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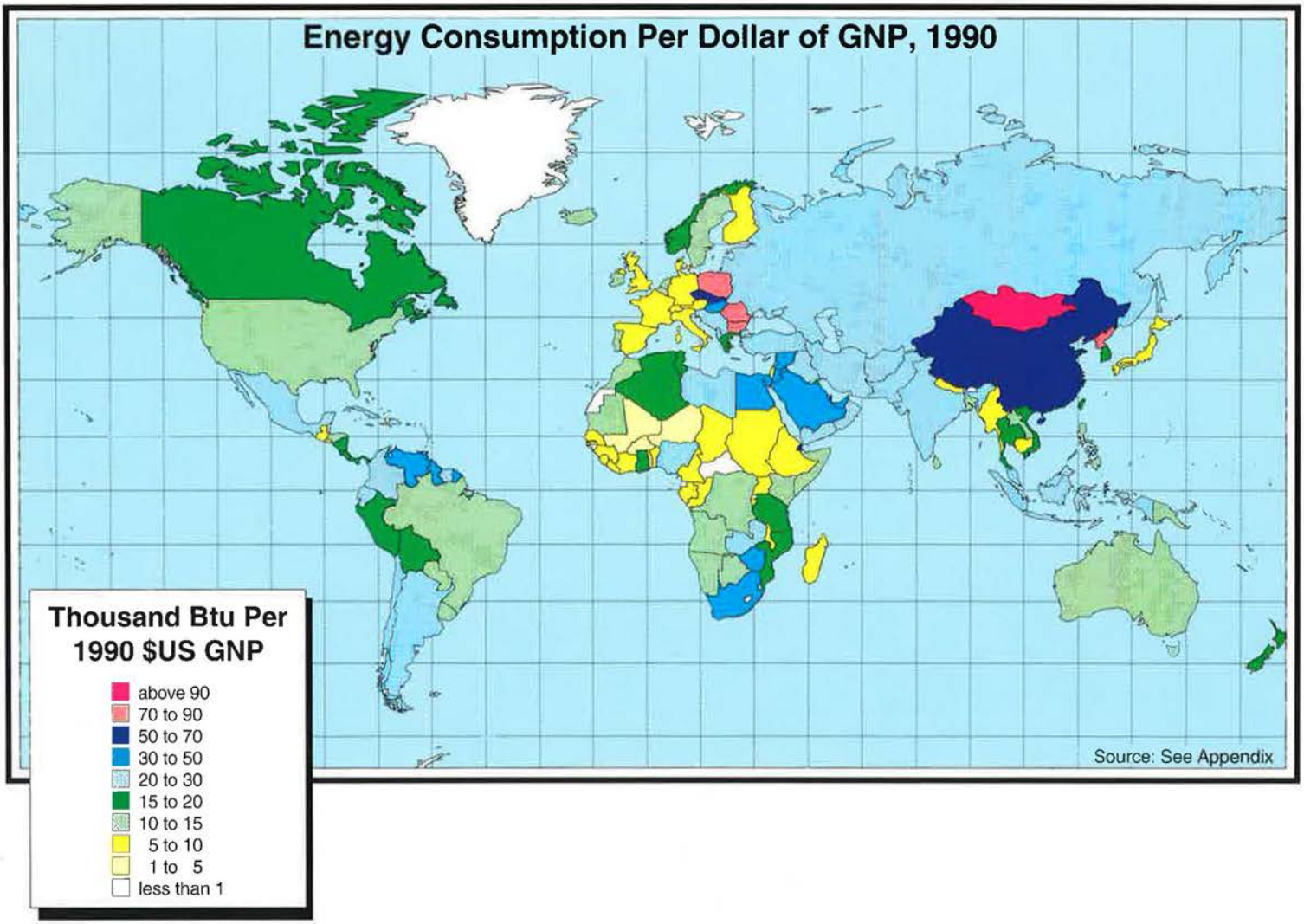
Energy Use and Carbon Emissions: Some International Comparisons

March 1994



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Energy Use and Carbon Emissions: Some International Comparisons

March 1994

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Preface

This study was undertaken in response to a request by U.S. Representative Philip R. Sharp, Chairman of the U.S House of Representatives Subcommittee on Energy and Power. Congressman Sharp's request sought a review of international energy and economic data to compare energy use patterns across countries and in the context of major energy end-use sectors. The purpose of the review was to identify differences in energy use patterns which could be suggestive of opportunities both to economize on the use of fossil fuel energy (i.e., oil, natural gas, and coal) and to reduce greenhouse gas emissions.

Congressman Sharp's request also asked for additional information that is not contained in this report. This report reflects a broad review of available international data and a report on the results of this review with particular emphasis on the developed countries. In coming months, additional material will be prepared for Congressman Sharp which will focus on sectoral energy use patterns in developing countries. Other work will also examine the potential impact of alternative policies and technological choices on energy consumption and carbon emissions patterns.

Common Abbreviations Used

Btu	British thermal unit (the amount of energy required to raise the temperature of 1 pound of water 1 degree fahrenheit; 8 gallons of gasoline contain 1 million Btu)	GDP	Gross domestic product
		GNP	Gross national product
		GPO	Gross product originating
		G-7	Group of Seven (Canada, France, Italy, Japan, Germany, United Kingdom, United States)
CPEs	Centrally-planned economies		
DCs	Developing countries	OECD	Organization for Economic Cooperation and Development (for list of countries in OECD, please see Appendix, endnote #2)
DD	Degree day		
E/GDP	Ratio of energy consumption to gross domestic product		
E/GNP	Ratio of energy consumption to gross national product	PPP	Purchasing power parity
		Quads	Quadrillion Btu

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Highlights

In recent years, there has been a growing level of concern that anthropogenic (i.e., caused by human activities) emissions of carbon dioxide and other so-called "greenhouse gases" are contributing to "global warming." (Greenhouse gases also include: methane; nitrous oxide; chlorofluorocarbons and related compounds; non-methane volatile organic compounds; and water vapor.[1]) As a result of this concern, interest has risen regarding possible cost-effective options to help reduce greenhouse gas emissions. Interest has focused primarily on limiting the burning of fossil fuels, which releases carbon (mainly in the form of carbon dioxide) into the atmosphere. One of the most frequently mentioned options in this regard has been reducing the amount of energy needed to produce a given unit of economic output. This option is seen by many as offering the potential for stabilizing (or even reducing) carbon emissions without sacrificing economic growth. A similar consequence could be achieved by substituting low carbon fuels (such as natural gas) for high carbon fuels (coal, for instance), or noncarbon-emitting fuels (hydroelectric, nuclear, solar, etc.) for fossil fuels.

Energy use and economic welfare are closely intertwined. Economically advanced societies use more energy per capita than those which are not. The process of economic development entails increasing levels of consumption of commercially-produced energy. However, historical experience demonstrates that the relationship between economic growth and energy use is not unique. Nations experiencing similar paths of economic expansion may exhibit significant differences in energy use growth rates. Moreover, nations with similar levels of economic output per capita vary widely in per capita energy consumption. Additionally, nations with similar levels of energy consumption may have significantly different rates of carbon emissions. Examining historical variations in energy use growth rates and differences in international energy use patterns substantiates the conclusion that there is scope for long run flexibility in the relationship between energy consumption, economic activity, and carbon emissions.

This review surveys energy use and carbon emissions patterns in a world context. The presentation is divided into three major sections. In Section 1, an analysis of energy use and carbon emissions is presented contrasting trends in economically developed and developing areas of the world since 1970. Section 2 presents a disaggregated view of the "Group of Seven" (G-7) key industrialized countries (Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States). This is followed in Section 3 by an examination of sectoral energy use patterns within each of the G-7 countries. At a later time, a disaggregated review of selected developing countries will be completed as a supplement to this document.

It is hoped that the materials presented here will promote a better understanding of the character of change evident in world energy use and carbon emissions over the past two decades. The report may also help to prioritize future policy analyses which seek to identify opportunities for energy conservation and development of alternate fuels.

Key conclusions of this study include:

- ✓ **The relationship between economic development and energy use varies across country groups.** In developed countries, energy use grew slowly relative to economic growth during the 1970's and 1980's. In the developing countries (including the current and former centrally-planned economies), energy use overall increased as fast or faster than economic growth, even after the 1973 and 1979 oil price shocks.

- ✓ **Energy consumption and carbon emissions grew fastest in the developing countries.** Most of the growth in worldwide energy consumption and carbon emissions over the past two decades took place in developing countries such as China, Brazil, India, and South Korea. These countries generally use much more energy (and release more carbon) in generating a dollar of economic output than do the developed countries.

- ✓ **Fuel use patterns in the developing countries were consistently more carbon-intensive than in the developed countries over the past two decades.** China and Canada represent extremes in terms of their carbon emissions per unit of energy use, with China's emissions (reflecting heavy use of coal) twice those of Canada (with its large hydro power resources).

- ✓ **The world share of noncarbon-emitting energy sources increased over the past two decades, particularly in the developed countries.** Most of this increase was due to growth in nuclear power generation. In the developing countries, noncarbon-emitting energy sources grew from 4 percent in 1970 to 9 percent of total energy supply in 1991. Noncarbon-emitting energy sources grew even more rapidly in the developed countries, increasing their share from 7 percent in 1970 to 17 percent in 1991.

- ✓ **Partly as a result of these trends, the developed countries' share of world carbon emissions declined between 1970 and 1992, although it remains large.** In 1992, for instance, the developed countries accounted for 48 percent of world energy-related carbon emissions (down from 57 percent in 1970). Between 1970 and 1992, carbon emissions increased only 30 percent in the developed countries, compared to 80 percent in the developing countries.

- ✓ **Electricity use worldwide increased significantly faster than overall energy use, particularly in the developing countries.** This conclusion in turn suggests a potential course of action: namely, the widespread adoption of best-available electricity generation technologies.

- ✓ **Within the developed countries, energy use patterns vary widely.** Energy use per capita, for instance, is more than twice as high in Canada and the United States than in Japan and G-7 Europe. Such differences between developed countries have persisted over time despite a common tendency towards less energy use per capita and per unit of output.

Introduction

Energy Use and Carbon Emissions: Some International Comparisons

This report examines international energy use patterns, trends, and energy-related carbon emissions since 1970. The main focus of this study is on the developed countries, represented by the members of the Organization for Economic Cooperation and Development, or OECD[2]. The study is organized as follows: 1) the OECD is placed in a world context; 2) aggregate-level information is then presented for an important part of the OECD, namely the Group of Seven (G-7) major industrialized countries (the United States, Canada, Japan, the United Kingdom, France, Italy, and Germany - defined in this report as western Germany only, except where indicated); and 3) individual economic sectors within the G-7 countries are broken out for detailed review.

Background: Economic Growth, Energy Consumption and the Environment

Since the industrial revolution, consumption of fossil fuels (oil, gas, and coal) has been critical to economic growth. Early on, however, it was apparent that fossil fuel consumption had unwanted adverse environmental effects - namely, pollution of the air, water, and land. In recent years, concern over these effects has been heightened by the possibility that the release of greenhouse gases--the most important of which are carbon dioxide, methane, and nitrous oxide--contribute to global warming. Human activities promote emissions of each of these gases, adding to existing natural background levels contained in the atmosphere. Quantitatively, the most important man-made greenhouse gas emission is carbon dioxide, which is released with the burning of coal, oil, and natural gas.

Background: The June 1992 "Earth Summit"

To address these (and other) environmental concerns, representatives from more than 140 countries met in June 1992 at the United Nations Conference on Environment and Development (also known as the "Earth Summit") in Rio de Janeiro. At the Earth Summit, participating countries agreed to "protect the climate system" by taking "precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects." Earth Summit participants also agreed: 1) that all Parties should adopt national programs to address greenhouse gas emissions and to periodically report on them; 2) that developed countries "should take the lead in combating climate change," through such measures as technology cooperation with developing countries; 3) that developing countries had "specific needs and special circumstances"; and 4) that industrial nations should aim to reduce greenhouse gas emissions to 1990 levels by the year 2000 (although there is no requirement to do so). On October 7, 1992, the U.S. Senate ratified the global climate change treaty.

The Future: Options for Reducing Greenhouse Gas Emissions

Since fossil fuel consumption is responsible for a large share of anthropogenic greenhouse gas emissions, it follows that reducing fossil fuel consumption will help significantly in cutting such emissions. Lowering fossil fuel consumption can be accomplished by 1) shifting away from fossil fuels towards "cleaner" sources of energy (such as solar and wind) or 2) by reducing the amount of fossil energy needed to produce a given unit of economic output (either by structural shifts away from energy-intensive industries, or by increased efficiency of energy use at various levels of the economy).

Fuel Mix and Carbon Emissions Between 1970 and 1991, world carbon emissions rose 50 percent, while energy use rose 64 percent. Emissions rose more slowly than energy use, in part because reliance on noncarbon-emitting energy sources increased. In the OECD, the energy share of noncarbon fuels rose from 7 percent to 17 percent between 1970 and 1991, reflecting mainly the increased use of nuclear power. During the same period, OECD reliance on natural gas and coal changed little. However, oil's share of the OECD's overall energy consumption fell from 54 percent to 43 percent.

Noncarbon-emitting energy sources have played a relatively smaller role in the fuel mix of developing countries. In 1970, the noncarbon fuel share of developing countries' energy consumption was 4 percent, increasing to 9 percent by 1991. Again, much of the change resulted from increasing reliance on nuclear power. The largest overall change in developing countries' fuel mix, however, involved diminished reliance on coal and increased reliance on natural gas.

For the world as a whole, were the fuel mix of 1970 to be projected to 1991, carbon emissions would have been 11 percent (or 624 million metric tons) higher than actual levels. For the developed countries, emissions would have been 11 percent (or about 306 million metric tons) higher given the OECD fuel mix of 1970. For the developing countries, energy consumption at 1970 fuel mix rates would have increased carbon emissions by 13 percent (or 408 million metric tons).

Factors Affecting Energy Use Trends The energy crises and oil price spikes of the 1970's sparked extensive debate and research on the determinants of energy demand and the relation of energy demand to economic growth. This research revealed that a variety of energy consumption patterns and growth paths are consistent with any given standard of living or economic growth rate. This helps account for the wide degree of variation in international energy use patterns revealed in this report.

In the 1970's and early 1980's, for instance, the rate of growth in OECD energy use fell markedly relative to the rate of OECD economic expansion. Substantial aggregate reductions in energy use per unit of economic output were achieved throughout the OECD during this period, particularly in response to the oil price shocks of 1973 and 1979. As a group, the G-7 countries achieved a 54-percent increase in per capita income between 1970 and 1991, while energy consumption per unit of output declined 27 percent. In contrast, the ratio of energy use to economic output actually rose slightly in the developing countries over that time period.

A variety of factors helps explain this observed divergence in energy use patterns over different country groupings. Of central importance are levels of economic development and the rates of economic change over time. Expanded levels of economic activity, for instance, are highly correlated with increased levels of energy consumption and carbon emissions. Economic growth, which is often accompanied by industrialization, electrification, and improved living standards, helps foster demand for energy in the form of industrial feedstocks, heat, light, and motive power. Not surprisingly, therefore, average per capita consumption in countries with developed economies is six times greater than in the developing countries. As developing countries evolve into newly industrialized economies based on modern systems of transportation, distribution and power generation, rapid rates of growth in energy demand are likely to occur.

The rate of population growth is another key factor affecting economic development and the

demand for energy. In the developed countries, relatively slow population growth over the past several decades relative to rates of economic expansion have been reflected in sharply higher per capita incomes. In contrast, many developing countries have experienced rapid population growth, meaning that economic expansion in these areas has served largely to maintain rather than improve per capita living standards. In this context, energy demand growth may serve not so much to improve living standards but to sustain those so far achieved.

Still another factor conditioning national energy consumption and carbon emissions patterns is the relative mix of energy-intensive industries in particular countries. Some countries, for instance, contain a higher proportion of relatively energy-intensive raw materials and chemical processing industries. Such differences in industrial mix can result in considerable variation in energy demand even among countries with similar levels of per capita income. Differential factor endowments explain much of this variation. Countries with relatively cheap, abundant energy resources (like Canada and the United States), therefore, will commonly specialize in energy-intensive activities.

Differences in energy use technologies to produce comparable products can also give rise to variations in overall energy demand. Technological advance in a particular production process may permit savings in the energy needed to yield a unit of product. Technology practices often differ widely across nations. Identifying best-available practices and promoting widespread adoption of such practices can help foster energy conservation. The degree to which variation in energy demand among countries with similar economic circumstances is due to differences in the penetration of energy efficient technologies is uncertain. However, in particular industries at particular points in time, significant differences have been identified.

Energy prices and social policy also significantly condition national energy demand and carbon emission characteristics. Countries with centrally-planned economies, for instance, generally have pursued economic development policies which foster growth in energy-intensive industries and set energy prices at artificially low levels. As a result, these countries have been commonly characterized by large energy requirements and carbon emissions per unit of economic output compared to more market-oriented economies.

The relative importance of these six factors (economics, population, industrial mix, technology, prices and social policy) on energy demand has fluctuated across countries and over time. The search for and implementation of efficiency improvements, for instance, accelerated mainly after the oil price shocks of 1973 and 1979 and were focused primarily in the developed countries. Although these oil price shocks prompted similar reductions in housing, transportation, and industrial energy intensities throughout the developed countries, national differences in energy use were not eliminated. Countries with heavy reliance on energy-intensive industries at the beginning of the 1970's, for example, were still reliant on them in 1990. A similar finding is true for personal transportation. Since 1970, however, countries with the highest taxes on gasoline also had the highest rate of growth in vehicle registrations. Thus, factors other than price must also have played a strong role in the demand for personal transportation.

A review of historic trends and cross-national comparisons indicates substantial flexibility in the relationship between energy consumption and economic activity. Changes in energy prices, for instance, appear to accelerate efforts to conserve on energy use in developed market economies. Despite the historical experience, uncertainty remains regarding the extent to which energy conservation can achieve stabilization or reduction in energy demand without reducing living

standards and/or raising costs of production. Two potential paths to increased conservation exist. One involves identifying best available practices with regard to energy use and encouraging widespread implementation of such practices. The other involves improving technology so that underlying production possibilities can be sustained while overall energy use is reduced or carbon-based energy is replaced by noncarbon or renewable energy sources.

Report Outline

This report presents an array of national- and sectoral-level energy use indicators across countries and across time. The level of detail presented here is highly aggregated, and as such does not focus on specific energy end-use practices in any one country or at a detailed level within a particular economic sector. However, these summary measures are helpful tools in identifying the effects of differing energy end-use practices. The identification of broad differences in energy-use trends across areas and economic sectors will help to focus further analyses regarding national and international energy and environmental policies. For example, evidence showing a growing share for electricity in worldwide energy consumption underscores the importance of minimizing carbon emissions from the electricity generation sector. This conclusion in turn suggests a potential course of action: namely, the widespread adoption of best-available electricity generation technologies. Thus, the broad review of international energy use patterns presented here should be viewed as a necessary and important starting point for identifying potential opportunities for energy conservation and carbon emission control.

Data Sources

Energy data used in this report were gathered primarily from three main sources: 1) the Energy Information Administration's *International Energy Annual 1992*; 2) the OECD's *Energy Balances of OECD Countries 1990-1991* (and prior editions); and 3) the OECD's *Energy Statistics and Balances of Non-OECD Countries*. Economic and price information is taken mainly from the OECD's *National Accounts, Volume 1: 1960-1991 and Volume 2: 1978-1990*; The WEFA Group's *World Economic Service: Historical Data, July 1993*; and the International Energy Agency's *Energy Prices and Taxes, First Quarter 1993*. Other data sources for this report include: 1) the American Automobile Manufacturer's Association (*World Motor Vehicle Data, 1993 Edition*) for world motor vehicle registration trends; and 2) the Lawrence Berkeley Laboratory for information on residential space heating, automobile utilization, and gasoline fuel efficiency. More detailed sources for all graphs are included in the appendix of this report.[3] Data are available upon request. All gross domestic product[4] statistics for the G-7 countries are expressed in 1985 U.S. dollars, calculated on a purchasing power parity[5] basis. For world comparisons, GDP's are expressed in 1985 U.S. dollars, calculated on a standard exchange-rate basis.

Energy and Carbon Emissions in a World Context

The purpose of this section is to place the developing countries (defined throughout the report to include the current and former centrally-planned economies) and developed countries (members of the OECD) in a global perspective with regards to such indicators as: economic output; energy consumption; and energy-related carbon emissions.

Key findings of this section include:

- ✓ **Since 1970, world economic growth rates have exceeded increases in energy use and energy-related carbon emissions.** Between 1970 and 1992, world gross domestic product increased 85 percent, while energy use and carbon emissions rose 66 percent and 51 percent, respectively.

- ✓ **Growth in world carbon emissions has been less than growth in energy consumption.** This has resulted partly from the increased relative importance of noncarbon-emitting energy sources, primarily nuclear power, and partly from a switch away from coal and towards natural gas in the non-OECD.

