CHAPTER - 1

Introduction – Energy Fundamental Concepts, Sources and Utilization

1.1 Introduction

Energy is the ability to do work and is associated with all our activities. When a force is applied to an object over a distance, work is done (Work = Force × Distance). The energy of an object or of a system is how much work the object or system can do on some other object or system. It is a measure of the capability of an object or system to do work on another system or object. Energy can be transferred from place to place and every time energy moves or changes it will effect some changes in associated objects like they become hotter or colder, some physical movement etc., which can be used for our various applications.

Most of the energy we use today comes from primary and secondary energy forms. Primary energy sources are sources which can be found naturally such as fossil fuels - coal, oil, and natural gas, biomass, radioactive minerals etc., which have not been subject to any sort of man-made conversion process. When primary energy is converted to a different form like electricity, gasoline etc., they are secondary forms of energy, also known as energy carriers and they need to be made using these primary energy sources.

Globally the nonrenewable, primary energy sources are providing nearly 80% of our energy needs (32% from oil, 26% from coal and 21% from natural gas). Hydro and nuclear sources are responsible for around 5% each of our global energy needs, while biomass and waste provide almost 10%. This is primarily due to wood burning in developing countries.

As the nonrenewable energy sources are generally more reliable, affordable and easier to store and transport their consumption is increasing significantly throughout the globe resulting in the decline of their reserves. Rapidly reducing primary energy reserves are prompting global focus on the development of innovative cost effective renewable energy technologies such as wind, solar, ocean and geothermal which currently supply nearly 0.5% of total energy needs.

The fundamental concepts of Energy Science and Technology, utilization patterns of various energy resources and emerging renewable technologies are presented in this book which may be useful for graduate students pursuing energy studies as a major focus.

1.2 Energy Cycle of the Earth

Energy cycles of the Earth control the Earth’s energy budget. There are three main sources for Earth's energy.

(i) ***Solar Energy:*** The source of energy for many processes occurring on the earth's surface comes from the sun. It drives the winds, ocean currents and the waves, causes rocks and the soil to weather, provides the energy necessary to drive the cycles of the Earth. Solar radiation heats the earth unevenly, creating air movements in the atmosphere. The transmitted radiation will be either absorbed or reflected at the Earth’s surface. Shortwave length solar radiation is transformed into sensible heat, latent energy (involving different water states), potential energy, and kinetic energy before being emitted as longwave radiation energy. Energy may be stored for some time, transported in various forms, and converted among the different types, giving rise to a rich variety of weather or turbulent phenomena in the atmosphere and ocean. Further the Earth’s climate is a solar power driven system as the energy balance can be upset in various ways, changing the climate and associated weather.

Globally, in an year, the elements of Earth like land surfaces, oceans, and atmosphere absorb an average of about 240 watts of solar power per square meter (one watt is one joule of energy every second). If the Earth takes in more energy than it uses, the climate on Earth will get warmer and if it releases more than the Sun gives, it will get cooler. If the earth did not have an atmosphere, surface temperatures would be too cold to sustain life. If too many gases which absorb and emit infrared radiation are present in the atmosphere, surface temperatures would be too hot to sustain life. No matter where the energy comes from, it is important to remember that the laws of thermodynamics apply to each situation (Energy is neither created nor destroyed, and only changes from one form to another).

The results of several sources is used to calculate the global mean energy budget of Earth (Fig. 1.1). Incoming radiant energy may be scattered and reflected by clouds and aerosols or absorbed in the atmosphere.

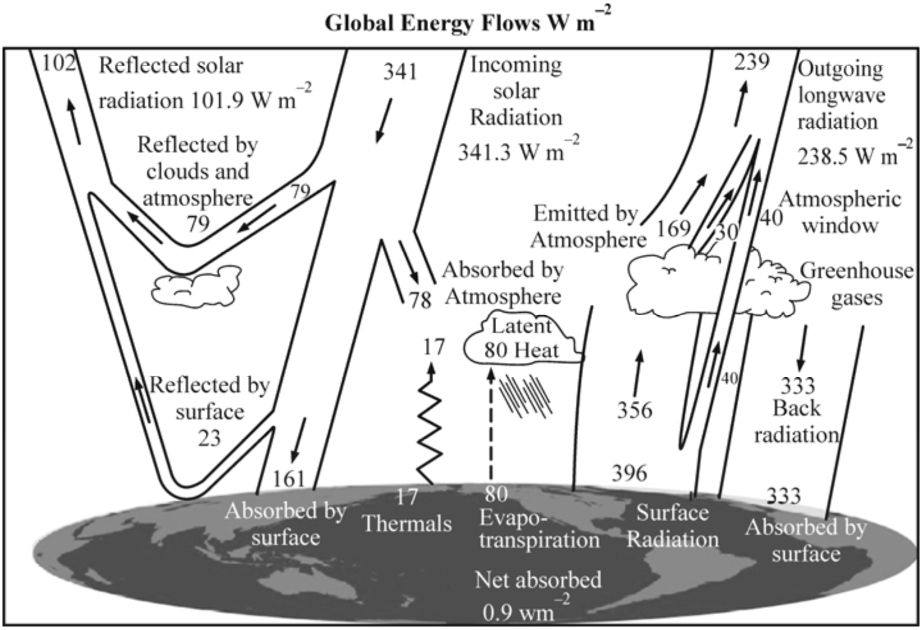

Fig 1.1 The Global annual mean Earth's energy budget is indicated by (W m^{-2}). The broad arrows indicate the schematic flow of energy in proportion to their importance.

Source: American Meteorological Society, 2009.

Solar energy is used by plants to create chemical energy through a process called photosynthesis, which supports the life and growth of plants. Further dead plant materials decay, and over millions of years are converted into fossil fuels (oil, coal, etc.).

(ii) ***Geothermal Energy*** comes from the core of the Earth, drives the movement of Earth's tectonic plates in resulting volcanoes and earth quakes.

(iii) ***Tidal Energy*** results from the moon's gravitational pull on the Earth which slows down the Earth's rotation.

1.3 Scientific Concepts of Energy

1.3.1 Different Forms of Energy

Energy is expressed in the following forms.

Kinetic Energy: The energy of an object or system arising out of its motion vibration, forward motion, turning, and spinning are referred as kinetic energy. Kinetic energy is directly proportional to the mass of an object. When two objects which differ in their masses twice and move at the same speed, then the object with twice the mass will have twice the kinetic energy.

Work is done by a moving object having kinetic energy and work has to be done on an object to change its kinetic energy. Thus the kinetic energy E of an object of mass (m) and speed (v) can be expressed as

$$E = \tfrac{1}{2} mv^2$$

Potential Energy: It is the energy possessed by an object due to its position above the ground and is considered as energy waiting to be released. Thus potential energy is the energy associated to the gravitational force near the surface of the Earth. For example any object kept above the ground has potential energy because it can be set in motion by gravity. Compressed or extended springs also have potential energy.

Combinations of kinetic and potential energy are also expressed as other forms of energy described below.

Thermal or Heat Energy: The kinetic energy due to the motion or vibration of molecules in a substance results in thermal energy or heat energy. As the atoms/molecules in a substance move faster, the object becomes hotter and heat flows in or out of the system. In heat energy transfer, heat flows from hot bodies to cold ones which increase the kinetic energy of the particles of colder part and thus elevate their temperature. Heat flow may also change the arrangement of the particles making up a substance by increasing their potential energy. This is what happens to water when it reaches a temperature of 100^oC. The molecules of water move further away from each other, thereby changing the state of the water from a liquid to a gaseous one. During the phase transition, the temperature of the water does not change.

Mechanical Energy: It is the sum of its kinetic and potential energy which keeps any object in motion. Wheels, pulleys and inclined planes are the basic elements of most machines.

Chemical Energy: It is the energy stored in molecules and chemical compounds, and is found in food, wood, coal, petroleum and other fuels. When the chemical bonds are broken, either by combustion or other chemical reactions, the stored chemical energy is released in the form of heat or light.

Electrical Energy: All matter is made up of atoms, and atoms are made up of smaller particles called protons (which have positive charge), neutrons (which have neutral charge), and electrons (which are negatively charged). Electrons orbit around the center or nucleus of atoms, just as the moon orbits the earth. The nucleus is made up of neutrons and protons. Some materials, particularly metals, have certain electrons that are loosely attached to their atoms. They can easily be made to move from one atom to another if an electric field is applied to them. When those electrons move among the atoms of matter, a current of electricity is created. This is what happens in a piece of wire when an electric field, or voltage, is applied. The electrons pass from atom to atom, pushed by the electric field and by each other (they repel each other because like charges repel), thus creating the electrical current. The measure of the extent of conduction of electricity by any material is called its conductivity, and the reciprocal of conductivity is called the resistance. Thus electrical energy is produced when unbalanced forces between electrons and protons in atoms create moving electrons called electric currents. For example, when we spin a copper wire through the poles of a magnet we induce the motion of electrons in the wire and produce electricity. Electricity can be used to perform work such as lighting a bulb, heating a cooking element on a stove or powering a motor. However, electricity is a "secondary" source of energy as other sources of energy are needed, produce electricity.

Electromagnetic or Radiant Energy: Atoms/molecules emit energy in the form of electromagnetic radiation which includes visible light, ultraviolet (UV) radiation, infrared (IR) radiation, microwaves, radio waves, gamma rays and X-rays due to differences in the internal energy of particles.

As discussed earlier, electromagnetic radiation from the sun, particularly light, is of utmost importance in environmental systems because biogeochemical cycles and virtually all other processes on earth are driven by them.

Sound Energy: Sound waves are compression waves associated with the potential and kinetic energy of air molecules. When an object moves quickly, for example the head of drum, it compresses the air nearby, giving that air potential energy. That air then expands, transforming the potential energy into kinetic energy (moving air). The moving air then pushes on and compresses other air, and so on down the chain.

Nuclear Energy: Nuclear Energy is energy that comes from the binding of the protons and neutrons that make up the nucleus of the atoms. As per Einstein’s Theory of Special Relativity, the energy intrinsically stored in a piece of matter at rest equals its mass times the speed of light squared.

$$E = mc^2$$

Nuclear energy can be released from atoms in two different ways: nuclear fusion or nuclear fission. In nuclear fusion, energy is released when atoms are combined or fused together. This is how the Sun produces energy. In nuclear fission, energy is released when atoms are split apart. Nuclear fission is used in nuclear power plants to produce electricity. Uranium 235 is the fuel used in most nuclear power plants because it undergoes a chain reaction extremely rapidly, resulting in the fission of trillions of atoms within a fraction of a second.

1.3.2 Properties of Energy

(a) Energy can be transferred from one object or system to another through the interaction of forces between the objects.

(b) Energy comes in multiple forms: kinetic, potential, thermal (heat), chemical, electromagnetic, and nuclear energy.

(c) In principle, energy can be converted from any one of these forms into any other, and vice versa, limited in practice only by the Second Law of Thermodynamics.

(d) Though energy can be converted from one form to another, energy cannot be created or destroyed. This principle is called the law of conservation of energy. For example, in an automobile, the chemical energy of the fuel changes to kinetic energy. In a Television electricity is converted into kinetic energy and wave energy (sound/ visual picture).

Machines can be used to convert energy from one form to another. Some of the energy always turns into heat when using a machine.

1.3.3 Energy Sinks

An energy sink is anything that collects a significant quantity of energy that is either lost or not considered transferable in the system under study. Sources and sinks have to be included in an energy budget when accounting for the energy flowing into and out of a system

1.3.4 Energy Units

In the International System of Units (SI), the unit of work or energy is the Joule (J). For very small amounts of energy, the erg (erg) is sometimes used. An erg is one ten millionth of a Joule:

1 Joule = 10, 000, 000 ergs

Power is the rate at which energy is used. The unit of power is the Watt (W), named after James Watt, who perfected the steam engine.

1 Watt = 1 Joule/second

Power is sometimes measured in horsepower (hp):

1 horsepower = 746 Watts

Electrical energy is generally expressed in kilowatt-hours (kWh):

1 kilowatt-hour = 3,600,000 Joules

Heat energy is often measured in calories. One calorie (cal) is defined as the heat required to raise the temperature of 1 gram of water from 14.5 to 15.5 ºC

1 Calorie = 4.189 Joules.

An old, but still in use unit of heat is the British Thermal Unit (BTU). It is defined as the heat energy required to raise the energy temperature of 1 pound of water from 63 to 64F.

