UNIT 2 ENERGY CONSUMPTION

Structure

2.1 INTRODUCTION

In the previous unit, you have learnt about the crucial role of energy in the economic growth of industrialising countries. You have also studied about the energy resource base of the Earth and learnt that energy is a useful metric for estimating the carrying capacity of the Earth. You would agree that to promote the sustainable use of energy, we need to evaluate the current energy consumption and bring the issue of equity in energy use to the forefront of the energy-environment debate.

While studying Unit 1, you have come across many units like joules, ergs, watt, Btu, Gtoe, etc. We begin this unit by defining these terms. Then we present the data about the patterns of energy consumption in the world and discuss the current energy demand and future projections.

In the next unit, we discuss the technologies currently used for energy production as these are equally important in any analysis of energy-environment relationship.

Objectives

After studying this unit, you should be able to:

- define various units of energy and power;
- analyse the world-wide patterns of energy consumption region wise as well as by fuel type;
- discuss the energy consumption pattern of Asian countries, in general and India, in particular; and
- analyse the future energy demand projections region wise and by fuel type.

2.2 ENERGY UNITS

You have learnt about the concept of energy in the course MED-001. It is defined as the **capacity to do work**. Energy is measured in ergs or joules. Although it is common to talk of 'energy generation' and 'energy consumption', strictly speaking, energy is never 'created' or 'consumed'; it is just 'converted' from one form to another.

Therefore, a more useful entity is that of **power**, defined **as the rate at which energy is used or converted from one form to another**. The unit of power most commonly used is watt.

One watt is equal to one joule per second. In symbols, it is written as

$1W = 1\ Js^{-1}$, where W stands for watt, J for joules and s for second.

You would have come across electric heaters of 1 kilowatt rating. What does this mean? One kilowatt (kW) is equal to 1,000 watts. So one kilowatt rating means that the device consumes 1000 joules of energy in one second. Horse Power (H.P.) is yet another unit of power. One H.P. is equal to work done at a rate of 550 ft lbs^{-1} (foot-pounds per second). It is equal to 748 watts:

$$1 \text{ H.P.} = 748 \text{ watts}$$

Water pumping systems are generally rated in terms of H.P., for example, 0.5, 0.75, 1, 1.5 and 2 H.P. etc.

A 1 H.P. pump can move 1 pound water to a distance of 550 feet in one second.

Almost all energy generating or consuming devices carry a power rating (or rated capacity) in watts and multiples of watts, e.g., kilowatt, megawatt and so on. You may have read in the newspapers that such and such a city requires 500 megawatts of power. How much energy does the city need in one second? You can calculate this by making use of the conversion factors given in Table 2.1.

Table 2.1: Units of power and conversion factors

Unit and symbol	Conversion factor (in Watts)
kilowatt (kW)	1 kW = 1000 W = 10^3 W
megawatt (MW)	1 MW = 1,000 kW = 10^6 W
gigawatt (GW)	1 GW = 1000 MW = 10^9 W
terawatt (TW)	1 TW = 1000 GW = 10^{12} W

To give you an idea of scale, a typical large modern coal or nuclear power station has a rated capacity of around 1.3 gigawatts (GW), while India produced a total of 533 terawatts of electricity in 2001.

Kilowatt-hours or (kWh) is the unit by which electricity and gas are sold in many countries including India. **One unit** measured by the electricity meters in our homes is equal to **1 kilowatt-hour**.

The amount of energy converted (generated or consumed) by a device is defined as the product of the power of the device multiplied by the time for which it is used:

1 kilowatt-hour = 1 kilowatt × 1 hour = 1 unit of energy

A device of rating 1 kW consumes one kilowatt-hour or one unit of energy in one hour. So, if you run a geyser of 2 kW rating for one hour, it ideally consumes 2 units of energy.

Given this information, can you work out the energy consumption in one day in your home or office? Give it a try.

SAQ 1

Write down the power ratings of various devices that you use in your homes. Some examples are given below:

Fluorescent tube	40 W
CFL	5 W, 7 W, 9 W, 11 W, 13 W, 15 W
Electric bulb	15 W, 40 W, 60 W, 100 W
Fan	
Refrigerator	
Cooler	
Water Pump	
TV	
Radio	
Washing machine	
AC	
Microwave oven	

Calculate the power consumed in your home on **one** typical day in various seasons. For example, in Delhi, you could do the calculations for a day in summer (e.g., month of May/ June), winter (e.g., month of December/ January) spring (e.g., month of March/ April) and autumn (e.g., month of September/ October), respectively.

Can you discern an energy consumption pattern from this data? How can you optimise or reduce your consumption?

For larger quantities of energy, multiples of kWhs are used. The most commonly used unit is the terawatt hour (TWh) which is 1,000,000,000 kWh or 10^9 kWh.

To give you an idea of scale, the total electricity consumption in India was about 497 TWh in 2001. Remember, however, that this represents consumption of **electricity**, and not **total energy consumption**. It does not include all the direct heat supplies (kerosene, wood, gas, etc.) or transport fuels like petrol, diesel, etc.

You have also come across the unit of Btu in Unit 1 (recall Fig. 1.2). It is the **British thermal unit**, an old measure for the heat content of various fuels. In terms of kilowatt-hours, it is given as

$$1 \text{ kWh} = 3,413 \text{ Btu.}$$

The USA still uses the Btu.

The total amount of energy used is often measured in terms of **primary energy consumption** that is **the amount of energy in the basic fuels used by energy conversion devices**, whether for electricity production, heating or transport.

However, you must remember that **primary energy figures** for the total energy in the fuels used by energy conversion devices **are much larger than the finally delivered energy**, as utilised by consumers. This is because there are **losses in the conversion process** in power plants and along the **transmission and distribution (T&D)** grid network.

This is particularly true of electricity: conventional coal or nuclear-fired power plants have conversion efficiencies of around 35 %. Even the best modern gas-fired power stations can only convert around 50 % of the energy in the input fuel to electricity. Moreover, up to 10 % of the electricity may be lost when it is transmitted along power lines to consumers, depending on the distances involved. Finally, consumer devices operate with varying degrees of efficiency. For example, some part of the energy used by coolers or heaters is lost due to poor insulation in buildings.

Primary energy figures, therefore, tell us only a part of the story. As we shall see in the subsequent units, there is also a need, when comparing technologies and energy systems to consider the overall efficiency of energy conversion and transmission, and the use to which the energy is put.

The Battle of the Units

Measuring energy is not as simple as it might seem to you. Given that there are many ways in which energy is generated and used, it is not surprising that there are many different, often confusing, ways in which it is measured.

We have mentioned kWh, which is the most familiar unit to us since it is used in our electricity bills.

