4,864	105	46.2
Petroleum and Coal Products	76,803	12,679	6.1
Petroleum Refining	75,121	8,478	8.9
Rubber and Miscellaneous Plastics Products	6,320	2,455	2.6
Leather and Leather Products	402	41	9.8
Stone, Clay and Glass Pruducts	25,092	12,185	2.1
Cenent, Hydraulic	8,518	6,676	1.3
Primary Metal Industries	64,553	49,121	1.3
Blast Furnaces and Steel Mills	45,638	43,790	1.0
Primary Aluminun	6,199	235	26.4
Fablicated Metal Industries	8,644	1,640	5.3
Machinery, except Electrical	6,911	1,861	3.7
Electronic and Electronic Equipment	5,414	3,456	1.6
Transportation Equipment	8,688	3,879	2.2
Instruments and Related Products	2,848	258	11.1
Miscellaneous Manufacturing Establishments	1,033	191	5.4
Total Manufacturing	371,986	123,341	3.0
Percent of Heavy Industries**	76.5%	81.9%	

Sources: Manufacturing Energy Consumption Survey: Consumption of Energy, 1988 (1991)
Statistical Abstract of the United States 1991 (1991)
The Structural Survey of Energy Consumption in Commerce, Mining and Manufacturing, 1989 (1991)
Census of Manufactures 1989: Report by Industries (1991)

* Onsite electricity generation is included as output level (Assumed generating efficiency is 35%).

** Paper, Chemicals, Petroleum and Coal Products, Stone, Clay and Glass Pruducts, and Primary Metals.

Table 3.6 Industrial Energy Intensity (TOE per millions of 1988 US dollars)

	U.S. (1988)		Japan (1989)		U.S./Japan	
	Output	VA	Output	VA	Output	VA
Food and Kindred Products	68.7	186.3	30.5	91.4	2.3	2.0
Tobacco Manufactures	25.2	35.3	4.4	39.0	5.7	0.9
Textile Mill Products	109.9	269.6	72.6	198.3	1.5	1.4
Apparel and Other Textile Products	17.6	32.8	10.4	22.3	1.7	1.5
Lumber and Wood Products	133.2	314.2	17.3	53.0	7.7	5.9
Furniture and Fixtures	42.7	77.9	8.7	21.4	4.9	3.6
Paper and Allied Products	375.8	801.6	198.1	571.6	1.9	1.4
Papar Mills	701.4	1,385.7	384.4	1,139.1	1.8	1.2
Paparboard Mills	1,177.0	2,154.9	332.7	1,046.7	3.5	2.1
Printing and Publishing	22.7	32.8	7.9	16.1	2.9	2.0
Chemicals and Allied Products	268.9	520.3	119.7	239.0	2.2	2.2
Industrial Inorganic Chemicals, nec	472.3	793.6	287.1	642.4	1.6	1.2
Plastics Materials and Resins	226.6	556.1	165.6	367.0	1.4	1.5
Industrial organic Chemicals, nec	474.4	1,017.9	345.8	837.2	1.4	1.2
Nitrogenous Fertilizers	2,046.2	4,840.9	427.3	1,305.4	4.8	3.7
Petroleum and Coal Products	583.0	3,126.4	274.8	2,282.3	2.1	1.4
Petroleum Refining	620.3	3,529.6	197.6	1,737.7	3.1	2.0
Rubber and Miscellaneous Plastics Products	72.8	140.5	35.2	94.0	2.1	1.5
Leather and Leather Products	37.7	82.9	11.4	30.5	3.3	2.7
Stone, Clay and Glass Pruducts	409.0	740.2	271.7	535.8	1.5	1.4
Cenent, Hydraulic	1,998.4	3,797.6	1,404.0	2,838.7	1.4	1.3
Primary Metal Industries	433.3	1,129.7	322.7	976.1	1.3	1.2
Blast Furnaces and Steel Mills	979.2	2,359.4	689.5	1,685.4	1.4	1.4
Primary Aluminun	776.2	1,645.6	273.3	648.5	2.8	2.5
Fablicated Metal Industries	55.4	110.9	21.7	55.2	2.6	2.0
Machinery, except Electrical	27.5	50.1	11.1	30.1	2.5	1.7
Electronic and Electronic Equipment	30.2	55.4	10.3	28.5	2.9	1.9
Transportation Equipment	24.9	59.7	13.7	53.0	1.8	1.1
Instruments and Related Products	22.7	32.8	9.1	23.6	2.5	1.4
Miscellaneous Manufacturing Establishments	30.2	55.4	9.0	23.3	3.4	2.4
Total Manufacturing	136.8	290.4	70.8	200.1	1.9	1.5
Heavy Industries*	389.8	918.6	231.2	601.2	1.7	1.5
Other Manufacturing	43.0	84.8	17.1	49.8	2.5	1.7
Exclude Energy Industry	113.8	232.4	65.3	181.2	1.7	1.3

Sources: Manufacturing Energy Consumption Survey: Consumption of Energy, 1988 (1991)
Statistical Abstract of the United States 1991 (1991)
The Structural Survey of Energy Consumption in Commerce, Mining and Manufacturing, 1989 (1991)
Census of Manufactures 1989: Report by Industries (1991)

* Paper, Chemicals, Petroleum and Coal Products, Stone, Clay and Glass Pruducts, and Primary Metals.

Table 3.7 Energy Consumption and Tons of Products in Heavy Industries

	U.S. (1988)			Japan (1989)		
	Energy (1000TOE)	Production (1000ton)	Intensity (TOE/ton)	Energy (1000TOE)	Production (1000ton)	Intensity (TOE/ton)
Paper	23,238	34,793	0.67	6,912	15,726	0.44
Paperboard	19,669	34,567	0.57	1,765	11,083	0.16
Cement	8,518	71,034	0.12	6,676	79,717	0.08
Raw Steel	45,638	90,651	0.50	43,790	107,908	0.41
Aluminum	6,199	3,944	1.57	235	35	6.71

Sources: Manufacturing Energy Consumption Survey: Consumption of Energy, 1988 (1991)
Statistical Abstract of the United States 1991 (1991)
The Structural Survey of Energy Consumption in Commerce, Mining and Manufacturing, 1989 (1991)
Census of Manufactures 1989: Report by Industries (1991)
CRB Commodity Year Book (1991)
Nihon No Toukei (1992)

Table 3.8 U.S./Japan Ratios Under Various Measures of Energy Intensity

	By Output using CER*	By VA using CER*	By Output using PPP*	By VA using PPP*	By tons of products
Paper	1.8	1.2	1.2	0.8	1.5
Paperboard	3.5	2.1	2.4	1.4	3.6
Cement	1.4	1.3	1.0	0.9	1.4
Iron & Steel	1.4	1.4	1.0	0.9	1.2
Aluminum	2.8	2.5	1.9	1.7	0.2

* Current Exchange Rate: 1$=137.97¥, PPP rate: 1$=203.77¥ (1989 average)

3.3 Transportation Sector

Characteristics of Transportation

The transportation sector is considered to play a biggest role for the higher energy use in the U.S. than in Japan. In the U.S., population density is more than 10 times smaller and public transportation is less developed than in Japan. Passenger travel in the U.S. is about 4 times higher than that in Japan and freight movement is 8 times higher (see Table 3.9). Modal structure, especially rail, is significantly different. In Japan, rail is mainly used for passenger transport, while in the U.S. it is almost used for freight movement.