1 BTU = 1055 Joules.

Units for Comparing Energy: Some popular units for comparing energy include British Thermal Units (BTU), barrels of oil equivalent, metric tons of oil equivalent, metric tons of coal equivalent, and terajoules.

In the United States, the BTU, a measure of heat energy, is the most commonly used unit for comparing fuels Table 1.1. Because energy used in different countries comes from different places, the BTU content of fuels varies slightly from country to country.

Table 1.1 BTU content of common energy units

Fuel	BTU Content
1 barrel (42 gallons) of crude oil	5,800,000 BTU
1 gallon of gasoline	124,000 BTU
1 gallon of diesel fuel	139,000 BTU
1 gallon of heating oil	139,000 BTU
1 barrel of residual fuel oil	6,287,000 BTU
1 cubic foot of natural gas	1,028 BTU
1 gallon of propane	91,000 BTU
1 short ton of coal	19,988,000 BTU
1 kilowatthour of electricity	3,412 BTU

1.4 Classification of Energy Resources

Energy sources are classified into two groups — nonrenewable (an energy source that we are using up and cannot recreated) and renewable (an energy source that can be easily replenished). Renewable and nonrenewable energy sources can be used to produce secondary energy sources including electricity and hydrogen. Renewable energy sources are essentially flows of energy, whereas nonrenewable are stocks of energy like fossil and nuclear fuels

1.4.1 Nonrenewable Energy Sources

Most of our present global energy needs are met from nonrenewable energy sources, which include the fossil fuels like oil, natural gas, coal etc. These were formed over millions and millions of years by the action of heat from the Earth's core and pressure from rock and soil on the remains (or "fossils") of dead plants and creatures like microscopic diatoms. Uranium, whose atoms when split (through a process called nuclear fission) provide heat which can be converted into electricity is another nonrenewable resource available to supplement our energy needs .

In general, global energy consumption comes from six primary sources: 44% petroleum, 26% natural gas, 25% coal, 2.4% hydroelectric power, 2.2% nuclear power, and 0.2% non-hydro renewable energy

1.4.2 Renewable Energy Sources

Renewable energy sources include

- ***Biomass:*** Any plant matter used directly as fuel or converted into other forms before combustion which include wood, vegetable waste such as wood waste and crop waste, animal materials and wastes, sulphite lyes (also known as black liquor, a sludge that contains the lignin digested from wood for paper making), are considered as solid biomass. Biogas and liquid biomass derived principally from the anaerobic fermentation of biomass and solid wastes, landfill gases and gases from sewage and animal waste which can be combusted to produce heat and electrical power also fall under this category. Energy from liquid biomass uses liquid derivatives from biomass as a fuel. Ethanol is the main form of liquid biomass produced from plants, which includes firewood from trees, ethanol from corn, and biodiesel from vegetable oil.
- ***Solar energy:*** Solar energy is harnessed using two primary methods. Solar-thermal power exploits solar radiation for hot water production and electricity generation by flat plate collectors (mainly of the thermo siphon type, for domestic hot water or for the seasonal heating of swimming pools) or solar thermal-electric plants. Solar power from photovoltaics involves the conversion of solar energy to electricity in photovoltaic cells. Passive solar energy for the direct heating, cooling and lighting of dwellings or other buildings is not included in this category.
- ***Wind energy:*** The kinetic energy of wind can be used to generate electrical power in wind turbines.
- ***Geothermal energy:*** It is available as heat emitted from earth's crust, usually in the form of hot water or steam which can be exploited for electricity generation using dry steam or high enthalpy brine after flashing, or directly as heat for district heating, agriculture, etc.
- ***Hydropower:*** It is generated by conversion of potential and kinetic energy of water into electricity. In developing countries this contributes significantly in total energy usage.
- ***Marine energy:*** Tidal, wave, current energy, ocean thermal energy conversion, saline gradient, marine bio mass, tide, wave, ocean power are processes in which the mechanical energy is captured and transformed into electrical power.

1.5 Availability of Global Nonrenewable Energy Resources

As per some estimates the world's economically recoverable fossil fuel reserves are nearly over one trillion short tons of coal, more than one trillion barrels of petroleum, and about quadrillion cubic feet of natural gas. In addition over three million metric tons of uranium reserves which can provide nuclear energy is also available. The majority of the world's fossil fuel reserve (45%, 70%, and 68% of the world's coal, crude oil, and natural gas, respectively) are located (Table 1.2(a),(b)) in the middle-income developing countries (the major oil-producing Middle Eastern countries).

China and Russia together contain 62% of the total Coal Reserves (484 billion short tons) among the middle income countries. Other coal-possessing middle-income countries contain reserves ranging from 54.6 billion short tons (11%, South Africa) to 1 million short tons (0.0002%, Bolivia), and 54 middle-income countries have zero recorded coal reserves.

The 47 middle income group countries possess 700 billion barrels of oil reserves, with a bulk of those reserves lying in Saudi Arabia (261.8 billion barrels, 36%), Iraq (112.5 billion barrels, 16%), and Iran (89.7 billion barrels, 12%). Significant reserves are also located in Venezuela (77.7 billion barrels), Russia (48.6 billion barrels), Libya (29.5 billion barrels), Mexico (26.9 billion barrels), and China (24 billion barrels). The remaining oil-possessing, middle-income countries each contain one percent or less of the total among this group.

Natural gas is present in 46 nations. With 1,680 trillion cubic feet (tcf), Russia has by far the largest reserves, comprising 45% of the total among middle-income states. Other major reserves are also in Iran (812.3 tcf), Saudi Arabia (219.5 tcf), Algeria (159.7 tcf), Venezuela (147.6 tcf), Iraq (109.8 tcf), and Turkmenistan (101 tcf).

The developed countries though have lower fossil fuel reserves than the developing world (42% of the world's coal, 25% of oil, and 24% of natural gas), their reserves are more than the countries of low-income category. Out of the 452 billion short tons of coal reserves available in high income group countries, majority of it exists in United States (274 billion short tons), with other major reserves located in Australia (90.5 billion short tons) and Germany (72.8 billion short tons). The remaining seventeen countries each have less than 2% of the total among high-income states. 258 billion barrels of crude oil reserves are concentrated not only in the United States (22.4 billion barrels), but also predominantly in several high-income Middle Eastern states: Kuwait (96.5 billion barrels), United Arab Emirates (97.8 billion barrels), and Qatar (15.2 billion barrels). Eighteen other high-income states contain oil reserves, but most of these do not exceed 1 billion barrels. As with the developing states, natural gas is the most common fossil fuel, with 22 high-income states possessing known reserves.

Since natural gas often exists along with petroleum, the United States, Kuwait, United Arab Emirates, and Qatar have substantial reserves (177.4 tcf, 52.2 tcf, 212.1 tcf, 508.5 tcf, respectively). Other major reserves also exist in Canada (59.7 tcf), United Kingdom (26 tcf), the Netherlands (62.5 tcf), and Norway (44 tcf). However, the largest national reserves of oil and natural gas in the high-income countries do not exceed the reserves in Russia and the Middle Eastern middle-income developing countries.

Developing countries contain a little over half of the world’s uranium reserves, and a substantial majority of known worldwide recoverable reserves of all three major fossil fuels: coal (58%), oil (75%), and natural gas (77%).

Table 1.2 Recoverable fossil fuel reserves for all countries and income groups in 2001.

Table 1.2(a) Developing countries

Low Income					**Middle-income countries**			
	Petroleum (1000 barrels)	**Natural gas (billion cubic feet)**	**Coal (million short tons)**			**Petroleum (1000 bbl)**	**Natural gas (bcf)**	**Coal (mst)**
Afghanistan	0	3530	73		Albania	165000	100	0
Angola	5412000	1620	0		Algeria	9200000	159700	44
Armenia	0	0	0		American Samoa	0	0	0
Azerbaijan	1178000	4400	0		Argentina	2973700	27460	474
Bangladesh	56902	10615	0		Bahrain	124560	3249	0
Benin	8210	43	0		Belarus	198000	100	0
Bhutan	0	0	0		Belize	0	0	0
Burkina Faso	0	0	0		Bolivia	440500	24000	1
Burundi	0	0	0		Bosnia & Herzegovina	0	0	0
Cambodia	0	0	0		Botswana	0	0	4740
Cameroon	400000	3900	0		Brazil	8464744	7805	13149
Central African Republic	0	0	3		Bulgaria	15000	210	2988
Chad	0	0	0		Cape Verde	0	0	0
Comoros	0	0	0		Chile	150000	3460	1302
Congo	1505913	3200	0		China	24000000	48300	126216
Congo, DRC	187000	35	97		Colombia	1750000	4322	7328
Cote d'Ivory	100000	1050	0		Costa Rica	0	0	0
Eritrea	0	0	0		Croatia	92196	1237	43
Ethiopia	428	880	0		Cuba	750000	2500	0
Georgia	35000	300	0		Czech Republic	15000	140	6259
Ghana	16510	840	0		Djibouti	0	0	0
Guinea	0	0	0		Dominica	0	0	0
Guinea-Bissau	0	0	0		Dominican Republic	0	0	0
Haiti	0	0	0		Ecuador	2115000	3670	26

Table contd...

Low Income				Middle-income countries			
	Petroleum (1000 barrels)	Natural gas (billion cubic feet)	Coal (million short tons)		Petroleum (1000 bbl)	Natural gas (bcf)	Coal (mst)
Indonesia	5000000	92500	5919	El Salvador	0	0	0
Kyrgyzstan	40000	200	895	Estonia	0	0	0
Laos	0	0	0	Fiji	0	0	0
Lesotho	0	0	0	Gabon	2499000	1200	0
Liberia	0	0	0	Grenada	0	0	0
Madagascar	0	0	0	Guatemala	526000	109	0
Malawi	0	0	2	Guyana	0	0	0
Mali	0	0	0	Honduras	0	0	0
Mauritania	0	0	0	Hungary	110919	1282	1209
Moldova	0	0	0	Iran	89700000	812300	1885
Mongolia	0	0	0	Iraq	112500000	109800	0
Montserrat	0	0	0	Jamaica	0	0	0
Mozambique	0	0	234	Jordan	890	230	0
Myanmar	50000	10000	2	Kazakhstan	5417000	65000	37479
Nepal	0	0	2	Kiribati	0	0	0
Nicaragua	0	0	0	Latvia	0	0	0
Niger	0	0	77	Lebanon	0	0	0
Nigeria	24000000	124000	209	Libya	29500000	46400	0
Niue	0	0	0	Lithuania	12000	0	0
North Korea	0	0	661	Macedonia	0	0	0
Pakistan	298237	25078	2497	Malaysia	3000000	75000	4
Papua New Guinea	238345	12230	0	Maldives	0	0	0
Reunion	0	0	0	Malta	0	0	0
Rwanda	0	2000	0	Mauritius	0	0	0
Sao Tome & Principe	0	0	0	Mexico	26941000	29505	1335
Senegal	0	0	0	Morocco	1800	47	0
Sierra Leone	0	0	0	Namibia	0	2200	0
Solomon Is.	0	0	0	Oman	5506000	29280	0
Somalia	0	200	0	Panama	0	0	0
St. Helena	0	0	0	Paraguay	0	0	0
Sudan	563000	3000	0	Peru	323393	8655	1168
Tajikistan	12000	200	0	Philippines	178060	3693	366
Tanzania	0	800	220	Poland	114883	5119	24427
The Gambia	0	0	0	Puerto Rico	0	0	0
Togo	0	0	0	Romania	955620	3556	1606
Uganda	0	0	0	Russia	48573000	1680000	173074
Ukraine	395000	39600	37647	Samoa	0	0	0

Table contd...