- ✓ **Economic growth has been slightly faster in developing than developed countries.** OECD economies grew 83 percent between 1970 and 1992, compared to 88 percent in the non-OECD.

- ✓ **Since 1970, energy use trends have differed markedly for developed and developing countries.** Between 1970 and 1992, OECD energy consumption grew only half as fast as GDP; in contrast, energy consumption grew faster than GDP in the developing countries.

- ✓ **Since 1970, electricity use (and associated carbon emissions) worldwide have increased faster than overall energy use and GDP.** This trend has been especially pronounced in the developing countries.

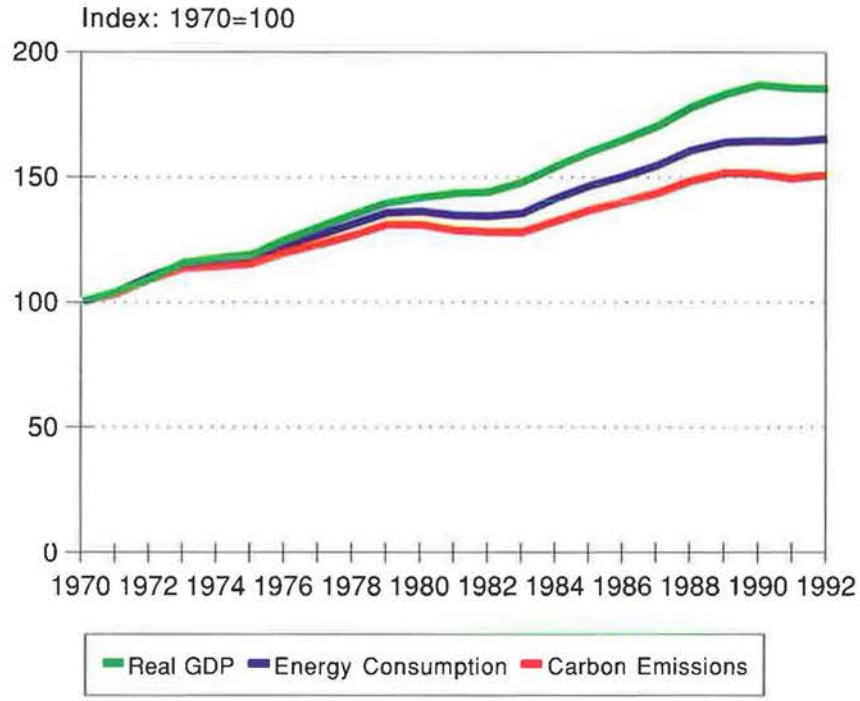
- ✓ **The OECD consistently used less energy to produce a unit of economic output than the rest of the world.** In 1991, for instance, the OECD produced a unit of output using little more than half the energy required by the non-OECD.

- ✓ **Nonetheless, developed countries, with 16 percent of world population as of 1992, accounted for 52 percent of world energy consumption.** The OECD countries in 1992 consumed about six times as much energy per capita as the non-OECD countries. Between 1970 and 1992, however, non-OECD countries increased their share of world energy consumption from 39 percent to 48 percent.

- ✓ **The developed countries as of 1992 accounted for about 48 percent of energy-related world carbon emissions.** As with energy consumption, the OECD's share of world carbon emissions declined between 1970 and 1992 (from 57 percent to 48 percent), while emissions from the developing countries grew rapidly.

- ✓ **Evolution of energy use and carbon emissions patterns in the developing countries towards patterns more like the developed countries is likely to have profound implications for world energy use and carbon emissions.** If developing countries had consumed fossil fuels and emitted carbon at the same per capita rates as developed countries did in 1990, for instance, world fossil fuel consumption would have tripled, while world carbon emissions would have nearly tripled from actual levels.

GDP, Energy Consumption, Carbon Emissions: World Trends



✓ This figure compares changes between 1970 and 1992 in: 1) real GDP (measured on an exchange-rate basis); 2) energy consumption; and 3) energy-related carbon emissions for the world as a whole, using an index based on 1970 levels for each indicator.

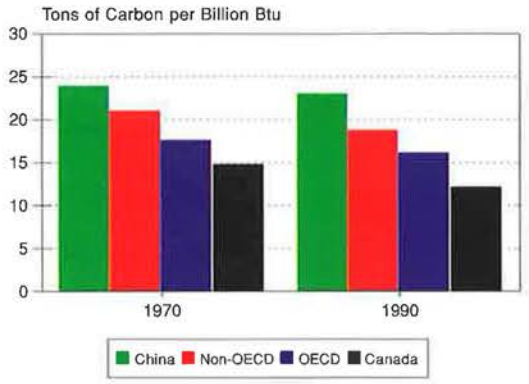
✓ World GDP in constant dollars grew more than 85 percent between 1970 and 1992, while energy consumption and energy-related carbon emissions increased 66 percent and 51 percent, respectively.

✓ Energy consumption and energy-related carbon emissions grew during the 1970's, stabilized after the 1979 oil price shock, increased again following the oil price collapse of the mid-1980's, and levelled off as a result of an economic slowdown in the early 1990's.

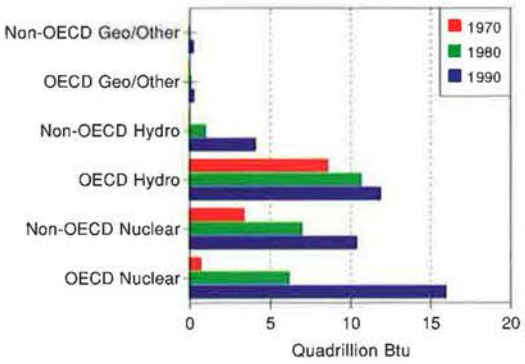
✓ Increased use of noncarbon-emitting energy sources and substitution from coal to natural gas caused carbon emissions to grow less rapidly than energy use.

Carbon Intensity and Non-Fossil Fuels

Carbon Emissions per Unit of Energy Consumption



Non-Fossil Energy Consumption: OECD vs. Non-OECD



✓ The amount of carbon emitted per unit of energy consumption depends on the mix of energy types consumed. Countries like China, which consume large amounts of carbon-rich coal, emit the most carbon per Btu of energy. Countries like Canada, on the other hand, with large shares of non-fossil fuels (hydroelectric, nuclear, geothermal, etc.) are the least "carbon intensive."

✓ The non-OECD is carbon intensive relative to the OECD, due largely to its lower share of nuclear power and the higher share of coal in its fuel mix. Both OECD and non-OECD carbon intensity fell between 1970 and 1990, partly as a result of increased non-fossil fuel consumption, and partly because of reductions in coal use relative to natural gas.

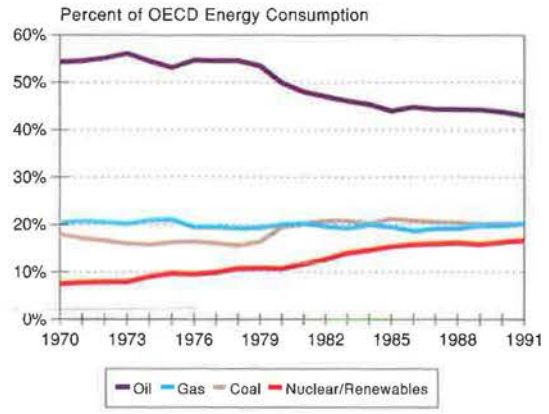
✓ Of all non-fossil fuels, nuclear grew the most rapidly between 1970 and 1990, from 0.9 quads to 20.3 quads (a 2000 percent increase). Much of this growth was concentrated in the OECD countries. During the same period, hydroelectric generation nearly doubled, from 12.2 quads to 22.5 quads.

✓ Commercial power generated from geothermal, solar, wind, and other non-hydroelectric "renewables" rose more than fourfold between 1970 and 1990.

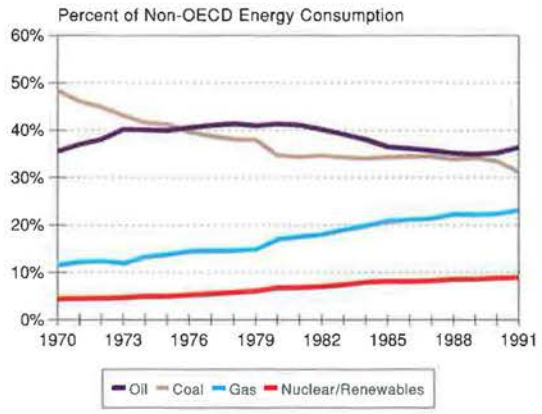
✓ It is important to point out that in both the OECD and non-OECD, the most important "renewable" sources of energy are fuelwood and waste, neither of which are normally reflected in commercial energy data (and are not included in the above graph). In the OECD, consumption of fuelwood and waste was stable at about 3.5 quads between 1970 and 1990. According to the United Nations *Energy Statistics Yearbook* (1979, 1982, and 1991 editions), non-OECD consumption of these "non-commercial" fuels rose from 11 quads to 17 quads during the period.

Fuel Mix in the OECD and Non-OECD

OECD



Non-OECD



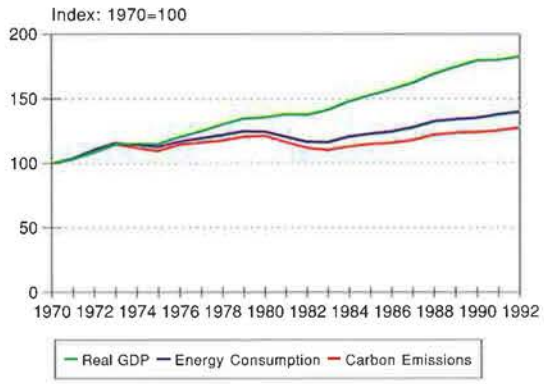
✓ Between 1970 and 1991, oil's share of total OECD energy consumption fell sharply, from 54 percent to 43 percent. Oil was replaced in the fuel mix mainly by nuclear and other renewables, whose share increased from 7 percent to 17 percent. During the same period, the shares of natural gas and coal remained approximately stable.

✓ In contrast to the OECD, oil's share in the non-OECD held steady between 1970 and 1991, while the natural gas share grew rapidly (from 12 percent to 23 percent). Nuclear and renewables also grew during the period. However, the decline in coal use relative to natural gas contributed most to lower carbon emissions intensity in the developing countries.

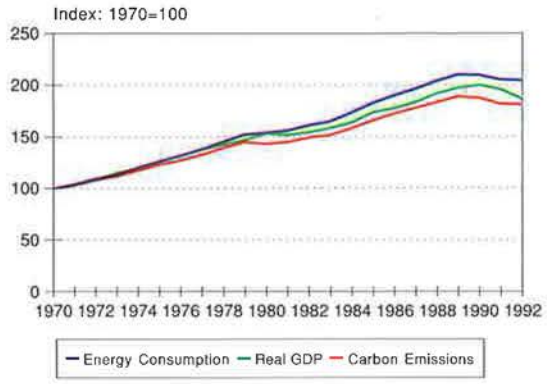
✓ For the world as a whole, the share of fossil fuels in the overall energy mix fell from 94 percent in 1970 to 87 percent in 1991. Among the fossil fuels, only natural gas increased its share, from 17 percent to 22 percent of world energy consumption. The shares of oil and coal both fell sharply - oil from 47 percent to 40 percent, and coal from 30 percent to 26 percent.

GDP, Energy Consumption, Carbon Emissions: Developed vs. Developing

Developed Country Trends:
GDP, Energy, Carbon



Developing Country Trends:
GDP, Energy, Carbon



✓ These figures compare changes between 1970 and 1992 in: 1) real GDP (measured on an exchange-rate basis); 2) energy consumption; and 3) energy-related carbon emissions for the developed and developing countries (including the current and former centrally-planned economies), using an index based on 1970 levels for each indicator.

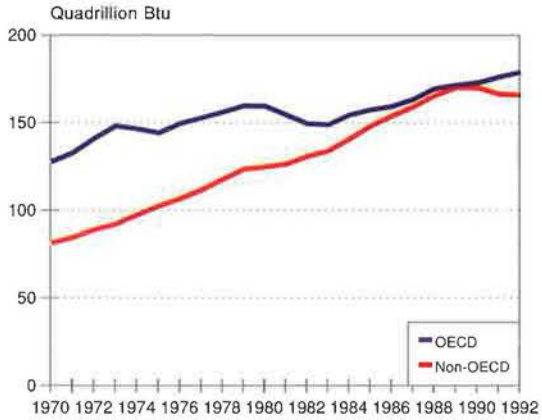
✓ For the developed countries, GDP grew significantly faster than energy consumption between 1970 and 1992. This took place as a result of shifts away from the industrial sector and towards the service sector, reductions in energy intensity within sectors, and improvements in energy efficiency throughout the economy.

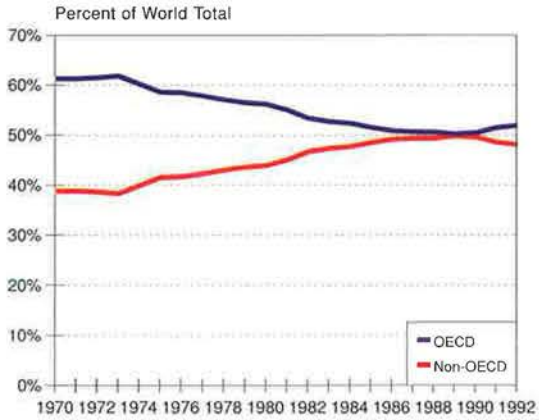
✓ For the developing countries (including current and former centrally-planned economies), energy consumption grew slightly faster than GDP between 1970 and 1992 partly as a result of electrification, industrial development, and growth in private vehicle ownership.

✓ In both developing and developed countries, carbon emissions grew slower than energy consumption and GDP, largely as a result of increased output of nuclear and hydroelectric power (which emit no carbon). (*See attached map for country detail on world carbon emissions per dollar of economic output*)

✓ The decline in energy consumption and carbon emissions after 1990 in developing countries is due to the economic collapse of the former Soviet Union and eastern European countries.

Energy Consumption: Developed vs. Developing





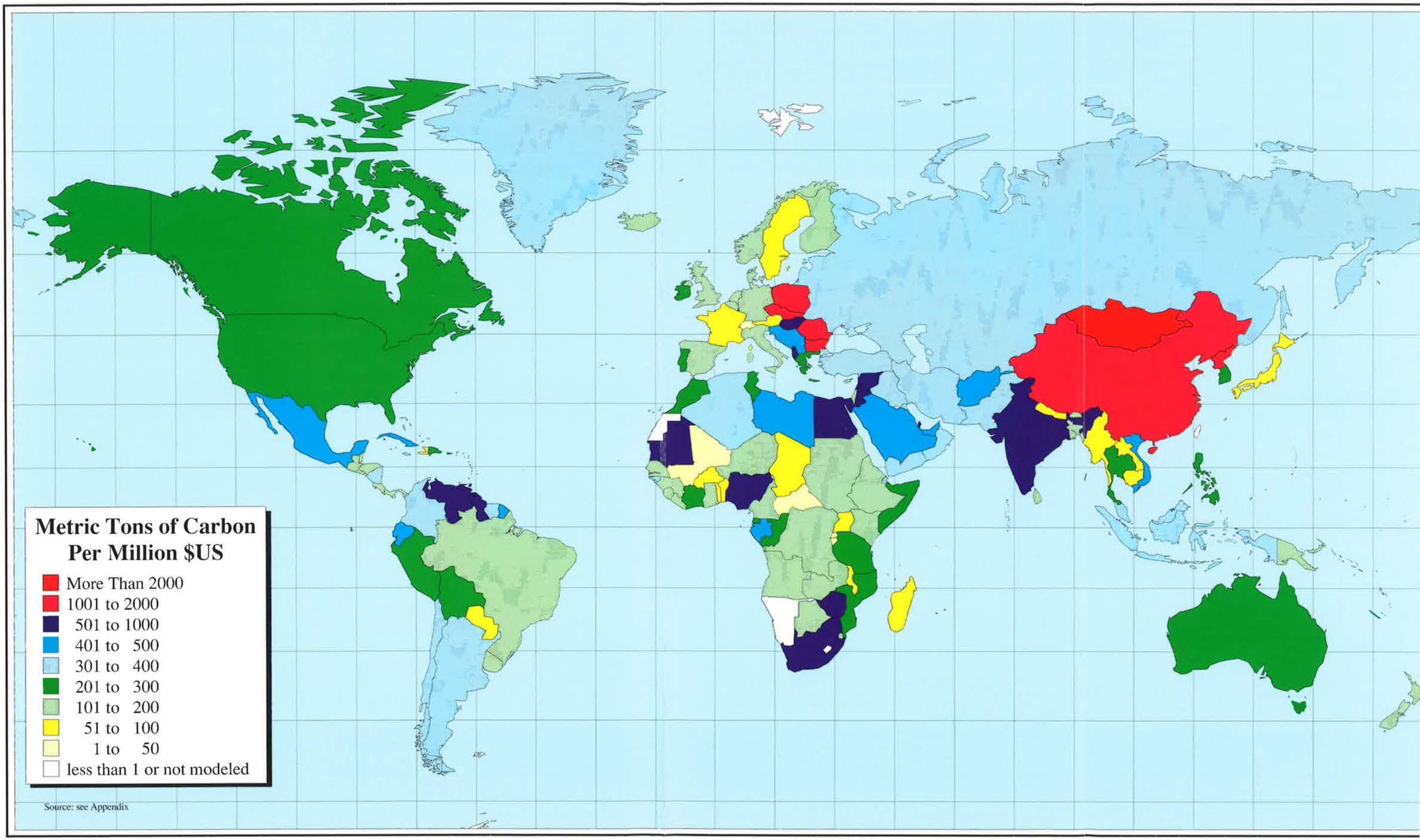
✓ In absolute terms, total world energy demand grew 66 percent from 1970 to 1992, from 208 quadrillion Btu (quads) to more than 340 quads. Non-OECD energy demand more than doubled during the period, while OECD energy demand grew 40 percent.

✓ The OECD share of world energy consumption fell significantly between 1970 and 1992, while the non-OECD share grew rapidly. In fact, if not for the disintegration of the Soviet bloc, which resulted in sharp downturns in economic output and energy consumption in that region, the non-OECD share of world energy demand likely would have surpassed the OECD share during the early 1990's.

✓ Escalating oil prices were a major factor in the decline in OECD energy consumption during the late 1970's and early 1980's. As oil prices fell in the mid-1980's, OECD energy consumption growth resumed.

✓ Energy demand continued to grow in developing countries despite the oil price shocks of the 1970's. This was due largely to the prevalance of price controls and energy subsidies in many of these countries, especially those with centrally-planned economies.

Energy-Related Carbon Emissions Per Dollar GNP, 1990



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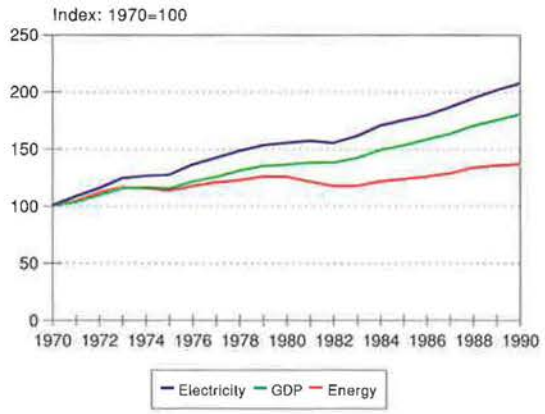
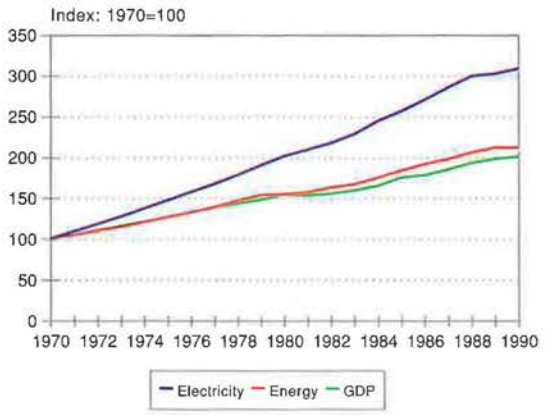
Electricity, Energy, and GDP: Developed vs Developing

Developed Countries



Developing Countries



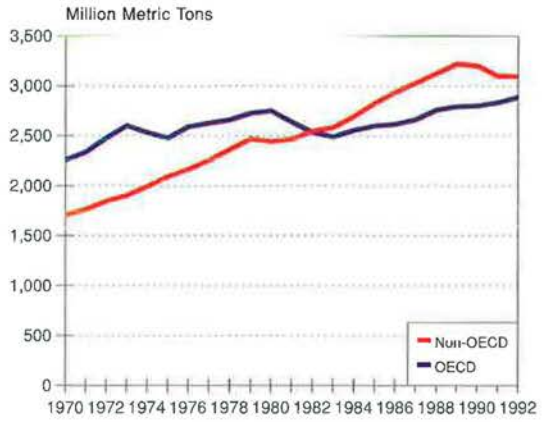
- ✓ These figures compare changes between 1970 and 1990 in: 1) electricity consumption; 2) total energy consumption; and 3) real GDP (measured on an exchange-rate basis) for the developed and developing countries (including the current and former centrally-planned economies), respectively, using an index based on 1970 levels for each indicator.