However, energy analysts sometimes use the basic unit of energy, the joule (J) or multiples of joules. Since one watt is one joule per second,

$$\begin{aligned} 1 \text{ kWh} &= 1000 \text{ W} \times 1 \text{ hour} \\ &= 1000 \text{ joules per second} \times 60 \text{ minutes} \times 60 \text{ seconds} \\ &= 36,00,000 \text{ joules} \end{aligned}$$

The joule (J) is, however, a very small unit. In the energy sector, larger multiples of joules are used, e.g., peta-joules (PJ) and exa-joules (EJ):

$$1 \text{ PJ} = 1{,}000 \text{ tera joules} = 10^{15} \text{ joules}$$

$$1 \text{ EJ} = 1{,}000 \text{ peta joules} = 10^{18} \text{ joules}$$

We have also used units like **mtoes** or the **gtoes** in Unit 1, which are the European standard units. These render the energy content of all fuels, mainly for statistical comparison purposes, in terms of the equivalent of oil that would have the same amount of energy content. The energy content of all fuels is now presented in terms of tons of oil equivalent, or more commonly, million tons of oil equivalent (mtoes). Gtoe is giga-tons of oil equivalent.

However, in this course, we will use the more familiar units like kWh, Twh, etc. We give the conversion factor for the sake of completeness:

$$1 \text{ mtoe} = 11.63 \text{ TWh, and } 1 \text{ TWh} = 0.086 \text{ mtoe.}$$

You need not memorise all the units explained here. But you should know what these terms mean. Having familiarised you with the units of energy and power that we will be using throughout this course, we now focus on various patterns of energy consumption.

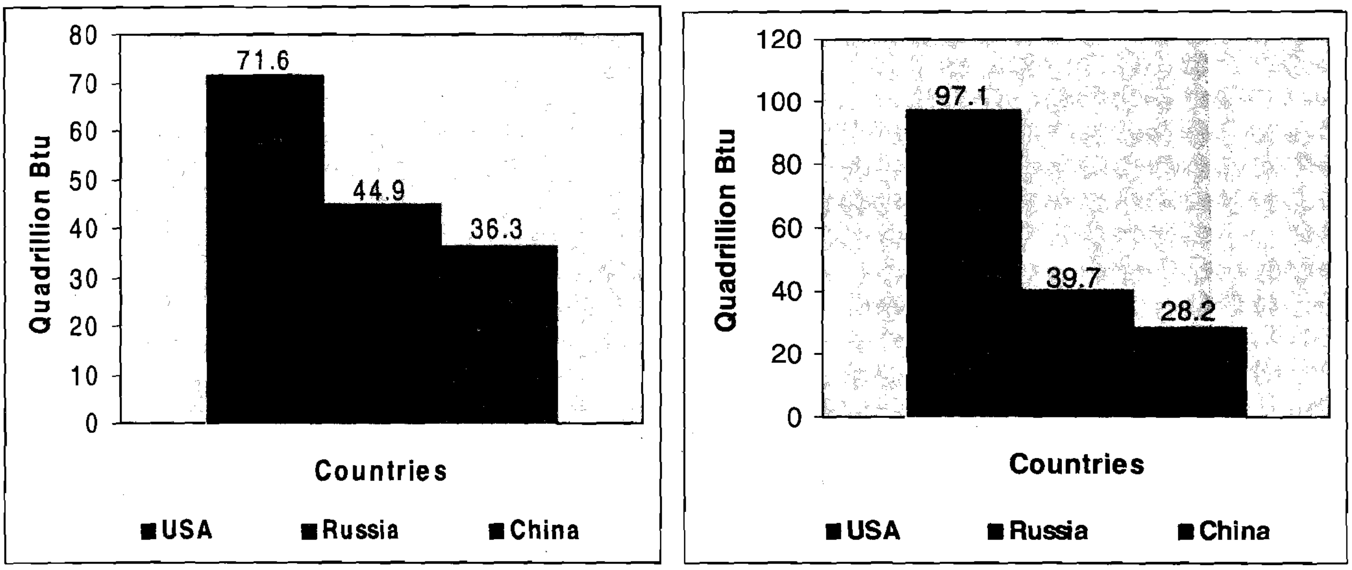
2.3 CURRENT PATTERNS OF ENERGY CONSUMPTION

A study group conducted a primary treatment of the data extracted from the Energy Statistics Yearbook of the United Nations, the World Energy Statistics and Balance by OECD/IEA and other energy-related statistics including the Yearbook of Forest Products by FAO. The interim report provides a preliminary summary of the present energy consumption patterns as a result of the above endeavour. The International Energy Outlook 2004 and the Energy Statistics Yearbook of the United Nations provides information on the energy consumption pattern for analysing global environmental problems, by country and by region and by degree of socio-economic development.

World Major Energy Producers and Consumers

In 2001, three countries – the United States, Russia, and China – were the leading producers and consumers of world energy. The United States supplied 71.6 quadrillion Btu of primary energy, significantly more than the

44.9 quadrillion Btu produced by Russia or the 36.3 quadrillion Btu produced by China (see Fig. 2.1a). These three countries produced 38 percent and consumed 41 percent of the world's total energy.



(a) (b)

Fig.2.1: Leading a) producers and b) consumers of world energy in 2001

The United States, Russia, China, Saudi Arabia, and Canada were the world's five largest producers of energy in 2001, supplying 47.9 percent of the world's total energy. The next five leading producers of primary energy were the United Kingdom, Iran, Norway, Australia, and Mexico, and together they supplied an additional 12.8 percent of the world's total energy.

Let us now look at the world energy consumption so far (Fig. 2.2).

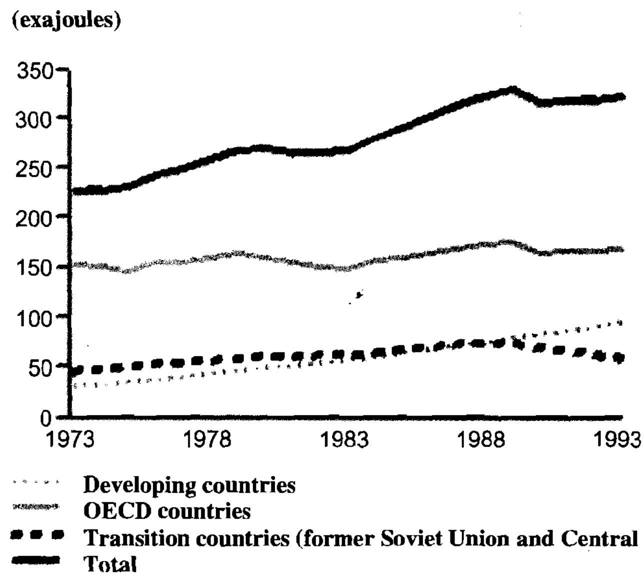


Fig.2.2: Total energy consumption by region up to 1993

The United States, China, Russia, Japan, and Germany were the world's five largest consumers of primary energy in 2001, accounting for 49.8 percent of world energy consumption. They were followed by India, Canada, France, the United Kingdom, and Brazil, which together accounted for an additional 13.5 percent of world energy consumption. The United States consumed 97.1 quadrillion Btu, almost two and one-half times as much as the 39.7 quadrillion Btu consumed by China, while Russia consumed 28.2 quadrillion Btu (see Fig.2.1b). Compare these numbers with the 12.8 quadrillion Btu consumed in India in 2001. How does the per capita energy consumption in India compare with the other countries? You may like to work it out. Try SAQ 2.