Low Income				Middle-income countries			
	Petroleum (1000 barrels)	**Natural gas (billion cubic feet)**	**Coal (million short tons)**		**Petroleum (1000 bbl)**	**Natural gas (bcf)**	**Coal (mst)**
Western Sahara	0	0	0	Slovakia	9000	530	190
Yemen	4000000	16900	0	South Africa	15680	1	54586
Zambia	0	0	11	South Korea	0	0	86
Zimbabwe	0	0	553	Sri Lanka	0	0	0
Total (low income)	**49530695**	**452986**	**146707**	St. Kitts & Nevis	0	0	0
				St. Lucia	0	0	0
				St. Vincent & the Grenadines	0	0	0
				Suriname	74000	0	0
				Swaziland	0	0	229
				Syria	2500000	8500	0
				Thailand	515690	12705	1398
				Tonga	0	0	0
				Trinidad & Tobago	716000	23450	0
				Tunisia	307560	2750	0
				Turkey	295760	310	4066
				Turkmenistan	546000	101000	0
				Uruguay	0	0	0
				Vanuatu	0	0	0
				Venezuela	77685000	147585	528
				Yugoslavia	77500	1700	17919
				Total (middle income)	**723765015**	**3714140**	**484149**

Data from *International Energy Annual 2001 Edition* released by the Energy Information Administration of the U.S. Department of Energy and from Oil and Gas Journal 99(52) (December 24, 2001).

Table 1.2(b) Developed countries

	Petroleum (1000 bbl)	**Natural gas (bcf)**	**Coal (mst)**
Antarctica	0	0	0
Antigua & Barbuda	0	0	0
Aruba	0	0	0
Australia	3500000	90000	90489

Table contd...

	Petroleum (1000 bbl)	**Natural gas (bcf)**	**Coal (mst)**
Austria	85680	915	28
Barbados	2508	5	0
Belgium	0	0	0
Bermuda	0	0	0
British Virgin Is.	0	0	0
Brunei	1350000	13800	0
Canada	4858000	59733	7251
Cayman Is.	0	0	0
Cook Is.	0	0	0
Cyprus	0	0	0
Denmark	1113300	2719	0
Falkland Is.	0	0	0
Faroe Is.	0	0	0
Finland	0	0	0
France	140040	403	40
French Guiana	0	0	0
French Polynesia	0	0	0
Germany	364300	12088	72753
Gibraltar	0	0	0
Greece	9000	18	3168
Greenland	0	0	202
Guadeloupe	0	0	0
Guam	0	0	0
Iceland	0	0	0
Ireland	0	700	15
Israel	3840	1470	0
Italy	621763	8072	37
Japan	58577	1414	852
Kuwait	96500000	52200	0
Luxembourg	0	0	0
Martinique	0	0	0
Nauru	0	0	0
Netherlands Antilles	0	0	0
Netherlands	106927	62542	548
New Caledonia	0	0	2
New Zealand	89533	2083	631
Norway	9447290	44037	1
Portugal	0	0	40
Qatar	15207000	508540	0
Singapore	0	0	0
Slovenia	0	0	303
Spain	21009	18	728
St. Pierre & Miquelon	0	0	0

Table contd…

	Petroleum (1000 bbl)	**Natural gas (bcf)**	**Coal (mst)**
Sweden	0	0	1
Switzerland	0	0	0
Taiwan	4000	2700	0
The Bahamas	0	0	0
Turks & Caicos Is.	0	0	0
United Arab Emirates	97800000	212100	0
United Kingdom	4930000	25956	1653
United States	22045000	177427	273656
Virgin Is.	0	0	0
Wake I.	0	0	0
Total (high income)	**258257767**	**1278940**	**452398**
WORLD TOTAL	**1031553477**	**5446066**	**1083254**

1.6 Trends of Global Energy Usage

1.6.1 Energy Consumption by Energy Type

Total global energy use exceeds 350 quadrillion British Thermal Units (BTUs) per year, which is equivalent to over 170 million barrels of oil each day.

Oil, gas and coal represent around 90% of commercial energy used worldwide. The rate of growth in the global usage of different types of energy resources from 1965 to 2005 are shown in Fig 1.2, which clearly shows that inspite of development of several innovative technologies in making use of alternative energy sources, fossil fuels still dominate world energy scenario.

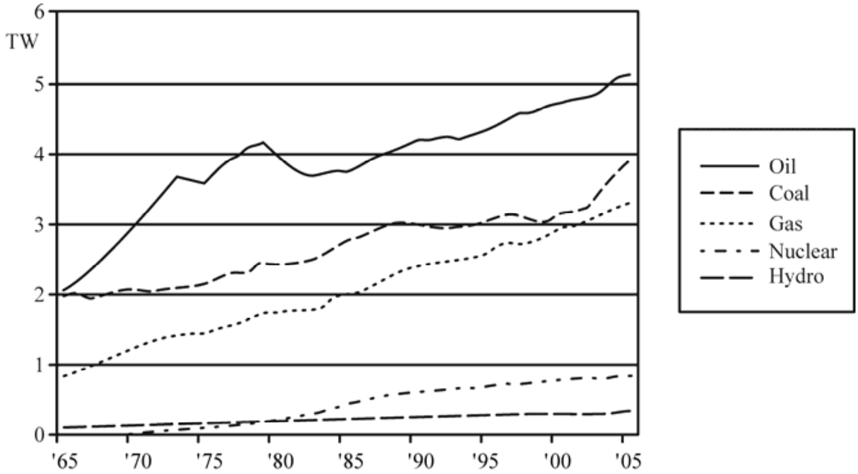

Fig. 1.2 Rate of world energy usage in terawatts (TW), 1965–2005 (http://en.wikipedia.org/wiki/Image:World_Energy_consumption.png).

The developing and developed worlds demonstrate striking disparities in annual energy consumption per capita (Fig 1.3).

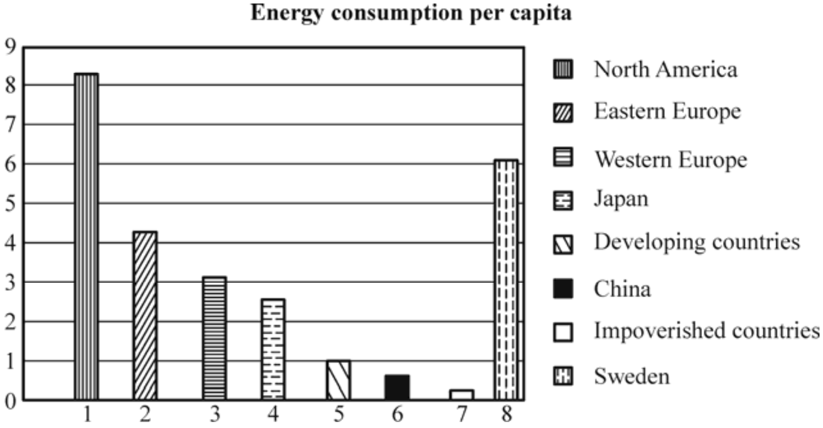

Fig. 1.3 Energy consumption per capita of different countries (http://www.livets-mening.nu/series2/images/3.4_Per_capita.gif).

While the average person in the developing countries consumes 32 million British thermal units (BTUs) per year, equivalent to about 6 barrels of oil, the average person in the developed countries consumes 210 million BTUs/year, equivalent to nearly 40 barrels of oil. The poorest 10% of countries consume only 3.4 million BTUs per capita per year, while the richest 10% consume 218 million BTUs per capita per year. This is equivalent to about 39 more barrels of oil consumed per person per year by the richest countries than by the poorest. Also striking are disparities within the developing world: the middle-income countries annually consume 50 million BTUs (about nine barrels of oil) per capita, while the low-income countries annually consume only 13 million BTUs (about two and a half barrels of oil) per capita. These relationships between wealth and energy consumption suggest that as a country becomes richer, its people tend to consume substantially more energy.

1.6.2 Fuel Wise Usage Nonrenewable Energy Sources by Various Countries

Not only do the three income groups show wide disparities in energy consumption per capita, but they also exhibit different trends in the composition of energy types consumed (Fig. 1.4(a) & (b)).

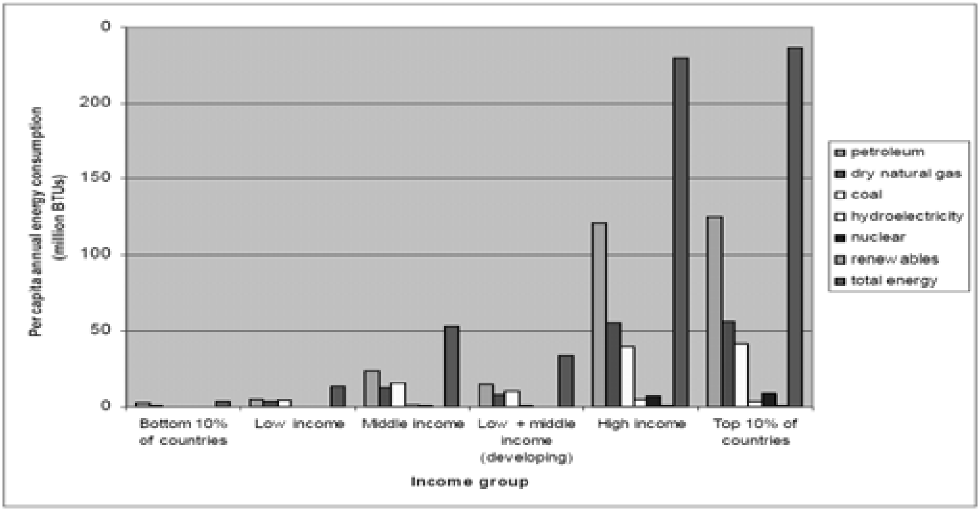

Fig. 1.4(a) Percapita consumption of energy types by different countries

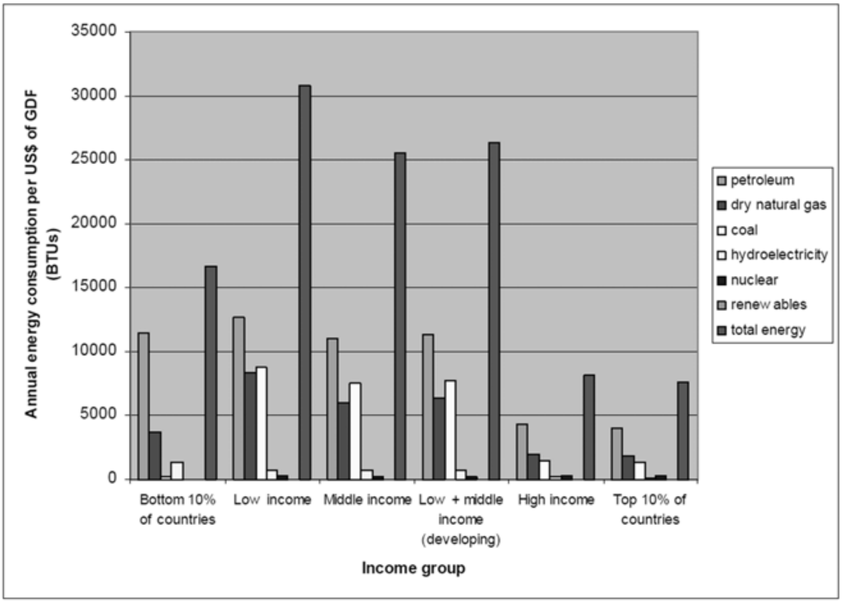

Fig. 1.4(b) Consumption of energy types per US$ of GDP, by income group, in 2000,

Source: Science 302 (5650), 28 November 2003. Resources for the Future (www.rff.org). © 2003.

1.6.3 Energy Consumption by Sector

Across the five major economic sectors considered (industry, transportation, agriculture, commercial and public services, and residential), per capita energy consumption among the industrialized countries exceeds than that the developing world (Fig. 1.5).