Capacity Factor (= passenger travel or freight movement divided by vehicle kilometers traveled, CF) is an important factor for energy consumption. Generally speaking, the higher capacity factor is, the less energy is consumed. For example, energy required for 2 persons to move 1 kilometer (CF = 2) is less than energy required for 1 person to move 2 kilometers (CF = 1). In this sense, except for bus and freight movement by rail, the U.S. tends to consume more energy than Japan (see Table 3.10). However, this effect isn't analyzed in this research because of data unavailability.

Energy Consumption and Intensities

As for energy consumption, passenger travel in the U.S. consumes about 8 times more energy than in Japan and freight movement does 5 times more[13] (see Table 3.11). In contrast to the amount of energy, the shares of each mode are quite similar: automobiles consume more than 80% of energy in each country. Table 3.12 shows energy intensities by mode. Overall, the U.S. consumes about 2 times more energy for passenger travel, but only one third for freight transport. This gap still remains as 1.5 and half respectively even if the difference in modal structure is adjusted (discussed in Section 4).
In comparing energy intensity of truck, attention must be paid that freight movement in Japan is undertaken by considerable number of trucks for personal use (small size). It has high mile per gallon (mpg) value but energy intensity measured by ton-km is inefficient. If we compare the U.S. truck efficiency with that of trucks for business use in Japan, they get close to each other (see Table 3.13).

As mentioned earlier, the differences in capacity factor are expected to contribute to the improvement of energy efficiency. Y. Nagata et. al. (1991) indicated additional 100 kg weight increase will reduce vehicle mpg of passenger car by 2.4 in Japan. This means if capacity factor will increase from one Pas./V to two Pas./V, vehicle mpg will decline by less than 10% while passenger travel will double. Therefore, energy intensity per passenger travel will decrease by 45%. However, Table 3.10 indicates there is no considerable difference in capacity factor of passenger car between the U.S. and Japan. Similarly, if marginal energy requirement for additional load is assumed to be negligible, large portion of the difference in energy intensity between the U.S. and Japan can be explained. For rail passenger transport, remaining difference is expected to come from higher rate of electrification and various countermeasures for energy conservation (VVVF control, chopper control, energy recovering brake, etc.) in Japan.

[13] Energy consumption doesn't coincide with nationwide data shown in Table 3.1. National data for the U.S. includes energy consumption of pipeline and military use, but they are excluded for consistency with Japanese data.

Table 3.9 Passenger Travel and Freight Movement by Mode (1989)

	U.S.				Japan			
	Passenger Travel (bil. pas.-km)		Freight Movement* (bil. ton-km)		Passenger Travel (bil. pas.-km)		Freight Movement (bil. ton-km)	
Passenger Car**	4,216.0	84.2%	---	---	736.0	58.1%	---	---
Bus	193.0	3.9%	---	---	109.1	8.6%	---	---
Truck	---	---	1,152.0	28.0%	---	---	262.9	51.2%
Rail	41.2	0.8%	1,631.3	39.7%	368.8	29.1%	25.1	4.9%
Plane	558.9	11.2%	16.4	0.4%	47.1	3.7%	0.8	0.1%
Ship	---	---	1,312.2	31.9%	6.0	0.5%	224.7	43.8%
Total	5,009.1	100.0%	4,112.0	100.0%	1,267.0	100.0%	513.4	100.0%

Source: Transportation Energy Data Book (1992)
Transportation in America (1991)
Highway Statistics 1990 (1992)
Un-yu Kankei Enerugii Youran (1991)
*Intercity only.
**Data include light trucks, not include motorcycles.

Table 3.10 Vehicle Kilometers Traveled (bil. V-km) and Capacity Factors (1989)

	U.S.				Japan			
	Vehicle-km		Capacity Factor		Vehicle-km		Capacity Factor	
Passenger Car*	2,841.6	83.2%	1.5	(Pas./V)	341.4	57.1%	1.6	(Pas./V)
Bus	9.1	0.3%	21.2	(Pas./V)	7.0	1.2%	15.7	(Pas./V)
Truck	505.8	14.8%			240.9	40.3%	1.1	(Ton/V)
(Intercity)	220.0		5.2	(Ton/V)				
Rail**	43.8	1.3%			8.3	1.4%		
(Passenger)	1.7		24.4	(Pas./V)	6.9		53.2	(Pas./V)
(Freight)	42.1		38.7	(Ton/V)	1.4		18.1	(Ton/V)
Plane	13.2	0.4%	44.0	(Pas./V)	0.3	0.0%	179.6	(Pas./V)
(Certificated)	6.0		89.4	(Pas./V)				
(General Av.)	7.2		2.7	(Pas./V)				
Total	3,413.6	100.0%			597.9	100.0%		

Source: Transportation Energy Data Book (1992)
Highway Statistics 1990 (1992)
Un-yu Kankei Enerugii Youran (1991)
*Data include light trucks (USA Only), not include motorcycles (both).
**Based on train car-kilometers.

Table 3.11 Transportation Energy Use by Mode (MTOE, 1989)

	U.S.				Japan			
	Passenger Travel		Freight Movement*		Passenger Travel		Freight Movement	
Passenger Car**	296.8	85.9%	---	---	34.9	79.5%	---	---
Bus	3.0	0.9%	---	---	1.7	3.8%	---	---
Truck	---	---	62.1	76.4%	---	---	---	---
(+Local)	---	---	122.3	---	---	---	27.1	88.8%
Rail***	2.0	0.6%	10.9	13.4%	3.7	8.5%	0.3	1.1%
Plane	43.9	12.7%	****	---	1.9	4.3%	0.4	1.3%
Ship	---	---	8.3	10.2%	1.7	3.9%	2.7	8.8%
Total	345.7	100.0%	81.3	100.0%	43.9	100.0%	30.5	100.0%
(+Local)			141.5					

Source: Transportation Energy Data Book (1992)
Highway Statistics 1990 (1992)
Un-yu Kankei Enerugii Youran (1991)
*Intercity only.
**Data include light trucks, not include motorcycles.
***Electricity is converted as input level.
****Data are not available.
Note: Original U.S. data includes energy used as pipeline and military operations.

