Chapter 7

ENERGY, MATERIAL, INFORMATION FLOWS

7.1 Changing Global Patterns of Energy and Water Consumption—from Ancient to Modern Times

The history of human use of resources is one of sequential exhaustion, followed by innovation. By sequential exhaustive use is meant first using resources available more easily, or requiring less inputs of energy or technology and after they are depleted taking up use of resources that are available less easily, or require greater inputs of energy or technology. Necessity, it is said is the mother of invention and the compulsions posed by resource scarcities have led to innovations.

The universal source of energy for people and their animal ancestors is calories in their food. Our ancestral species too initially consumed uncooked food. This cannot include the highly abundant grass seeds that are indigestible for humans unless cooked. When our African ancestors discovered the use of fire some 3 lakh years ago, they added a major source of energy, the grass seeds, to their repertoire. This fire was primarily wood fire. For the whole range of activities people used their own muscle power till they domesticated first cattle and then horse beginning around 12000 years ago, first in the "fertile crescent" in the middle east, and then slowly all over. The use of animal muscle power allowed them to move over greater distances, as also to intensify agricultural operations. As wood was exhausted, especially in colder regions such as Britain, people switched to coal. This also seems to have happened where coal was abundantly available near surface in areas of high population densities in Magadhan empire around 2000 years ago. As coal too became scarcer and energy demands escalated following the industrial revolution, petroleum came into use. There has been a gradual use of petroleum from deeper and deeper deposits, first on land, and later under sea. Innovation is also now permitting use of less dense energy sources such as shale.

A few centuries ago, people began to tap water power by use of water mills. Such water mills were used, for instance, to grind grain in Garhwal region of Himalayas. Following the industrial revolution in England water mills were used to run textile factories and other industrial operations as well. Water then came to be used for generation of hydro-electric power on a large scale in the last century. The last century also saw development of newer energy sources such as nuclear energy.

Wind and solar energy are ancient sources of energy, but are being intensively investigated now.

Demands for water too have gradually escalated over historic times from water for drinking, cooking and bathing to manifold uses. With beginning of agriculture water became crucial for crop production. For the first few thousand years agriculture remained entirely dependent on rainfall. But gradually people began to canalise water from streams to fields, for instance, such canals have been found in 3500 years old archaeological sites in South India. About the same time people of Mohenjodaro-Harappan civilisation had begun to tap ground water by digging wells. Over centuries as demands for water have escalated for a variety of other uses such as industrial manufacture, air-conditioning and recreation, people have taken to building larger and larger reservoirs and digging deeper and deeper wells. In places like Kuwait desalination of sea water on a large scale has been initiated to meet a whole range of demands for water. Finally, water has become an important source of sink for waste products, ranging from sewage to industrial effluents.

7.2 Energy and Water Consumption and Quality of Life

Water: Water is the most common yet most precious resource on earth without which there would be no life on earth. The quality of life and health of the human

society depends on the access to quality water and the availability of water.

Sources of Water: The major sources of water in India are rainfall, ground water and surface water (rivers, lakes, etc.). With an average annual rainfall of 1170mm, India is one of the wettest countries. India's ground water resources are almost ten times its annual rainfall. According to the Central Ground water Board, India has an annual exploitable ground water potential of 26.5 million hectare-meters. Nearly 85 per cent of currently exploited ground water is used for irrigation. Ground water accounts for as much as 70-80 per cent of the value of farm produce attributable to irrigation. There are 14 major, 44 medium and 55 minor river basins in India. Water consumption in India is estimated to be 470 cubic meters per person per year.

The share of different sectors in total amount of water consumed (605 billion cubic meter) in India is given in figure 7.2a.

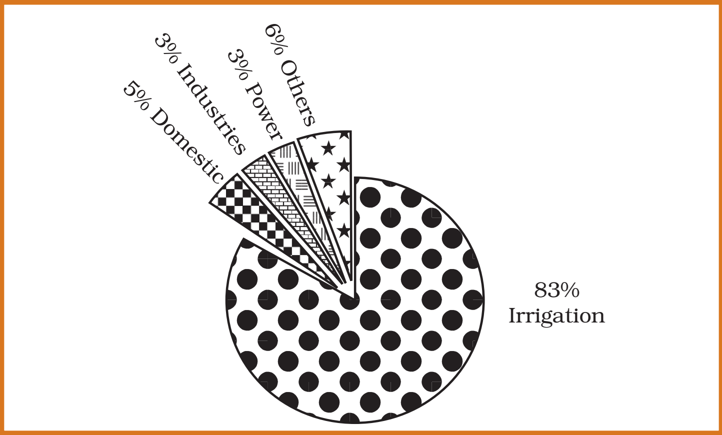

Fig. 7.2a: Water consumption by different sectors in India

Environmental implications of water consumption: A rapidly growing population, economy, and non-sustainable water management is leading to ground water depletion, silting of water bodies, excessive runoff and water pollution. India is already facing severe water stress as depicted in figure 7.2b, which shows depleting water availability with increase in human population.