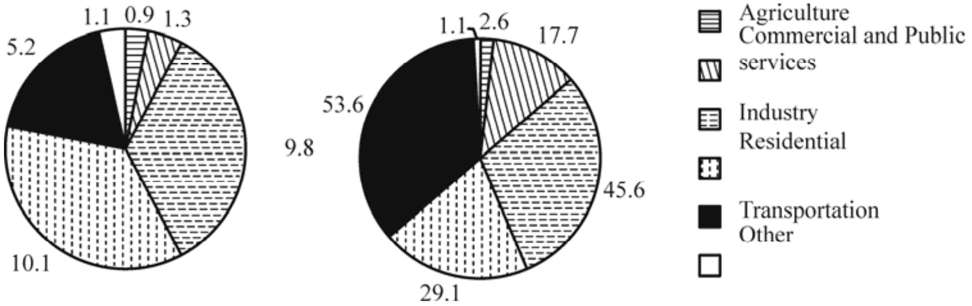

Fig. 1.5 Global Per capita Energy Consumption by Sectorial End Use
(A) the developing world (B) Developed World (106BTU)

At more than 10 million BTUs/year per capita, the residential sector is the greatest energy consumer among the developing countries, followed by industry (9.8 million BTUs/year per capita), transportation (5.2 million BTUs/year per capita), services (1.3 million BTUs/year per capita), and agriculture (0.9 million BTUs/year per capita). In contrast, the same sectors in high-income countries consume around three to fourteen times the energy, depending on the sector. Among the developed countries, transportation has the greatest energy consumption (53.6 million BTUs/year per capita), followed by industry (45.6 million BTUs/year per capita), residential (29.1 million BTUs/year per capita), services (17.7 million BTUs/year per capita), and agriculture (2.6 million BTUs/year per capita). In the developing world, the residential and industrial sectors are the dominant energy consumers, with 34% and 35% respectively of the total (Fig. 1.6). In the developed world, the dominant sectors are industry (29%) and transportation (35%). It is important to note that residential consumption of energy in many regions included among developing states is predominantly combustible resources and waste such as fuel wood, manure, and other biofuels, rather than the forms of energy described in the analyses above. For both the developing and developed world, services and agriculture consume the least energy per capita.

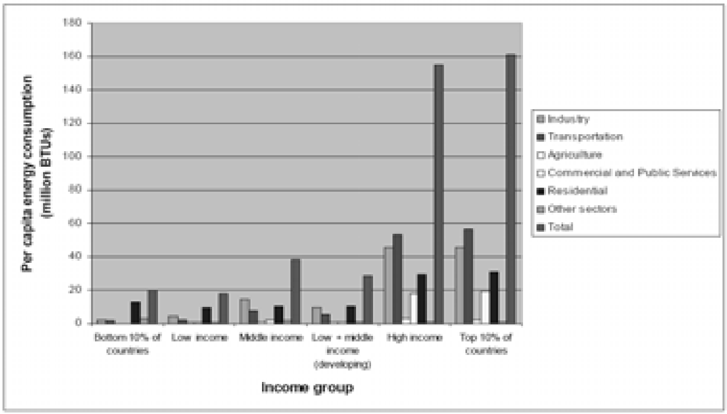

Fig. 1.6 Sectorial end-use energy consumption by income group, in 2000

1.7 Mix of Utilization Energy Resources

The global energy utilization systems are under great stress due to increased consumption and are going through a transition from fossil fuels to renewable energy. New energy technologies will play a growing role in energy consumption structure. The new energy consumption structure is going to play significant role for many countries due to the continuous advancement of the new energy technologies, the rising costs of fossil fuels and the global commitment to reducing carbondioxide emissions.

However, whether or not new energy can become a genuine substitute for traditional energy sources in the future will be largely decided by each country by their technology development costs, the degree of their technological maturity and their effects on the environment

In view of major change coming in the form of a growing role for renewable energy and increasing international concern about global warming, governments, policy makers, are reexamining the question of the right mix of energy consumption structure and the factors that should play a determining role concerning that mix.

In fact, the share of renewable energy in the global energy mix is expected to rise from 3% today to 17% in 2030. With nuclear energy accounting for another 15%, hydrocarbons will nevertheless remain the backbone of energy generation for the foreseeable future.

1.7.1 Energy Resources and their Utilization – USA

Fig. 1.7 shows the energy consumption by United States from different sources as per 2009 data. Nonrenewable energy sources account for 92% of all energy used in US. Biomass, the largest renewable source, accounts for over half of all renewable energy and 4% of total energy consumption. (Note: 50% of 8% is 4%.).

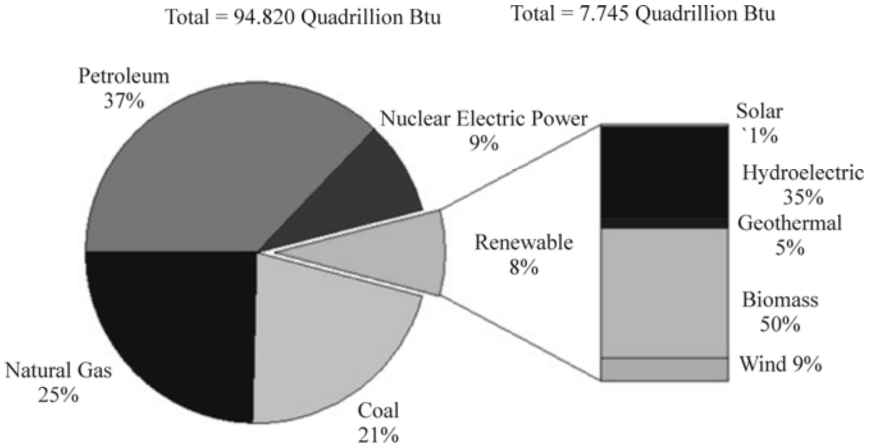

Fig. 1.7 Renewable Energy Consumption in the US Energy Supply, 2009

Source: U.S. Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels http://www.eia.gov/fuelrenewable.html.

1.7.1.1 Changing Energy Mix of USA

The energy mix of the USA is at present quite diverse, though the growing role of coal is clear. Because of their original heavy reliance on oil and gas (63%) the total US energy supply in 2050 is expected to decline to about 23% from its 2009 level (Fig. 1.8)

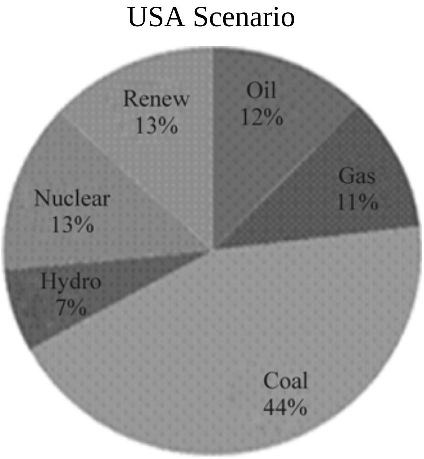

Fig. 1.8 Energy mix of US 2050

1.7.2 Energy Resources and their Utilization – India

In the recent years, India's consumption of both primary and secondary energy in different sectors has been increasing at one of the fastest rates in the world due to increasing population, expanding economy and quest for improved quality of life. India ranks fifth in the world in terms of primary energy consumption, accounting for about 3.5% of the world commercial energy demand, as per 2003 data.

Primary commercial energy demand grew at the rate of 6% between 1981 and 2001 (Planning Commission of India 2002). Despite the overall increase in energy demand, per capita energy consumption in the country – 323 kilograms of oil equivalent in 2003 – is still very low compared to other developing countries Ministry of Petroleum and Natural Gas (MoPNG) 2004.

The relative trends in energy consumption growth from 1971 to 1999 are presented with respect to total energy, and energy type in Fig 1.9(a) and (b) respectively.

Table 1.3 gives the growth trend in the production of different energy sources in the period 1970-2004.

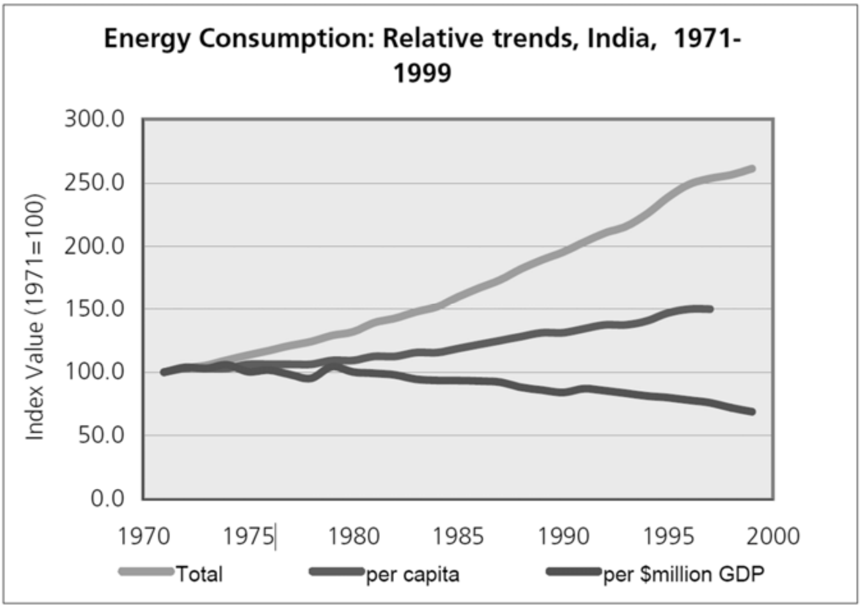

Fig. 1.9(a) India's Energy consumption relative trends 1971-2000

Source: Earth trends 2003.

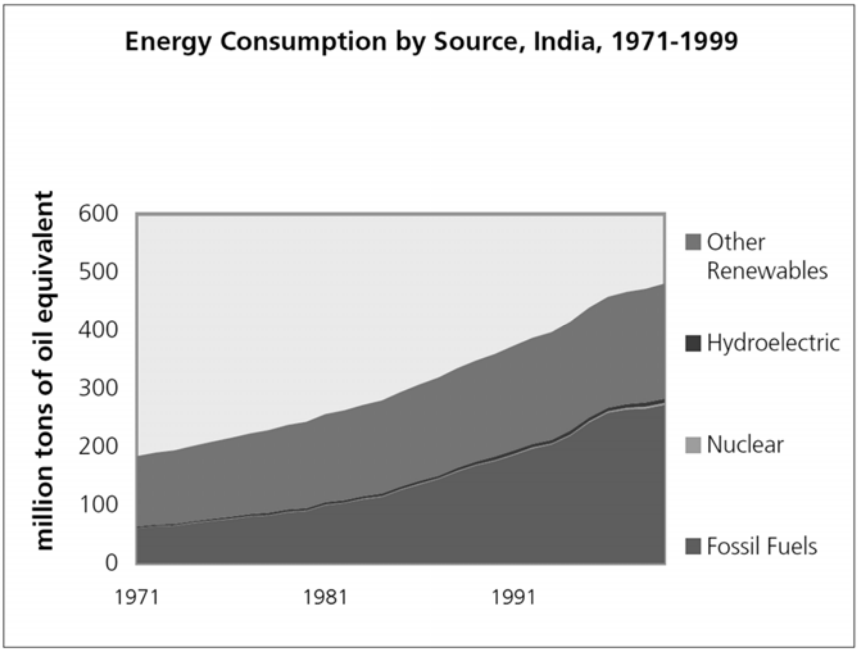

Fig. 1.9(b) India's energy consumption source wise - relative trends 1971-2000

Source: Earth Trends 2003.

Table 1.3 Production of primary energy sources of conventional energy in India

Source	Unit	1970/71	1980/81	1990/91	2001/02	2002/03	2003/04
Coal and lignite	MT	76.34	119.02	228.13	352.6	367.29	389.11
Crude oil	MT	6.82	10.51	33.02	32.03	33.04	33.38
Natural gas	BCM	1.45	2.36	18	29.71	31.4	31.95
Nuclear power	bkWh	2.42	3	6.14	19.48	19.39	17.78
Hydro power	bkWh	25.25	46.54	71.66	73.7	64.1	75.33
Wind power	bkWh	–	–	0.03	1.97	2.1	3.4

MT – million tonnes; BCM – billion cubic metres; bkWh – billion kilowatt-hours,

Source: MoC (2004); CEA (2005).

Coal, oil, and natural gas are the three primary commercial energy sources. Coal was by far the largest source of energy. The coal production increased 7.8% to 492.95 million tone (mt) in 2008-09 from 457.08 mt during 2007-08. The contribution from open cast (OC) mines continued to increase further whereas the supply from under ground (UG) mines remained stable in quantity but declined in percentage share of total raw coal production Coal Ministry India (2008-09). China and India rely heavily on coal as a major supplier of its energy needs supply. It is likely that this dependence will continue in the years and decades to come. As Indian coal is traditionally high ash coal and of low calorific value, imports are expected to grow (Table 1.4) in coming decades too.