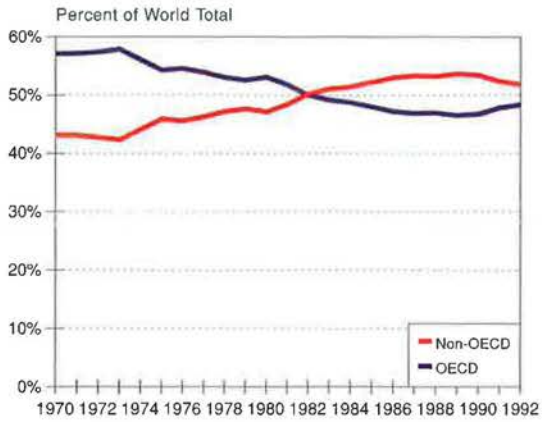
- ✓ Throughout the world, electricity consumption grew significantly faster than overall energy consumption (and GDP) between 1970 and 1990.

- ✓ For the developed countries, electricity consumption doubled between 1970 and 1990, while GDP and energy consumption grew 80 percent and 36 percent, respectively.

- ✓ For the developing countries (including current and former centrally-planned economies), electricity consumption more than tripled between 1970 and 1990, while energy consumption and GDP each approximately doubled.

Carbon Emissions: Developed vs. Developing





✓ Overall, world carbon emissions increased 51 percent between 1970 and 1992, from around 4 billion tons in 1970 to nearly 6 billion tons in 1992. Most of this growth was accounted for by the non-OECD (developing and centrally-planned economies) countries, where carbon emissions grew 82 percent during the period. In contrast, OECD carbon emissions grew 28 percent between 1970 and 1992.

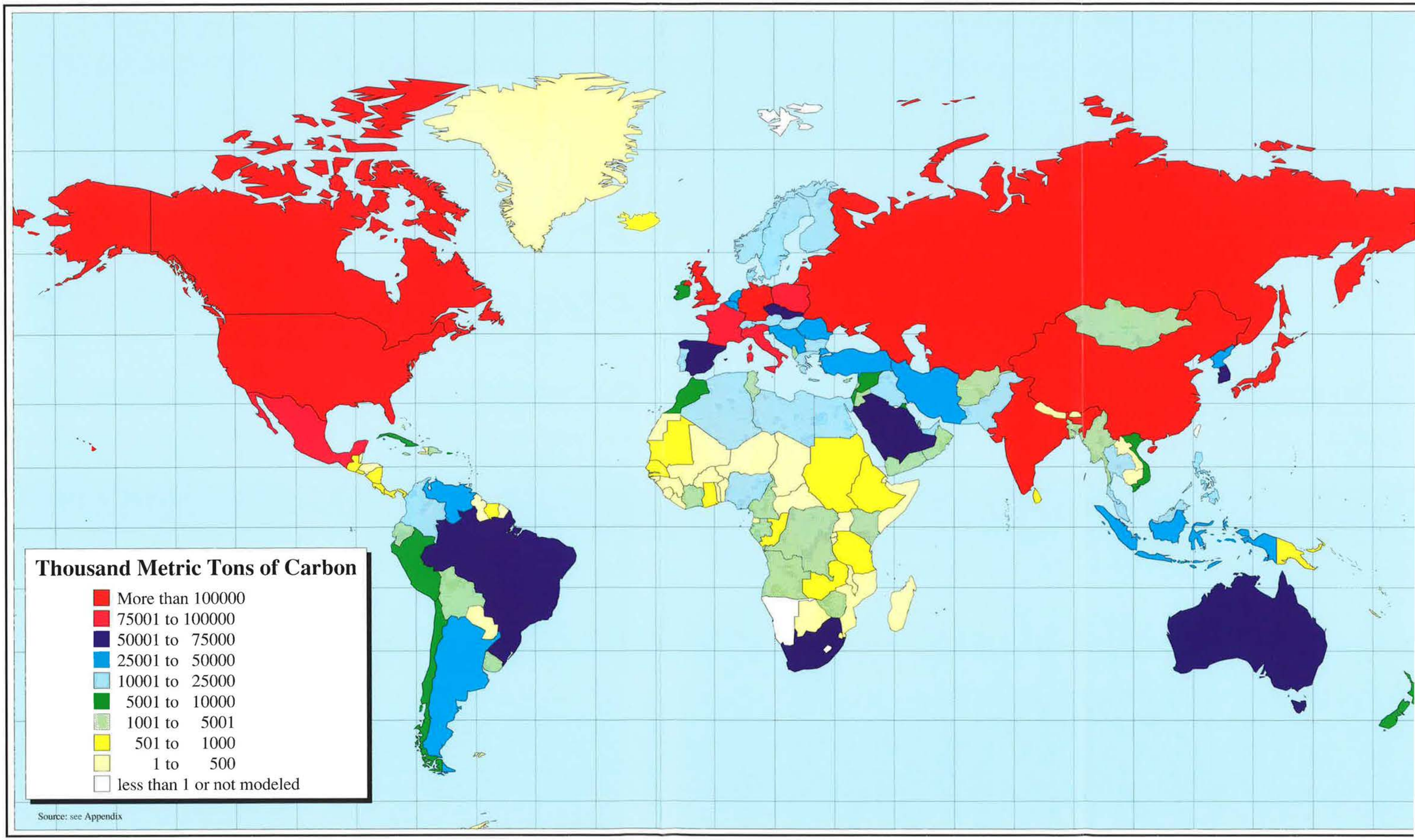
✓ As a result of these differing growth rates, the OECD share of world carbon emissions fell from 57 percent in 1970 to around 48 percent in 1992. In contrast, the non-OECD produced 43 percent of world carbon emissions in 1970, surpassed 50 percent in 1982, and reached 54 percent in 1989, before falling back slightly to 52 percent in 1992 (mainly as a result of sharp economic declines in the former Soviet Union and Eastern Europe).

✓ As a general rule, world carbon emissions have grown along with world energy consumption, although at a slower rate. In the non-OECD, for instance, energy consumption more than doubled between 1970 and 1992, while carbon emissions increased 82 percent. In the OECD, energy consumption increased 40 percent between 1970 and 1992, while carbon emissions grew 28 percent.

✓ The slower growth of carbon emissions relative to energy consumption between 1970 and 1992 can be explained largely by increased nuclear and hydroelectric power generation during the period.

✓ The United States was the world's largest single source of energy-related carbon emissions in 1990, accounting for 22 percent, followed by the former Soviet Union (17 percent) and China (11 percent). (*See attached map for country detail on world carbon emissions*)

Energy-Related Carbon Emissions, 1990



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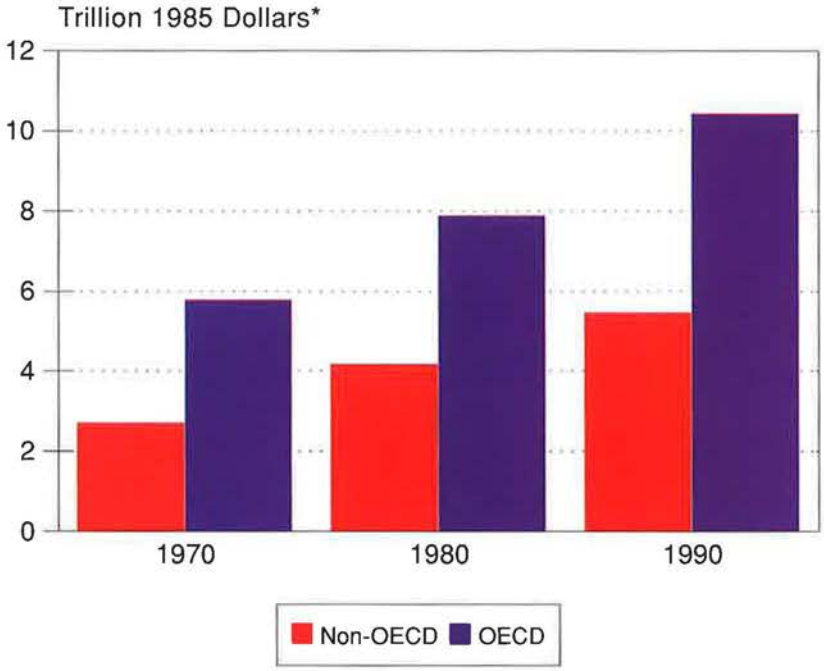
Gross Domestic Product: Developed vs. Developing



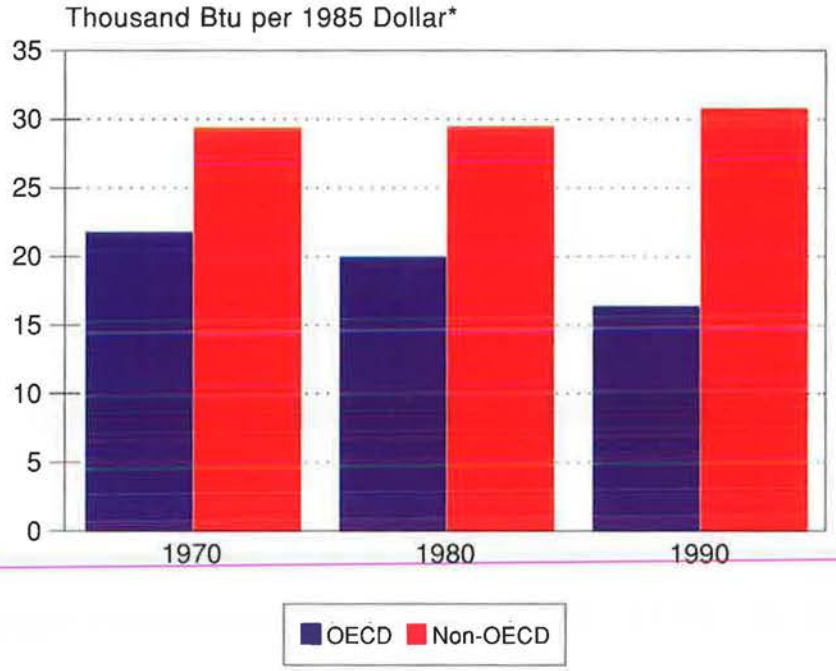
*Exchange rate basis

✓ World gross domestic product (in constant 1985 dollars, measured on an exchange-rate basis) grew 87 percent between 1970 and 1990, from $8.5 trillion to $15.9 trillion. The non-OECD, which contains more than 80 percent of the world's population, has consistently accounted for less than 35 percent of world economic output.

✓ The developed countries as of 1990 accounted for 66 percent of world gross domestic product. The OECD's share of world GDP declined from 68 percent in 1970, due to a slightly faster rate of economic growth in the developing countries.

✓ In developed countries, real per capita GDP increased 51 percent between 1970 and 1990, from about $8,100 to $12,200 per person. In comparison, per capita income in the developing countries, where population grew rapidly, increased during the same period by 35 percent, from about $900 to $1,200 per person.

Energy Consumption per Dollar of GDP: Developed vs. Developing



*Exchange rate basis

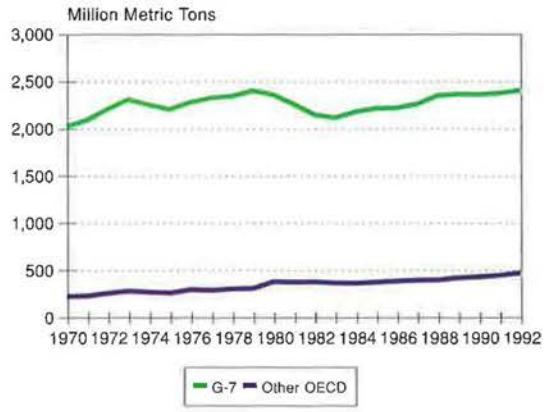
✓ In the non-OECD, energy consumption grew more rapidly than GDP between 1970 and 1990. As a result, non-OECD energy consumption per dollar of GDP increased during the period, to more than 30,000 Btu per dollar of output (in constant 1985 dollars, measured on an exchange-rate basis).

✓ In contrast to the non-OECD countries, OECD energy consumption grew much more slowly than GDP between 1970 and 1990. This resulted in a sharp decline in the OECD energy consumption per unit of economic output, from 22,000 Btu per dollar in 1970 to only 16,500 Btu per dollar in 1990.

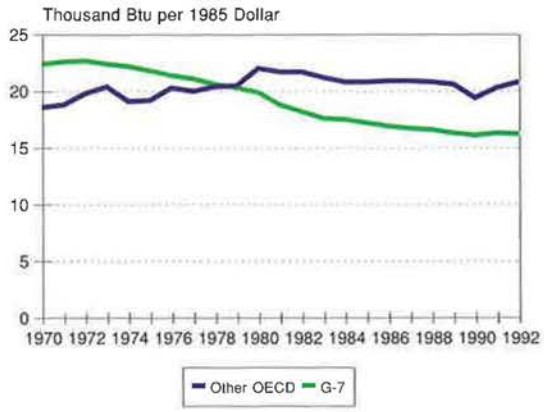
✓ As a result of these opposing trends, the gap between OECD and non-OECD energy use per dollar of GDP widened significantly between 1970 and 1990. As a consequence, by 1990 the OECD was able to produce a unit of economic output using little more than half the energy required by the developing countries.

Developed Countries: Carbon Emissions; Energy Consumption per Dollar of GDP

Energy-Related Carbon Emissions



Energy Consumption per Dollar of GDP



- ✓ Total OECD energy-related carbon emissions grew 28 percent (or 627 million tons) between 1970 and 1992, from 2.3 billion metric tons to 2.9 billion metric tons.

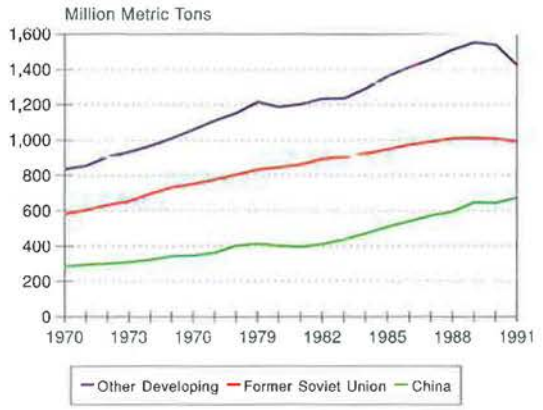
- ✓ "Group of Seven" (G-7) carbon emissions alone, however, grew only 19 percent between 1970 and 1992. Meanwhile, carbon emissions in the rest of the OECD (i.e., Australia, New Zealand, and Europe outside the G-7) more than doubled (from 226 to 472 million metric tons).

- ✓ G-7 energy consumption per constant dollar of GDP (measured on an exchange-rate basis) declined significantly between 1970 and 1992; in contrast, energy consumption per dollar of GDP increased slightly in the other developed countries during the period.

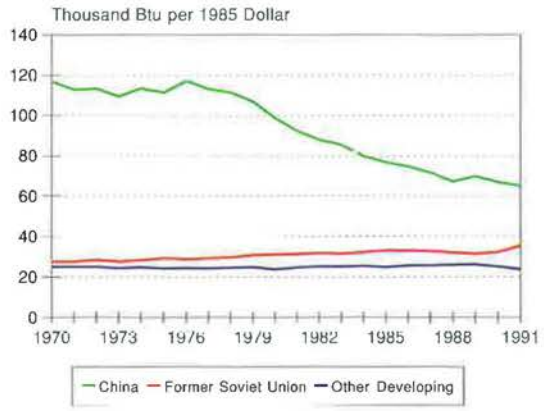
- ✓ The G-7 is broken out for three main reasons: 1) it makes up a sizeable share of the OECD in terms of GDP, energy consumption, and carbon emissions; 2) both aggregate and sectoral data are readily available for this group of countries; and 3) energy use per dollar of GDP has declined most rapidly in the G-7, which may provide broader lessons for improving energy performance elsewhere.

Developing Countries:
Carbon Emissions; Energy Consumption per Dollar of GDP

Energy-Related Carbon Emissions



Energy Consumption per Dollar of GDP



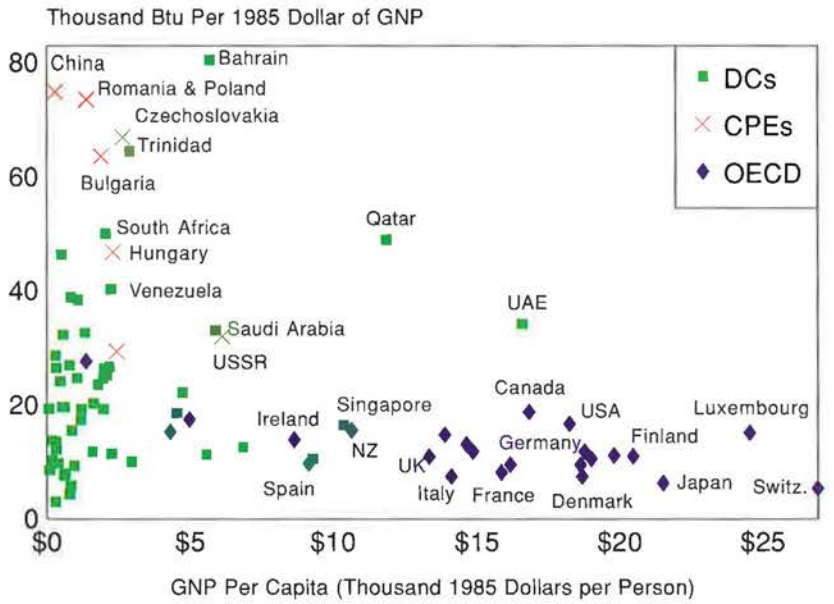
- ✓ Energy-related carbon emissions by developing countries increased 82 percent (or 1.4 billion metric tons) between 1970 and 1991, from 1.7 billion metric tons to 3.1 billion metric tons.

- ✓ China and the former Soviet Union combined accounted for nearly 58 percent (or 805 million metric tons) of the total increase in developing countries' carbon emissions between 1970 and 1991.

- ✓ China and the former Soviet Union also consistently consumed more energy per dollar of output between 1970 and 1991 than other developing countries. China's energy consumption per constant dollar of GDP (measured on an exchange-rate basis) declined significantly after the mid-1970's, but as of 1991 still remained more than twice as high as other developing countries.

Economic Development and National Energy Use Patterns

1990 Energy Consumption per Dollar of GNP vs.
Per Capita GNP for 83 Countries



✓ This figure compares: 1) energy consumption per dollar of gross national product (GNP, measured in constant 1985 dollars on an exchange-rate basis); and 2) GNP per capita for 83 countries (centrally-planned economies - CPE's, other developing countries - DC's, and developed countries - OECD) for 1990.

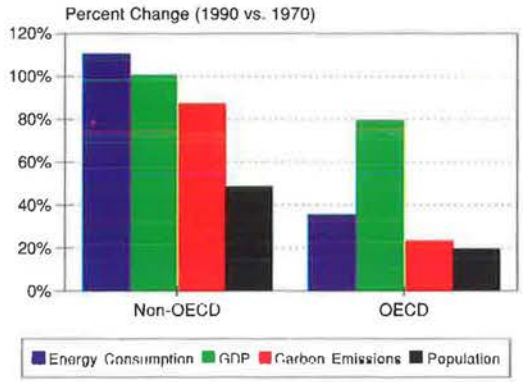
✓ The distribution pattern of this figure suggests three distinct country groupings: 1) developed countries tend to display relatively high per capita incomes and low levels of energy consumption per dollar of GNP (E/GNP); 2) developing countries exhibit low per capita incomes *and* low E/GNP ratios; and 3) centrally-planned economies exhibit the opposite pattern of the developed countries, with low per capita incomes and high energy consumption per dollar of economic output.

✓ Among the developing countries, major oil producers tend to consume the most energy per unit of GNP, while maintaining relatively high per capita income levels.

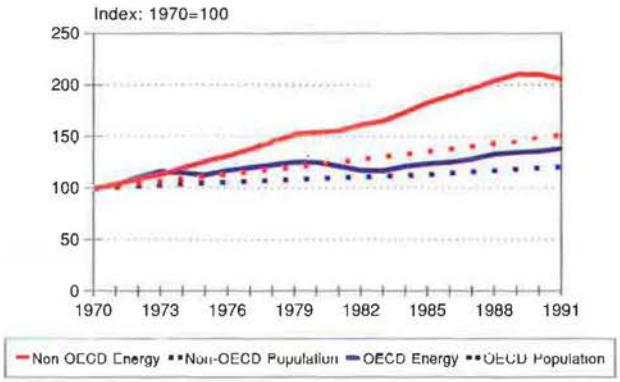
✓ Centrally-planned economies tend to use the most energy per unit of GNP, largely because their policies have kept energy prices artificially low.