SAQ 2

Use the data given so far and the population data of US, China, Russia and India in 2001 to calculate the per capita energy consumption for the following countries:

USA
China
Russia
India

You may now like to look at the consumption patterns in Asia in some detail.

Asian Energy Consumption Pattern and its Effects on the Global Environment

Asia, to which Japan belongs, is expected to increase its energy consumption at the fastest rate in the world because of its large population, accounting for about 50 percent of the world population, and the anticipated rapid economic growth of the **newly industrialising economies** (NIEs) and developing countries like China and India. However, the adverse effects of their energy consumption have already become evident, in the form of acid rain, for example. Concern is also expressed over such global atmospheric environmental effects as the greenhouse effect.

The knowledge on Asia's present energy consumption pattern, geo-scientific features and environment is not sufficient for formulating adequate measures to cope up with the environmental problems foreseen in the future. Besides, the great diversity amongst the Asian nations in energy consumption and socio-economic conditions will make such studies even more difficult.

The World Energy Statistics and Balance by OECD/IEA, issued in November 1988 as a bulletin and June 1989 as a formal report, provided for the first time a comprehensive coverage that included the developing countries. The summary of the report is as follows:

- Consumption of energy is growing in Asia faster than any other region of the world. Asia also depends heavily on coal, which imposes a heavy load on the environment. These trends are becoming even more pronounced recently.

- If we look at country wise consumption, China, Japan and India are the major consumers of energy in Asia. Both China and India have a pattern of energy consumption in which coal is the primary source of energy; further, their demands for energy are increasing fast.

- Overall, NIEs and Japan are shifting their dependence from liquid fuel to natural gas and nuclear power, both of which give rise to lesser environmental problems than petroleum. In contrast, India has an ambitious programme to use a liquid fuel i.e., ethanol in the transport sector. It is presently marketed under the name, "gasohol". The idea is to replace the conventional gasoline fuel by ethanol to the extent of about 5% in the first instance. However, the rate of solid fuel consumption is also increasing. The Least Developed Countries (LDCs) are introducing natural gas and developing hydroelectric generation. This trend should be highly valued from the viewpoint of global environmental conservation.

- On the subject of energy consumption by sector, Japan in recent times has exhibited a tendency for decreasing share of the industry sector while increasing its energy shares of the transportation and household sectors. By contrast, the

ASEAN countries, LDCs and NIEs are increasing the energy share of the industry sector. The transportation sector is notably increasing its share in NIEs.

- Forests are declining in Southeast Asia at the fastest rate; the rate is faster than even the forest decline of Brazil. Charcoals are cited as a major cause for the forest decline. Firewood and charcoal production accounts for the majority of timber production.

In MED-001, you have studied that global warming due to GHG emissions is one of the major environmental problems being faced today. CO_2 has the maximum share in the GHGs. We now discuss briefly the impact of fossil fuel consumption on the CO_2 emissions.

Carbon Dioxide Emissions from the Consumption and Flaring of Fossil Fuels

The total world carbon dioxide emissions from the consumption of petroleum, natural gas, and coal, and the flaring of natural gas increased from 5.894 billion metric tons carbon equivalent in 1992 to 6.568 billion metric tons in 2001, or by 11.4 percent. The average annual growth rate of carbon dioxide emissions over the period was 1.2 percent (Note: Carbon dioxide emissions are measured here in metric tons carbon equivalent. Tons of carbon equivalent can be converted to tons of carbon dioxide gas by multiplying by 44/12.)

The United States, China, Russia, Japan, and India were the world's five largest sources of carbon dioxide emissions from the consumption and flaring of fossil fuels in 2001, producing 52 percent of the world total. The next five leading producers of carbon dioxide emissions from the consumption and flaring of fossil fuels were Germany, Canada, the United Kingdom, Italy, and South Korea, and together they produced an additional 12 percent of the world total. In 2001, the total United States carbon dioxide emissions from the consumption and flaring of fossil fuels were 1.565 billion metric tons carbon equivalent. This was more than one and three-fourths times as much as the 832 million metric tons produced by China, while Russia produced 440 million metric tons.

The developed countries account for a 79.8% of total world CO_2 emissions. The absolute emission ranking for selected countries is given in Table 2.2.

Table 2.2: Country wise percentage of world total CO_2 emissions

Country	Percentage of world total CO_2 emissions
United States	23.3%
China	12.96%
Russia	7.28%
Japan	5.30%
Germany	4.66%

You may also like to know the share of CO_2 emissions from each of the fuel types, viz., petroleum, coal and natural gas.

- **CO_2 emissions from the consumption of petroleum**

  In 2001, petroleum consumption was the world's primary source of carbon dioxide emissions accounting for 42 percent of the total CO_2 emissions from the consumption and flaring of fossil fuels. Between 1992 and 2001 emissions from the consumption of petroleum increased by 262 million metric tons carbon equivalent, or 10.5 percent, rising from 2.499 to 2.761 billion metric tons. The United States was the largest producer of carbon dioxide from the consumption of petroleum in 2001 and accounted for 24 percent of the world total. Japan was the second largest producer, followed by China, Russia, and Germany, and together these four countries accounted for an additional 20 percent.

- **CO_2 emissions from the consumption of coal**

  Coal ranked second as a source of carbon dioxide emissions from the consumption and flaring of fossil fuels in 2001, accounting for 37 percent of the total. World carbon dioxide emissions from the consumption of coal totalled 2.4 billion metric tons carbon equivalent in 2001, up 8.7 percent from the 1992 level of 2.2 billion metric tons. China and the United States were the two largest producers of carbon dioxide from the consumption of coal in 2001. Together they accounted for 49 percent of the world total. India, Russia, and Japan accounted for an additional 16 percent.

- **CO_2 emissions from the consumption of natural gas**

  Carbon dioxide emissions from the consumption and flaring of natural gas accounted for the remaining 21 percent of carbon dioxide emissions from the consumption and flaring of fossil fuels in 2001. Emissions from the consumption and flaring of natural gas increased from 1.162 billion metric tons carbon equivalent in 1992 to 1.379 billion metric tons in 2001, or by 18.7 percent. The United States and Russia were the two largest producers of carbon dioxide from the consumption and flaring of natural gas in 2001 and together they accounted for 40 percent of the world total. The United Kingdom, Germany, and Canada accounted for an additional 10 percent.

You may want to know about the **contribution of India to carbon emissions**. In 2001, India, with 251 million metric tons of carbon equivalent emitted, ranked fifth in the world in carbon emissions, behind the United States, China, Russia and Japan (see Fig. 2.3).