Though India’s oil production has been constant is the last decades, it currently imports about dries up two thirds of its oil requirements which keeps it in a very vulnerable position as the international export market dries up. The latest estimates indicate (TERI Report 2006 - National Energy Map for India-Technology Vision 2030) that India has about 0.4% of the world’s proven reserves of crude oil. The production of crude oil in the country has increased from 6.82 MT in 1970/71 to 33.38 MT in 2003/04 (Mo PNG 2004b). The quantity of crude oil imported increased from 11.66 MT during 1970/71 to 81 MT by 2003/04. Besides, imports of other petroleum products increased from 1 MT to 7.3 MT during the same period. The exports of petroleum products went up from about 0.5 MT during 1970/71 to 14 MT by 2003/04. The refining capacity, as on 1 April 2004, was 125.97 MTPA (million tons per annum). The production of petroleum products increased from 5.7 MT during 1970/71 to 110 MT.

Table 1.4 Annual production, import, and import dependency of coal

	2001/02	**2006/07**	**2011/12**	**2016/17**	**2021/22**	**2026/27**	**2031/32**
Production (million tonnes)	343	396	440	485	530	574	619
Import (million tonnes)	10	45	92	223	384	811	1438
Total (million tonnes)	353	440	532	708	913	1385	2057
Import dependency (%)	3	10	17	31	42	59	70

MT – million tonnes; BCM – billion cubic metres; bkWh – billion kilowatt-hours
Source: MoC (2004); CEA (2005).

Natural gas production in India has risen by 25% since 2000 but its imports have recently shown a sharp rise - from 0 in 2003 to 20% of their consumption in 2006. India’s consumption of natural gas has risen faster than any other fuel in the recent years. Natural gas demand has been growing at a growth rate of about 6.5% for the last 10 years. Industries such as power, fertilizer, and petrochemical are shifting towards natural gas. Although India’s natural gas demand has traditionally been met entirely through domestic production, for the past few years the core sectors of the economy have started facing a gas shortage. To bridge this gap, apart from encouraging domestic production, the import of LNG is being considered as one of the possible solutions.

India's hydro development is expected to be on par with the global projection. However, in this case the depletion of Himalayan glaciers due to global warming. India is also taking the development of nuclear power seriously, with 19 reactors currently in the planning or proposal stage.

There are significant opportunities for solar power in India, both in small photovoltaic installations and in the use of thermal solar generation. At present solar power is used for running specific services like pumps, lighting etc., where grid feeds are not available. To achieve renewables a greater role than natural gas by 2050 at least 5% growth in solar energy production is required.

Increasing pressure of population and increasing use of energy in different sectors of the economy are areas for of concern India. Sector-wise commercial energy consumption in the business-as-usual scenario from 2001 to 2031(projected values) are shown in Fig. 1.10.

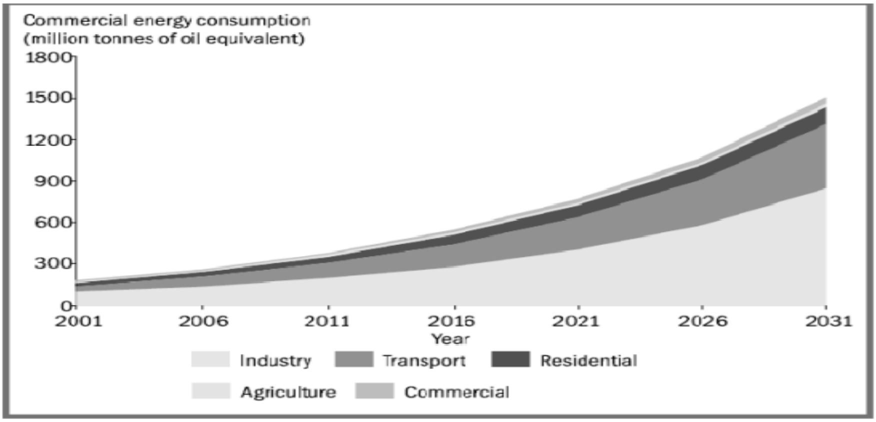

Fig. 1.10 India's energy consumption sector wise-2001-projected values 2031
Source: TERI Report 2006

With a GDP growth rate of 8% during the Tenth Five Year Plan (2002-2007), energy demand (Tables 1.5 and 1.6) has grown at the rate of 5.2%. Driven by the rising population, expanding economy, and a quest for improved quality of life, the total primary energy consumption is expected to be about 412 Mtoe (million tonnes of oil equivalent) and 554 Mtoe in the terminal years of the Tenth and Eleventh Five Year Plans, respectively (Planning Commission 1999).

Table 1.5 India's Estimated energy demand (TERI Report 2006).

Primary fuel	Unit	Demand (in original units)		Demand (Mtoe)	
		2006/07	2011/12	2006/07	2011/12
Coal	MT	460.5	620	190	254.93
Lignite	MT	57.79	81.54	15.51	22.02
Oil	MT	134.5	172.47	144.58	185.4
Natural gas	BCM	47.45	64	42.7	57.6
Hydro power	bkWh	148.08	215.66	12.73	18.54
Nuclear power	bkWh	23.15	54.74	6.04	14.16
Wind power	bkWh	4	11.62	0.35	1
Total commercial energy				411.91	553.68
Non-commercial energy				151.3	170.25
Total energy demand				563.21	723.93

MT – million tonnes; BCM – billion cubic metres;
bkWh – billion kilowatt-hours; Mtoe – million tonnes of oil equivalent
Source: Planning Commission (2002).

Table 1.6 Commercial energy requirements in the BAU (Mtoe) (TERI Report 2006).

Fuel	2001/02	2006/07	2011/12	2016/17	2021/22	2026/27
Coal	150	193	242	344	466	757
Natural gas	25	36	51	74	132	136
Oil	101	151	211	298	405	555
Hydro power (large and small)	7	9	18	24	30	36
Nuclear energy	2	2	4	8	13	13
Renewable energy	0	1	1	1	1	1
Total	285	391	527	749	1046	1497

BAU – business-as-usual; Mtoe – million tonnes of oil equivalent

1.7.2.1 The Changing Energy Mix India

India uses almost as high a proportion of coal as China, and it is unlikely that renewable energy will be able to help in reducing the oil/coal consumption in coming decades. As per TERI 2006 report oil consumption may reduce from 39% of 2006 value to projected 36% in 2031 (Fig. 1.11).

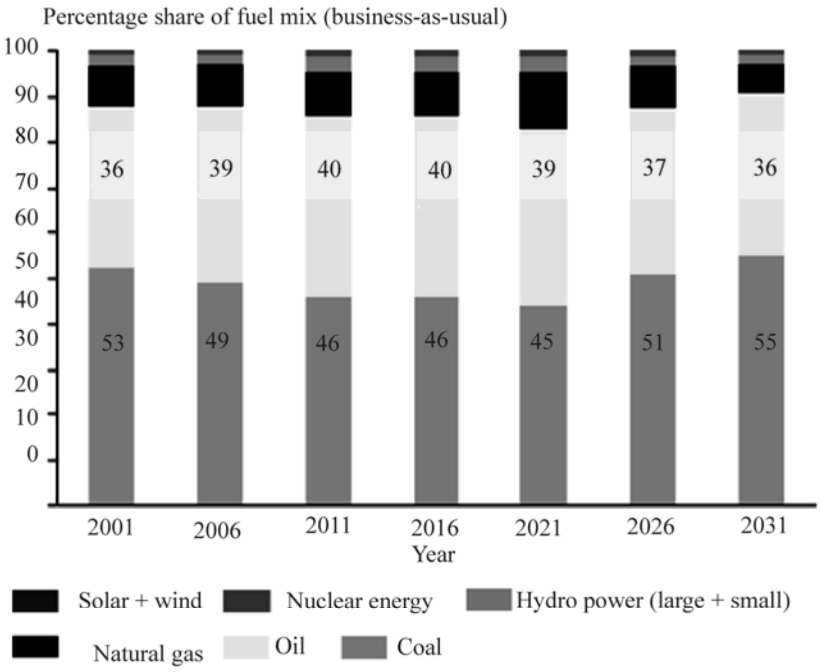

Fig. 1.11 Energy mix of India 2001-2031 (business-as-usual scenario).

1.8 Energy Parameters for National Developmental Planning

1.8.1 Energy Intensity

The energy efficiency of a nation's economy is measured in terms of energy intensity and is calculated as units of energy per unit of GDP.

- High energy intensities indicate a high price or cost of converting energy into GDP.
- Low energy intensity indicates a lower price or cost of converting energy into GDP.

The energy intensity of any country is influenced by many factors and can be used as a comparative measure between countries, whereas the change in energy consumption required to raise GDP in a specific country over time is described as its energy elasticity.

Energy intensity indicators show us

- how the intensity of energy use and its components are changing
- help raise public awareness about how and why energy intensity has changed over the years
- provide understanding of the impact of program or policy choices on energy intensity, such as supplementing energy demand forecasting or assessments of a program's influence on energy intensity changes
- improve understanding of the role of efficiency improvements in our changing energy markets.

1.8.2 Energy/GDP Ratio

The energy–GDP elasticity, defined as the ratio of the growth rate of energy to the growth rate of GDP, captures both the structure as well as efficiency of the economy. Known as the simple Energy/Gross Domestic Product (E/GDP) ratio, it is a measure of energy effectiveness of any country, and the nation's output of goods and services, as measured by inflation-adjusted Gross Domestic Product (GDP).

1.8.2.1 Energy/GDP Ratio-USA

In USA it increased more than six-fold, from $1.63 trillion to $10.75 trillion over the period 1949-2004. Total energy consumption increased three-fold, from 32 Quadrillion British thermal units (QBTU) to slightly less than 100 QBTU. As a broad measure of energy intensity, the ratio of energy to GDP (E/GDP ratio) declined by 47% over this 55-year period (Fig. 1.12).

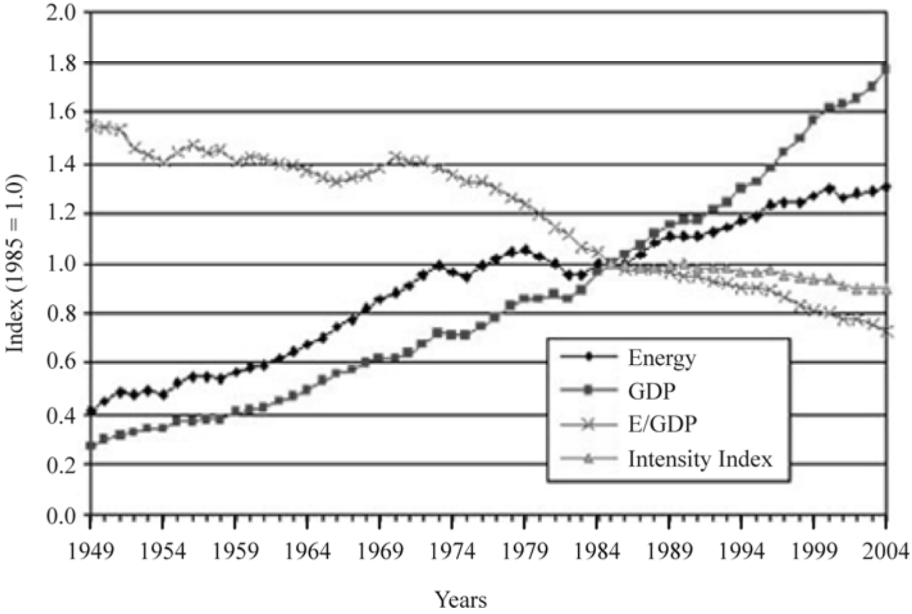

Fig. 1.12 Energy Intensity Index US-1949-2004

Source: Energy Intensity Indicators in US –DoE 2008

The growth in the oil consumption with respect to GDP, can be better understood by considering three sub-periods. In the period 1949-1973 when the Organization of Petroleum Exporting Countries (OPEC) oil embargo existed, total energy consumption increased little slower than GDP. Corresponding to this trend, energy intensity (measured by the E/GDP ratio), declined by 11%. The 1973-1974 oil embargo and subsequent price shocks of the late 1970s and early 1980s encouraged energy conservation and efficiency improvements in all sectors of the economy. Between 1973 and 1985, the E/GDP ratio decreased by 28%. Oil prices fell sharply in 1986, accelerating price declines in all fuels whose prices had peaked in the early 1980s. In spite of this development, after 1985 the E/GDP ratio has continued to decline, dropping another 26% by 2004. Translating these declines into annual average rates indicates that up to 1973, the E/GDP ratio declined at about 0.5% per year; between 1973 and 1985 it declined about 2.7% per year; and between 1985 and 2004, it declined to 1.6% per year.