Table 3.12 Energy Intensity by Mode of Transportation (1989, TOE per mil. P-km, T-km)

	U.S.			Japan			U.S./Japan		
	Pass. E/P-km	Freight** E/T-km	Vehicle mpg***	Pass. E/P-km	Freight E/T-km	Vehicle mpg	Pass.	Freight	Vehicle
Passenger Car*	70.4	---	18.7	47.4	---	23.0	1.5	---	0.8
Bus	15.5	---	6.0	15.4	---	8.2	1.0	---	0.7
Truck	---	53.9	6.9	---	103.0	17.6	---	0.5	0.4
Rail	49.5	6.7	---	10.1	13.6	---	4.9	0.5	---
Plane	78.5	---	---	40.2	544.5	---	2.0	---	---
Ship	---	6.3	---	284.1	11.9	---	---	0.5	---
Total	69.0	19.8	16.6	34.6	59.4	20.0	2.0	0.3	0.8

Source: Transportation Energy Data Book (1992)
Transportation in America (1991)
Highway Statistics 1990 (1992)
Un-yu Kankei Enerugii Youran (1991)
*Data include light trucks, not include motorcycles.
**Intercity only.
***Miles per gallon of gasoline heat equivalent.
****Intensities if Japanese mode of transportation is similar to those of USA.

Table 3.13 Structure of Freight Movement by Truck in Japan (1989)

	Business	Personal	Total
Number of registered trucks (mil.)	0.9	7.8	8.7
Freight movement (bil. ton-km)	184.3	78.6	262.9
Vehicle Kilometers Traveled (bil. V-km)	43.0	198.0	240.9
Capacity Factors (Ton/Vehicle)	4.3	0.4	1.1
Transportation Energy Use (MTOE)	11.4	15.7	27.1
Energy Intensity (TOE/mil. ton-km)	61.7	199.7	103.0
Energy Intensity (mpg)	7.5	24.9	17.6

Source: Un-yu Kankei Enerugii Youran (1991)
Un-yu Keizai Toukei Youran (1991)

This study does not explicitly analyze the car size. Compact car is about 15% more energy efficient than midsize car and 25% more efficient than large size car (DOT, 1990). However, average size of new passenger cars and average fuel economy between the U.S. and Japan have been getting close to each other[14] (see Figure 3.2[15]). Moreover, there is a special small-sized class called "Keijidosha" in Japan. "Keijidosha" is a small-sized car whose engine capacity is less than 0.66 liter. It has various tax advantages and constitutes about one third of total registered cars in Japan. If we compare it with the 0.66 liter car, the difference in energy intensity of the passenger car comes close from 1.5 to 1.3.

Other factor which affects energy efficiency is haul length. Longer haul length contributes to higher energy efficiency, because vehicles generally consume much more energy in starting and stopping. For example, average passenger trip length by certificated air in the U.S. is 1.6 times longer than in Japan (U.S. 1,274 km) (ORNL, 1992), Japan 784 km (JMT, 1991b), however this study does not include this effect because of lack of data.

3.4 Residential Sector

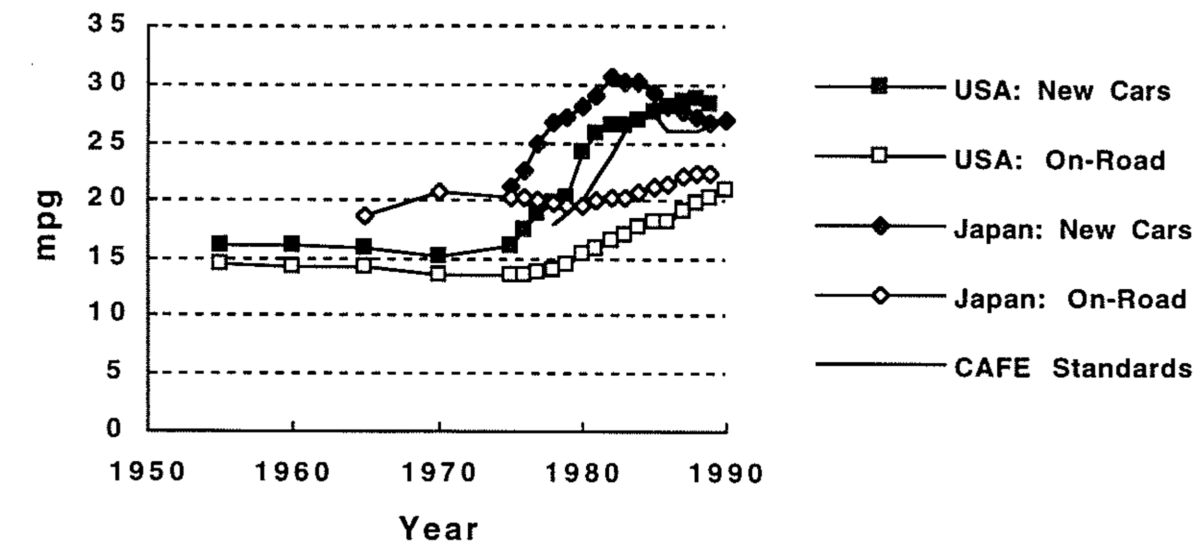
Among the G7 countries, the share of energy consumption in the residential and commercial sector in Japan is remarkably small (see Figure 3.1). It can be imagined that the potential of demand increase is highest in this sector in Japan.

In this sector, energy consuming unit is defined as household. Although persons per household and average floor space per home are different between the U.S. and Japan, it is reasonable because many appliances are owned by ones per household.

[14] Since 1989, the share of large car has been remarkably increasing in Japan. Main reason is tax change for owning a car. Marginal tax between cars whose engine size is 2,000 liter and 2,500 liter had been ¥42,000 before 1988 and has been ¥5,500 since 1989.

[15] CAFE means Corporate Average Fuel Economy set by the U.S. government. The data of new car fuel economy are not directory comparable because each country uses different methods of calculating it.

Figure 3.2 Average Fuel Economy of Passenger Cars



Source: Japan MITI. "Shou Enerugii Binran 1992".
Japan MOT. "Un-yu Keizai Toukei Youran", annual.
ORNL. "Transportation Eenrgy Data Book: Edition 12".
U.S. DOT. "Highway Statistics", annual.
U.S. DOT. "National Transportation Statistics: Annual Report".