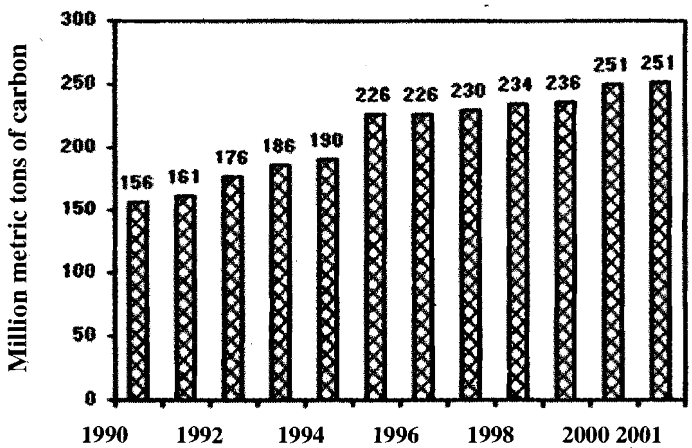


Fig.2.3: India's CO_2 emissions from 1990 to 2001 (Source: EIA)

However, India's carbon emissions stood at only 80% of Japan's (316 million metric tons of carbon equivalent) total and less than one-sixth of the United States' (1,565 million metric tons) carbon emissions during the same year. Between 1990 and 2001, India's carbon emissions increased by an astonishing 61%, a rate surpassed only by China's 111% increase during the same time period

Still, India's per capita carbon emissions are relatively low. At 0.25 metric tons of carbon per person in 2001, India's per capita carbon emissions were less than one-quarter of the world average and 22 times less than those for the United States. However, India's contribution to world carbon emissions is expected to increase in the coming years, with an estimated average annual growth rate of 3.1% between 2001 and 2025 (as compared to 3.4% in China and 1.5% in the United States). The absolute increase in emissions will partially be a function of the degree to which coal is relied upon as a major energy source.

The rise in India's carbon emissions has been mainly due to the low energy efficiency of its coal-fired power plants. It is also on account of the poor quality of the Indian coal, which means high ash content. Many of India's highly-polluting coal-fired thermal power plants will have to remain in operation for the next couple of decades for the following reasons:

- High capital costs associated with replacing existing coal-fired plants,
- A scarcity of capital, and
- The long lead time required to introduce advanced coal technologies.

If, however, coal consumption is substituted by oil and natural gas, India's overall carbon emissions would be surely reduced. India's per capita carbon emissions are also expected to increase in the coming years due to the rapid pace of urbanisation, a conversion away from non-commercial towards commercial fuels, increased vehicular usage and the continued use of older and more inefficient coal-fired plants. The growth of energy-intensive industries that has taken place in the country during the course of its economic expansion, coupled with the very little action on energy efficiency and conservation measures in most industrial sectors will also add to these emissions. In fact, due to fast-paced industrialisation, per capita emissions are expected to triple by 2020, which is a worrying scenario indeed.

In this section, we have presented data about the current trends in energy consumption and CO_2 emissions in the world, region wise as well as by fuel type. You have also learnt about the Indian scenario. You may now like to do an exercise based on these data.

SAQ 3

a) Compare the energy consumption trends and CO_2 emissions of India with those of the developed European nations, USA and other Asian countries like Japan and China from 1990 to 2001.

b) Analyse the statement: The richest countries with 20% of the world population consume 80% of all world energy.

Let us now examine the projections of world energy demand.

2.4 WORLD ENERGY DEMAND AND FUTURE PROJECTION

The total world energy consumption and energy consumption by region from 1970 to 2025 are shown in Figs. 2.4a and b. You can see that the world energy demand will continue its rapid growth. These projections tell us that the overall energy consumption will rise by 54 percent in 24 years, from 404 quadrillion British thermal units (Btu) in 2001 to 623 quadrillion Btu in 2025 (Fig. 2.4a).

In the industrialised world, energy use is expected to grow at the rate of 1.2 percent per year. In the transitional economies of Eastern Europe and the former Soviet Union (EE/FSU) growth in energy demand is projected to average 1.5 percent per year. However, in the developing world, primary energy consumption is projected to grow at an average annual rate of 2.7 percent between 2001 and 2025 (Fig. 2.4b). Thus, the developing nations are largely expected to account for the increase in world energy consumption. In particular, energy demand in the developing economies of Asia, which include China and India, is projected to more than double over the next quarter century. This is because faster than average growth is expected for the developing nations.

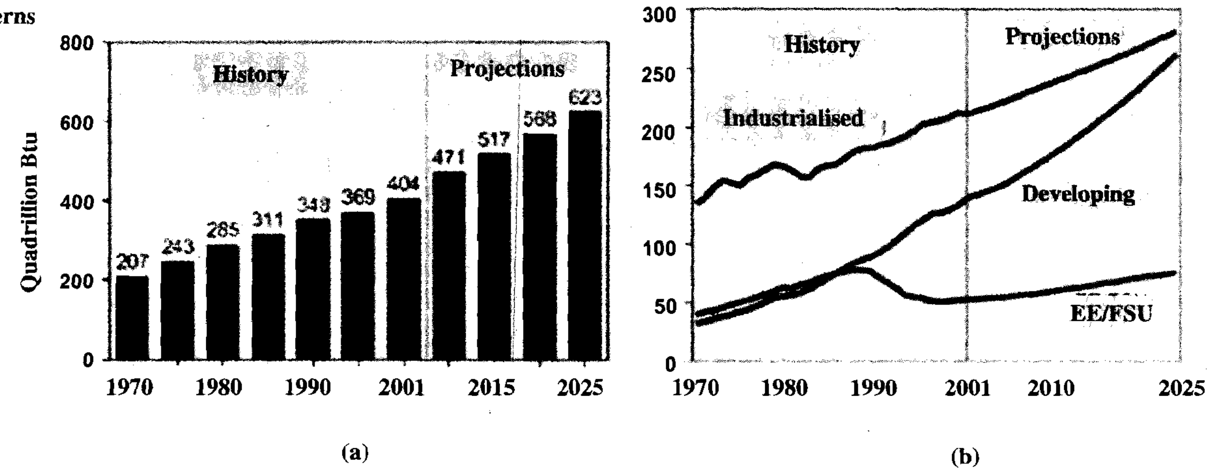


Fig.2.4: World primary energy consumption from 1970-2025: a) total; and b) by region. Here EE refers to Eastern Europe and FSU to former Soviet Union
(**Source:** EIA International Energy Outlook 2004)

Let us see how much of energy is derived from various sources of energy.

World Energy Consumption by Source of Energy

Fig. 2.5 shows the history and projections of world energy consumption by energy source. It suggests an increased consumption of all primary energy sources over the forecast period. An underlying assumption is that the fossil fuel prices would remain relatively low. Therefore, the costs of generating energy from other fuels are not expected to become competitive; as a result, much of the increase in future energy demand is projected to be supplied by oil, natural gas, and coal. It is possible, however, that as environmental programmes or government policies – particularly those designed to limit or reduce greenhouse gas emissions, such as the Kyoto Protocol – are implemented, the outlook changes. Then non-fossil fuels (including nuclear power and renewable energy sources such as hydroelectricity, geothermal, biomass, solar, and wind power) could become more attractive. These projections also assume that government laws in place as on October 1, 2003, remain unchanged over the forecast period.