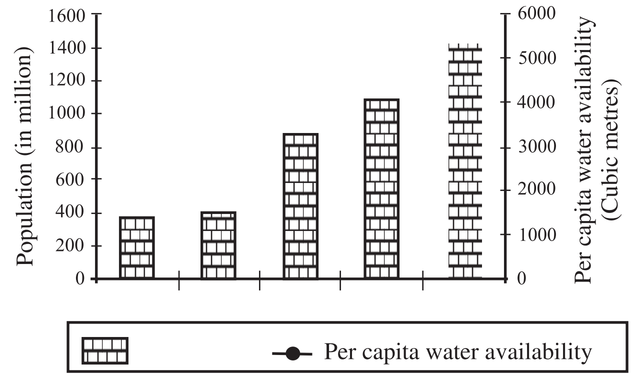

Fig. 7.2b: Growth in population and per capita water availability

Energy

Energy is fundamental to all production processes on earth, from cooking food to photosynthesis in plants to agricultural and industrial production. Energy is the prime mover of economic growth and human development. It encompasses all sectors of the economy and every section of society. There is a direct correlation between economic growth expressed as gross domestic product (GDP) and energy consumption. The main sources of energy are solar, wind, biomass (fuelwood, crop residue and cattle dung), hydroelectricity, coal, petroleum oil, natural gas and nuclear.

Energy consumption in India is estimated to be 479 kg of oil equivalence, where all sources of energy are converted to petroleum oil. However, the energy consumption in United Sates of America and Japan is estimated to be 8078 and 4084 kg of oil equivalence respectively, an indicator of economic development.

Energy is consumed for all activities in all sectors and the share of different sectors of India is given in figure 7.2c.

Environmental implications of energy use: India is already facing severe energy shortages. There is a shortage of fuelwood for cooking, electricity for pumping water and for industries and petroleum fuels for transportation. The current pattern of consumption of coal, petroleum and natural gas is leading to local air pollution, waste generation, and greenhouse gas

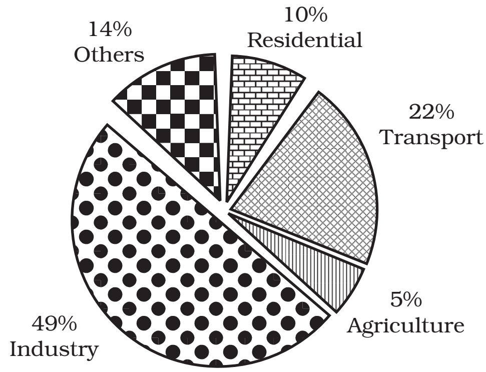

Fig. 7.2c: Consumption of commercial energy by different sectors in India.

emissions leading to global warming. Increase in the efficiency of energy use and shift to renewable sources of energy will reduce these adverse environmental implications.

7.3 Rising Demand for Energy and Water—Gap between Demand and Supply (Indian Context)

The demand for energy and water is continuously increasing due to rise in population, economic growth, industrialisation and urbanisation without any matching increase in supply leading to severe shortages. This high increase in demand has also resulted in serious environmental degradation.

Rising Demand for Energy

The demand for energy in India is growing at a rate of about 5 per cent annually. Assuming an annual economic growth rate of 8 per cent expressed in terms of gross domestic products (GDP), the demand for total primary energy (including coal, natural gas, petroleum oil and nuclear) is projected to increase from 381 million tonne of oil equivalent in 2006-07 to 1833 million tonne of oil equivalent by 2031-32 (by nearly 5 times). The projected increase in demand for energy from different sources is given in figure 7.3a.