Housing Characteristics

Table 3.14 shows the housing characteristics in both countries. Except for average floor space per home, percent of home with central heating, and percent of home with thermal integrity, the U.S. and Japan have almost same characteristics. With respect to degree days, the benchmark temperatures in Japan are different from those in the U.S. and they are corrected according to the U.S. benchmark16. It is known that energy requirement for space heating greatly changes by housing type (single-unit or multi-unit), however, this effect is expected to be small in comparing the U.S. with Japan.

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16 The U.S. benchmark is 65°F (18°C) for cooling degree days (CDDs) and heating degree days (HDDs). CDDs and HDDs are population-weighted for national average. Japanese benchmarks are 24°C (75°F) for CDDs and 14°C (57°F) for HDDs. Moreover the method of calculating HDDs is special: HDDs is calculated during the period when daily mean temperature is below 10°C (50°F) (see Figure 3.3). CDDs and HDDs in Japan based on 18°C benchmark was calculated in this study by linear approximation of daily mean temperature. They were calculated by following equations.

CDDs (18°C) = CDDs (24°C) + 6 • Cooling Days (24°C) + 3 • 3/7 • (365-Cooling and Heating Days)
HDDs (18°C) = HDDs (14°C) + 4 • Heating Days (14°C) + 8 • 4/7 • (365-Cooling and Heating Days)

Table 3.14 Housing Characteristics in the U.S. and Japan

	U.S. (1987)	Japan (1988)	U.S./Japan
Number of households (million)	90.5	37.6	2.4
Average Number of persons per household	2.7	3.2	0.8
Average living space per person (square meter)	57.7	27.9	2.1
Home ownership rates	64.0%	61.3%	1.0
Percent of single home detatched	60.9%	62.3%	1.0
Percent of home with central heating	86.0%	5.4%*	15.9
Percent of home with thermal integrity**	58.5%	28.4%	2.1
Energy expenditures as a percent of income***	4.3%	3.3%	1.3
Average number of rooms per home	5.3	4.9	1.1
Average floor space of new home (square meter)	161.0	81.2	2.0
Average floor space per home (square meter)	153.6	89.3	1.7
Average Heating Degree Days (18°C, deg*day)	2,606	2,061	1.3
Average Cooling Degree Days (18°C, deg*day)	643	712	0.9

Sources: Jutaku Tokei Chosa (1991)
Residential Energy Statistical Year Book (1991)
JIEE Report (1991)
IBEC Estimation (1991)
Statistical Abstract of the United States 1991 (1991)
American Housing Survey for the United States 1987 (1989)
Household Energy Consumption and Expenditures 1987: National Data (1990)
Monthly Energy Review (1992)
Energy Consumption and Conservation Potential:
Supporting Analysis for the National Energy Strategy (1990)
Annual Review of Energy vol. 10 (1985).

* Survey data in metropolitan area by JIEE.
** U.S.: Percent of single-family units (at least) with wall insulation.
Japan: Percent of total housing units with floor, ceiling, and wall insulation.
*** Not include energy expenditures on gasoline and motor oil.

Table 3.15 Household Energy Consumption by End Use (Mcal per Household per Year)

	U.S.(1987)	Japan(1988)	U.S./Japan
Space Heating	13,762	2,928	4.7
Natural Gas	9,414	355	26.5
Fuel Oil/Kerosene	2,924	2,137	1.4
Electricity	780	251	3.1
LPG	613	155	4.0
Water Heating	4,562	3,624	1.3
Air Conditioning	1,260	357	3.5
Appliance Usage	5,848	2,927	2.0
Total	25,432	9,836	2.6

Source: Household Energy Consumption and Expenditures 1987: National Data (1990)
Residential Energy Statistical Year Book (1991)
Denryoku Jukyu no Gaiyou (1991)