Population, Economic Growth, Energy and Carbon

Relative Change in Selected Indicators: 1970-1990



Population, Energy Consumption Trends: OECD vs. Non-OECD



✓ Growth in energy demand (and energy-related carbon emissions) is driven by two main forces - economic growth and population increases - both of which increase demands on many resources, including energy. (*See attached map for country detail on world carbon emissions per capita*)

✓ This has been particularly true in the developing countries, where population grew 49 percent between 1970 and 1990. Also promoting rapid growth in energy demand in the developing countries during this period were rapid electrification, industrialization, and increased automobile ownership.

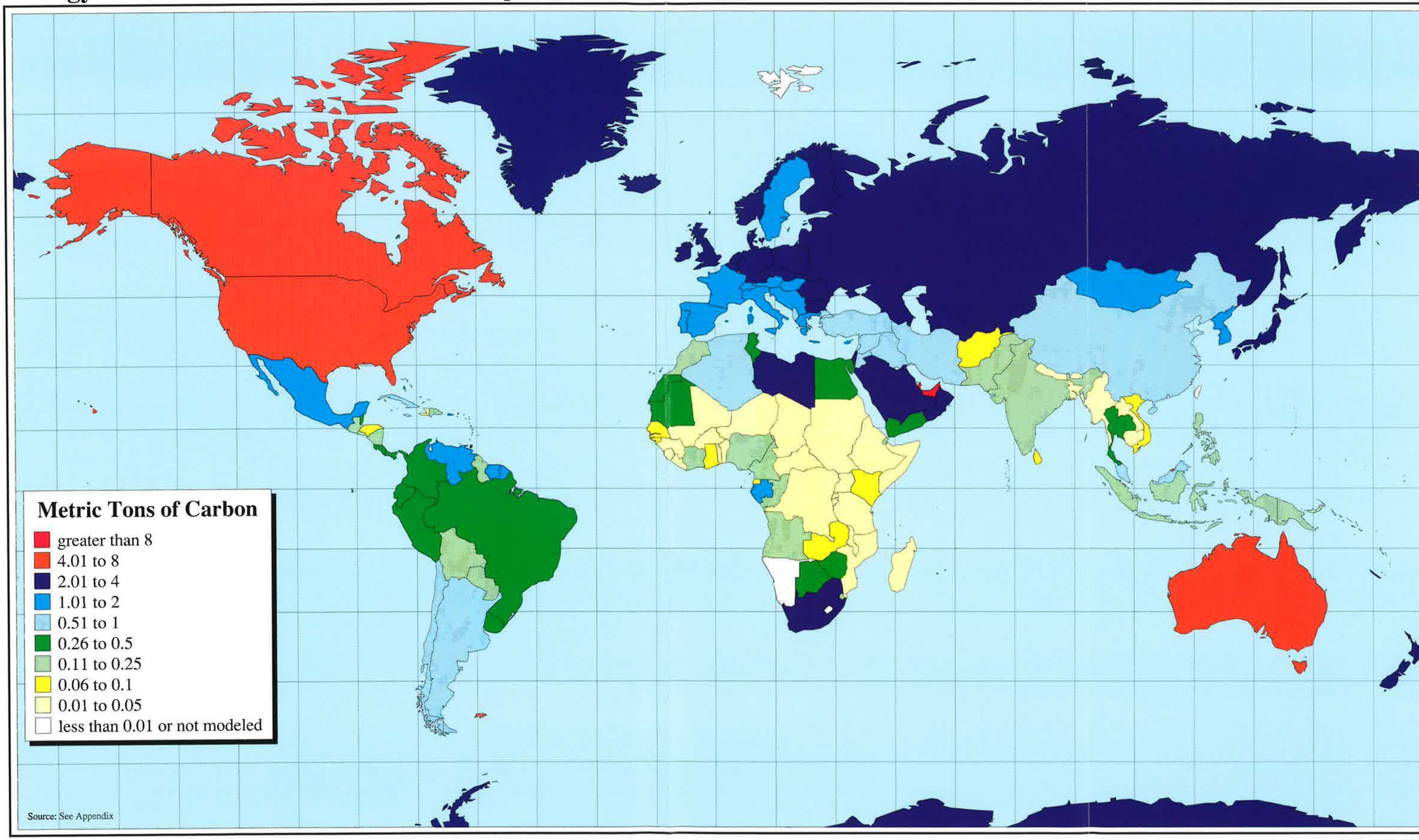
✓ Between 1970 and 1990, energy demand grew faster than population in both the non-OECD and the OECD. Energy demand also grew slightly faster than GDP in the non-OECD, but significantly slower than GDP in the OECD.

✓ Throughout the world, carbon emissions grew faster than population, but slower than GDP and energy consumption between 1970 and 1990.

✓ As a result of more rapid growth in world energy demand relative to population between 1970 and 1991, the amount of energy consumed per capita worldwide increased by 13 percent, from 56 to 63 million Btu per person.

✓ Growth in energy consumption per capita was more than twice as rapid in the non-OECD than in the OECD (35 percent vs. 15 percent) between 1970 and 1991. As of 1991, the OECD consumed nearly six times more energy per person than the non-OECD (204 million Btu vs. 36 million Btu per person).

Energy-Related Carbon Emissions Per Capita, 1990



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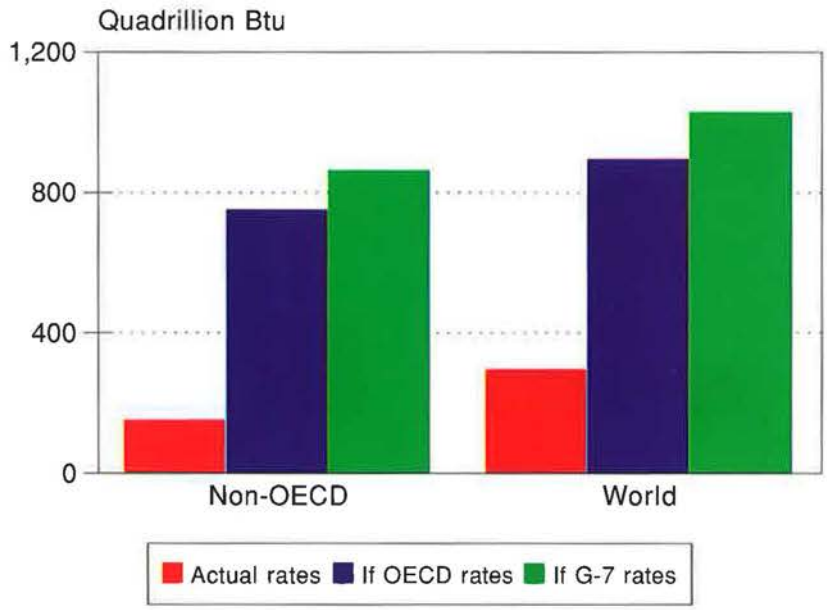
Economic Development and World Fossil Fuel Consumption

1990 World Fossil Fuel Consumption Assuming G-7 and OECD Fossil Fuel Consumption Rates per Capita



- ✓ This figure compares: 1) actual 1990 fossil fuel (oil, coal, and natural gas) consumption by the developing countries and the world as a whole; 2) *hypothetical* 1990 fossil fuel consumption if other countries had consumed as much fossil energy per person as the OECD average; and 3) *hypothetical* 1990 fossil fuel consumption if other countries had consumed as much fossil energy per person as the G-7 average.

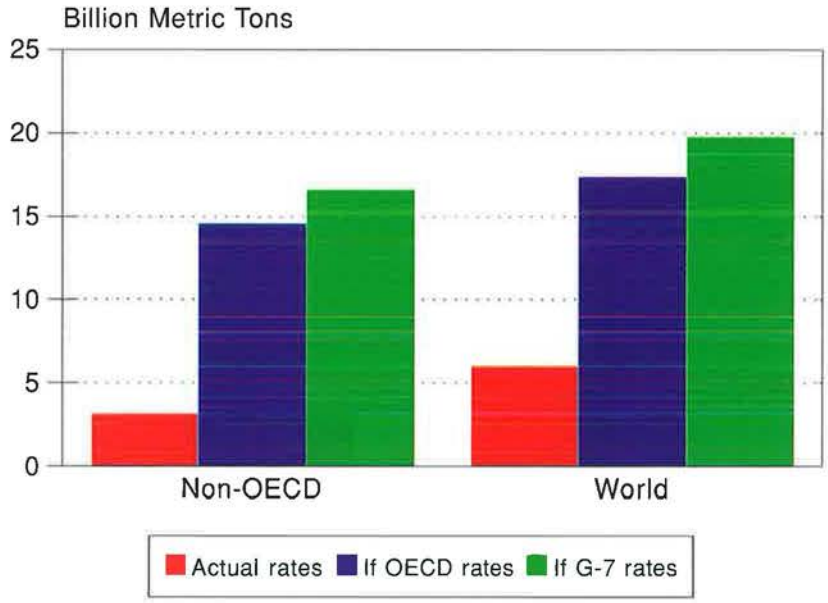
- ✓ If the rest of the world in 1990 had consumed fossil fuels at the same rate as the OECD, world fossil fuel consumption would have *tripled* from actual levels, while non-OECD fossil fuel consumption would have grown about *five-fold.*

- ✓ If the rest of the world in 1990 had consumed fossil fuels at G-7 average rates, world fossil fuel consumption would have *more than tripled*, while developing countries fossil fuel consumption would have grown *more than five-fold.*

- ✓ In sum, if fossil fuel consumption patterns in the rest of the world evolve towards OECD per capita rates, world fossil fuel consumption is likely to rise significantly.

Economic Development and World Carbon Emissions

1990 World Carbon Emissions Assuming G-7 and OECD Carbon Emissions Rates per Capita



✓ This figure compares: 1) actual 1990 energy-related carbon emissions by the developing countries and the world as a whole; 2) *hypothetical* 1990 energy-related carbon emissions if other countries had emitted as much carbon per person as the OECD average; and 3) *hypothetical* 1990 energy-related carbon emissions if other countries had emitted as much carbon per person as the G-7 average.

✓ If the rest of the world in 1990 had emitted carbon at the same rate as the OECD, world carbon emissions would have *nearly tripled* from actual levels, while non-OECD carbon emissions would have *more than quadrupled.*

✓ If the rest of the world in 1990 had emitted carbon at G-7 average rates, world carbon emissions would have *more than tripled*, while developing countries carbon emissions would have grown *more than five-fold.*

✓ In sum, if carbon emissions patterns in the rest of the world evolve towards OECD carbon emissions per capita rates, world carbon emissions are likely to rise significantly.

Energy Use, Economic Growth, and Carbon Emissions in the G-7

The purpose of this section is to provide information on differences in energy consumption patterns within the G-7, and to look at changes in these patterns by examination of aggregate indicators such as: world oil prices; energy consumption trends by fuel type; GDP (measured on a purchasing power parity basis), energy consumption, and carbon emissions per capita; energy consumption and energy-related carbon emissions per dollar of output; and overall energy-related carbon emissions.

Key findings of this section include:

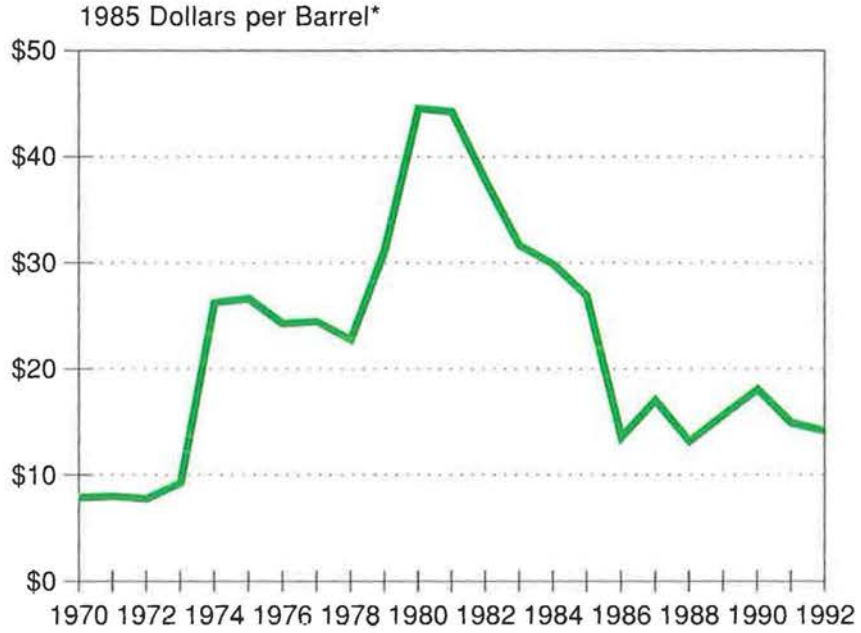
✓ **G-7 energy use per real dollar of output fell significantly between 1970 and 1991.** Most of this decline was achieved immediately following the oil price shocks of 1973 and 1979. Following the oil price decreases of the mid-1980's, energy use per dollar of output in the G-7 tended to stabilize.

✓ **G-7 energy-related carbon emissions were relatively stable between 1970 and 1992.** Although G-7 energy consumption increased 32 percent between 1970 and 1992, energy-related carbon emissions over the same period increased only 19 percent.

✓ **This reduction in G-7 carbon/GDP ratios since 1970 reflects two important trends.** First, G-7 countries reduced the amount of energy required to produce a unit of output. Second, G-7 consumption of nuclear and hydroelectric power (which emit no carbon) grew significantly, from around 6 percent in 1970 to nearly 16 percent of total energy consumption in 1992. As a result, although fossil fuel use increased between 1970 and 1992, its share in the total fuel mix declined significantly.

✓ **Except in the United States, G-7 energy use per capita increased between 1970 and 1991.** Differences among countries within the G-7 tended to persist over time.

World Oil Price

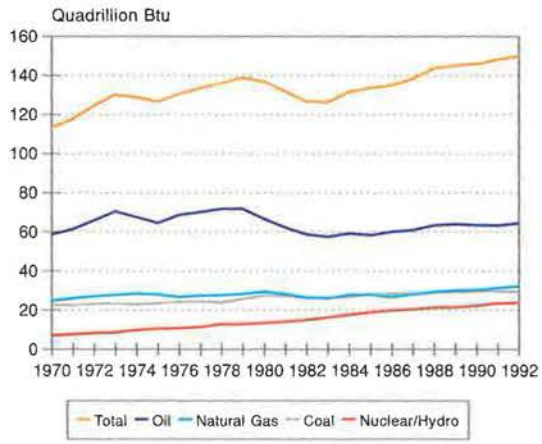


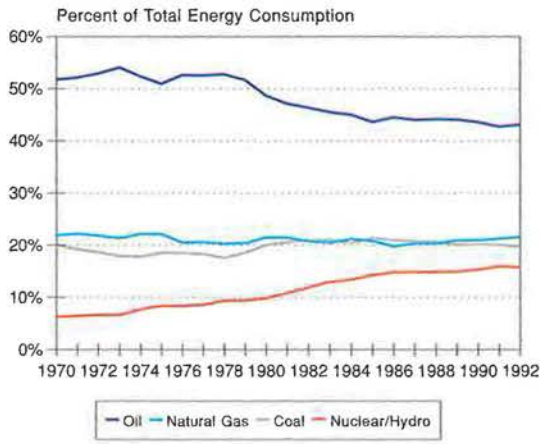
*Imported Refiner Acquisition Cost

✓ The price of oil (Imported Refiner Acquisition Cost) fluctuated greatly in constant 1985 dollars between 1970 and 1992, rising from less than $8 per barrel in 1970 to nearly $45 per barrel in 1980, before falling sharply in the mid-1980's.

✓ These fluctuations in oil prices have had far-reaching implications for energy consumption patterns and levels. For instance, the price shocks of the 1970's were followed by rapid declines in energy consumption per dollar of output in the developed countries. The price collapse of the mid-1980's tended to moderate this trend.

G-7 Energy Consumption by Fuel Type





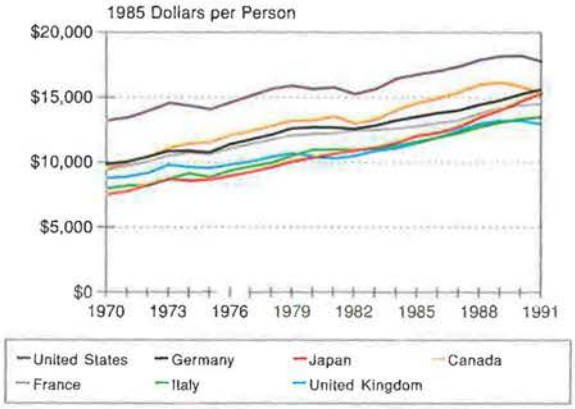
✓ Total energy consumption in the G-7 increased 36 quads between 1970 and 1992. Of this increase, nuclear and hydroelectric power accounted for more than 16 quads. G-7 fossil fuel consumption grew about 20 quads during this period, of which natural gas accounted for 7 quads, coal for 7 quads, and oil for 6 quads.

✓ As a share of G-7 total energy consumption, oil fell from 52 percent in 1970 to 43 percent in 1992, while natural gas and coal remained nearly constant. During the same period, nuclear and hydroelectric power increased their share of G-7 energy consumption, from 6 percent to 16 percent.

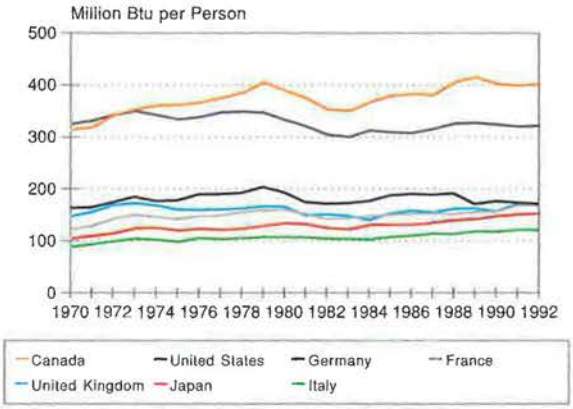
✓ The decline in oil's share of G-7 energy consumption was caused in large part by the oil price spikes of the 1970's. Since the oil price collapse of the mid-1980's, oil's share has not recovered.

GDP and Energy Consumption per Capita

GDP per Capita



Energy Consumption per Capita



✓ From 1970 to 1991, U.S. per capita income increased 34 percent. Over the same time frame, Japan's per capita income increased 104 percent, Italy's 70 percent, and the G-7 average 54 percent.

✓ Although per capita GDP increased 54 percent throughout the G-7 between 1970 and 1991, energy consumption per capita increased only 12 percent during the same period.

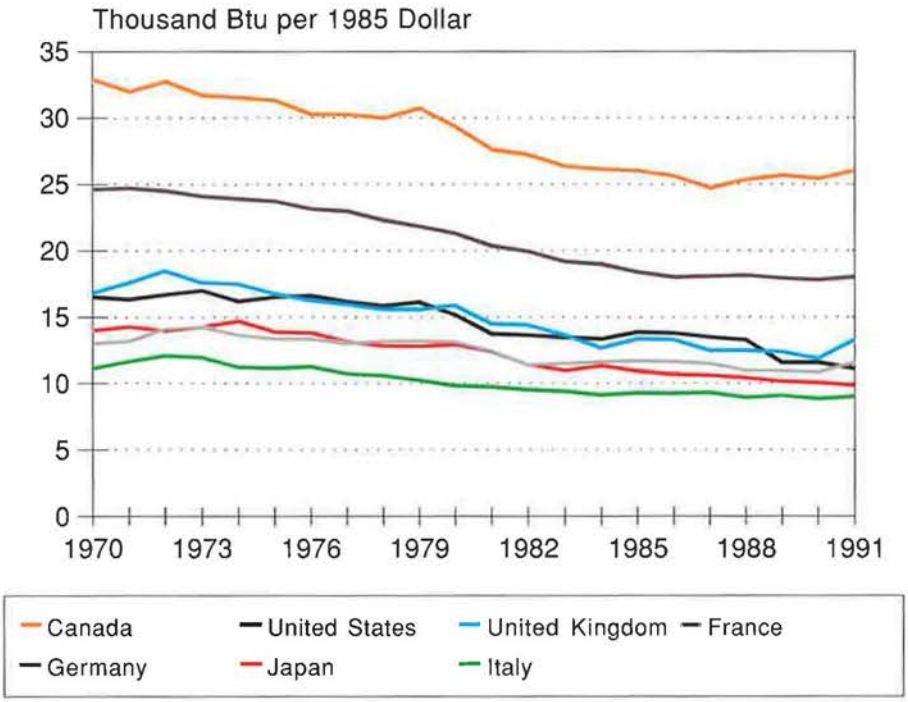
✓ Canada has generally maintained the highest energy consumption per capita among the G-7 countries. This results largely from Canada's heavy reliance on hydroelectric power to support energy-intensive industries, such as aluminum manufacturing.