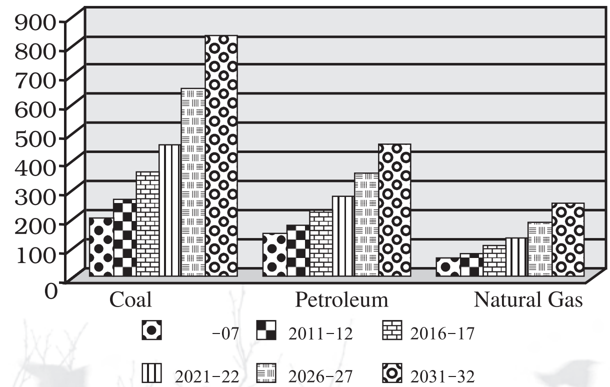

Fig. 7.3a: Projected energy demand (in million tonnes of oil equivalence) up to 2031-32, assuming 8% Gross Domestic Product growth rate

Demand and Supply Gap

India is experiencing severe shortages in the supply of electricity, petroleum fuels, and even fuelwood (for cooking).

Electricity: The demand for electricity is expected to grow at about 4.8 per cent whereas the increase in supply is not keeping this pace, adversely affecting agricultural and industrial production.

Petroleum fuels: India is importing currently 70 per cent of its petroleum fuel requirements and with an expected future growth in demand 4.5 per cent, the dependence on uncertain supplies and growing price of oil will lead to shortages and rise in cost of transportation of fuels.

Fuelwood: In rural India, majority of the households are expected to continue to depend on fuelwood sources due to the absence of access to other quality fuels such as LPG and kerosene.

Environmental Implications of Growing Demand for Energy

Increasing demand for fossil fuels will lead to the following environmental implications:

- Land degradation due to coal mining activities.
- Waste generation due to coal mining and power generation processes (fly ash and mining wastes).
- Emission of pollutants (nitrous oxide and sulphur dioxide, suspended particulate matter) from combustion of fossil fuels in power generation, industrial processes and transportation.

- Emission of greenhouse gases such as carbon dioxide, methane and nitrous oxide leading to global warming and climate change.
- Shortages and rising prices of fossil fuels accompanied by global concern about climate change may lead to positive implications for environment by shifting to renewable source of energy.

Water: Demand–Supply Gap

The demand for water is directly related to increase in population and economic growth. With the population growth projected to cross 1200 million in the next 30 years and economic growth likely at over 7-8 per cent, the projected demand for water is expected to rise very high.

Environmental Implications of Supply and Demand Gap

Demand for water for domestic, agricultural and industrial uses is increasing and on the other hand the sustainable sources of water are getting degraded, for example decline in ground water levels in all parts of India. Both ground and surface water sources are getting contaminated with biological and chemical contaminants. Figure 7.3b shows the major sources of contamination due to natural (geogenic) and human (anthropogenic) activities.

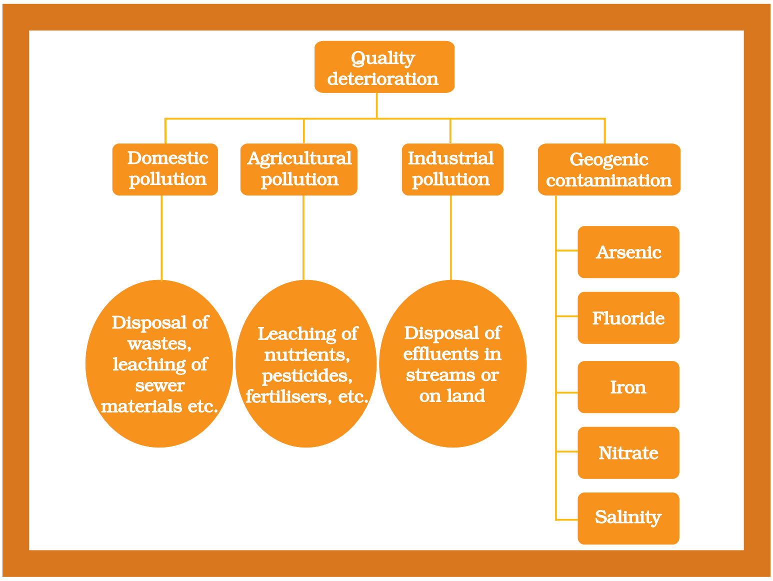

Fig. 7.3b: Major sources of contamination of water due to natural (geogenic) and human (anthropogenic) activities

Increasing demand for water coupled with loss of ground water may also lead to demand for enhanced surface water storage bodies such as artificial reservoirs, dams and irrigation tanks, all leading to submergence of forests, settlements and other lands, with socio-economic and environmental consequences.