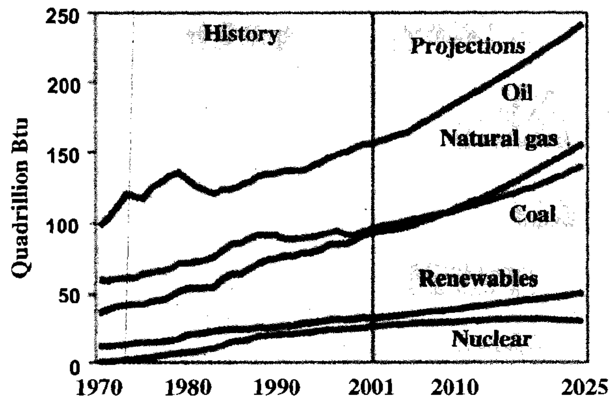


Fig. 2.5: World primary energy consumption from 1970 to 2025 by source of energy
(**Source:** EIA International Energy Outlook 2004)

Let us now look at these sources individually.

Oil

Oil is expected to remain the dominant energy fuel throughout the forecast period, with its share of total world energy consumption remaining unchanged at 39 percent through 2025. In the industrialised world, increases in oil use are expected to be primarily in the transportation sector, where there are currently no available fuels to compete significantly with oil products. Oil use for electricity generation is expected to decline, and other fuels (especially natural gas) are expected to provide more favourable alternatives.

In the developing world, oil consumption is projected to increase for all end uses unless the oil prices become prohibitive. In some countries where fuels such as wood have been widely used in the past for cooking, the use of alternatives is being encouraged, for example, gas, diesel generators (as well as distributed generators, such as solar photovoltaics) to dissuade rural populations from decimating surrounding forests and vegetation – most notably, in Sub-Saharan Africa, Central and South America, and Southeast Asia.

Natural Gas

Natural gas is projected to be the fastest growing primary energy source worldwide, maintaining average growth of 2.2 percent annually over the 2001-2025 period (Fig.2.6). In comparison, 1.9-percent average annual growth rates are projected for oil and for renewable sources, 1.6-percent annual growth is projected for coal, and 0.6 percent annual growth is projected for nuclear power. Total world natural gas consumption is projected to rise from 90 trillion cubic feet in 2001 to 151 trillion cubic feet in 2025. The infrastructure necessary to expand natural gas use has not been as widely established in the developing world as it has in the industrialised world. Therefore, natural gas use is not expected to grow enough in the developing world to accommodate all of the increased demand for energy.

Year	World total natural gas consumption (in trillion cubic feet)
2001	90
2010	105
2015	118
2020	134
2025	151

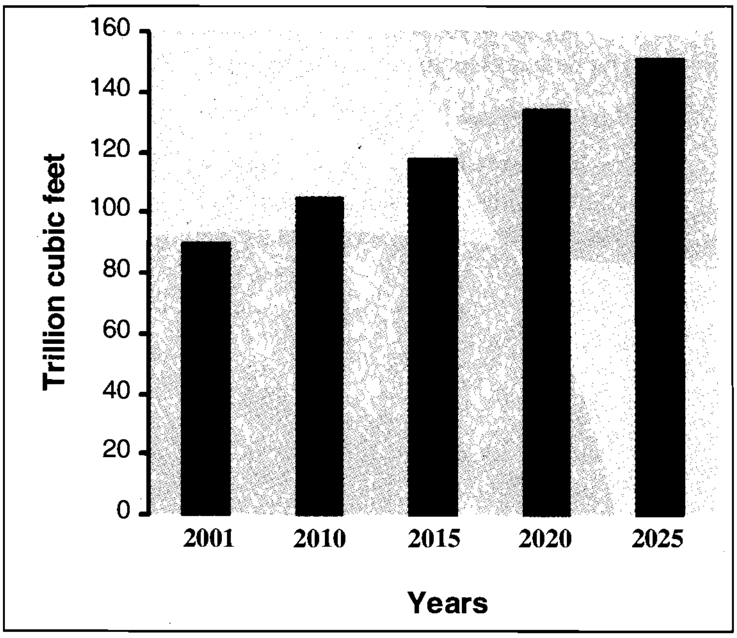


Fig.2.6: World natural gas consumption from 2001-2025 (**Source:** IEO, 2004)

Natural gas is expected to remain an important supply source for new electric power generation in the future. It is seen as the desired option for electric power, given its efficiency relative to other energy sources. Natural gas is also environmentally attractive because it emits less sulphur dioxide, carbon dioxide, and particulate matter than oil or coal. This fact makes it a more attractive choice for countries interested in reducing greenhouse gas emissions. Combined-cycle gas turbine power plants offer some of the highest commercially available plant efficiencies. Lately India too is basing some of its new power generating capacities on the use of natural gas. The objective is also to reduce its dependence on coal. India is also negotiating for a natural gas pipeline from Iran via Pakistan. Besides, India's capital city New Delhi has its public transport system running on the Compressed Natural Gas (CNG).

Coal

Coal use worldwide is projected to increase by 2.3 billion tons between 2001 and 2025. Substantial declines in coal use are projected for Western Europe and Eastern Europe, where natural gas is increasingly being used to fuel new growth in electric power generation and for other uses in the industrial and building sectors. In the developing world, however, larger increases in coal use are projected for China and India, where coal supplies are plentiful. Together, China and India account for 85 percent of the projected rise in coal use in the developing world and 70 percent of the total world increment in coal demand over the forecast period.

The demand projections for coal made by the Planning Commission, Government of India are based on end-use analysis of power, cement, iron and steel sectors assuming a GDP growth of around 4% in the period 1997 – 2012.

The annual average demand growth rate for coal projected for the above period is 6.8%. The domestic supply will be coming from the existing mines as well as new projects.

Table 2.2: Coal demand and supply forecasts for India (Million Tons)

	1997-98	2006-07	2011-12
Demand	323	576	872
Domestic supply	298	484	652
Deficit	25	92	220

The deficit is made up through imports.

Nuclear Power

The prospects for nuclear power have been reassessed in the light of the higher capacity utilisation rates reported for many existing nuclear facilities and no substantial change is foreseen (see Fig. 2.7).

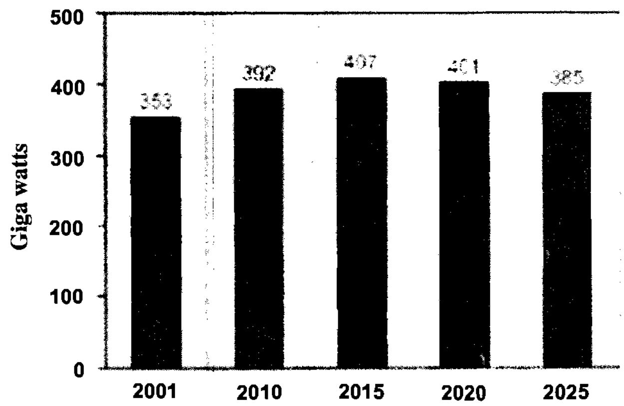


Fig.2.7: World installed nuclear capacity, 2001-2025 (**Source:** IEO, 2004)

It is expected that fewer retirements of existing plants will occur than previously projected. Extensions of operating licenses (or the equivalent) for nuclear power plants are expected to be granted among the countries of the industrialised world and the EE/FSU, slowing the decline in nuclear generation. India has recently drawn up plans for additional nuclear power capacity of more than 8000 MW within the next 5 to 7 years. The idea is to raise the cumulative nuclear power capacity within the country to some respectable levels.