Figure 3.3 Difference in Degree-Days between US and Japan

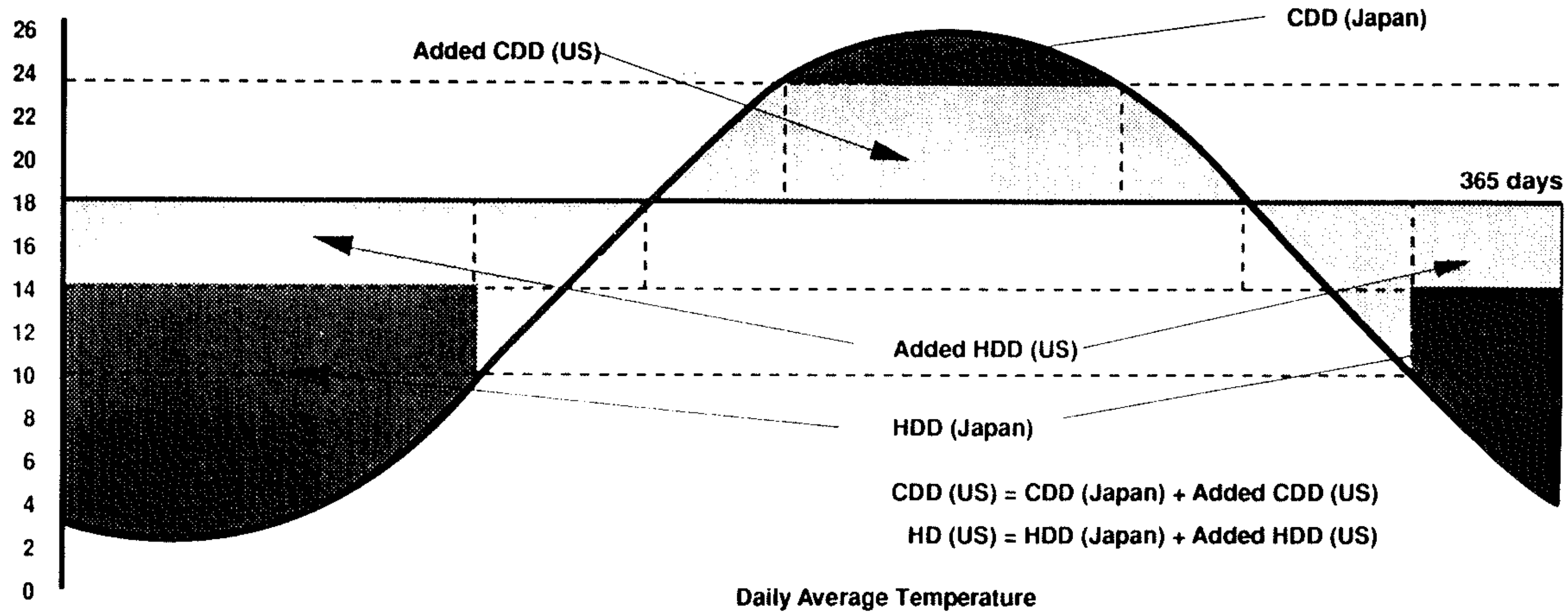


Table 3.16 Electricity Consumption by Selected Appliances and Diffusion Ratio

	U.S. (1987)		Japan (1988)	
	Consumption (kWh/Home)	Diffusion Ratio	Consumption (kWh/Home)	Diffusion Ratio
Total	5,569	---	2,191	---
Refrigerator	1,768	112.9%	726	109.8%
Clothes Dryer	504	50.7%	*	15%(1989)
Color TV	465	145.3%	323	165.7%
Freezer	454	34.7%	---	---
Range/Oven	339	56.8%	---	---
Furnace Fun	336	51.7%	---	---
Water-bed Heater	221	13.8%	---	---
Ceiling Fun	79	46.2%	---	---
Clothes Washer	76	73.4%	39	98.7%
Dishwasher	71	43.1%	---	---
Microwave Oven	61	60.8%	51	57.0%
Blanket	44	30.1%	42	98.3%
Lighting	*	---	541	---
Other	1,152	---	469	---

Source: Household Energy Consumption and Expenditures 1987: National Data (1990)
Residential Energy Statistical Year Book (1991)
Denryoku Jukyu no Gaiyou (1991)

* Included in other.

Energy Consumption and Intensities

The U.S. consumes 2.6 times more energy than Japan for all use, and in particular, does 4.7 times more for space heating per household. For heating energy, natural gas is most popular in the U.S. while kerosene is in Japan, and the share of electricity is small in both countries (see Table 3.15). This means conventional boiler is dominant for heating equipment and the share of innovative equipment such as heat pump is still small. Hence most difference in energy consumption for heating is supposed to come from non-technological factors.

As for electrical appliance usage, not only energy efficiency but also size, diffusion ratio, and operating time are important. Table 3.16 shows average electricity consumption by selected appliances and their diffusion ratios. Although diffusion ratio of major appliances such as refrigerator or color TV are quite similar between the U.S. and Japan, electricity consumption in the U.S. is about 1.5 to 3 times greater than that in Japan. Particularly the sizes of refrigerator are supposed to differ between the U.S. and Japan significantly. Average electricity consumption by refrigerator in Japan was 450 kWh per year in 1989 (Nagata, 1991) while the U.S. "Best Available" refrigerator is expected to be 515 kWh per year (DOE-EIA, 1990). Moreover, the U.S. households use many kinds of appliance which are not popular in Japan. They are clothes dryer, range/oven, water-bed heater, and dishwasher. These appliances consume about 20% of total electricity consumption. The U.S. data does not separate lighting, but it is supposed to have a considerable share of residual electricity consumption. Other report estimates it to 105 TWh in 1990 and 90% of this is consumed by inefficient incandescent lamps (OTA, 1992). It is equivalent to 1,124 kWh per home.

Table 3.17 Floor Space of Commercial Buildings (1989, million sq. meter)

	U.S.		Japan		U.S./Japan
Assembly	642	10.9%	n.a.	n.a.	n.a
Education	836	14.2%	307	24.5%	2.7
Food Service	108	1.8%	49	3.9%	2.2
Health Care	191	3.3%	63	5.0%	3.0
Lodging	323	5.5%	74	5.9%	4.3
Retail/Wholesale	2,008	34.2%	291	23.2%	6.9
Office	1,096	18.7%	300	24.0%	3.7
Other	665	11.3%	144	11.5%	4.6
Total	5,870	100.0%	1,251	100.0%	4.7

Source: Commercial Buildings Energy Consumption and Expenditures 1989 (1992) .
Survey based on a Questionnaire and Interviews on Energy Consumption in the Commercial Sector (1992).
n.a. = Not Available.

Remaining factors are the rate of homes with central heating and thermal integrity of each house. These factors may explain a large part of the differences in energy consumption for space heating and air conditioning.

3.5 Commercial Sector

In the commercial sector, energy consumption is characterized by building activity. This is because there is a big difference in energy intensity per floor space by building activity. On the other hand, energy consumption for space heating and air conditioning is considered to have less dependence on climate compared with the residential sector. For example, lighting is an effective heat source and air conditioning is used in most of countries even where it is not strictly necessary in terms of outside climate. Therefore adjustment by climate is not carried out in the commercial sector.

Commercial Building Characteristics

Table 3.17 shows the floor space of each activity in both countries in 1989. Total floor space in the U.S. is 4.7 times larger than that in Japan. This ratio is greater than that of GDP or population and it is supposed to reflect wider land area and relative size of the commercial sector to GDP in the U.S.. Retail/wholesale trade has the biggest difference. It can be imagined that the reason of this is the proportion of large sized stores is lower in Japan by governmental regulation.

Japanese data includes assembly in "Other" activity, however, the coverage of assembly appears different between the U.S. and Japan. The U.S. data includes floor space of church while Japanese data doesn't. Because floor space of church is supposed to have large amount of that of assembly, it is excluded for the further analysis.

Table 3.18 Commercial Energy Intensity (1989, Mcal per sq. meter)

	U.S.	Japan	U.S./Japan
Assembly	234.0	n.a.	n.a.
Education	406.6	112.8	3.6
Food Service	801.2	573.3	1.4
Health Care	801.5	418.2	1.9
Lodging	448.6	489.5	0.9
Retail/Wholesale	268.8	360.9	0.7
Office	382.2	227.0	1.7
Other	208.5	188.7	1.1
Total	336.0	260.2**	1.3
Exclude Assembly	348.5		1.3

Source: Commercial Buildings Energy Consumption and Expenditures 1989 (1992).
Survey based on a Questionnaire and Interviews on Energy Consumption in the Commercial Sector (1992).
*Intensity if Japanese activity structure is similar to that of U.S..
**Weighted average by floor space in 1989.
n.a. = Not Available.

Energy Intensities

Energy intensity is shown in Table 3.18. Because Japanese survey is quite old, floor space in 1989 is used for the calculation of average intensity assuming that energy intensities of each activity remain same since 1985[17]. The difference in energy consumption between national data and this estimation is about 6% (see Table 3.3) and it is considered to be in statistical discrepancy.