7.4 Conventional and Non-conventional Energy Sources—Potential and Limitations of each Source, Methods of Harnessing and Environmental Consequences of their Use with Special Reference to Indian Context

Worldwide there is a range of energy resources available to humans. These energy resources fall into two main categories, often called conventional and non-conventional energy resources. Each of these resources can be used to generate electricity or produce heat. The different sources of energy belonging to conventional and non-conventional categories are:

Conventional: Petroleum, Natural Gas, Coal and Nuclear.

Non-conventional: Solar, Hydroelectric, Wind, Tidal, Hydrogen, Geothermal, Wood energy and Bio-fuels.

Conventional Energy

Power or energy provided by traditional sources such as coal, natural gas and petroleum oil is referred to as conventional energy and these sources are also generally considered as non-renewable. Conventional sources of energy are extracted from the ground as liquid fuels (petroleum oil), gases (natural gas) and solid fuels (coal). Coal, petroleum and natural gas are all considered fossil fuels, since they are formed from the buried remains of plants and animal biomass that existed millions of years ago. Uranium ore, a solid, is mined and converted to a fuel. Uranium is not a fossil fuel. These energy sources are considered non-renewable because they cannot be replenished. The total potential conventional energy and hydropower resource and the current consumption level for India are given in table 7.4a.

Environmental implications of conventional energy sources: Environmental implications of extraction, processing, transportation and use of conventional energy sources lead largely to environmental degradation such as – degradation of land and water resources, generation of wastes (such as fly ash), air pollution, greenhouse gas emissions, etc.

Non- conventional Energy Sources

Energy sources that are renewable and ecologically safe, such as solar, wind, biomass, small-scale hydro and tidal energy are referred to as non-conventional

Energy Sources	Total Resources	Consumption in 2006
Coal and Lignite	256 billion tons	518 million tons
Petroleum oil	733 million tons	134 million tons
Natural Gas	750 billion cubic meters	47 billion cubic meters
Hydropower	600 TWh (Trillion Watt Hours)	148 TWh

Table 7.4a: Energy resources and consumption levels in India

energy resources. The non-conventional energy sources are often called renewable energy sources. Renewable energy effectively uses natural resources such as sunlight, wind, rain, tides and geothermal heat, which are naturally replenish. The potential of different non-conventional energy sources and their levels of use in India are given in the table 7.4b.

Environmental implications of non-conventional energy: Shift to non-conventional sources will lead to the following potential environmental benefits.

- Reduction in the emission of pollutants such as SO_2, CO, and suspended matter.
- Reduction in emission of greenhouse gases.
- Reclamation of degraded lands due to sustainable biomass plantations.

The share of conventional and non-conventional (renewable) energy sources globally is given in figure 7.4a.

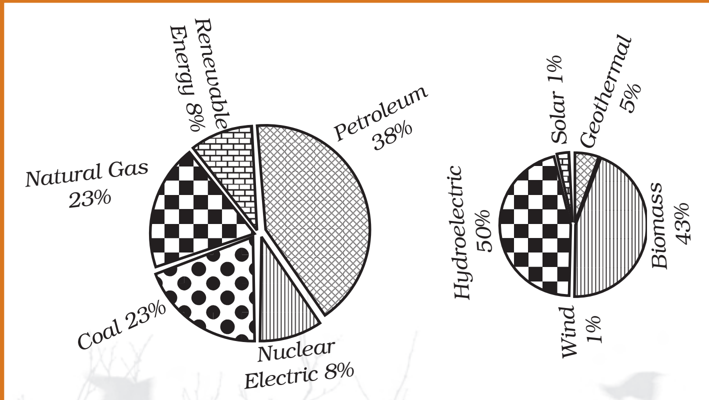

Fig 7.4a: Global share of conventional and non-conventional energy sources

Sources and units	Potential	Levels of use (2005)
Wind power (MW)	45,000	2980.0
Small hydropower (up to 25 MW) MW	15,000	1693.0
Biomass power (MW)	19,500	727.0
Solar Photovoltaics (MW/km^2)	20	191.0
Solar water heating (million m^2 collector area)	140.0	1.0
Waste-to-energy (MW)	1,700	46.5
Biogas plants (millions)	12	3.7
Improved biomass cook-stoves (millions)	20	33.9

Table 7.4b: The potential and levels of use of non-conventional or renewable energy sources

7.5 Energy Conservation — Efficiency in Production, Transportation and Utilisation of Energy

It is common to observe even today people expressing confusion over the terms "Energy Conservation" and "Energy Efficiency". Energy conservation means taking initiatives and adopting practices that reduce the amount of energy used to perform desirable activities and on the other hand energy efficiency means using improved technology to decrease energy demand. In other words, energy conservation usually means being more careful in the way we use energy whereas energy efficiency means using advanced technologies to get better services out of a given level of energy input. To put it in simple terms, energy efficiency is the technological solution to achieve energy conservation.