So far you have studied how the world energy demand is projected to grow in the next 20 years. You have also learnt about the projections of the use of energy from different sources. These are estimates made in 2004 and could change with any drastic changes in the situation. Energy intensity is one more parameter which should be analysed for the future projections.

Energy Intensity

The rate of energy intensity (defined as energy consumption per dollar of gross domestic product) growth is expected to be considerably higher. Of course, continued improvements in energy intensity are also expected. As per the IEO2000 forecast, energy intensity in the industrialised world was expected to improve (decrease) by 1.1 percent per year between 1997 and 2020. Energy intensity is also projected to improve in the developing countries by 1.0 percent per year as their economies begin to behave more like those of the industrialised countries. This would be due to an improvement in the standards of living that accompany the projected expansion. The energy intensity in Eastern Europe and the FSU is also projected to improve along with the expected recovery from the economic and social declines of the early 1990s (Fig. 2.8). However, they are expected to remain high relative to the industrialised and developing regions through 2020.

China has enjoyed particularly strong improvement in its energy intensity over the past two decades, attributable to the strong economic growth experienced in the country, falling from a high of 117.2 thousand Btu per dollar of GDP in 1976 to 39.6 thousand Btu per dollar in 1997. Between 1978 and 1995, gross domestic product increased by an average 10.0 percent per year in China, whereas energy use grew by 4.2 percent per year over the same period.

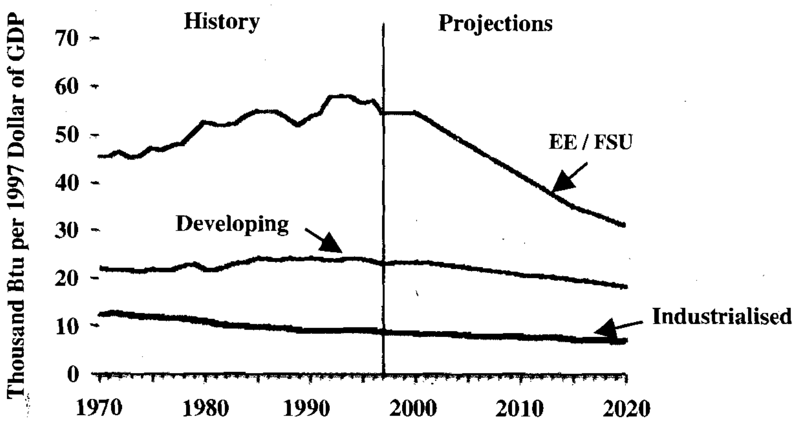


Fig.2.8: World energy intensity by region, 1970-2020
(**Source:** EIA, International Energy Outlook 2000)

In 2001, India's energy intensity (energy consumption per dollar of GDP) stood at 25,307 Btu per $1995. This figure is one of the highest in Asia, surpassed only by Pakistan (26,229 Btu per $1995) and China (35,619 Btu per $1995). India's still elevated energy intensity level is due in large part to the growth of energy-intensive industries that has taken place in the country during the course of its economic expansion. This is compounded due to the virtual absence of energy efficiency and conservation measures in most industrial sectors.

We should also look at the projections of carbon dioxide emissions to form a complete picture.

Carbon dioxide Emissions

World carbon dioxide emissions are expected to increase from about 24 billion metric tons in 2001 to 37 billion metric tons in 2025—growing by 1.9 percent per year (see Fig.2.9). According to this projection, world carbon dioxide emissions in 2025 would exceed 1990 levels by 72 percent. (Carbon dioxide emissions are measured here in metric tons carbon equivalent. Tons of carbon equivalents can be converted to tons of carbon dioxide gas by multiplying by 44/12.)

Carbon dioxide emissions from energy use in the **industrialised countries** are expected to increase by 4 billion metric tons, to 15.6 billion metric tons in 2025, or by about 1.2 percent per year. Of these, emissions from the combustion of petroleum products account for about 42 percent of the total increase expected for the industrialised world, natural gas 33 percent, and coal 24 percent.

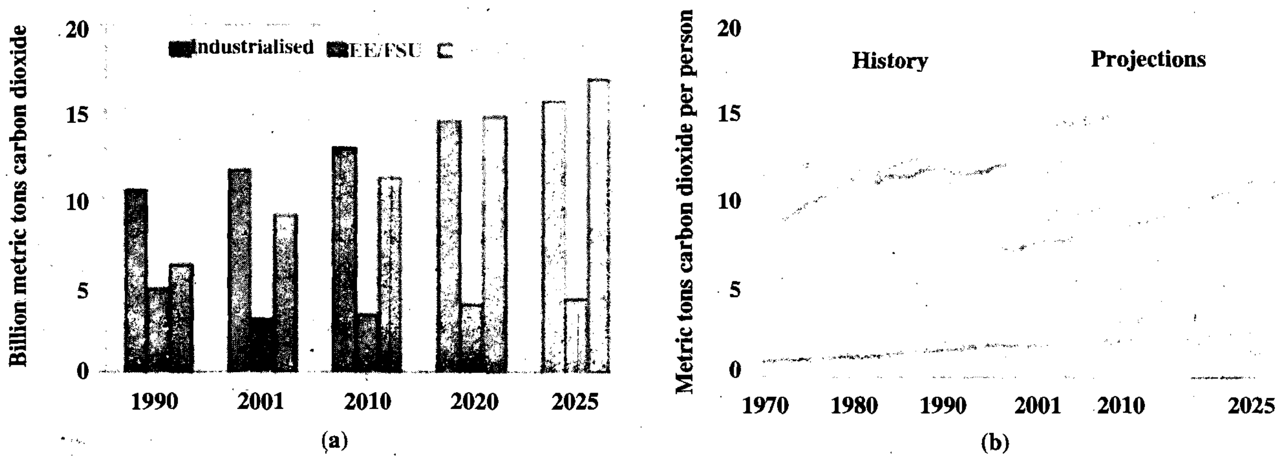


Fig.2.9: Energy related a) total and b) per capita carbon dioxide emissions by region from 1970 to 2025 (Source: IEO 2004)

Total emissions in **developing nations** are expected to increase from 9 billion metric tons in 2001 to a total of 17 billion metric tons in 2025, representing about 61 percent of the projected increase worldwide. In 2001, China and India together accounted for 17 percent of total world carbon dioxide emissions, as compared with the 24-percent share made up by U.S. emissions in the same year.

By 2025, carbon dioxide emissions in the developing world (including China and India) are expected to surpass those in the industrialised countries, even though developing countries are projected to use less total energy than industrialised countries at that time (Fig. 2.9a). Carbon dioxide emissions in **developing Asia** alone are projected to increase from 6 billion metric tons in 2001 to 11.8 billion metric tons in 2025. However, developing countries will continue to account for less than one-half of global carbon dioxide emissions through the 2025 forecast horizon.

In the EE/FSU region, carbon dioxide emissions are not expected to return to their Soviet-era levels during the projection period. The FSU appears to be in the midst of sustained economic recovery after the political, social, and economic upheavals that followed the break-up of the Soviet Union in the early 1990s. Carbon dioxide emissions are not expected to increase as quickly as energy use because of gains in energy efficiency resulting from the replacement of old, inefficient capital stock, and because in many countries in the region, natural gas is expected to displace coal, particularly for new electricity generation capacity.