Floor space averaged energy intensity in the U.S. is 1.4 times greater than that in Japan. This difference is smaller than energy intensities in other sectors shown before. By activity, energy intensity per floor space varies greatly and it is common in both countries. Education has the largest difference and it is expected that the weight of research affects energy intensity. Japanese survey estimates energy intensity of research institute is 6.5 times greater than that of school and both of them are included in "Education" activity.

[17] Rapid computerization in the commercial sector may increase energy intensity from 1985 data. Not only computer consumes electricity, but also it requires energy for air conditioning and lighting.

4. ESTIMATING ADJUSTED NATIONAL ENERGY INTENSITIES

Adjusted national energy intensities are estimated according to the method described in section 2. Energy consumption in Japan is adjusted if non-technological factors in Japan were similar to those in the U.S.. These factors are climate, population density, industry mix, product mix in industry, household mix, modal mix in transportation, and activity mix in the commercial sector. The contribution of each factor is evaluated if all other factors remain unchanged in the equations of disaggregation. Energy consumption in the U.S. highway transportation sector is adjusted if gasoline price in the U.S. has been same as that in Japan and CAFE standard has not been adopted.

Table 4.1 shows the results inside each sector. Adjustment of modal mix in the transportation sector has a quantitatively largest effect. It is expected that there is large potential for energy conservation by technological renovation in the U.S. manufacturing sector. On the other hand, it is supposed that the differences in life styles and living standard affect higher energy use in the U.S. residential sector significantly and it is difficult to reduce the gap between the U.S. and Japan. Combined result of disaggregating and modeling approach is shown in Table 4.2. It is estimated that non-technological factors contribute to increase the U.S. energy intensity by 68 TOE per million 1989 U.S. dollars. It is equivalent to 41% of the total difference and adjusted TPER/GDP ratio in Japan would be about 74% of that in the U.S. in 1989 (see Table 4.3). Related factors to the difference in land area has remarkable effect on the gap of energy intensity between the U.S. and Japan.

As mentioned in Section 2, GDP is conceptually a sum of value added of goods and services. If we bear this in mind it, energy consumed in the industrial, commercial, and public transportation sectors are considered to contribute to GDP production directly. Therefore, it is more appropriate to use it for the calculation of energy intensity. Based on this criterion, adjusted TPER/GDP ratio in Japan becomes to be about 81% of that in the U.S.. In other words, it means that inefficiencies of overall energy consuming technologies in the U.S. brings about 19% more energy consumption than in Japan (see Table 4.3 and Figure 4.1).

Table 4.1 Adjusted Energy Intensities

	U.S.	Japan			U.S./Japan	
	Actual	Actual	Adjusted	Diff.	Actual	Adjusted
Manufacturing (TOE/mil. 1988$)	113.8	65.3	61.6	-5.6%	1.7	1.8
Passenger Transport (TOE/mil. P-km)	69.0	34.6	45.1	30.1%	2.0	1.5
Freight Movement (TOE/mil. T-km)	19.8	59.4	40.2	-32.3%	0.3	0.5
Residential (Gcal/household/year)	25.4	9.8	13.9	40.8%	2.6	1.8
Commercial (Mcal/square meter)	348.5	260.2	285.7	9.8%	1.3	1.2

Table 4.2 Contribution of Non-Technological Factors to Higher Use of TPER per GDP in U.S. than in Japan (1989)

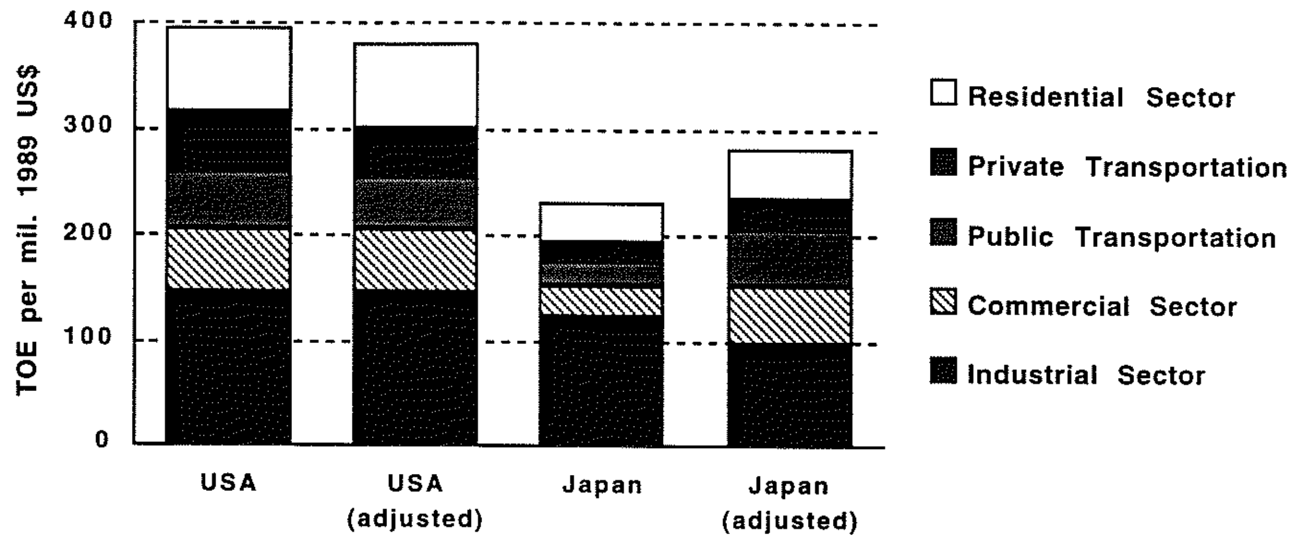
Sector or activity	TOE per mil. 1989 U.S.$	
Industrial Sector	-26.3	
Energy Mix		0.6
Industrial Structure		-4.0
Product Mix		-23.0
Passenger Transport	31.6	
Price Effect (U.S.)		11.8
Energy Mix		-3.0
Mode of Transportation		10.8
Volume of Pas.-km		12.1
Freight Transport	23.2	
Price Effect (U.S.)		4.2
Energy Mix		2.0
Mode of Transportation		-15.9
Volume of Ton-km		32.9
Residential Sector	12.0	
Energy Mix		-3.2
Climate		2.8
Floor Space per home		8.9
Interactive Effect		2.0
Persons per home		1.4
Commercial Sector	27.1	
Energy Mix		-1.1
Activity Structure		5.2
Floor Space		23.1
Total TPER/GDP variability	67.7	

Table 4.3 Adjusted Energy Consumption and Intensities (1989)