Technically, energy efficiency is the amount of useful energy extracted from a system divided by the total energy put into a system. It may also be thought of as the efficiency with which we are capable of utilising an energy resource. In simple terms it is the level of energy service derived from a given level of energy input. Let us take the example of a car. In order to run our car, the chemical potential energy present in petrol (or gasoline) must first be converted into thermal energy (or heat energy) by igniting the fuel in an internal combustion engine. The thermal energy is then converted into mechanical energy to make the car run. It has been estimated that this three-step process has an overall maximum efficiency of about 30 per cent. This means that 70 per cent of the energy initially stored in the gasoline was lost as waste heat, mostly in the form of thermal vibrations to the surrounding environment. This illustrates the importance of learning about energy efficiency and trying to find better ways to judiciously use the energy resources available to us.

From the above discussion, efficiency of an energy using process can be defined as:

$$e = \frac{\text{useful energy output}}{\text{energy input}}$$

This can be further illustrated with the example of heating water by a firewood burning stove.

Let,

E_I = energy input (calorific value of firewood)

E_O = useful energy output (heat absorbed by water)

E_L = heat losses (conductive, convective and radiant)

Then, the energy balance is given by

$$e = \frac{E_o}{E_I} = 1 - (E_L/E_I)$$

From the above example it is clear that energy is wasted (heat is lost) while it is being used in a device to derive some service (hot water). Such wastages are not just limited to energy utilisation (or usage); it can happen while producing an energy carrier (e.g., electricity production from coal) and while transporting the energy carrier (carrying electricity through transmission and distribution lines). It is a multi-step process to transform energy resources (as available in nature) to a form in which it can be actually used by the people. At every step of this transformation, energy is lost to the environment in different forms (as heat, light, sound, vibrations, etc.). This results in energy output being significantly less than the energy input at every step. Thus the overall energy efficiency or overall energy conservation potential of an energy system depends on "efficiency of energy production", "efficiency of energy transportation" and "efficiency of energy utilisation". The product of these individual efficiencies gives us the overall efficiency.

Let us illustrate this with an example. If we take the full cycle of electricity production from coal thermal power plants using coal and transportation of electricity through transmission and distribution (T&D) lines and finally utilisation of this electricity in an incandescent bulb (IB). In India, most of the coal thermal power plants operate at an efficiency level of 30 per cent. That means, out of 1 kg only 0.3 kg of coal is converted into electricity. The T&D system efficiency in India is at 75 per cent indicating that 1 kWh of electricity fed into the system becomes 0.75 kWh when it reaches the consumer. The efficiency of IB is 10 per cent and this means only 0.1 kWh of electricity is actually converted into light from 1 kWh of electricity supplied to the bulb. This is equivalent of a 100 Watt incandescent bulb providing lighting for 10 hours. From this information, the overall efficiency can be easily calculated as follows:

Overall efficiency =

$30\% \times 75\% \times 10\% = 0.30 \times 0.75 \; 0.10 = 0.0225 = 2.25\%$

In other words, we would be wasting 97.75 per cent of the energy in this process. This means you need about 44 kg of coal to provide 1 kg equivalent of lighting using an IB. On the other hand, if we use fluorescent tubes (or tube lights) with an efficiency level of 20 per cent, we need only about 22 kg of coal to get 1 kg equivalent of lighting. Still better option is compact fluorescent lamp with an efficiency of 30 per cent where it needs only 15 kg of coal to get 1 kg equivalent of lighting.

The above example clearly establishes the fact that the energy savings from energy efficiency improvement are substantial. The benefits derived out of these savings are multi-pronged: it saves money, reduces environmental damages and preserves precious natural resources.