✓ In the early 1970's, U.S. and Canadian per capita energy consumption ratios were approximately equal. Following the 1973 oil price shock, however, U.S. per capita energy consumption remained constant or fell slightly, while Canada's energy per capita ratio increased. As a result of these divergent trends, the United States in 1992 consumed about 20 percent less energy per person than Canada. Other G-7 countries consistently consumed far less energy per capita than Canada and the United States between 1970 and 1992.

✓ While energy use per dollar of output fell sharply between 1970 and 1991, the amount of energy consumed per capita *increased* in all G-7 countries except the United States.

✓ For the United States, population grew 17 percent between 1970 and 1986, while energy consumption increased only 11 percent, resulting in a decline in energy consumption per capita of 5.4 percent. Between 1986 and 1992, however, U.S. energy consumption grew nearly twice as fast as population, resulting in a 4.6 percent increase in energy consumption per capita.

Energy Consumption per Dollar of GDP



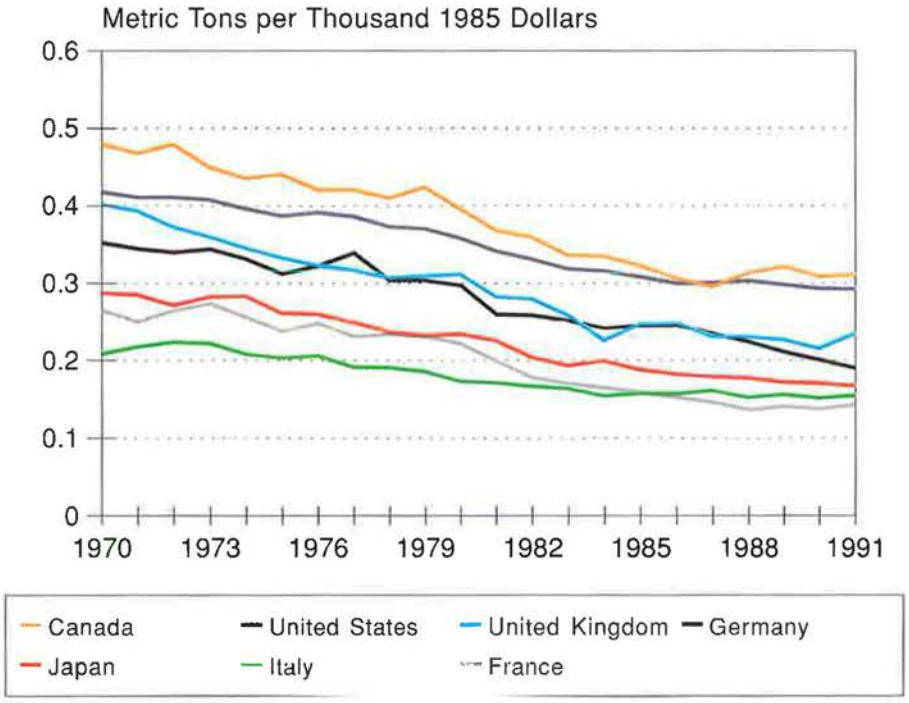
✓ Between 1970 and 1991, U.S. real GDP increased 66 percent, while energy consumption rose only 21 percent, indicating that economic output and energy consumption need not rise in lockstep. For the G-7 as a whole, real GDP increased 79 percent between 1970 and 1991, while energy consumption increased 31 percent.

✓ Most of this improvement followed the oil price shocks of 1973 and 1979. Following the 1986 oil price collapse, energy use per dollar of output stabilized or even increased in the G-7. For example, U.S. and Canadian energy use per dollar of output increased between 1986 and 1991 (by 0.2 percent and 1.7 percent, respectively), while the G-7 as a whole decreased slightly (by 3.7 percent).

✓ Energy use per dollar of output declined an average of 27 percent in the G-7 between 1970 and 1991. In relative terms, Germany fell the most (33 percent), France fell the least (11 percent), and the United States fell 27 percent. Differences between G-7 countries tended to persist over time.

✓ Canada consistently consumed by far the most energy per dollar of output among G-7 countries between 1970 and 1991. This resulted largely from Canada's relatively high reliance on energy-intensive industries based on the use of hydroelectric power. Overall, hydroelectricity accounted for 28 percent of Canada's total energy consumption in 1991, compared to 4 percent in the United States and 6 percent for the G-7 as a whole.

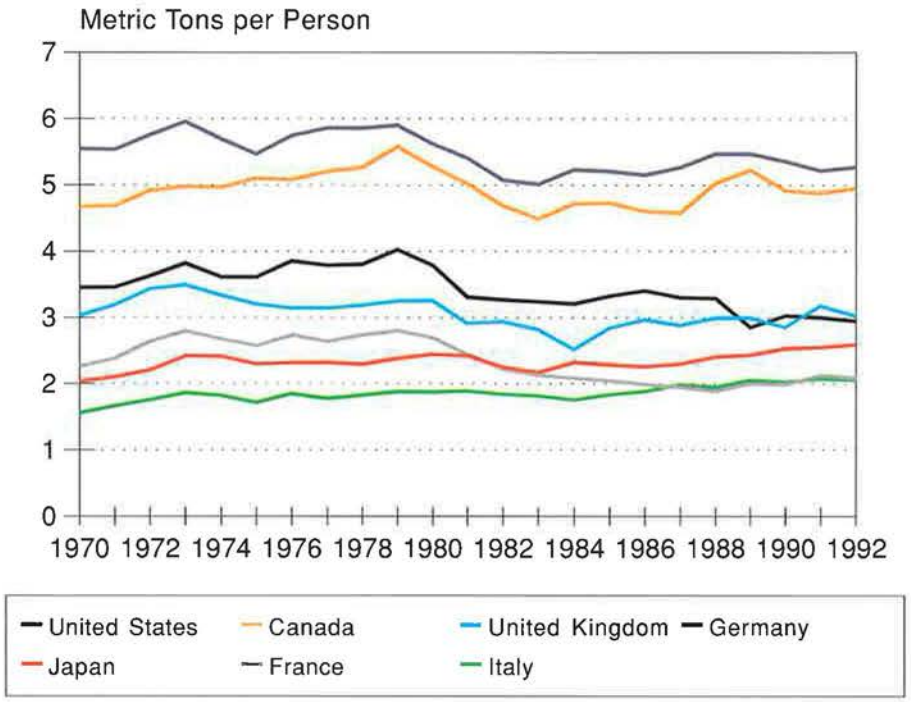
Energy-Related Carbon Emissions per Dollar of GDP



✓ The amount of carbon emitted per constant dollar value of output (carbon/GDP) in the G-7 countries fell significantly between 1970 and 1991. Throughout the period, the United States and Canada had the highest carbon/GDP ratios, while Japan, Italy, and France had the lowest.

✓ In all G-7 countries, the reduction in carbon/GDP ratios exceeded the decline in E/GDP ratios from 1970 to 1991. The largest relative decline in carbon/GDP ratios in those years occurred in Germany (43 percent), France (39 percent), and Japan (39 percent), with the smallest in Italy (22 percent), the United Kingdom (29 percent), the United States (30 percent), and Canada (35 percent).

Energy-Related Carbon Emissions per Capita

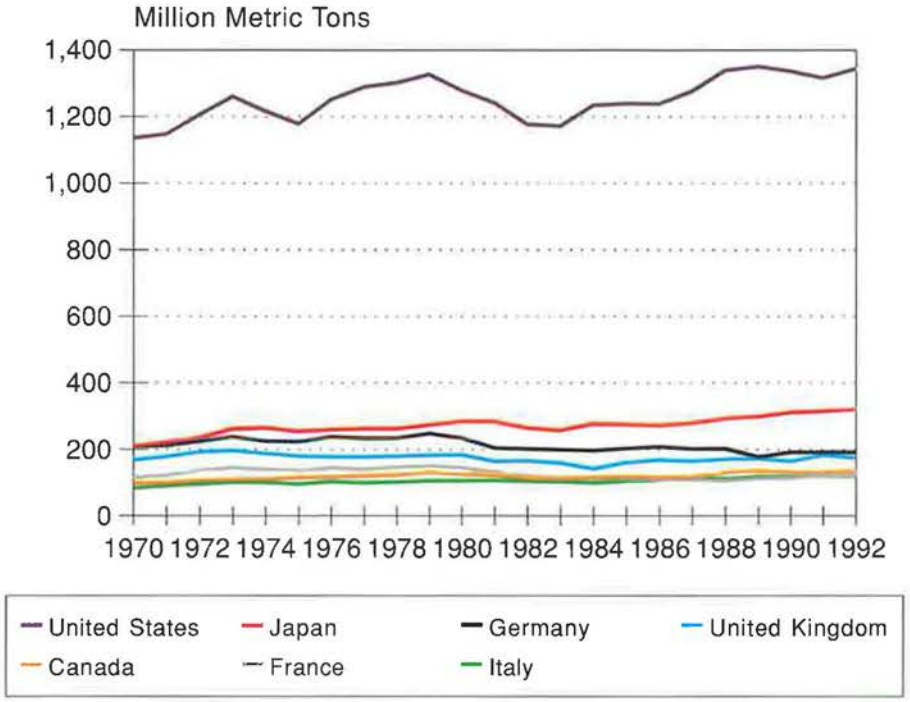


- ✓ The amount of carbon emitted on a per capita basis in the G-7 countries increased only 2 percent between 1970 and 1992.

- ✓ As a general rule, differences in per capita carbon emissions between G-7 countries tended to persist over time. Two important exceptions are France and Germany, where the growth in nuclear power resulted in a significant reductions in per capita carbon emissions beginning in the late 1970's.

- ✓ In general, carbon emissions per capita rose slowly during the 1970's, fell sharply for a few years following the 1979 oil crisis, but then tended to level off or rise slowly as oil prices fell in the mid-1980's.

Energy-Related Carbon Emissions



✓ In 1992, the G-7 alone accounted for 84 percent of OECD energy-related carbon emissions. Between 1970 and 1992, OECD energy-related carbon emissions grew 28 percent, to 2,879 million metric tons. During the same period, G-7 energy-related carbon emissions grew 19 percent, to 2,407 million metric tons.

✓ The United States has consistently accounted for about one half of energy-related carbon emissions within the G-7.

✓ Among the other G-7 countries, Japanese energy-related carbon emissions grew 53 percent between 1970 and 1992, while Italy increased 43 percent, and Canada 35 percent. U.K., French, and German energy-related carbon emissions remained approximately constant or fell slightly during the period.

G-7 Sectoral Analysis

*The purpose of this section is to provide information on structural differences among G-7 countries which help explain: 1) differences in energy consumption patterns within the G-7; and 2) changes in those patterns since 1970. To this end, the section will examine energy use patterns and trends in the major economic sectors (**industrial, transportation, and residential/commercial, including services**); as well as in **electricity generation**.*[6]

Key findings of this section include:

✓ **The G-7 countries differ in their sectoral shares of national energy consumption.** The U.S. transportation sector, for instance, accounted in 1990 for 28 percent of U.S. energy consumption; in contrast, Japan's transportation sector accounted for only about 18 percent of Japan's energy use.

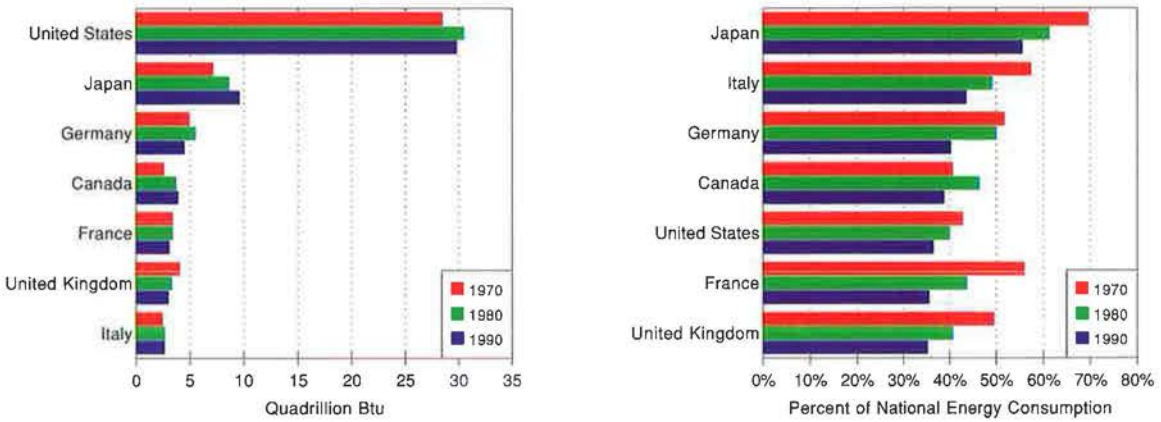
✓ **G-7 sectoral shares have changed over time.** Between 1970 and 1990, for instance, the transportation sector significantly increased its share of G-7 energy consumption, especially in Europe. During the same period, residential/commercial's share also increased throughout the G-7, particularly in Japan, while industry's share of total energy consumption declined throughout the G-7.

✓ **The G-7 countries differ in their energy use patterns within sectors.** In Canada and the United States, for instance, energy-intensive industries (such as paper and pulp, primary metals, and petroleum refining) in 1990 accounted for around 60 percent (or more) of total industrial energy consumption. In other G-7 countries, energy-intensive industries were relatively less important, and appear to have declined since 1970.

✓ **The G-7 countries differ in their lifestyles and living standards.** The average American, for instance, has a relatively larger home and more cars compared to citizens of other G-7 countries. Throughout the G-7, living standards (as measured by vehicles per person, appliance ownership, etc.) increased significantly between 1970 and the early 1990's.

✓ **The G-7 countries differ in their retail energy prices, primarily due to differences in their tax regimes.** Gasoline prices, for instance, ranged in 1992 from $3.89 per gallon in Italy to $1.13 per gallon in the United States. Average fleet efficiencies tend to be higher in those countries with higher gasoline prices.

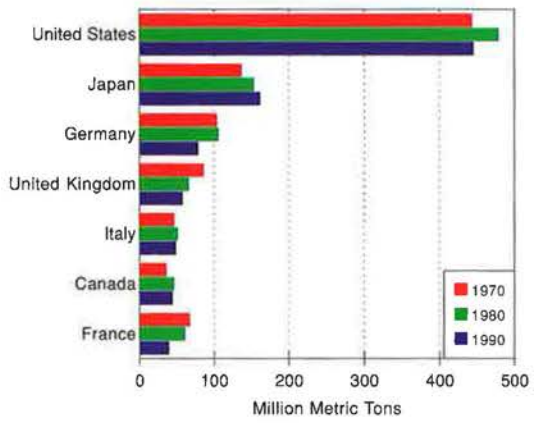
Industrial Sector Energy Consumption

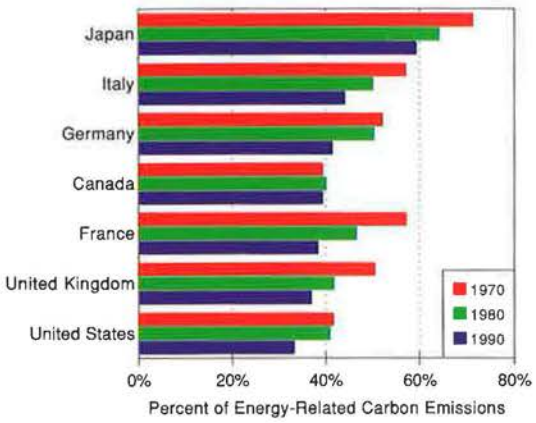


✓ Energy consumption by the industrial sector rose slightly in the G-7 between 1970 and 1990, with the largest increases in Japan, the United States, and Canada.

✓ Despite this, the *share* of energy consumed by G-7 industrial sectors fell on average from 48 percent in 1970 to 40 percent in 1990. As of 1990, industrial sector energy consumption accounted for 56 percent of total Japanese energy consumption, compared to between 36 and 41 percent in the United Kingdom, United States, Canada, Germany and France.

Industrial Sector Carbon Emissions





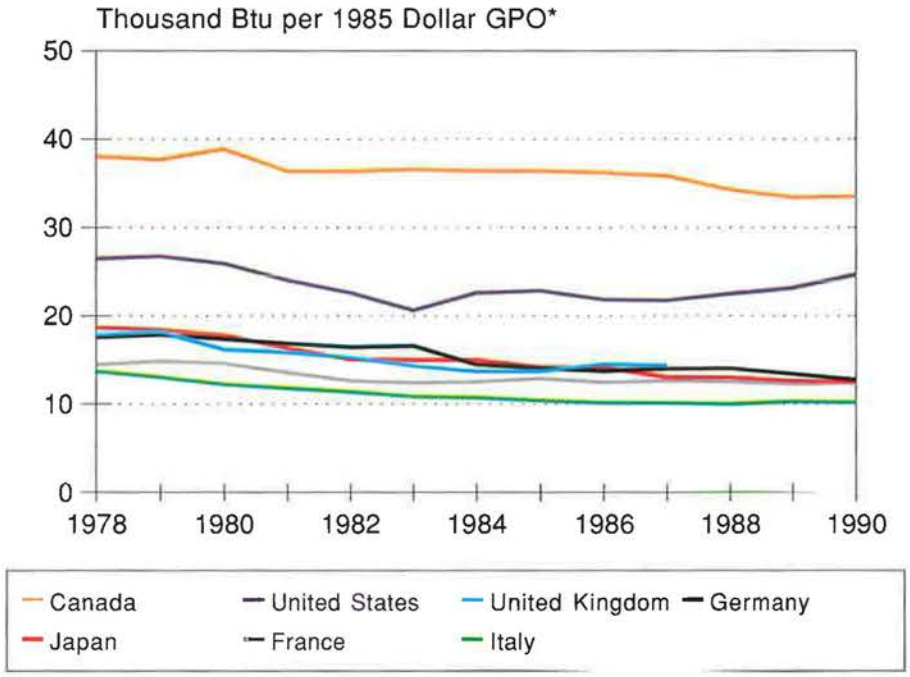
- ✓ G-7 industrial sector carbon emissions declined from 921 million metric tons in 1970 to 875 million metric tons in 1990, with significant reductions in France, Germany, and the United Kingdom.

- ✓ Between 1970 and 1990, the relative amount of carbon emitted by G-7 industrial sectors fell on average from 48 percent of total carbon emissions to 38 percent.

- ✓ In relative terms, France reduced its industrial carbon emissions the most, from 57 percent in 1970 to only 38 percent of its national energy-related carbon emissions in 1990. Rapid growth in nuclear power consumption by French industry was largely responsible for this reduction.

- ✓ In 1990, the industrial sector accounted for only 33 percent of U.S. carbon emissions, the lowest share in the G-7 group. In comparison, the Japanese industrial sector accounted for 59 percent of Japan's energy-related carbon emissions in 1990.

Industrial Energy Intensity



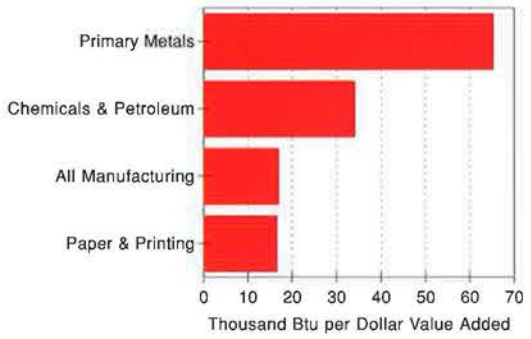
*GPO: Gross Product Originating in Industrial Sector

✓ Between 1978 and 1990, industrial energy intensities (defined as the amount of energy consumed per constant 1985 dollar of output produced by the industrial sector) generally declined throughout the G-7, especially in Japan, Italy, and the United Kingdom. After 1986, however, this trend slowed in many G-7 countries, and reversed in the United States. Thus, between 1978 and 1986, the U.S. industrial energy intensity declined 18 percent; between 1986 and 1990, however, it increased 13 percent.

✓ Canada and the United States are the most intensive of the G-7 countries in their industrial energy use, largely as a consequence of their abundant (and relatively cheap) indigenous energy, mineral, and other natural resource endowments. As a result of this comparative advantage, Canada and the United States tended historically to develop energy-intensive industries (such as chemicals and petroleum, primary metals, and paper and printing), which specialized in manufacture and fabrication of items from raw materials.