1.8.3 Energy Planning

It is the process of developing long-range policies to help guide the future of a local, national, regional or even the global energy system. Energy planning is often conducted within governmental organizations using integrated approaches that consider both the provision of energy supplies and the role of energy efficiency in reducing demands. Energy planning should always reflect the outcome of population growth.

Energy planning has traditionally played a strong role in setting the framework for regulations in the energy sector (for example, influencing what type of power plants might be built or what prices are charged for fuels). But in the past few decades, many countries have deregulated their energy systems so that the role of energy planning has been reduced and decisions have increasingly been left to the market. This has arguably led to increased competition in the energy sector, although there is little evidence that this has translated into lower energy prices for consumers.

Due to growing concerns over the environmental impacts of energy consumption and production, particularly in light of the threat of global climate change, which is caused largely by emissions of greenhouse gases from the world's energy systems, this trend now seems to be reversing.

Many OECD countries and some states in America or USA are now moving to more closely regulate their energy systems. For example, many countries and states have been adopting targets for emissions of CO_2 and other greenhouse gases. In light of these developments, it seems likely that integrated energy planning will become increasingly important.

A new trend in energy planning known as Sustainable Energy Planning takes a more holistic approach to the problem of planning for future energy needs. It is based on a structured decision making process based on seven key steps, namely:

1. Exploration of the context of the current and future situation.
2. Formulation of particular problems and opportunities which need to be addressed as part of the Sustainable Energy Planning process. This could include such issues as "Peak Oil" or "Economic Recession/Depression".
3. Create a range of models to predict the likely impact of different scenarios. This would consist of mathematical modeling but is evolving to include "Soft System Methodologies" such as focus groups, peer ethnographic research, "what if" logical scenarios etc.
4. Based on the output from a wide range of modeling exercises and literature reviews, open forum discussion etc., the results are analyzed and structured in an easily interpreted format.
5. The results are then interpreted in order to determine the scope, scale and likely implementation methodologies which would be required to ensure successful implementation.
6. This stage is a quality assurance process which actively interrogates each stage of the Sustainable Energy Planning process and checks if it has been carried out rigorously, without any bias and that it furthers the aims of sustainable development and does not act against them.
7. The last stage of the process is to take action. This may consist of the development, publication and implementation of a range of policies, regulations, procedures or tasks which together will help to achieve the goals of the Sustainable Energy Plan.

1.8.4 India – Energy – GDP – Elasticity

Since 1999, India's energy intensity has been decreasing and is expected to continue to decrease. The energy intensity of India is nearly twice that of the developed economies, which are represented by the OECD (Organization of Economic Co-operation and

Development) member countries and much higher than the emerging economies—the Asian countries.

The indicator of energy – GDP (gross domestic product) elasticity, that is, the ratio of growth rate of energy to the growth rate GDP, captures both the structure of the economy as well as the efficiency. The energy–GDP elasticity during 1953–2001 has been above unity (1.213) (Centre for Monitoring Indian Economy (CMIE), 2002 data) and that of the primary energy - GDP elasticity 1991-2000 was less than unity (0.907) (Planning Commission of India, 2002). This could be attributed to several factors, some of them being demographic shifts from rural to urban areas, structural economic changes towards lesser energy industry, impressive growth of services, and improvement in efficiency of energy use, and inter-fuel substitution.

The energy sector in India has been receiving high priority in the planning process. The total outlay on energy in the Tenth Five-year Plan (2002-2007) was projected at 4.03 trillion rupees at 2001/02 prices, which is 26.7% of the total outlay which is an increase of 84.2% over the ninth Five-year Plan in terms of the total plan outlay on energy sector. Realizing that under-performance of the energy sector can be a major constraint in delivering a growth rate of 8% GDP during the mid 10th plan period review, the Government of India accelerated the reforms process by adopting an integrated energy policy.

1.9 Environmental Effects of Energy Usage

Extraction of Energy Resources: Energy resources such as coal, oil, gas or uranium are buried deep in the ground. Extracting them can damage local ecosystems by changing water flow, disrupting wildlife, polluting water and eroding soil.

Transport**:** Often, energy resources are found far from their users. Transport consumes energy and generates exhaust. Coal and uranium must be transported long distances on trains and trucks. Oil transport may involve pipelines, trucks and tankers, all of which can spill oil into the environment. Electricity moves through transmission lines which, like oil and gas pipelines, cut through forests and other landscapes.

Use**:** The combustion of coal, oil and other fuels adds carbon dioxide to the atmosphere and may lead to long-term climate change, called global warming. Coal-fired power plants contribute to acid rain. The waste materials of nuclear power are hazardous for thousands of years if not stored properly. Emissions from homes and vehicles add carbon dioxide to the atmosphere. Nitrogen compounds from vehicle exhaust contribute to acid rain. More power we use, the more of these waste products we generate.

Most important environmental impacts caused by use of energy sources are global climate change and acid rain – both of which have the origin in the combustion of fossil fuels and lead to global or Trans boundary effects.

1.9.1 Climate Change – Greenhouse Gas (CO_2) Emissions from Energy Usage

Climate change or global warming means a gradual increase in the global average air temperature at the earth's surface. Huge data on change on earth's surface temperatures indicate that global climate has warmed during the past 150 years. The majority of scientists now believe that global warming is taking place, at a rate of around 0.3 deg. C per decade, and that it is caused by increases in the concentration of so called "greenhouse gases" in the atmosphere. The most important single component of these greenhouse gas emissions is carbon dioxide (CO_2) and combustion of fossil fuels (power plants, automobiles, industry etc.) contributes around 80% to total world-wide anthropogenic CO_2 emissions.

As the worldwide population continues to grow and societies continue to industrialize, the overall demand for energy increases. From 1973 to 2007, the total primary energy supply increased from 6115 to 12,029 million tons of oil equivalent (Mtoe), the latter roughly equal to 500 EJ (500×10^{18} J) of energy (IEA 2009). Although a variety of means are currently employed to meet these growing energy demands, the vast majority is met through the use of fossil fuels. As shown in Figure 1.13, coal, oil, and gas make up 81.4% of the total global energy supply, while energy from renewable sources such as geothermal, wind, and solar makeup only 0.7%. Other includes geothermal, solar, wind, etc.

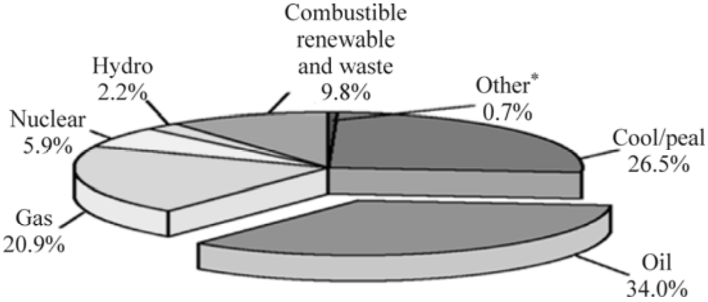

Fig. 1.13 Global share of total primary energy supply, 2007 (IEA 2009).

Different fossil fuels produce different amounts of CO_2 per unit of energy released. Coal is largely carbon, and so most of its combustion products are CO_2. Natural gas, which is methane, produces water as well as CO_2 when it is burned, and so emits less CO_2 per unit of energy than coal. Oil falls somewhere between gas and coal in terms of CO_2 emissions, as it is made up of a mixture of hydrocarbons. The amount of CO_2 produced per unit of energy from coal, oil and gas is in the approximate proportion of 2 to 1, 5 to 1. This is one of the reasons why there is a move towards greater use of natural gas instead of coal or oil in power stations, despite the much greater abundance of coal. Another source for CO_2 build up in atmosphere is global deforestation. Trees remove carbon dioxide from the air as they grow. When they are cut and burned that CO_2 is released back into the atmosphere. Massive deforestation around the globe is releasing large amounts of CO_2 and decreasing the forests' ability to take CO_2 from the atmosphere. The second major greenhouse gas is methane (CH_4). It is a minor by-product of burning coal, and also comes from venting of natural gas (which is nearly pure methane). As shown in Figure 1.14, carbon dioxide (CO_2) from fossil fuel use accounts for 56.6% of total global GHG emissions.

It is hard to deny, that energy production from fossil fuels plays a significant role in global climate change. Although it is difficult to accurately predict the effects of climate change and to define tolerable greenhouse-gas levels, there is a consensus among scientists that action should be taken to reduce emissions. In its Fourth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC 2007) concluded that "most of the observed increase in global average temperatures since the mid-20th century is very likely (i.e., with a probability of over 90%) due to the observed increase in anthropogenic greenhouse-gas concentrations due to usage of fossil fuels" (Fig. 1.15).

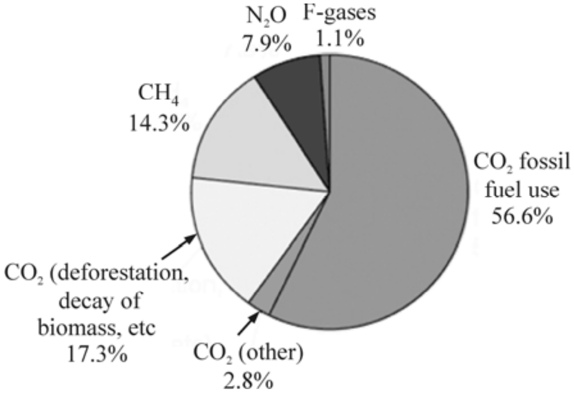

Fig. 1.14 Global anthropogenic greenhouse gas emissions in 2004 (IPCC 2007)

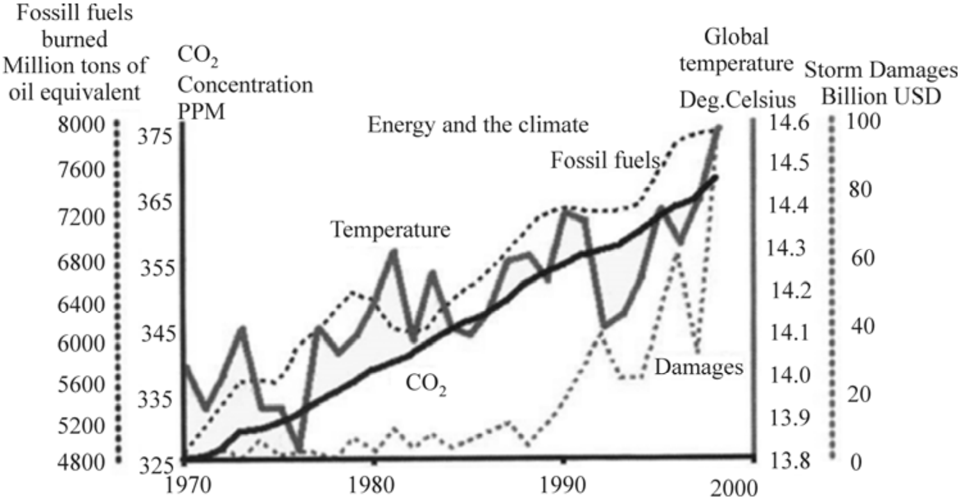

Fig. 1.15 Energy usage and climate

In addition to the issues of global warming and climate change, there are other more obvious and immediate problems associated with the use of fossil fuels. Many fossil fuel power plants release various other forms of air pollutants, directly impacting environmental and human health. Coal-fired power plants in particular, are among the largest contributors to the unhealthy levels of ozone, mercury, and particulate pollution which as many as sixty percent of Americans are exposed to (American Lung Association, 2009). Other social and environmental issues are associated with the acts of mining, processing, and transportation of fossil fuels. Finally, issues of economic and political instability often arise due to reliance on foreign supplies of oil.