	U.S.	Japan	U.S./Japan
TPER (MTOE)	1,967.2	548.0	3.6
for Residential*	419.1	95.8	4.4
for Private Transportation	235.9	51.8	4.6
TPER for GDP (MTOE)	1,312.2	400.5	3.3
TPER/GDP (TOE/mil. $)	381.0	281.9	1.4
TPER/GDP (TOE/mil. $)**	254.1	206.0	1.2
TPER/Pop. (TOE/person)	7.9	4.5	1.8
TPER/Pop. (TOE/person)**	5.3	3.3	1.6

*Include energy conversion losses.
**TPER for GDP (MTOE)

Figure 4.1 Sectoral Energy / GDP (1989)



5. CONCLUSION AND FUTURE WORK

The U.S. consumes about 1.7 times more energy per GDP in Japan. However, there are many non-technologically originated factors for higher energy use in the U.S.. This study analyzed energy consumption in each sector and evaluated the magnitude of these factors. General conclusions are summarized as follows:

1. Non-technological factors has considerable effect on the difference in energy consumption between the U.S. and Japan, and it is expected that these factors contribute about 41% of total difference. It is about 68 ton oil equivalent per million 1989 U.S. dollars and wider land area of the U.S. has a biggest effect.

2. Even though non-technological factors are taken into account, the U.S. still consumes more energy than Japan and the potential for energy conservation is expected to be large in the U.S. except for freight movement.

3. The problem using Energy/GDP ratio as a national energy intensity is indicated. Consider the concept of GDP, energy consumption in the residential and private transportation sector should be excluded for this accounting. After this adjustment, the ratio of energy intensities decreases to 1.23 and the U.S. is still expected to have larger potential for energy conservation.

Many factors considered to affect energy consumption remains unanalyzed. They are capacity factor and haul length in the transportation sector, diffusion rate, average size, and operating time of appliances in the residential sector and thermal integrity of buildings in the commercial and residential sector. For instance, average fuel efficiency of passenger car measured by mile per gallon is comparable between the U.S. and Japan, however the lower capacity factor in the U.S. makes the passenger-km intensity inefficient. Likewise, the higher diffusion ratio of central heating causes the U.S. households to consume 2.4 times more energy for space heating in spite of better insulation.

Also this study does not analyze the price effect in the industrial, commercial, and residential sectors. It is important to develop energy demand model that includes detailed energy consuming technologies and economies of them (typical example is cost curve of conserved energy) for the further analysis.

Supplement

This report is a result of collaborative study between the Energy Modeling Forum (EMF), Stanford university and CRIEPI from October 1991 to September 1992. The EMF is supported by multiple public and corporate sources, and provides a unique opportunity for parties to come together in regard to specific energy problems. The studies at the EMF in the period of this study were "Global Climate Change: Impacts of Greenhouse Gas Emission Control Strategies" and "Energy Conservation". Because these studies were closely related to this study, I attended meetings as an observer and collected information.

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Appendix: Highway Transportation Energy Model

To clarify the price effects in highway transportation sector, a simple econometric model was developed. This model was used to evaluate how much energy consumption will decrease if gasoline price in the U.S. has been same as that in Japan. Gasoline price in the U.S. is about half of it in Japan, and if it will rise, energy consumption will decrease in various ways. This model can analyze the effect of decrease in number of cars, improvement in efficiency, and driving less distance. The effects of modal substitution or macro economy (changes in GDP, CPI, or world oil price) aren't included[18]. The development of this model greatly owes Itoh's (1990) previous study.

Vehicles are divided into passenger car (not include motorcycle), personal truck (for personal travel use), and other truck (for freight movement use). For only passenger car, average fuel efficiency of model year is estimated to evaluate the effect of the CAFE standard. The names of variable are shown in Table A-1.

Table A-1 Variable Names in the Highway Transportation Energy Model

NEWCAR	: New Car Registration
CARS	: Total Number of Passenger Cars
PTRUCKS	: Total Number of Personal Trucks[19]
OTRUCKS	: Total Number of Other Trucks
VMCAR	: Vehicle Miles Traveled by Passenger Car
AVCAR	: Average Miles per Passenger Car
AVPT	: Average Miles per Personal Trucks
AVOT	: Average Miles per Other Trucks
FCCAR	: Fuel Consumption by Passenger Car
FCPT	: Fuel Consumption by Personal Trucks
FCOT	: Fuel Consumption by Other Trucks
MPGNEW	: Mile per Gallon (MPG) of New Cars
MPGCAR	: MPG of Passenger Cars
MPGPT	: MPG of Personal Trucks
MPGOT	: MPG of Other Trucks
DPSCRAP	: Depreciation Rate for Cars
PGASO	: Gasoline Price
CPI	: Consumers Price Index
IIP	: Index of Industrial Production
GNP	: Gross National Product
PGNP	: GNP Deflator
TIME	: Time Trend (Year in 1960=1, 1961=2, 1963=2, •••)
DUM6079	: Dummy Variable for the CAFE Standard (1960-1979=1)

[18] In Japan, the cost of owning a car is extremely more expensive than that in the U.S. Besides energy prices, the charges for parking and highway use and yearly tax for owning a car are very expensive in Japan. This study does not consider this effect.

[19] Personal truck is trucks mainly used for passenger travel. Numbers, vehicle miles, and fuel consumption are estimated by the Oak Ridge National Laboratory (ORNL, 1992). Personal trucks are included in passenger car in Section 3.

The equations of model are shown in Table A-2. Number of cars, vehicle miles traveled, and average fuel economy are estimated to embody the effects shown in Table 2.5. Main explaining variables are gasoline price, income, time lag, and time trend. Time trend is a substitutable variable for technological progress. For the estimation of new car registration of passenger car, dummy variable for the CAFE standard is included. Each variable satisfies the sign conditions presumed beforehand.