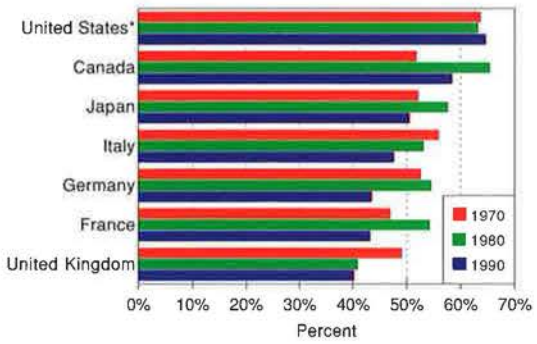
Energy-Intensive Industries

Energy Intensity by Industry
(G-7 Average, 1988*)



*Data for United Kingdom unavailable

Energy Intensive Industries Energy Consumption
as a Share of Industrial Energy Consumption



*U.S. data are for 1974, 1980, and 1991

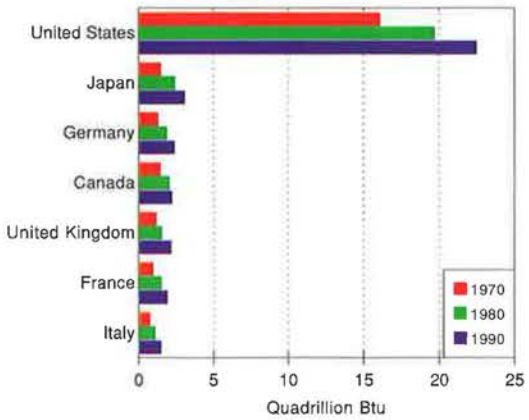
✓ Differences between G-7 countries in energy consumption per unit of output can be explained partly by differences in the *mix of industries* in the seven countries. Three major industries are considered particularly energy-intensive (i.e., consuming a large amount of energy per unit of output): 1) Primary Metals (i.e., steel, aluminum, copper); 2) Chemicals and Petroleum; and 3) Paper and Printing.

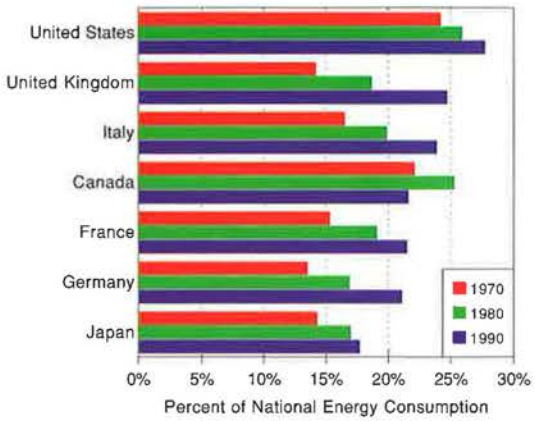
✓ These three industries alone accounted for a large share of G-7 industrial energy consumption in 1990, ranging from 40 percent in the United Kingdom to 65 percent in the United States.

✓ Between 1970 and 1990, the energy consumption share of energy-intensive industries generally fell in G-7 countries, except for the United States (which remained about constant) and Canada (which increased). Both of these countries continued to specialize in energy-intensive industries based on their relatively plentiful energy resources.

INDUSTRY

Transportation Sector Energy Consumption



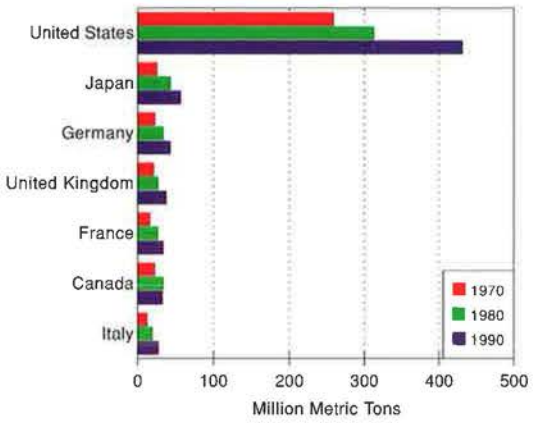


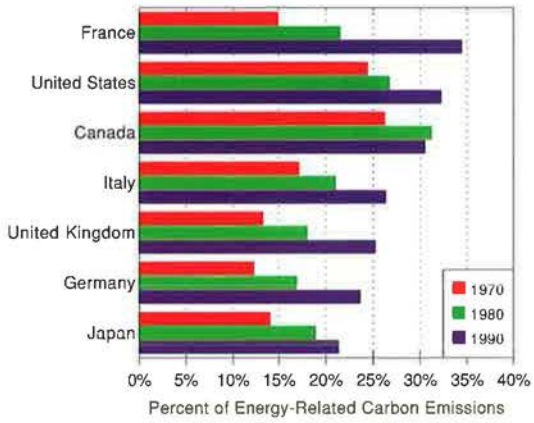
✓ Energy consumption by G-7 transportation sectors increased from 23 quads in 1970 to 36 quads in 1990, with the largest absolute increases in the United States and Japan.

✓ As a result of this rapid increase, the *share* of energy consumed by G-7 transportation sectors rose on average from 21 percent in 1970 to 25 percent in 1990.

✓ The transportation sector's share of national energy consumption increased between 1970 and 1990 in all G-7 countries except Canada. As of 1990, the United States had the highest transportation share, mainly as a result of high vehicle ownership per capita and high average annual distances driven per vehicle.

Transportation Sector Carbon Emissions



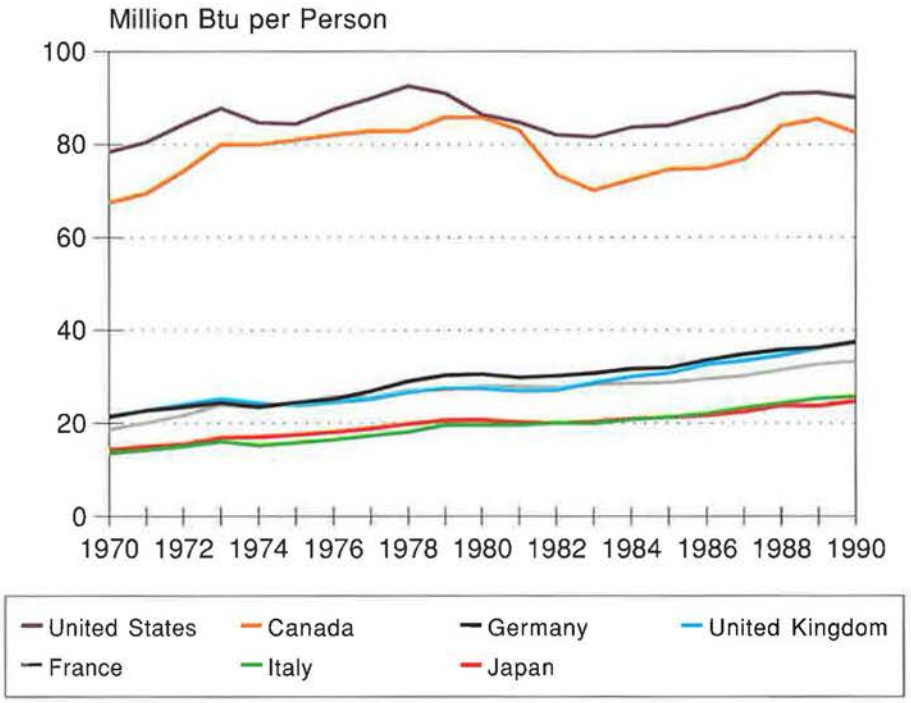


✓ G-7 transportation sector carbon emissions increased significantly between 1970 and 1990, both in absolute terms as well as relative to total energy-related carbon emissions. The Japanese, French, and Italian transportation sectors each more than doubled their carbon emissions between 1970 and 1990.

✓ Throughout the G-7, transportation sector carbon emissions rose as a result of rapid increases in per capita vehicle ownership. On average, the G-7 transportation sector share of carbon emissions increased from 21 percent in 1970 to 30 percent in 1990.

✓ In 1990, the transportation sector accounted for less than 25 percent of Japanese energy-related carbon emissions, the lowest share in the G-7 group. In comparison, the U.S., French, and Canadian transportation sectors each accounted for more than 30 percent of national energy-related carbon emissions.

Transportation Energy Consumption per Capita



✓ The United States and Canada between 1970 and 1990 consistently used much more energy per person in the transportation sectors compared to other G-7 countries.

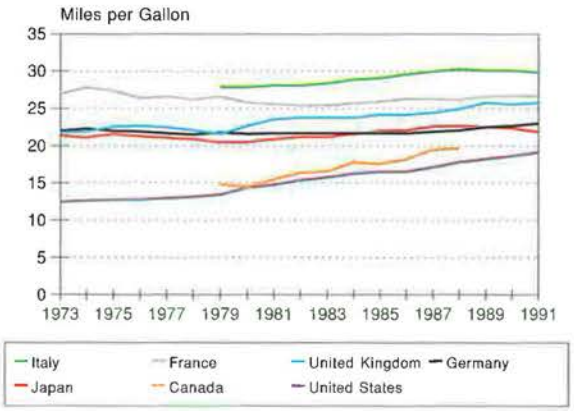
✓ Overall, between 1970 and 1990, transportation energy consumption per capita increased 15 percent and 22 percent, respectively, in the United States and Canada. In comparison, other G-7 country ratios rose much faster, ranging from 74 percent growth in Japan to a 90 percent increase in Italy.

✓ In the United States and Canada, transportation energy consumption per capita peaked in the late 1970's, then declined sharply following the 1979 oil price shock caused by the Iranian Revolution. The ratios in both countries then began to climb again in the mid-1980's as oil prices fell.

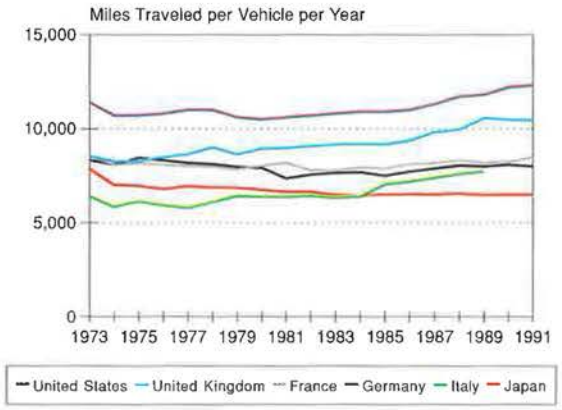
✓ In Europe and Japan, on the other hand, transportation energy consumption per capita ratios rose steadily between 1970 and 1990 and were affected less than in the United States by fluctuations in world oil prices. This is mainly because taxes consistently have accounted for a much larger share of end-use transportation energy prices in Europe and Japan than in the United States, thus reducing the *relative* impact of changes in the world oil price.

Automobile Efficiency and Utilization

Average Gasoline Fuel Economy



Vehicle Usage Trends



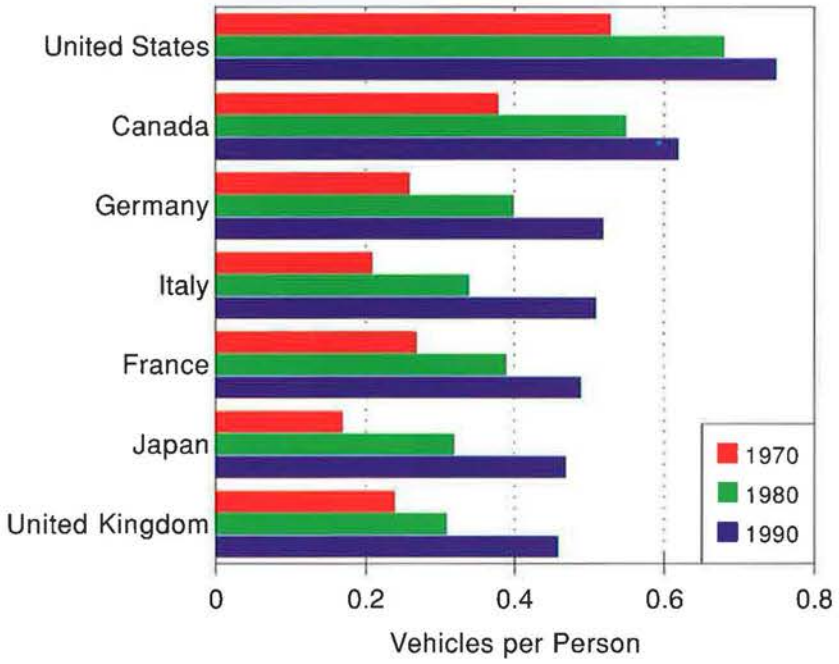
- ✓ Overall fleet fuel efficiencies improved in the United States, Canada, the United Kingdom, and Italy following the oil price shocks of 1973 and 1979, as relatively energy-efficient new cars replaced older, less efficient models. In other G-7 countries, improvements in efficiency were somewhat less noticeable, and tended to level off after the oil price collapse of 1986.

- ✓ Despite rapid improvement in U.S. and Canadian fleet fuel efficiencies since the 1970's, those two countries continued as of 1991 to rank behind most other G-7 countries.

- ✓ The annual number of miles driven per vehicle rose slightly in most G-7 countries between 1970 and 1991. Vehicle utilization increased in the United States, United Kingdom, and Italy following the oil price collapse of 1986.

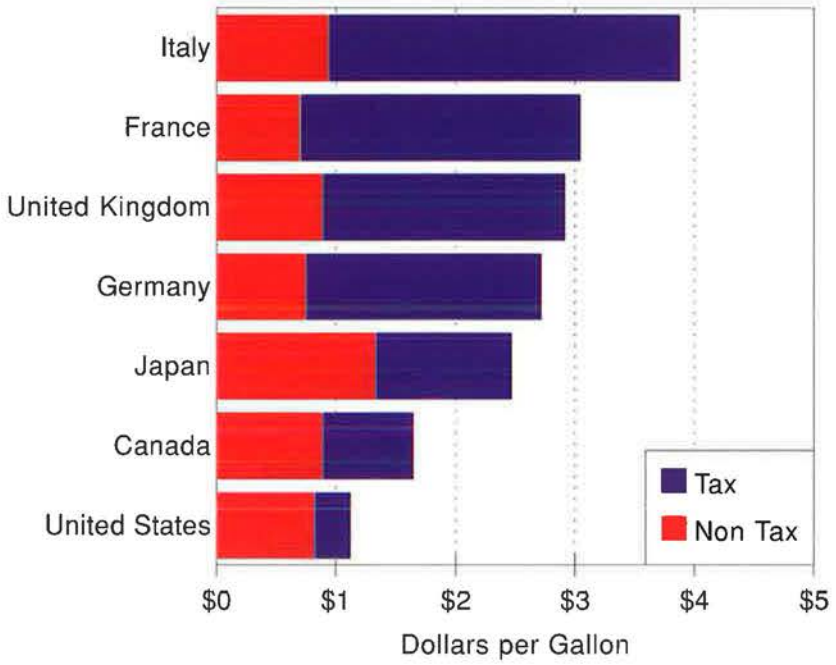
- ✓ Countries with high gasoline taxes (France and Italy, for example) tended to have high average fleet efficiencies as well.

Vehicle Registrations per Capita



- ✓ Vehicle registrations per capita increased significantly in all G-7 countries between 1970 and 1990, largely as a result of higher per capita incomes.
- ✓ The rate of increase in vehicle registrations per capita was greatest outside the United States and Canada.
- ✓ Nonetheless, the United States and Canada in 1990 maintained more registered vehicles per capita than other G-7 countries.
- ✓ By 1990, vehicle registrations per capita in other G-7 countries generally reached U.S. 1970 registration levels. The growth in vehicle registrations throughout the G-7 had important implications for higher total vehicle miles driven and increased transportation fuel consumption.

Gasoline Prices and Taxes, 1992

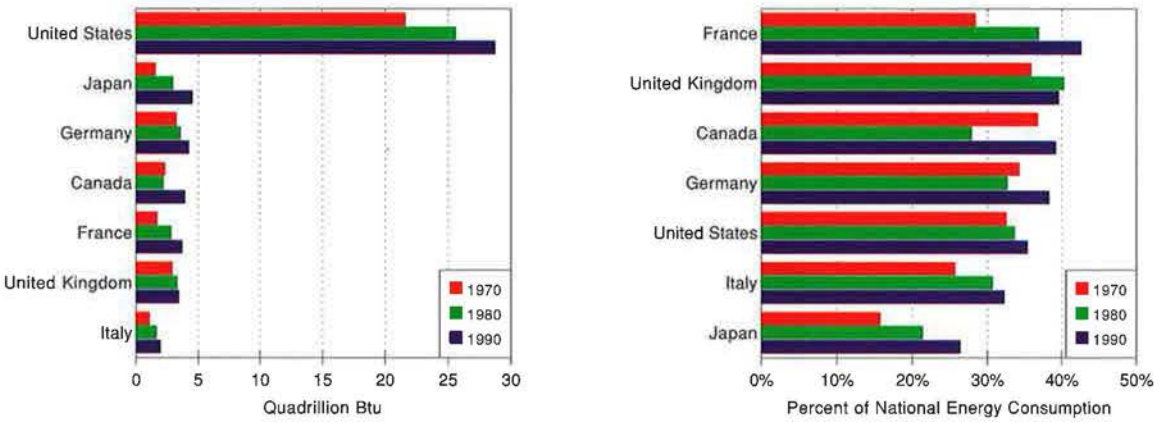


✓ Gasoline prices vary widely among G-7 countries. In 1992, for instance, gasoline cost $1.13 per gallon in the United States, compared to $3.89 per gallon in Italy (using purchasing power parity exchange rates).

✓ Most of the differences in gasoline prices among G-7 countries result from differences in taxes. In 1992, for instance, taxes accounted for 27 percent of the U.S. gasoline price, compared to 46 percent in Japan and Canada, and 70 percent or higher in France, Italy, Germany, and the United Kingdom.

✓ Even in those G-7 countries with high gasoline prices, rapid increases in vehicle registrations and transportation energy consumption levels occurred during the 1970's and 1980's.

Residential/Commercial Sector Energy Consumption

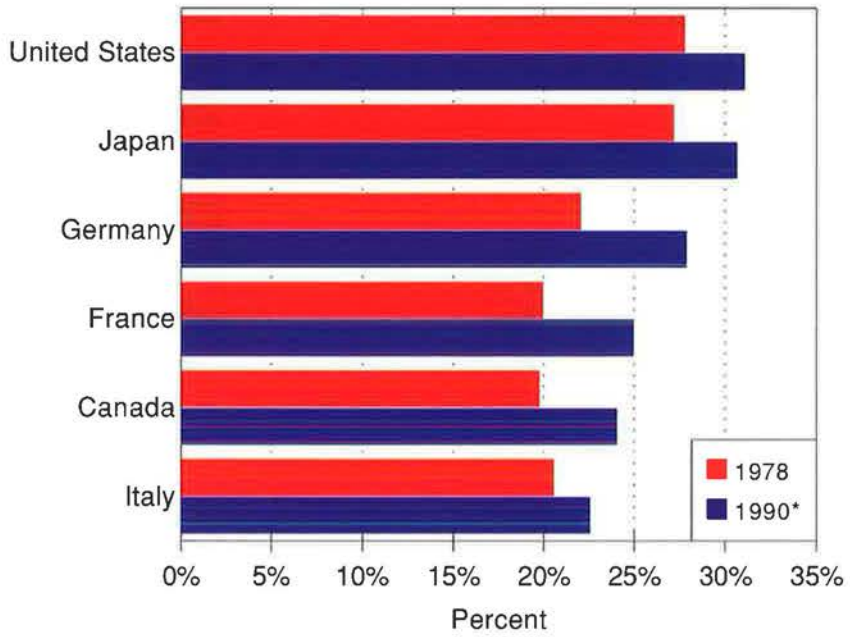


✓ G-7 energy consumption by the residential/commercial sector rose rapidly between 1970 and 1990, from 35 quads to 51 quads. Residential/commercial energy consumption nearly tripled in Japan, doubled in France, and increased significantly elsewhere.

✓ As a result, the residential/commercial sector's share of national energy consumption increased in every G-7 country between 1970 and 1990. For the G-7 as a whole, residential/commercial's share of total energy consumption rose from 31 percent in 1970 to 35 percent in 1990.

✓ Japan's residential/commercial sector as of 1990 accounted for 27 percent of Japanese total energy consumption, the lowest such share in the G-7. Despite dramatic increases in residential/commercial energy consumption between 1970 and 1990, this sector remained relatively small in Japan due primarily to relatively small average Japanese home size, a relative lack of central heating and cooling, and relatively broad tolerance for cooler household temperatures in the winter.

Service Sector Share of GDP



*1988 Statistics for Canada

✓ The service sector (defined here to include financial, insurance, real estate, business, community, and personal services) includes those economic activities which produce services as opposed to goods, and constitutes much of what is often referred to as the "commercial" sector. The service sector accounts for a significant share of commercial energy consumption.