There are many strategies that can help to reduce the use of fossil fuels, from overall energy conservation to the use of alternative energy sources. Options such as nuclear power or carbon capture and sequestration (CCS) offer GHG-free possibilities for energy production, but not without associated negative environmental implications as well as uncertainties with respect to issues of safety or reliability. Indeed, no alternative currently exists to which no single social, environmental, or moral objection may be made. It can be argued, however, that many of the sustainable sources of energy (wind, solar, hydro, geothermal, wave, biomass, etc.) offer merit as alternatives that have, under the right conditions, limited negative implications. Furthermore, as technology continues to improve, many of these sustainable alternatives are becoming competitive with fossil fuel sources on an economic basis.

1.10 Renewable Energy Sources and their Importance

Renewable energy sources can meet many times the present world energy demand, so their potential is enormous. They can enhance diversity in energy supply markets, secure long-term sustainable energy supplies, and reduce local and global atmospheric emissions. They can also provide commercially attractive options to meet specific needs for energy services (particularly in developing countries and rural areas), create new employment opportunities, and offer possibilities for local manufacturing of equipment.

There are many renewable technologies (Fig. 1.16). Although often commercially available, most are still at an early stage of development and not technically advanced. They demand continuing research, development, and demonstration efforts. In addition, few renewable energy technologies can compete with conventional fuels on cost, except in some niche markets. But substantial cost reductions can be achieved for most renewables, closing gaps and making them more competitive. This will require further technology development and market deployment and boosting production capacities to mass production.

In 1998, renewable energy sources supplied 56 ± 10 exajoules, or about 14 percent of world primary energy consumption. The supply was dominated by traditional biomass (38 ± 10 exajoules a year). Other major contributions came from large hydropower (9 exajoules a year) and from modern biomass (7 exajoules). The contribution of all other renewable – small hydropower, geothermal, wind, solar, and marine energy – was about 2 exajoules, which means that the energy supply from new renewables was about 9 exajoules (about 2% of world consumption). The commercial primary energy supply from renewable sources was 27 ± 6 exajoules (nearly 7% of world consumption), with 16 ± 6 exajoules from biomass. For the long term and under very favourable conditions, the lowest cost to produce electricity might be \$0.01–0.02 a kilowatt-hour for geothermal, \$0.03 a kilowatt-hour for wind and hydro, \$0.04 a kilowatt-hour for solar thermal and biomass, and \$0.05–0.06 a kilowatt-hour for photovoltaics and marine currents. The lowest cost to produce heat might be \$0.005 a kilowatt-hour for geothermal, \$0.01 a kilowatt-hour for biomass, and \$0.02–0.03 a kilowatt-hour for solar thermal. The lowest cost to produce fuels might be \$1.5 a gigajoule for biomass, \$6–7 a gigajoule for ethanol, \$7–10 a gigajoule for methanol, and \$6–8 a gigajoule for hydrogen. Scenarios investigating the potential of renewables reveal that they might contribute 20–50% of energy supplies 2050.

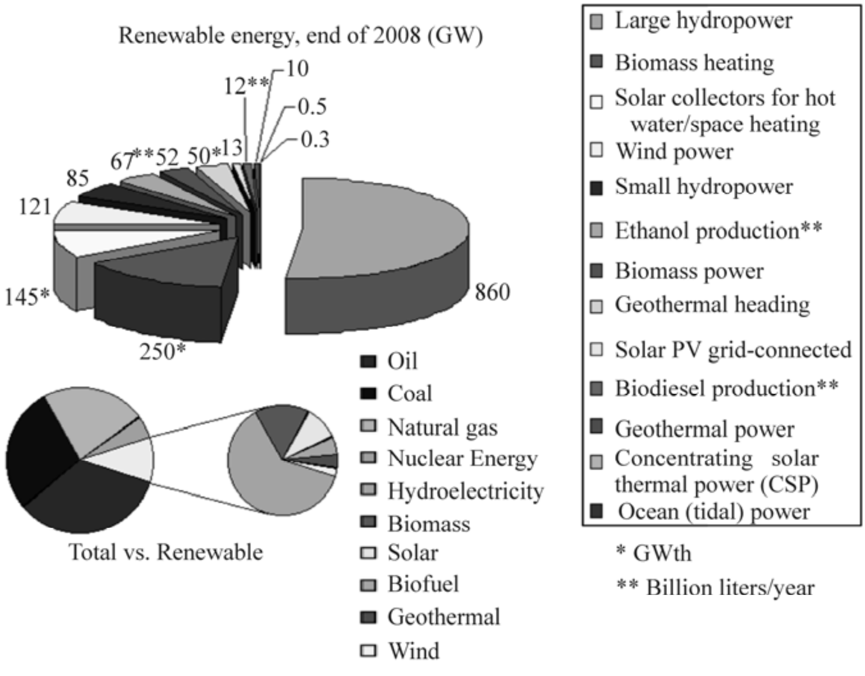

Fig. 1.16 Renewable technologies and their relative contribution. (http://www.ren21.net), BP Statistical Review [http://www.bp.com/statisticalreview].

A transition to renewables-based energy systems would have to rely on successful development and diffusion of renewable energy technologies that become more competitive and cost effective. Table 1.17 summarizes the various categories of Renewable Energy Conversion Technologies.

Table 1.17 Categories of renewable energy conversion technologies.

Technology	Energy Product	Applications
Biomass Energy		
Combustion (Dynamic Scale)	Heat (Cooking, space heating) Process heat, Steam Electricity	Wide Applications; improved technologies available
Combustion (Industrial Scale)	Electricity, Heat (CHP)	Wide Applications; technologies potential for improvement
Gasification/Power Production	Hydro Carbons, Methanol, H_2	Demonstration phase
Gasification /fuel production	Ethanol	Development Stage
Hydrolysis and fermentation	Bio Oils	Commercially applied in sugar & starch Industries; production from wood under development
Pyrolysis/production of liquid fuels	Charcoal	Poilot Phase Production/Technical barriers
Pyrolysis production of solid fuels	Biodiesel Biogas	Widely applied; wide range of efficiencies
Extraction		Applied; relatively expensive
Digestion		Commercially applied
Wind Energy		
Water pumping & battery charging	Movement, power	Small wind machines, widely applied
Onshore wind turbine	Electricity	Widely applied commercially
Offshore wind turbines	Electricity	Development and demonstration stage
Solar energy		
Photovoltaic solar energy conversion	Electricity	Widely applied; rather expensive, further development needed
Solar thermal electricity	Heat, steam, electricity	Demonstrated; further development needed
Low-temperature solar energy use	Heat (water & space heating, cooking, drying) and cold	Solar collectors commercially applied; solar cookers widely applied in some regions; solar drying demonstrated and applied.
Passive solar energy use	Heat, cold, light, ventilation	Demonstrations and applications; no active parts
Artificial photosynthesis	H_2 or H_2 rich fuels	Fundamental and applied research

Table contd…

Technology	Energy Product	Applications
Hydro Power	Power, electricity	Commercially applied, small and large scale application
Geothermal Energy	Heat, steam and electricity	Commercially applied
Marine energy		
Tidal Energy	Electricity	Applied; relatively expensive
Wave Energy	Electricity	R&D and demonstration phase
		R&D phase
Current Energy	Electricity	R&D and demonstration phase
Ocean thermal energy conversion	Heat, electricity	Theoretical Option
Salinity gradient/ osmotic energy	Electricity	R&D phase
Marine biomass production	Fuels	

1.10.1 Environmental Effects of Renewable Energy Resources

Renewable energy has the ability to help reduce the effects of climate change and generally provides "clean" or low-pollution alternatives to fossil fuels. However, renewable energy development is not free of environmental impacts. Development must be well planned out and carefully sited, and the effects on the surrounding ecosystem must be measured and monitored, in order to minimize detrimental effects to local wildlife habitat and natural resources. Indirect effects should also be considered when evaluating the environmental impacts of different types of renewable energy. For example, although air emissions associated with renewable resources are typically low, one must also consider the indirect effect of air pollution emissions from the manufacture of material. As with conventional energy production, there are environmental issues to be considered while using renewable energy resources also.

Wind Energy: It is hard to imagine an energy source more benign to the environment than wind power. It produces no air or water pollution, involves no toxic or hazardous substances (other than those commonly found in large machines), and poses no threat to public safety. And yet a serious obstacle facing the wind industry is public opposition reflecting concern over the visibility and noise of wind turbines, and their impacts on wilderness areas.

Solar Energy: Since solar power systems generate no air pollution during operation, the primary environmental, health, and safety issues involve how they are manufactured, installed, and ultimately disposed off. Energy is required to manufacture and install solar components, and any fossil fuels used for this purpose will generate emissions. Thus, an important question is how much fossil energy input is required for solar systems compared to the fossil energy consumed by comparable conventional energy systems. Although this varies depending upon the technology and climate, the energy balance is generally favorable to solar systems in applications where they are cost effective, and it is improving with each successive generation of technology. According to some studies, for example, solar water heaters increase the amount of hot water generated per unit of fossil energy invested by at least a factor of two compared to natural gas water heating and by at least a factor of eight compared to electric water heating.

Materials used in some solar systems can create health and safety hazards for workers and anyone else coming into contact with them. In particular, the manufacturing of photovoltaic cells often requires hazardous materials such as arsenic and cadmium. Even relatively inert silicon, a major material used in solar cells, can be hazardous to workers if it is breathed in as dust. Workers involved in manufacturing photovoltaic modules and components must consequently be protected from exposure to these materials. There is an additional small- danger that hazardous fumes released from photovoltaic modules attached to burning homes or buildings could injure fire fighters.

The large amount of land required for utility-scale solar power plants-approximately one square kilometer for every 20-60 megawatts (MW) generated-poses an additional problem, especially where wildlife protection is a concern. But this problem is not unique to solar power plants. Generating electricity from coal actually requires as much or more land per unit of energy delivered if the land used in strip mining is taken into account. Solar-thermal plants (like most conventional power plants) also require cooling water, which may be expensive or scarce in desert areas.

Large central power plants are not the only option for generating energy from sunlight, and are probably among the least promising. Because sunlight is dispersed, small-scale, dispersed applications are a better match to the resource. They can take advantage of unused space on the roofs of homes and buildings and in urban and industrial lots. And, in solar building designs, the structure itself acts as the collector, so there is no need for any additional space at all.

Geothermal Energy: Geothermal energy is heat contained below the earth's surface. The only type of geothermal energy that has been widely developed is hydrothermal energy, which consists of trapped hot water or steam. However, new technologies are being developed to exploit hot dry rock (accessed by drilling deep into rock), geopressured resources (pressurized brine mixed with methane), and magma.

The various geothermal resource types differ in many respects, but they raise a common set of environmental issues. Air and water pollution are two leading concerns, along with the safe disposal of hazardous waste, and land subsidence. Since these resources would be exploited in a highly centralized fashion, reducing their environmental impacts to an acceptable level should be relatively easy. But it will always be difficult to site plants in scenic or otherwise environmentally sensitive areas.

The method used to convert geothermal steam or hot water to electricity directly affects the amount of waste generated. Closed-loop systems are almost totally benign, since gases or fluids removed from the well are not exposed to the atmosphere and are usually injected back into the ground after that are up their heat. Although this technology is more expensive than conventional open-loop systems, in some cases it may reduce scrubber and solid waste disposal costs they give enough to provide a significant economic advantage.

Scrubbers reduce air emissions but produce a watery sludge high in sulfur and vanadium, a heavy metal that can be toxic in high concentrations. Additional sludge is generated when hydrothermal steam is condensed, causing the dissolved solids to precipitate out. This sludge is generally high in silica compounds, chlorides, arsenic, mercury, nickel, and other toxic heavy metals. One expensive method of waste disposal involves drying it as thoroughly as possible and shipping it to licensed hazardous waste sites. Research under way at Brookhaven National Laboratory in New York points to the possibility of treating these wastes with microbes designed to recover commercially valuable metals while rendering the waste nontoxic.

Usually the best disposal method is to inject liquid wastes or redissolved solids back into a porous stratum of a geothermal well. This technique is especially important at geopressured power plants because of the sheer volume of wastes they produce each day. Wastes must be injected well below fresh water aquifers to make certain that there is no communication between the usable water and waste-water strata. Leaks in the well casing at shallow depths must also be prevented.

Biomass: Biomass power, derived from the burning of plant matter, raises more serious environmental issues than any other renewable resource except hydropower. Combustion of biomass and biomass-derived fuels produces air pollution; beyond this, there are concerns about the impacts of using land to grow energy crops. How serious these impacts are, will depend on how carefully the resource is managed. The picture is further complicated because there is no single biomass technology, but rather a wide variety of production and conversion methods, each with different environmental impacts.