Worldwide, **carbon dioxide emissions per person** are projected to increase from about 4.1 metric tons in 1990 to 4.7 metric tons in 2025. Per capita emissions in the industrialised countries remain much higher than those in the rest of the world throughout the projection period, increasing from 11.8 to 12.9 metric tons per person between 1990 and 2010 and then to 14.7 metric tons per person in 2025 (see Fig. 2.9b).

If we look at the carbon emissions by fuel, the combustion of petroleum products contributes about 5.7 billion metric tons to the projected increase from 2001, coal

4 billion metric tons and natural gas about 3 billion metric tons (Fig. 2.10). Although coal use is projected to grow at a slower rate than natural gas use over the projection period, coal is also a more carbon-intensive fuel than gas. As a result, the absolute increase in carbon dioxide emissions from coal combustion is larger than the increase in emissions from natural gas combustion.

The sizable rise in emissions projected for the developing nations results in part from their continued heavy reliance on coal, the most carbon-intensive of the fossil fuels. Coal is used extensively in the countries of developing Asia, which have the highest expected rates of economic growth and energy consumption growth in the forecast. Coal use is also not expected to decline among the FSU countries. In fact, Russia's coal use is expected to increase slowly until 2015 before it begins to decline.

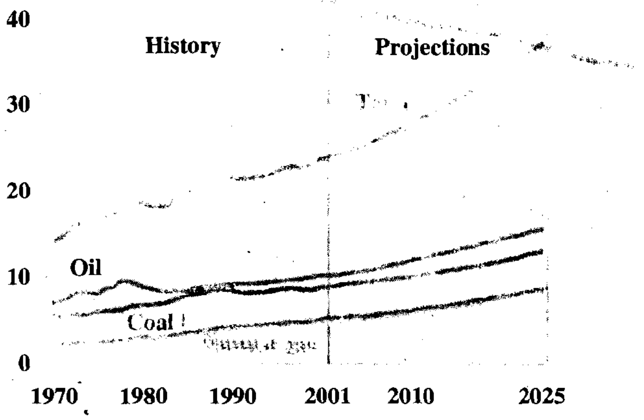


Fig.2.10: World energy related CO_2 emissions by fuel type from 1970 to 2025

We end this section by considering the growth of electricity consumption.

Growth of Electricity Consumption

Long-term growth in electricity consumption is expected to be strongest in the developing countries of Asia, followed by those of Central and South America. Rapid growth in population and income, along with heavy industrialisation and more widespread household electrification will be responsible for such an increase. The net electricity consumption is projected to rise by 3.5 percent per year in the developing world, compared with a projected average increase of 2.3 percent per year worldwide. Robust economic growth in many of the developing nations is expected to boost demand for electricity to run newly purchased home appliances for cooking, space and water heating and cooling, refrigeration, air conditioning, etc.

Electricity generation is expected to nearly double between 2001 and 2025, from 13,290 billion kWh to 23,702 billion kWh. Strongest growth is projected for the countries of the developing world. For the industrialised world and the transitional economies of the EE/FSU, where electricity markets are more mature, more modest annual growth rates of 1.5 and 2.0 percent, respectively, are projected.

Natural gas is expected to be the fuel of choice for much of the new electricity generation capacity built over the next two decades. The natural gas share of total energy used to generate electricity is expected to increase from 18% in 2001 to 25% in 2025, at the expense of oil and nuclear power, both of which are expected to lose market share of the world's electricity by 2025. The shares of hydroelectricity and other renewable energy resources, as well as that of coal use for electricity generation, are expected to remain fairly stable over the projection period. Worldwide consumption of electricity generated from nuclear power is expected to increase from 2,521 billion kWh in 2001 to 2,906 billion kWh in 2025.

To a large extent, future growth in the world's electricity generation will depend upon the progress made in connecting more of the world's population to national electricity grids. Electricity demand and investment in the electric power sector infrastructure have responded positively to the recent net improvement in the global economic conditions, and to the movement toward privatisation in many parts of the world. So far, many developing countries have been motivated to encourage various forms of private investment so as to raise the capital necessary to meet the rapidly growing demand for electricity. In the developing world alone, $142 billion in private capital flowed into electricity projects between 1990 and 1998.

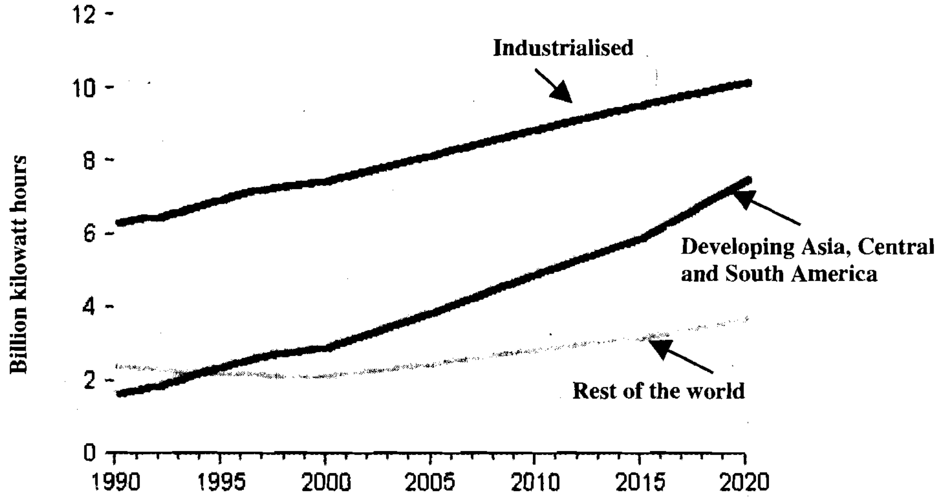


Fig.2.11: World Net electricity Consumption by Region, 1990-2020 (Source: IEO, 2000)

One way of looking at the future of world energy demand is to consider trends in **end-uses** of energy. We take this up in the next section. But you may like to reflect on the information presented in this section.

SAQ 4

Consider the projections in energy demand given for developing nations, and trends in the demand for various sources of energy as well as the CO_2 emissions. What energy options should a developing country like ours promote for sustainable energy use? Support your answer with well reasoned argument and evidence.

2.5 ENERGY END USE

We shall consider four sectors for analysing energy use: **residential, agricultural, commercial,** and **industrial**. The mix of energy use in the residential, commercial, and industrial sectors can vary widely from country to country, depending on a combination of factors, such as

- the availability of energy resources and infrastructure,
- the level of economic development including income levels, and
- political and social factors.

We do not take up the transportation sector, which is almost universally dominated by petroleum products.

Residential Sector

Energy end use in the residential sector is defined as energy consumed by households, excluding transportation uses. The type and amount of energy used by households varies from country to country. In general, households in developed countries use more energy than those in transitional or developing nations. Space and water heating and other appliances such as the refrigerators, washing machines, etc. account for most of the energy used by households in the industrialised nations.