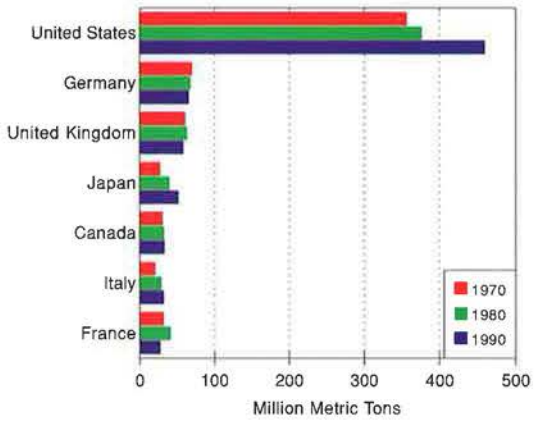
✓ Between 1978 and 1990, the service sector grew rapidly as a share of G-7 economies. On average, the service sector accounted for about 28 percent of G-7 real GDP in 1990, compared to 23 percent in 1978.

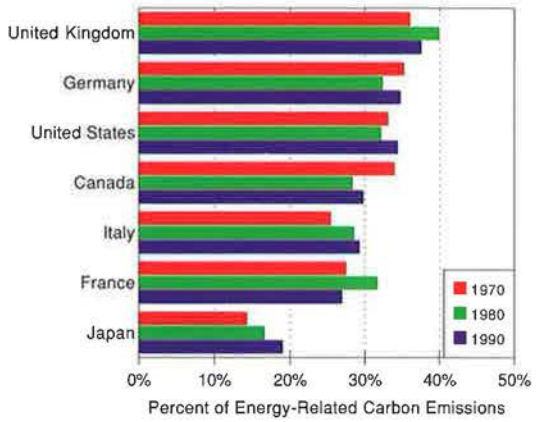
✓ As of 1990, the service sector made up more than 30 percent of the U.S. and Japanese economies, as well as sizable shares of the German, French, Canadian, and Italian economies.

✓ Since the service sector tends to consume less energy per dollar of output than the industrial or transportation sectors, the growth in services has contributed to reductions in overall energy intensity ratios in the G-7 since the 1970's.

RESIDENTIAL/
COMMERCIAL

Residential/Commercial Sector Carbon Emissions





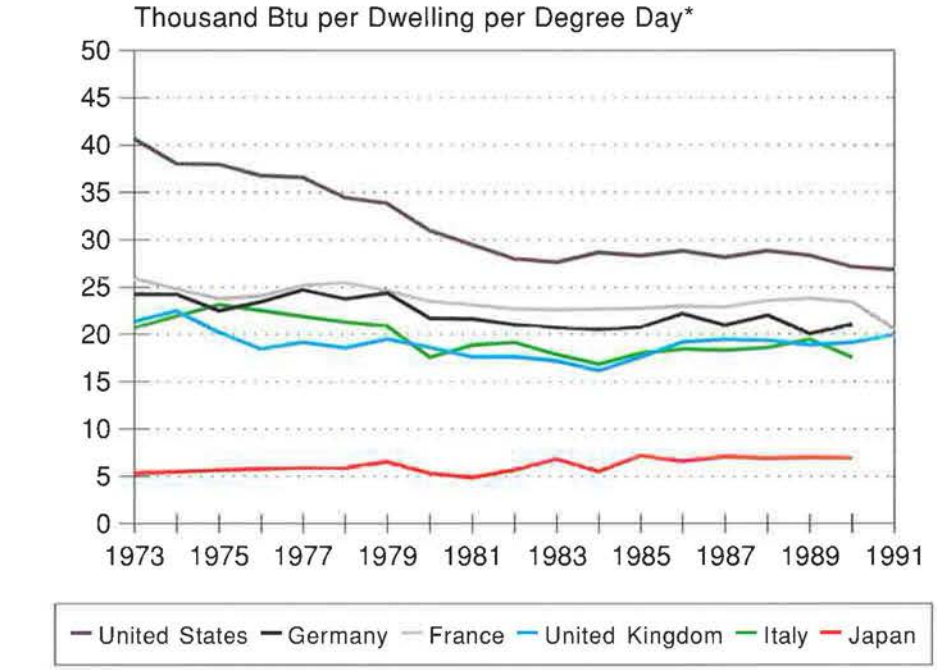
- ✓ G-7 residential/commercial carbon emissions increased from 601 million metric tons in 1970 to 729 million metric tons in 1990. The United States and Japan, where residential/commercial sector energy consumption grew rapidly, accounted for nearly all of this increase.

- ✓ Residential/commercial carbon emissions as a share of total energy-related carbon emissions remained relatively stable in most G-7 countries between 1970 and 1990.

- ✓ In 1990, the residential/commercial sector accounted for 19 percent of Japanese carbon emissions, compared to 32 percent for the G-7 as a whole. In the same year, the U.S., German, and U.K. residential/commercial sectors each accounted for between 34 and 38 percent of national energy-related carbon emissions.

RESIDENTIAL/
COMMERCIAL

Residential Space Heating per Dwelling



*Primary energy used for space heating; climate corrected

✓ Space heating accounts for by far the largest portion of household energy use (with water heating a distant second). Differences between countries in space heating per dwelling are generally the result of differences in climate; dwelling size, type, and thermal integrity; heating services demanded; and heating equipment efficiency.[7]

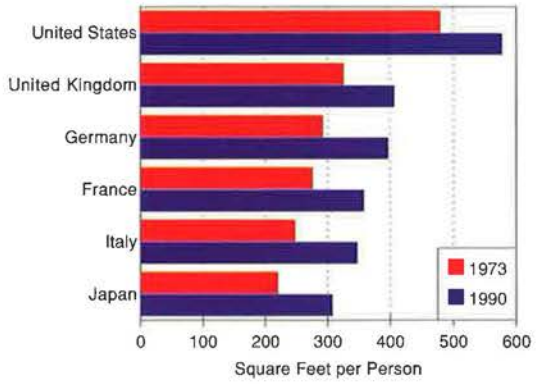
✓ When corrected for differences in climate, the United States consumes much more energy to heat its homes than any other G-7 nation. (Note: comparable data for Canada were not available.) This mainly results from the fact that homes in the United States are larger on average than in other G-7 countries.

✓ Between 1973 and 1991, U.S. home heating intensity per dwelling fell 34 percent, more than in any other G-7 country. Improvements in U.S. home heating intensities occurred mainly in the 1970's, when large-scale retrofit programs were encouraged for older homes, while newer homes were built with improved thermal integrity and heating equipment.

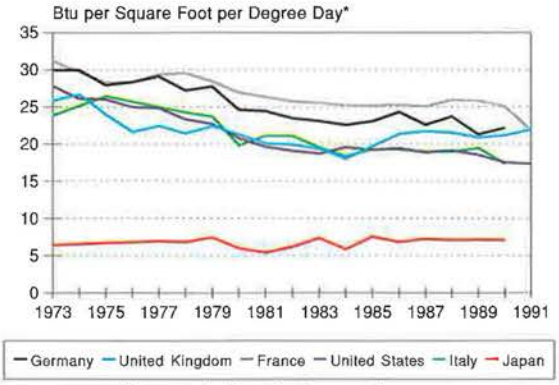
✓ Japan, which has the least housing area per capita in the G-7, also uses the least energy to heat its homes. In addition, Japanese households tend to maintain lower temperatures than in other G-7 countries. Between 1973 and 1990, Japan's heating use per dwelling rose 30 percent as average new-home size increased and as the use of central heating and air conditioning became more widespread.

Residential Space Heating per Square Foot

Housing Area per Capita



Heating Intensities: Floor Space



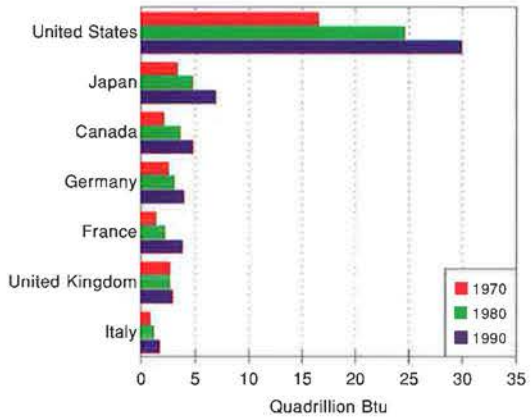
*Primary energy used for space heating; climate corrected

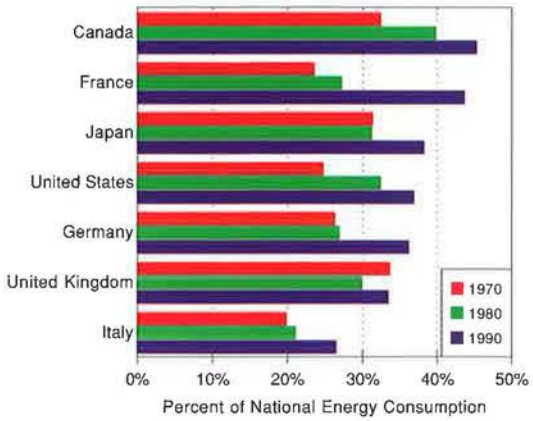
✓ Between 1973 and the early 1990's, average floor space per capita increased throughout the G-7. Over that period, Japan experienced the greatest relative increase (40 percent) in floor space per person, while the United States had the smallest (20 percent).

✓ Although the United States has relatively large homes, its use of energy for home heating as of 1991 was actually among the lowest in the G-7 when corrected for differences in living space. (Note: comparable data for Canada were not available.)

✓ Despite increasing floor space, Germany, the United Kingdom, France, the United States, and Italy reduced their heating intensities (energy consumed to heat a square foot of household area) between 1973 and the early 1990's, with U.S. heating intensity declining the most in both absolute and relative terms. Despite a slight increase in recent years, Japan's heating intensity per square foot remains by far the lowest in the G-7 (less than half the U.S. level).

Primary Electricity Consumption





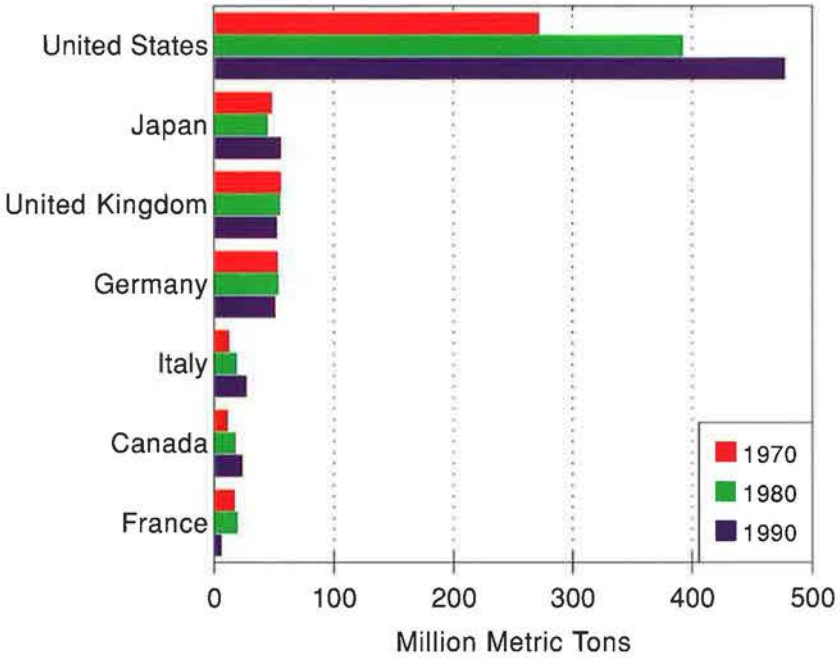
✓ These two figures present electricity consumption on a primary basis. Primary electricity is defined to include all energy inputs used in generating electricity. Generally, three units of energy inputs are required to produce one unit of electricity output, with the other two units being lost as heat.

✓ G-7 primary electricity consumption increased 82 percent between 1970 and 1990, from 30 quads to 55 quads. Much of this growth was met by rapid addition of nuclear power capacity during those years, particularly in the United States, France, and Japan. In Canada, hydroelectric power capacity grew rapidly between 1970 and 1990.

✓ As a consequence, G-7 primary electricity consumption as a share of national energy consumption increased on average from 27 percent in 1970 to 38 percent in 1990.

✓ Electricity use grew partly as a result of increased penetration of home appliances such as refrigerators, freezers, clothes washers, and dishwashers. Utilization of electricity for air conditioning and heating (often carried out by electric heat pumps) also increased, especially in the United States and Japan. Electricity also grew in importance as an energy input in the industrial sector.

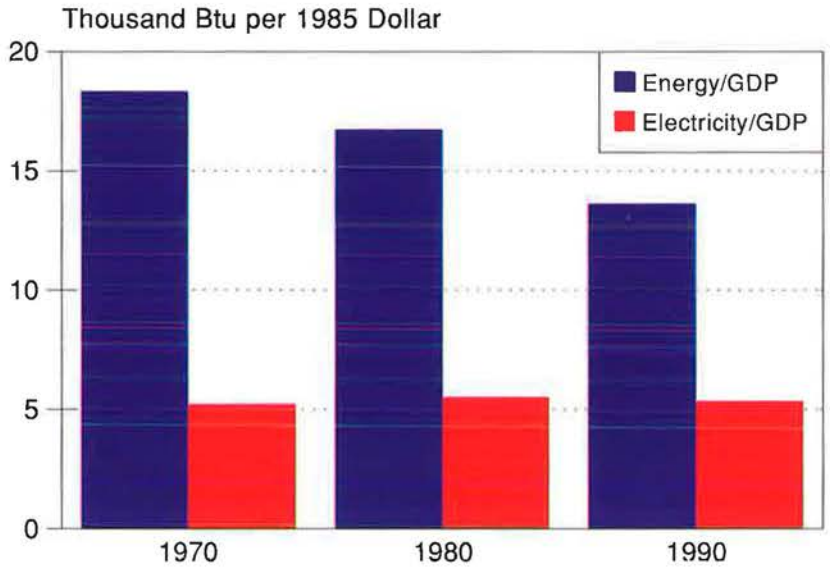
Carbon Emissions from Electricity Generation



- ✓ G-7 carbon emissions resulting from the generation of electricity increased 220 million metric tons between 1970 and 1990.
- ✓ Nearly all of this increase was accounted for by the United States, where electricity sector carbon emissions grew 75 percent between 1970 and 1990. Large proportional increases also took place in Italy and Canada.
- ✓ Carbon emissions from electricity generation declined significantly in France between 1980 and 1990 as a result of rapid growth in nuclear power (and corresponding decline in fossil fuel-generated electricity).
- ✓ Increased use of nuclear power and a shift from coal- to natural gas-fired power plants helped stabilize carbon emissions from electricity generation in Germany, the United Kingdom, and Japan between 1970 and 1990.

Electricity Overview

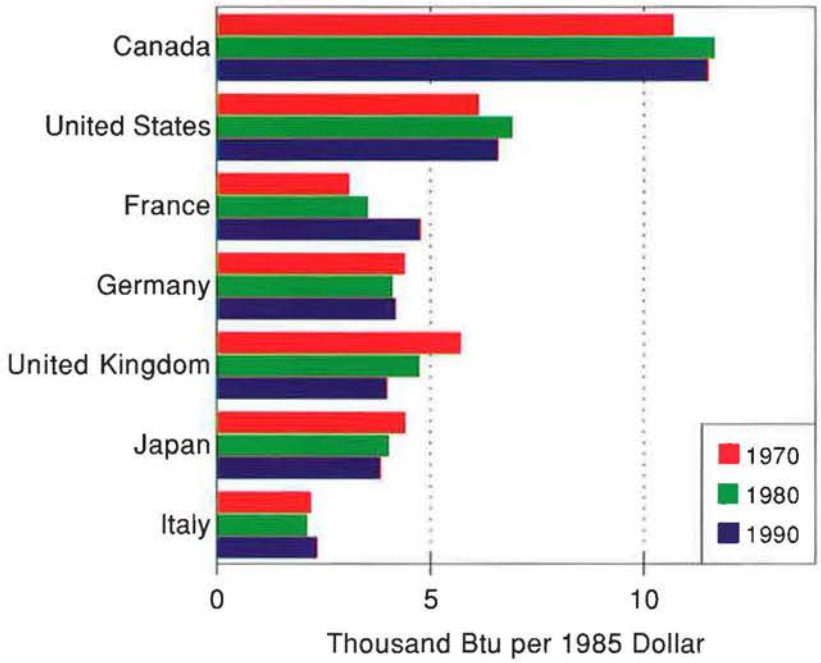
Electricity vs. Energy Consumption per Dollar of GDP (G-7 Average)



✓ The amount of primary electricity consumed in the G-7 per dollar of output between 1970 and 1990 remained nearly constant, while the overall amount of energy consumed per dollar of output fell 28 percent.

✓ G-7 primary electricity consumption and real GDP increased 82 and 78 percent, respectively, between 1970 and 1990. During the same period, total G-7 energy consumption increased only 29 percent.

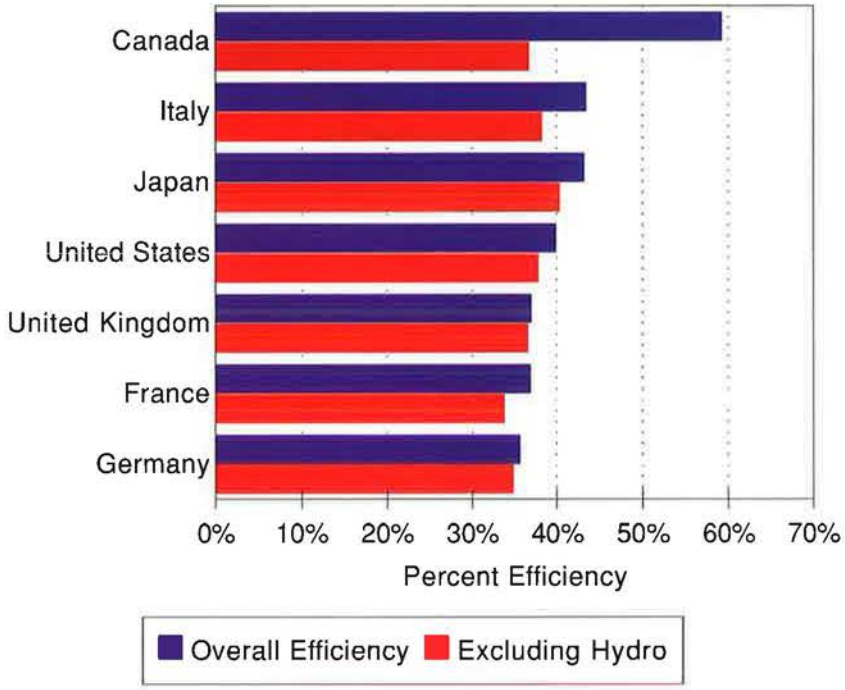
Primary Electricity Consumption per Dollar of GDP



✓ The amount of primary electricity consumed per unit of output (electricity intensity) increased in four of the G-7 countries between 1970 and 1990. Germany's electricity intensity remained approximately stable, while Japan's and the United Kingdom's electricity intensity fell during the period.

✓ For the G-7 as a whole, primary electricity consumption between 1970 and 1990 increased at about the same rate as real GDP.

Electricity Generation Efficiency, 1991

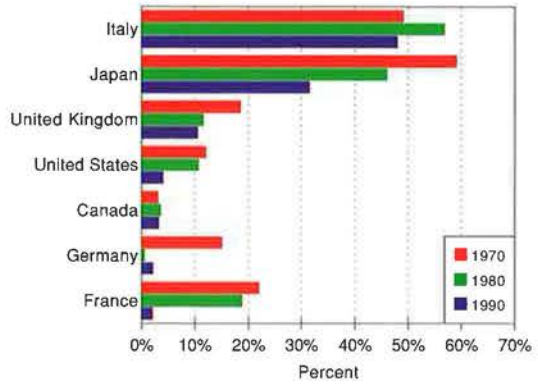


✓ Electricity generation efficiency is a relative measure comparing energy inputs to electricity output. In 1991, Canada had the highest overall electric generation efficiency in the G-7, although this was mainly the result of its abundant hydroelectric power (which is assumed to achieve 100 percent generation efficiency).

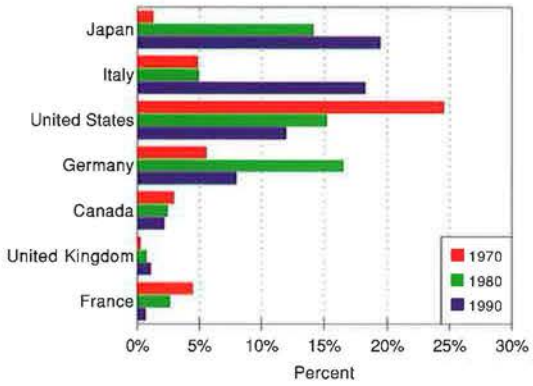
✓ Excluding hydroelectricity provides a more realistic comparison of electric generation efficiencies among G-7 countries. Using this measure, G-7 countries generally achieve between 35 and 40 percent electric generation efficiency.