Air Pollution: Inevitably, the combustion of biomass produces air pollutants, including carbon monoxide, nitrogen oxides, and particulates such as soot and ash. The amount of pollution emitted per unit of energy generated varies widely by technology, with wood-burning stoves and fireplaces generally the worst offenders. Modern, enclosed fireplaces and wood stoves pollute much less than traditional, open fireplaces for the simple reason that they are more efficient. Specialized pollution control devices such as electrostatic precipitators (to remove particulates) are available, but without specific regulation to enforce their use it is doubtful they will catch on.

Emissions from conventional biomass-fueled power plants are generally similar to emissions from coal-fired power plants, with the notable difference that biomass facilities produce very little sulfur dioxide or toxic metals (cadmium, mercury, and others). The most serious problem is their particulate emissions, which must be controlled with special devices. More advanced technologies, such as the whole-tree burner (which has three successive combustion stages) and the gasifier/combustion turbine combination, should generate much lower emissions, perhaps comparable to those of power plants fueled by natural gas.

Facilities that burn raw municipal waste present a unique pollution-control problem. This waste often contains toxic metals, chlorinated compounds, and plastics, which generate harmful emissions. Since this problem is much less severe in facilities burning refuse-derived fuel (RDF)-pelletized or shredded paper and other waste with most inorganic material removed-most waste-to-energy plants built in the future are likely to use this fuel. Co-firing RDF in coal-fired power plants may provide an inexpensive way to reduce coal emissions without having to build new power plants.

Using biomass-derived methanol and ethanol as vehicle fuels, instead of conventional gasoline, could substantially reduce some types of pollution from automobiles. Both methanol and ethanol evaporate more slowly than gasoline, thus helping to reduce evaporative emissions of volatile organic compounds (VOCs), which react with heat and sunlight to generate ground-level ozone (a component of smog). According to Environmental Protection Agency estimates, in cars specifically designed to burn pure methanol or ethanol, VOC emissions from the tailpipe could be reduced 85 to 95%, while carbon monoxide emissions could be reduced 30 to 90%. However, emissions of nitrogen oxides, a source of acid precipitation, would not change significantly compared to gasoline-powered vehicles.

Greenhouse Gases: A major benefit of substituting biomass for fossil fuels is that, if done in a sustainable fashion, it would greatly reduce emissions of greenhouses gases. The amount of carbon dioxide released when biomass is burned is very nearly the same as the amount required to replenish the plants grown to produce the biomass. Thus, in a sustainable fuel cycle, there would be no net emissions of carbon dioxide, although some fossil-fuel inputs may be required for planting, harvesting, transporting, and processing biomass. Yet, if efficient cultivation and conversion processes are used, the resulting emissions should be small (around 20% of the emissions created by fossil fuels alone). And if the energy needed to produce and process biomass came from renewable sources in the first place, the net contribution to global warming would be zero.

Similarly, if biomass wastes such as crop residues or municipal solid wastes are used for energy, there should be few or no net greenhouse gas emissions. There would even be a slight greenhouse benefit in some cases, since, when landfill wastes are not burned, the potent greenhouse gas methane may be released by anaerobic decay.

Questions

1. What are main sources for Earths energy? Explain Earth’s Energy Budget. Explain different forms of Energy and their characteristics?
2. What are non renewable and renewable energy resources? Compare their relative utilization in a developed country like USA and developing country like India.
3. Discuss the availability of the non renewable Energy Resources in developed, developing and middle income group Did you mean countries. Discuss their relative trends in utilization of these energy resources sector wise.
4. What is energy mix and its role in environmental protection? Discuss the changing energy mix planned for 2050 for USA and India?

5. Explain the terms energy, intensity and elasticity in energy planning. Discuss the key steps in sustainable energy planning.
6. Discuss how overutilization of non renewable energy resources damage environmental quality and influence Global climate change.
7. What are the contemporary commercially matured renewable energy technologies and their relative contribution to global energy needs? Do they also contribute to environmental degradation?

Multiple Choice Questions

1. Life on Earth would not be possible without Sun's ____
   (a) nuclear energy (b) electrical energy
   (c) sound energy (d) wind energy
2. Kinetic energy depends on ____
   (a) mass and volume (b) weight and height
   (c) speed and weight (d) speed and mass.
3. Gravitational potential energy depends on ____
   (a) mass and speed (b) mass and weight
   (c) weight and height (d) height and distance.
4. Which of the following is NOT a renewable resource?
   (a) wind energy (b) solar energy
   (c) nuclear energy (d) geothermal energy
5. Which of the following is a conversion from chemical energy to thermal energy?
   (a) food is digested and used to regulate body
   (b) temperature
   (c) charcoal is burned in a barbecue pit
   (d) coal is burned to boil water
   (e) all of the above
6. Machines can _____
   (a) increase energy (b) convert energy
   (c) transfer energy (d) both (b) and (c)
7. In every energy conversion, some energy is always converted into
   (a) kinetic energy (b) thermal energy
   (c) potential energy (d) mechanical energy

8. An object that has kinetic energy must be ____
   (a) at rest
   (b) in motion
   (c) lifted above the earth's surface
   (d) none of the above

9. Which of the following is NOT a fossil fuel?
   (a) gasoline (b) firewood
   (c) coal (d) natural gas

10. Which of the following is NOT an energy resource?
    (a) falling water (b) an electric generator
    (c) plant matter (d) the heat inside the earth

11. The kinetic energy of an object can be found if the object’s following properties are known ____
    (a) volume and density (b) speed and mass
    (c) weight and height (d) distance and time

12. An object’s mechanical energy is _____
    (a) its energy of motion
    (b) not related to the object’s mass
    (c) the waste energy it produces by friction
    (d) the sum of its potential and kinetic energies

13. Of the following, which type of energy is NOT correctly described?
    (a) thermal energy: a measure of particle motion
    (b) sound energy: energy that can travel through a vacuum
    (c) electrical energy: the energy of moving electrons
    (d) light energy: the result of vibrations of electrically charged particles

14. Suppose you are jumping on a trampoline. At the top of your jump, you’re ___
    (a) mechanical energy is zero
    (b) kinetic and potential energy are equal
    (c) potential energy is at a maximum’s
    (d) potential energy is zero.

15. When one object does work on another, energy is ___
    (a) destroyed (b) created
    (c) transferred (d) All of the above

16. What is the kinetic energy of a car with a mass of 4000 kg traveling at 20 m/s?
    (a) 80,000 J (b) 1,600,000 J
    (c) 800,000 J (d) 160,000,000 J

17. Which of the following vehicles has high kinetic energy?
    (a) large truck traveling 30 m/s (b) small car traveling 30 m/s
    (c) large truck traveling 25 m/s (d) small car traveling 25 m/s

18. Which of the following vehicles has the lowest kinetic energy?
    (a) large truck traveling 50 m/s (b) small car traveling 30 m/s
    (c) minivan traveling 45 m/s (d) bicycle traveling 10 m/s

19. Because work and energy are so closely related, they are both expressed in ___
    (a) calories (b) kilocalories
    (c) Joules

20. Energy is stored in a stretched rubber band ___
    (a) kinetic energy (b) light energy
    (c) potential energy (d) chemical energy

21. Mechanical energy can be ____
    (a) all potential energy
    (b) part potential and part kinetic energy
    (c) all kinetic energy
    (d) all of the above

22. The energy used to cook food in a microwave is a form of ____
    (a) chemical energy (b) sound energy
    (c) electrical energy (d) light energy

23. The chemical energy of the food we eat is a result of a conversion of ____
    (a) thermal energy to light energy
    (b) potential energy to nuclear energy
    (c) light energy to chemical energy
    (d) potential energy to sound energy

24. When rolling downhill, a roller coaster's potential energy is converted into __
    (a) kinetic energy (b) sound energy
    (c) thermal energy (d) All of the above

25. Our most important energy resource is ____
    (a) solar energy (b) fossil fuels
    (c) plants (d) wind

26. The cleanest burning fossil fuel is ____
    (a) coal (b) petroleum
    (c) oil (d) natural gas

27. Our most important nonrenewable resource is/are ___
    (a) solar energy (b) fossil fuels
    (c) wind energy (d) geothermal energy

28. If fossil fuels are nonrenewable, why do we use them for energy?
    (a) they do not produce pollution
    (b) they provide a large amount of thermal energy per unit of mass
    (c) they do not cause acid rain
    (d) all of the above

29. Fossil fuels originally received their energy from the ___
    (a) wind (b) water
    (c) sun (d) earth's heat

30. Plants, wood, and waste are all examples of ____
    (a) nonrenewable resources (b) biomass
    (c) inorganic matter (d) fossil fuels

31. Coal, petroleum, and natural gas are all examples of ___
    (a) fossil fuels
    (b) super-concentrated forms of the sun's energy
    (c) nonrenewable resources
    (d) all of the above

32. Which nonrenewable resource is used the most to heat businesses and homes?
    (a) oil (b) natural gas
    (c) coal (d) petroleum

33. Which fossil fuel creates the most fuel emissions?
    (a) oil (b) natural gas
    (c) coal (d) petroleum

34. The United States' primary source of electrical energy is generated by ____
    (a) falling water (b) burning fossil fuels
    (c) the wind (d) burning biomass

35. Fossil-fuel and nuclear power plants use to turn a turbine that rotates the generator __

(a) wind	(b) steam
(c) water	(d) electricity

36. Non-industrialised countries rely for energy heavily on ___

(a) biomass	(b) nuclear power
(c) solar power	(d) geothermal power

37. If an object's mechanical energy remains constant and its kinetic energy increases, it's __

    (a) potential energy remains the same

    (b) potential energy increases

    (c) potential energy decreases

    (d) total potential energy plus kinetic energy increases.

38. When you turn on a light bulb, you convert _____

    (a) potential energy into electrical energy and light energy

    (b) electrical energy into kinetic energy and light energy

    (c) electrical energy into light energy and thermal energy

    (d) chemical energy into light energy and thermal energy

39. If you were to climb 3 m up a tree and then pause on a branch to enjoy the view, you would have ____

(a) kinetic energy	(b) light energy
(c) potential energy	(d) chemical energy

References

National Energy Map for India-Technology Vision 2030 (TERI Report 2006).

World Consumption of Primary Energy by Energy Type and Selected Country Groups, 1980-2004" (XLS). Energy Information Administration, U.S. Department of Energy. July 31, 2006. http://www.eia.doe.gov/pub/international/iealf/table18.xls. Retrieved 2007-01-20.

"Energy Consumption: Total energy consumption per capita". Earthtrends Database. World Resources Institute. http://earthtrends.wri.org/text/energy-resources/variable-351.html. Retrieved 2011-04-21

National Energy Map for India-Technology Vision 2030 (TERI Report 2006).

BP Statistical review of world energy June 2006" (XLS). British Petroleum. June 2006. http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/reports_

"Renewables, Global Status Report 2006" (PDF). Renewable Energy Policy Network for the 21st Century. 2006.

http://www.ren21.net/globalstatusreport/download/RE_GSR_2006_Update.pdf.

World Energy Intensity: Total Primary Energy Consumption per Dollar of Gross Domestic Product using Purchasing Power Parities, 1980–2004" (XLS). Energy Information Administration, U.S. Department of Energy. August 23, 2006. http://www.eia.doe.gov/pub/international/iealf/tablee1p.xls. Retrieved 2007-04-03.

World energy use in 2010: over 5% growth, Enerdata Publication.

Global Energy Review in 2009, Enerdata Publication.

State of the World 2009, Worldwatch Institute, 2009.

World Energy Outlook 2006. International Energy Agency. 2006. ISBN 9-264-10989-7.

MacKay, David J C (2008). Sustainable Energy—without the hot air. Cambridge: UIT. ISBN 978-0-954452933. http://www.withouthotair.com.

Smil, Vaclav (2003). Energy at the crossroads. MIT Press. ISBN 0-262-19492-9.

Tester, Jefferson W; et al. (2005). Sustainable Energy: Choosing Among Options. The MIT Press. ISBN 0-262-20153-4.

Yergin, Daniel (1993). The Prize. New York: Simon & Schuster. ISBN 0-671-79932-0.