Higher incomes have also led to an increased demand for more and more electric appliances, such as home computers, home theatre systems, and the like. Although the fuels used to heat both space and water vary from country to country, the recent trend has been toward natural gas and away from oil, coal, and biomass (wood and peat, for example) in most industrialised countries. That trend is expected to continue in future.

Developing World

Energy use in the residential sector in the developing nations (China, India, Central and South America, Africa, the Middle East, and Other Developing Asia) is projected to increase more rapidly than in other regions over the coming decades. Population growth and urbanisation in populous China and India are expected to produce large increases in demand for residential energy services. Rising incomes and rural electrification efforts are generally expected to increase the demand for electricity-based home appliances in most of the developing countries. As you know, India's electricity supply system is struggling to meet the demand of its customers, both in urban and rural areas.

In most developing countries, energy use for space heating is much less important due to climate as well as scarcity of energy. In the poorest areas of our country, for instance, available wood, wood waste, cattle dung and other solid wastes are used for cooking, and other purposes. However, as you know, the traditional sources of wood are becoming scarcer and alternatives need to be thought of.

Commercial Sector

The commercial sector or the services sector consisting of businesses, institutions, and organisations that provide services encompasses many different types of buildings and a wide range of activities and energy-related services. Examples are schools, markets, stores, parks, restaurants, hotels, hospitals, museums, office buildings, banks, stadiums, cinema halls, etc. Energy is used for lighting, cooking, space heating, water heating, cooling, etc. Energy consumed for public places and services such as traffic lights and city water and sewer services, is also categorised as commercial sector energy use.

Economic and population growth trends drive commercial sector activity and the resulting energy use. Higher levels of economic activity and disposable income lead to increased demand for hotels and restaurants to meet business and leisure requirements; for office and retail space to house and service new and expanding businesses; and for cultural and leisure space such as theatres, galleries, cinema complexes, etc.

The rate of increase in the developed region's commercial energy demand is also expected to slow as its population growth continues slowing. In addition, as energy-using equipment is replaced with newer, more efficient products, energy demand growth is likely to decrease. Of course, strong commercial growth in developed countries is expected to increase energy use in areas such as retail and wholesale trade and business, financial, and leisure services. Electricity demand growth in industrialised countries is becoming more dependent on advances in technology and the introduction of new electronic appliances and equipment.

Developing World

The commercial sector typically represents a smaller share of energy consumption in developing countries than in developed countries. However, economic growth and commerce are expected to increase rapidly in the developing nations, making additional energy demand in the services sector. Faster population growth is also expected in the developing world than in the other regions, increasing the need for education, health care, and social services and the energy required to provide them. Thus, commercial electricity demand is expected to grow rapidly in developing countries as more clinics, schools, and businesses gain access to electricity. The projected increase in commercial electricity demand is compounded in nations with quickly growing economies, such as China and India, as they continue to shift away from heavy manufacturing toward services.

Industrial Sector

Energy is consumed in the industrial sector by a diverse group of industries—including manufacturing, mining, and construction—and for a wide range of activities, such as process and assembly uses, space conditioning, and lighting. Overall energy demand in the industrial sector varies across regions and countries of the world, based on the level and mix of economic activity, technological development, and population, among other factors. Industrialised countries accounted for one-half of all energy consumption in the industrial sector worldwide in 2001, and the United States accounted for one-half of the total in the industrialised countries. On the other hand, the industrialised countries have lower energy intensity, i.e., they use much less energy per dollar of GDP than do countries in the developing regions.

On a per capita basis, delivered energy consumption in the industrial sector is higher in the industrialised countries than in the developing countries.

Developing World

Industrial energy consumption in the developing countries was nearly 40 percent of the worldwide industrial sector total in 2001, and their share is projected to increase to almost one-half of all industrial sector energy consumption by 2025 as a result of the more rapid economic growth expected in the region. The ratio of industrial sector energy consumption to GDP is projected to decline at approximately the same rate as in the industrialised countries. China leads the developing countries in terms of both economic growth and industrial energy consumption. Two energy-intensive industries, iron and steel and chemicals, are projected to increase capacity, both to meet domestic needs and to supply international markets. As the standard of living in China rises, however, less energy-intensive light industries are projected to increase output even faster, in order to meet growing demand for consumer products.

Agriculture Sector

Agriculture is the backbone of South Asian economy. It is dependent to a very large extent on the water pumping. Pumps are used widely for drawing water from the wells. These pumps are often driven either by electrical motors or by diesel engines. Energy is used not only for water pumping in this key sector, but also for running tractors, and several other agriculture tools and implements. In addition, energy is used in manufacturing and fertilisers pesticides.

You have learnt in this unit that the energy consumption by fuel and by region will increase in all sectors of economy. This will affect the environment adversely unless the consumption patterns undergo a drastic change in the industrialised as well as developing countries. Some of the damages could be offset by using appropriate and improved energy production technologies. The key concern is to conserve energy as far as possible. "Energy saved is energy produced" is no longer a fancy slogan, but a meaningful message receiving enough attention now a days in the key sectors of cement, iron and steel industries. India is poised to popularise all possible means of saving energy under its massive energy conservation programme. We now summarise the contents of this unit.

2.6 SUMMARY

- The **unit** of **energy** is **erg** or **joule. Power** is defined as the rate of energy consumed and its unit is **watt.** Specific energy generating or consuming devices are given a power rating (or rated capacity) in watts and multiples of watts.

- The amount of **energy** converted is defined by the power of the device multiplied by the time for which it is used (i.e. watts × seconds). It is usually measured in **kilowatt-hours** or (kWh). 1 kWh = 3,600,000 joules.

- Consumption of energy is growing in Asia faster than any other region of the world. China, Japan and India are the major consumers of energy in Asia. Both China and India have a pattern of energy consumption in which coal is the primary source of energy.

- Total world carbon dioxide emissions from the consumption of petroleum, natural gas, and coal, and the flaring of natural gas are increasing. The world's use of energy will continue its rapid growth in the foreseeable future, particularly in the developing nations. The demand for energy in the world has experienced a sudden increase in the developing regions, particularly in Asia.

- Long-term growth in electricity consumption is expected to be strongest in the developing countries of Asia, followed by those of Central and South America. Natural gas is projected to be the fastest-growing component of primary world energy consumption. Currently oil provides a larger share of world energy consumption than any other energy source and is expected to remain in that position throughout the forecast period. Electricity consumption worldwide will increase in all sectors of economy, viz. residential, commercial and industrial. Future growth in the world's electricity generation will depend upon the progress made in connecting more of the world's population to national electricity grids.

2.7 TERMINAL QUESTIONS

1. Rank the countries for which data is given in this unit from highest to the lowest in terms of the production and consumption of energy, respectively.

2. Describe the trends of energy consumption in Asia. Describe the end uses of energy in India in residential, commercial and industrial sectors.

3. Highlight a few measures that can be used to save energy in the residential, commercial and industrial sectors in India.

4. Analyse the current world energy demand by fuel type and by region type. What conclusions can you draw about the current consumption patterns?

5. Give a brief description of the future projection of world energy demand as per IEO2004.