Electricity Generation by Fuel Type

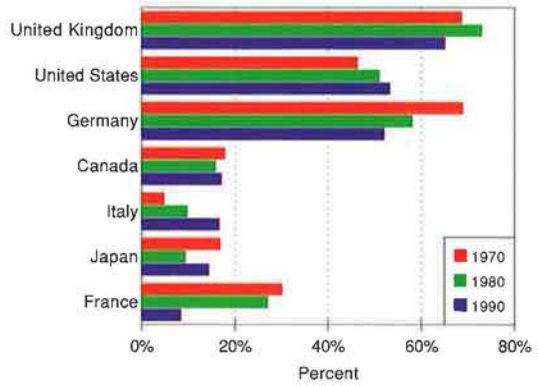
Oil Share



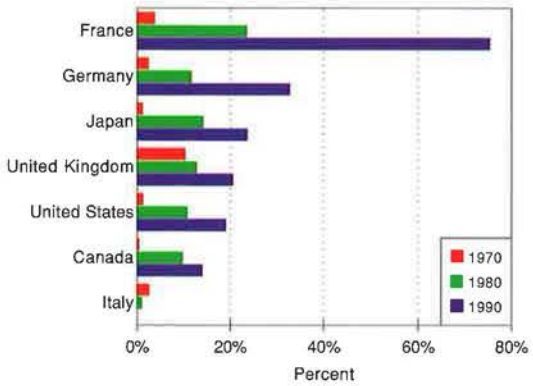
Natural Gas Share



Coal Share



Nuclear Share



✓ Between 1970 and 1990, the share of electricity generated by oil fell throughout the G-7, with particularly sharp declines in Japan, France, the United Kingdom, Germany, and the United States. As of 1990, Italy maintained the highest oil share of electricity generation.

✓ During the same period, natural gas-fired electricity generation increased sharply in Japan and Italy, and fell sharply in the United States and France.

✓ Coal's share increased somewhat in the United States and Italy, and fell in most other G-7 countries (especially in France and Germany). The shares of oil, gas, and coal remained relatively constant in Canada, which relies mainly on hydroelectric power.

✓ Nuclear power increased its share of total electric generation dramatically in all G-7 countries except Italy, which has phased out nuclear power entirely. As of 1990, France maintained by far the largest nuclear share of electricity generation in the G-7.

Conclusion

International comparisons of energy use and carbon emissions patterns reveal considerable variation in a wide range of indicators. Energy consumption per capita, for instance, is highest in the developed countries. In recent decades, however, energy consumption has been rising more slowly than economic growth in the developed countries. Although this trend was stimulated largely by the oil price shocks of the 1970's, there were other important factors at work. Sectoral shifts in demand towards less energy-intensive products and services, more efficient production processes for using energy and producing electric power, and government tax and regulation policies designed to foster demand for energy-efficient products all played a role. These factors also affected OECD carbon emissions, which rose less rapidly than energy consumption over the past 20 years, mainly as a result of the rapid growth in noncarbon-emitting fuels, especially nuclear power and hydroelectricity.

Energy consumption rose much more rapidly in the developing countries than in the OECD since 1970. Growth was spurred in part by the process of industrialization, which introduces modern systems of transportation, distribution, and power generation, all more energy-intensive than pre-industrial methods. Growth in population also played an important role. Between 1970 and 1990, developing country population rose 49 percent, compared to a 20 percent rise in developed countries. Government policies also were a powerful influence on energy use patterns in the developing countries. Former centrally-planned economies, including China, the former Soviet Union, and the countries of Eastern Europe, all consistently exhibited unusually high energy usage rates relative to economic activity. These high usage patterns were spurred largely by government policies designed to encourage the development of energy-intensive industries. In addition, most energy prices were subsidized or controlled at below-market levels.

Although containing over 80 percent of the world's population, the developing nations have historically consumed significantly less than half of the world's energy consumption, but that share rose rapidly during the 1970's and 1980's. As a result, the developing countries by 1992 accounted for 48 percent of the world's energy consumption (up from 39 percent in 1970) and 52 percent of world energy-related carbon emissions (up from 43 percent in 1970).

On a worldwide basis, fuel use and carbon emission increases derive principally from increased generation of electric power and increased use of motor fuel for transport. In both developed and developing areas of the world, electricity demand has increased faster than economic growth. In developed countries, electricity demand doubled between 1970 and 1990. In developing areas, the increase was 300 percent. Carbon and noncarbon fuels compete in power generation. In countries with access to hydroelectric and nuclear power, substantial gains in electric output have been achieved with little impact on carbon emissions. For most countries, however, fossil fuels continue to represent the main incremental fuel source to meet increased electric power needs.

Demand for transport fuel appears to be powerfully impacted by rising per capita income. Even in developed countries with traditionally high gasoline price policies, income growth encouraged rapid growth in new vehicle registrations between 1970 and 1990. In Germany, Italy, Japan, and the United Kingdom, for instance, vehicle registrations per capita more than doubled during those years and approached U.S. levels of 1970. Italy exhibited the highest rate of growth in vehicle registrations between 1970 and 1990, even though it maintained the highest prices for gasoline. Within the G-7, Europe and Japan have consistently maintained higher gasoline taxes than the United States and Canada. Though gasoline prices do not appear to significantly deter growth in vehicle purchases, they do appear to affect choice of fuel-efficient vehicles. Countries with high gasoline taxes (i.e., Europe and Japan) generally also possess more fuel-efficient car fleets.

APPENDIX:
DATA SOURCES and END NOTES

ENERGY AND CARBON EMISSIONS IN A WORLD CONTEXT

GDP, Energy Consumption, Carbon Emissions: World Trends (Page 8)

Sources: The WEFA Group. *World Economic Service: Historical Data* (Bala Cynwyd, PA, July 1993); Energy Information Administration (EIA). *International Energy Annual 1992* (Washington, DC, 1994) and internal data from the International Statistics Branch; Carbon emissions derived from conversion factors in: EIA. *Annual Energy Outlook 1993* (Washington, DC, 1993).

Carbon Intensity and Non-Fossil Fuels (P. 9)

Sources: EIA. *International Energy Annual 1992* (Washington, DC, 1994) and internal data from the International Statistics Branch; EIA. Carbon emissions derived from conversion factors in: *Annual Energy Outlook 1993* (Washington, DC, 1993).

Fuel Mix in the OECD and Non-OECD (P. 10)

Source: EIA. *International Energy Annual 1992* (Washington, DC, 1994) and internal data from the International Statistics Branch.

GDP, Energy Consumption, Carbon Emissions: Developed vs. Developing (P. 11)

Sources: The WEFA Group. *World Economic Service: Historical Data* (Bala Cynwyd, PA, July 1993); EIA. *International Energy Annual 1992* (Washington, DC, 1994) and internal data from the International Statistics Branch; Carbon emissions derived from conversion factors in: EIA. *Annual Energy Outlook 1993* (Washington, DC, 1993).

Energy Consumption: Developed vs. Developing (P. 12)

Source: EIA. *International Energy Annual 1992* (Washington, DC, 1994) and internal data from the International Statistics Branch.

Electricity, Energy, and GDP: Developed vs. Developing (P. 13)

Source: EIA. *International Energy Annual 1992* (Washington, DC, 1994) and internal data from the International Statistics Branch.

Carbon Emissions: Developed vs. Developing (P. 14)

Sources: EIA. *International Energy Annual 1992* (Washington, DC, 1994) and internal data from the International Statistics Branch; EIA. Carbon emissions derived from conversion factors in: *Annual Energy Outlook 1993* (Washington, DC, 1993).

Gross Domestic Product (GDP): Developed vs. Developing (P. 15)

Source: The WEFA Group. *World Economic Service: Historical Data* (Bala Cynwyd, PA, July 1993).

Energy Consumption per Dollar of GDP: Developed vs. Developing (P. 16)

Sources: The WEFA Group. *World Economic Service: Historical Data* (Bala Cynwyd, PA, July 1993); EIA. *International Energy Annual 1992* (Washington, DC, 1994) and internal data from the International Statistics Branch.

Developed Countries: Carbon Emissions; Energy Consumption per Dollar of GDP (P. 17)

Sources: The WEFA Group. *World Economic Service: Historical Data* (Bala Cynwyd, PA, July 1993); EIA. *International Energy Annual 1992* (Washington, DC, 1994) and internal data from the International Statistics Branch; Carbon emissions derived from conversion factors in: EIA. *Annual Energy Outlook 1993* (Washington, DC, 1993).

Developing Countries: Carbon Emissions; Energy Consumption per Dollar of GDP (P. 18)

Sources: The WEFA Group. *World Economic Service: Historical Data* (Bala Cynwyd, PA, July 1993); EIA. *International Energy Annual 1992* (Washington, DC, 1994) and internal data from the

International Statistics Branch; Carbon emissions derived from conversion factors in: EIA. *Annual Energy Outlook 1993* (Washington, DC, 1993).

Economic Development and National Energy Use Patterns (P. 19)
Sources: OECD. *Energy Balances of OECD Countries, 1990-1991* (Paris, 1993); OECD. *Energy Statistics and Balances of Non-OECD Countries* (Paris, 1992); World Bank. *World Tables 1993* (Baltimore, 1993).

Population, Economic Growth, Energy and Carbon (P. 20)
Sources: The WEFA Group. *World Economic Service: Historical Data* (Bala Cynwyd, PA, July 1993); EIA. *International Energy Annual 1992* (Washington, DC, 1994) and internal data from the International Statistics Branch; Carbon emissions derived from conversion factors in: EIA. *Annual Energy Outlook 1993* (Washington, DC, 1993.

Economic Development and World Fossil Fuel Consumption (P. 21)
Sources: The WEFA Group. *World Economic Service: Historical Data* (Bala Cynwyd, PA, July 1993); EIA. *International Energy Annual 1992* (Washington, DC, 1994) and internal data from the International Statistics Branch.

Economic Development and World Carbon Emissions (P. 22)
Sources: The WEFA Group. *World Economic Service: Historical Data* (Bala Cynwyd, PA, July 1993); EIA. *International Energy Annual 1992* (Washington, DC, 1994) and internal data from the International Statistics Branch; Carbon emissions derived from conversion factors in: EIA. *Annual Energy Outlook 1993* (Washington, DC, 1993).

ENERGY USE, ECONOMIC GROWTH, AND CARBON EMISSIONS IN THE G-7

World Oil Price (P. 24)
EIA. *Annual Energy Review 1992* (Washington, DC, June 1993); EIA. *Monthly Energy Review, December 1993* (Washington, DC, December 1993).

G-7 Energy Consumption by Fuel Type (P. 25)
Source: EIA. *International Energy Annual 1992* (Washington, DC, 1994) and internal data from the International Statistics Branch.

GDP and Energy Consumption per Capita (P. 26)
Sources: OECD. *National Accounts, Volume 1: 1960-1991* (Paris, 1993); EIA. *International Energy Annual 1992* (Washington, DC, 1994) and internal data from the International Statistics Branch.

Energy Consumption per Dollar of GDP (P. 27)
Sources: OECD. *National Accounts, Volume 1: 1960 1991* (Paris, 1993); EIA. *International Energy Annual 1992* (Washington, DC, 1994) and internal data from the International Statistics Branch.

Energy-Related Carbon Emissions per Dollar of GDP (P. 28)
Sources: OECD. *National Accounts, Volume 1: 1960-1991* (Paris, 1993); EIA. *International Energy Annual 1992* (Washington, DC, 1994) and internal data from the International Statistics Branch; Carbon emissions derived from conversion factors in: EIA. *Annual Energy Outlook 1993* (Washington, DC, 1993).

Energy-Related Carbon Emissions per Capita (P. 29)
Sources: OECD. *National Accounts, Volume 1: 1960-1991* (Paris, 1993); EIA. *International Energy Annual 1992* (Washington, DC, 1994) and internal data from the International Statistics Branch; Carbon emissions derived from conversion factors in: EIA. *Annual Energy Outlook 1993* (Washington, DC, 1993).

Energy-Related Carbon Emissions (P. 30)
Sources: EIA. *International Energy Annual 1992* (Washington, DC, 1994) and internal data from the International Statistics Branch; Carbon emissions derived from conversion factors in: EIA. *Annual Energy Outlook 1993* (Washington, DC, 1993).

G-7 SECTORAL ANALYSIS

INDUSTRY

Industrial Sector Energy Consumption (P. 32)
Sources: OECD. *Energy Balances of OECD Countries, 1990-1991* (Paris, 1993); OECD. *National Accounts, Volume 2: 1978-1990* (Paris, 1992).

Industrial Sector Carbon Emissions (P. 33)
Sources: OECD. *Energy Balances of OECD Countries, 1990-1991* (Paris, 1993); OECD. *National Accounts, Volume 2: 1978-1990* (Paris, 1992); Carbon emissions derived from conversion factors in: EIA. *Annual Energy Outlook 1993* (Washington, DC, 1993).

Industrial Energy Intensity (P. 34)
Sources: OECD. *Energy Balances of OECD Countries, 1990-1991* (Paris, 1993); OECD. *National Accounts, Volume 2: 1978-1990* (Paris, 1992).

Energy-Intensive Industries (P. 35)
Sources: OECD. *Energy Balances of OECD Countries, 1990-1991* (Paris, 1993); OECD. *National Accounts, Volume 1: 1960-1991* (Paris, 1992); OECD. *National Accounts, Volume 2: 1978-1990* (Paris, 1992); EIA. *Manufacturing Energy Consumption Survey: Consumption of Energy, 1988* (Washington, DC, May 1991); EIA. *Manufacturing Energy Consumption Survey: Consumption of Energy, 1991 (Preliminary)* Mohr, Michael F., "Gross National Product by Industry, 1987-1989." *Survey of Current Business, April 1991* (Washington, DC, April 1991); U.S. Department of Commerce. *Annual Survey of Manufactures, 1975* (Washington, DC, September 1977).

TRANSPORTATION

Transportation Sector Energy Consumption (P. 36)
Sources: OECD. *Energy Balances of OECD Countries, 1990-1991* (Paris, 1993); OECD. *National Accounts, Volume 2: 1978-1990* (Paris, 1992).

Transportation Sector Carbon Emissions (P. 37)
Sources: OECD. *Energy Balances of OECD Countries, 1990-1991* (Paris, 1993); EIA. *Annual Energy Outlook 1993* (Washington, DC, 1993); Carbon emissions derived from conversion factors in: EIA. *Annual Energy Outlook 1993* (Washington, DC, 1993).

Transportation Energy Consumption per Capita (P. 38)
Sources: OECD. *Energy Balances of OECD Countries, 1990-1991* (Paris, 1993); OECD. *National Accounts, Volume 1: 1960-1991* (Paris, 1993).

Automobile Efficiency and Utilization (P. 39)
Source: Lawrence Berkeley Laboratory.

Vehicle Registrations per Capita (P. 40)
Sources: American Automobile Manufacturer's Association. *World Motor Vehicle Data, 1993 Edition* (Detroit, 1993); OECD. *National Accounts, Volume 1: 1960-1991* (Paris, 1993).

Gasoline Prices and Taxes, 1992 (P. 41)
Source: International Energy Agency. *Energy Prices and Taxes, First Quarter 1993* (Paris, 1993).

RESIDENTIAL/COMMERCIAL

Residential/Commercial Sector Energy Consumption (P. 42)

Sources: OECD. *Energy Balances of OECD Countries, 1990-1991* (Paris, 1993); OECD. *National Accounts, Volume 2: 1978-1990* (Paris, 1992).

Service Sector Share of GDP (P. 43)

Source: OECD. *National Accounts, Volume 2: 1978-1990* (Paris, 1992).

Residential/Commercial Sector Carbon Emissions (P. 44)

Sources: OECD. *Energy Balances of OECD Countries, 1990-1991* (Paris, 1993); EIA. *Annual Energy Outlook 1993* (Washington, DC, 1993); Carbon emissions derived from conversion factors in: EIA. *Annual Energy Outlook 1993* (Washington, DC, 1993).

Residential Space Heating per Dwelling (P. 45)

Source: Lawrence Berkeley Laboratory.

Residential Space Heating per Square Foot (P. 46)

Source: Lawrence Berkeley Laboratory.

ELECTRICITY

Primary Electricity Consumption (P. 47)

Sources: OECD. *Energy Balances of OECD Countries, 1990-1991* (Paris, 1993).

Carbon Emissions from Electricity Generation (P. 48)

Sources: OECD. *Energy Balances of OECD Countries, 1990-1991* (Paris, 1993); Carbon emissions derived from conversion factors in: EIA. *Annual Energy Outlook 1993* (Washington, DC, 1993).

Electricity Overview (P. 49)

Sources: OECD. *Energy Balances of OECD Countries, 1990-1991* (Paris, 1993); OECD. *National Accounts, Volume 1: 1960-1991* (Paris, 1993).

Primary Electricity Consumption per Dollar of GDP (P. 50)

Sources: OECD. *Energy Balances of OECD Countries, 1990-1991* (Paris, 1993); OECD. *National Accounts, Volume 1: 1960-1991* (Paris, 1993).

Electricity Generation Efficiency, 1991 (P. 51)

Sources: OECD. *Energy Balances of OECD Countries, 1990-1991* (Paris, 1993).

Electricity Generation by Fuel Type (P. 52)

Sources: OECD. *Energy Balances of OECD Countries, 1990-1991* (Paris, 1993).

MAPS

Energy Consumption per Dollar of GNP, 1990 (Cover)

Sources: EIA. *International Energy Annual 1992* (Washington, DC, 1994) and internal data from the International Statistics Branch; World Bank. *Socio-economic Time-series Access and Retrieval System, Version 2* (Washington, DC, April 1992).

Energy-Related Carbon Emissions per Dollar of GNP, 1990

Sources: Oak Ridge National Laboratories, Carbon Dioxide Information Analysis Center. *Estimates of CO2 Emissions from Fossil Fuel Burning and Cement Manufacturing, Based on the United Nations Energy Statistics and the U.S. Bureau of Mines Cement Manufacturing Data* (Oak Ridge, TN, 1992); World Bank. *Socio-economic Time-series Access and Retrieval System, Version 2* (Washington, DC, April 1992).

Energy-Related Carbon Emissions, 1990

Source: Oak Ridge National Laboratories, Carbon Dioxide Information Analysis Center. *Estimates of CO2 Emissions from Fossil Fuel Burning and Cement Manufacturing, Based on the United Nations Energy Statistics and the U.S. Bureau of Mines Cement Manufacturing Data* (Oak Ridge, TN, 1992).

Energy-Related Carbon Emissions per Capita, 1990

Source: Oak Ridge National Laboratories, Carbon Dioxide Information Analysis Center. *Estimates of CO2 Emissions from Fossil Fuel Burning and Cement Manufacturing, Based on the United Nations Energy Statistics and the U.S. Bureau of Mines Cement Manufacturing Data* (Oak Ridge, TN, 1992); World Bank. *Socio-economic Time-series Access and Retrieval System, Version 2* (Washington, DC, April 1992).

ENDNOTES

1. See EIA's report, *Emissions of Greenhouse Gases in the United States, 1985-1990* (Washington, DC, September 1993).

2. Throughout this report, the OECD is used as a proxy for the "developed countries." Members of the OECD in 1993 included: Australia; Austria; Belgium; Canada; Denmark; Finland; France; Germany; Greece; Guam; Iceland; Ireland; Italy; Japan; Luxembourg; Netherlands; New Zealand; Norway; Portugal; Puerto Rico; Spain; Sweden; Switzerland; Turkey; U.S. Virgin Islands; United Kingdom; United States. All other countries of the world are defined as "non-OECD." These include the current and former centrally-planned economies (CPE's) and other developing countries. The term "non-OECD" is equivalent to "developing," except where otherwise noted.

3. Complete annual data for the time periods in question are not always available for all countries. An effort is made, however, to include the latest available data for each graph.

4. Gross Domestic Product, or GDP, is used whenever available throughout this report. According to the OECD *National Accounts, Vol. 1: 1960-1991*, GDP is defined as equal to "the total of the gross expenditure on the final uses of the domestic supply of goods and services...less imports of goods and services." Gross National Product, or GNP, is substituted for GDP in this report when GDP statistics are not available. GNP is the same as GDP, except that it does not exclude imports of goods and services.

5. Purchasing power parity (PPP) exchange rates are used whenever available throughout this report. According to the OECD *National Accounts, Vol. 1: 1960-1991*, PPP is defined as the rate of currency conversion that will buy the same basket of goods and services in different countries. This is considered by many economists to represent a more realistic basis than standard exchange rates for international economic comparisons.

6. Energy consumption in the industrial, transportation, and residential/commercial sectors includes all inputs used to generate electricity consumed in each sector.

7. See L. Schipper, S. Meyers, R. Howarth and R. Steiner, *Energy Efficiency and Human Activity: Past Trends, Future Prospects* (Cambridge University Press: Cambridge, 1992).