Table A-2 Equations of the Highway Transportation Energy Model

SER: Standard Error of Regression, D.W.: Durbin-Watson Statistic

Passenger Cars

- New Car Registrations

NEWCAR = 10698.5 +31700.1•(GNP/GNP(-1)-1) -1377.30•(PGASO/CPI)
(12.56) (5.25) (-2.02)
(1970-1990) $R^2 = 0.681330$, SER = 625.488, D.W. = 1.47155

- EPA MPG of New Cars

LOG(MPGNEW) = -20.6027 +0.136402•LOG(PGASO/CPI) +0.011049•TIME
(-3.09) (2.97) (3.18)
+0.597769•LOG(MPGNEW(-1)) -0.071001•DUM6079
(5.22) (-1.50)
(1966-1989) $R^2 = 0.981974$, SER = 0.786027, D.W. = 1.50003

- Total No. of Passenger Cars

CARS = CARS(-1)•(1-DPSCRAP) +NEWCAR

- Vehicle-Miles Traveled by Passenger Cars

LOG(VMCAR) = 0.078018 +0.245856•LOG(GNP) -0.069528•LOG(PGASO/CPI)
(0.52) (2.90) (-3.57)
+0.711508•LOG(VMCAR(-1))
(8.05)
(1965-1990) $R^2 = 0.991996$, SER = 18.9032, D.W. = 1.70376

- Average Vehicle-Miles Traveled per Passenger Cars

AVCAR = VMCAR/CARS•1000000

- On-Road MPG of Passenger Cars

MPGCAR = -0.161489 +0.998079•(MPGN•NEWCAR
(-0.52) (50.46)
+MPGCAR(-1)•(CARS-NEWCAR))/CARS
(1966-1989) $R^2 = 0.991043$, SER = 0.221518, D.W. = 2.03322

- Fuel Consumption by Passenger Cars

FCCAR = CARS•AVCAR/MPGCAR/1000000

Personal Trucks

- Total No. of Personal Trucks

$$PTRUCKS/PTRUCKS(-1) - 1 = 6.44074 + 0.248424 \cdot (GNP/GNP(-1) - 1)$$
(7.66) (2.43)
$$-0.015003 \cdot PGASO(-1)/CPI(-1) - 0.00322192 \cdot TIME$$
(-1.46) (-7.62)

(1969-1990) $R^2 = 0.998799$, SER = 196.107, D.W. = 2.78596

- Average Vehicle-Miles Traveled per Personal Trucks

$$LOG(AVPT) = -4.61547 - 0.067388 \cdot LOG(PGASO/CPI) + 0.00382531 \cdot TIME$$
(-1.40) (-2.66) (1.71)
$$+0.678761 \cdot LOG(AVPT(-1))$$
(4.99)

(1970-1990) $R^2 = 0.953181$, SER = 195.786, D.W. = 1.65362

- On-Road MPG of Personal Trucks

$$LOG(MPGPT) = -24.0997 + 0.076802 \cdot LOG(PGASO/CPI) + 0.013192 \cdot TIME$$
(-4.68) (3.98) (4.69)
$$+0.179395 \cdot LOG(MPGPT(-1))$$
(1.02)

(1967-1990) $R^2 = 0.991191$, SER = 0.124262, D.W. = 1.54665

- Fuel Consumption by Personal Trucks

$$FCPT = PTRUCKS \cdot AVPT/MPGPT/1000000$$

Other Trucks

- Total No. of Other Trucks

$$OTRUCKS = -4066.06 + 1298.97 \cdot LOG(IIP) - 219.475 \cdot (PGASO/PGNP)$$
(-1.27) (1.61) (-1.06)
$$+0.895467 \cdot OTRUCKS(-1)$$
(16.18)

(1970-1990) $R^2 = 0.996908$, SER = 148.319, D.W. = 1.61807

- Average Vehicle-Miles Traveled per Other Trucks

$$LOG(AVOT) = -14.7147 - 0.053613 \cdot LOG(PGASO/CPI) + 0.010143 \cdot TIME$$
(-2.57) (-2.05) (2.68)
$$+0.445031 \cdot LOG(AVOT(-1))$$
(2.35)

(1970-1990) $R^2 = 0.968018$, SER = 339.194, D.W. = 1.40819

- On-Road MPG of Other Trucks

$$LOG(MPGOT) = -6.11055 + 0.016971 \cdot LOG(PGASO/PGNP) + 0.00349496 \cdot TIME$$
(-1.99) (0.92) (2.04)
$$+0.611210 \cdot LOG(MPGOT(-1)))$$
(3.71)

(1970-1990) $R^2 = 0.959174$, SER = 0.101575, D.W. = 1.63150

- Fuel Consumprion by Other Trucks

$$FCOT = OTRUCKS \cdot AVOT/MPGOT/1000000$$

Internal simulation was performed to evaluate the price effect. Gasoline prices in the U.S. were equalized to those in Japan using PPP from 1980 to 1989. Gasoline prices are shown in Table A-3. At the same time, the CAFE standard is excluded to equalize the condition between the U.S. and Japan.

The results are shown in Table A-4. The numbers mean the deviation rate from actual records in 1989. Energy efficiency of new passenger car is improved by 11.2% and reaches 31.5. This value is technically feasible even now[20]. With respect to stock level, however only 0.6% gain is achieved. The reason of this is the large numbers of existing stock and decrease in new car registration. Besides the decrease in total number of cars, decrease in average miles traveled per vehicle is significant. Some portion of this is expected to be substituted by other mode of transportation, but this model does not account it. Energy consumption is reduced by 17 to 32% and they are included in Table 4.2 as price effect in the U.S..

The effect of changes in gasoline price on macro economy is not also included in this model. It is expected to affect each variable through changes in income and commodity prices. These factors have opposite effect on energy consumption because increase in commodity prices decreases the relative price of gasoline. Moreover, they depend greatly on revenue recycling if price increase is performed by taxation.

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[20] It may accompany the use of smaller cars and losing comfort.

Table A-3 Calcuration of Gasoline Price

Year	U.S.*	Japan**		PPP	Japan/U.S.
	($/gal.)	(¥/liter)	($/gal.)	(¥/$)	
1980	122	152	220	262	1.8
1981	135	161	247	247	1.8
1982	128	172	276	236	2.2
1983	123	151	249	230	2.0
1984	120	149	251	225	2.1
1985	120	145	247	222	2.1
1986	93	123	210	221	2.3
1987	96	128	226	214	2.4
1988	96	120	218	208	2.3
1989	106	126	234	204	2.2
1990	122	133	254	198	2.1

Source: Monthly Energy Review (1992)
JIEE: Energy Data Bank
* Sales weight average of all types of motor gasoline.
** Unleaded gasoline.

Table A-4 Impacts of Increasing US Energy Price in Highway Transportation (1989)

	New Passenger Cars	Passenger Cars	Personal Trucks	Other Trucks
No. of Vehicles	-12.1%	-9.7%	-15.0%	-9.0%
Average Miles per Vehicle	---	-7.8%	-14.4%	-7.1%
Average MPG	+11.2%	+0.6%	+6.5%	+2.8%
(Value)	(28.3→31.5)	(20.1→20.4)	(13.6→14.4)	(8.6→8.8)
Total Fuel Consumed	---	-17.3%	-31.6%	-17.8%