7.6 Planning and Management of Energy; Future Sources of Energy—Hydrogen, Alcohol, Fuel Cells

Hydrogen

Biological hydrogen production is the most challenging area of biotechnology with respect to environmental problems. Hydrogen gas is seen as a future energy carrier by virtue of the fact that it is renewable, does not evolve the "greenhouse gas" CO_2 in combustion, liberates large amounts of energy per unit weight (122 kg/g) on combustion, and is easily converted to electricity by fuel cells. Biological hydrogen production has several advantages over H_2 production by photo electrochemical or thermochemical processes. H_2 is commercially produced via chemical and electrochemical routes. Conventional method includes production from fossil fuel and biomass: steam reforming of natural gas, partial oxidation of heavy oils, and coal gasification, from water by thermal and thermochemical methods and also from water (electrolysis and photolysis). These technologies of H_2 production from fossil and non fossil fuels need high energy input. The present fossil fuel-based industrial processes are not sustainable in the long term, and are already causing intractable environmental problems. At present, H_2 is seen as an expensive option, because it is costly to produce in large quantities at the industrial level, and because fuel cells rely on scarce metals such as platinum. H_2 and electricity could team to provide attractive options in transportation and power generation. A challenging problem in establishing H_2 as a source of energy for the future is the renewable and environmental friendly generation of large quantities of H_2 gas. It has the potential to reshape the entire energy industry. If all vehicles were run on hydrogen fuel cells, it would be a huge step towards solving air pollution and human health problem.

The need for development of cost effective technologies have forced us to look for newer processes such as biological H_2 production. Molecular hydrogen is widely used by micro-organisms as a source of energy. However, under certain conditions microbes produce H_2 by fermentation of different substrates. The conversion of sugars and carbohydrates to H_2 is achieved by a multienzyme system such as hydrogenases. In bacteria, glucose is converted to 2 moles of pyruvate and 2 moles of NADH formed by Embden-Meyerhof Pathway. The pyruvate is then oxidised through a pyruvate ferredoxin oxidoreductase and hydrogenase. As a result, 4 moles of H_2 can be produced from 1 mole of glucose under ideal conditions. H_2 production from simple molecules like glucose, xylose, maltose and lactose is observed in *Bacilllus, Clostridium* and *Escherichia* sp. and several anaerobes. In addition to simple sugars and carbohydrates, fermentation of raw starch of corn, potato, cassava peel, etc., has also resulted in H_2 generation. A comparison of various methods of H_2 production has revealed dark fermentative route to be the most effective: certain organic wastes like damaged wheat grains, pea-shells and apple waste can be fermented to H_2 with mixed and pure microbial isolates such as *Bacillus licheniformis* and *B. subtilis*. It is a relatively new technology and untested on a large scale. Since the process has a large untapped potential, it is worth it to look for new hydrogen-producers, which have the good abilities to utilise wastes as well. Energy generation is linked to waste stabilisation and management. The future of biological hydrogen production depends not only on research advances, i.e., improvement in efficiency through genetically engineering micro organisms and/or the development of bioreactors, but also on economic considerations (the cost of fossil fuels), social acceptance, and the development of H_2 energy systems.

Biofuels

With rapid economic development, global consumption of oil has increased tremendously and so have oil prices soared in accompaniment. Increase in worldwide energy consumption from 2001 to 2025 is projected to be by 54%. Hike in price coupled with increasing awareness on climate change has brought in growing concern over increasing consumption of fossil fuels and also to look for clean, safe, sustainable alternative to petroleum. Biofuel provides a readymade solution to this problem. It is highly preferable as it is environment friendly and reduces energy threat. In simple terms, this is the conversion of the energy trapped from the sun through photosynthesis by plants for human use.

Liquid biofuels are derived from biomass, the oldest source of renewable energy if properly managed. Alcohol fuels (ethanol and methanol) and vegetable oils (sunflower, sesame, linseed, etc.) are the two main categories of biofuels. Ethanol obtained from starch/sugar/cellulose containing crops is the most widely used biofuel today. It can be used in its pure form or blended with gasoline. In US, approximately 1.5 billion gallons of ethanol is added to gasoline every year. Biodiesel, a renewable substitute of diesel can be prepared by chemically combining any natural oil or fat with an alcohol. It is being used as a fuel additive in 20 per cent blends with petroleum diesel in compression ignition engines.

Adoption of biofuels reduces the use of fossil fuels thereby reducing greenhouse gas (GHG) emissions and improving air quality. They replace toxic parts of gasoline with components that biodegrade easily in the environment. Therefore biofuel spills do not contaminate soil/water and much of the wastes is recyclable, and hence are not environmental hazard. It also reduces the ever growing threat of dependence on petroleum thus providing energy security and strengthening economy as it help ease dependence on foreign oil imports. Beside these, the effort has socio-economic impacts as it creates domestic jobs in plant construction, operation, maintenance and support in the surrounding communities.

The Brazilian alcohol programme was the first successful large scale programme in the world. It resulted in rural development, diversification of energy sources, lower dependence on oil imports, reduction in local pollutants from vehicle exhaust, and net reduction in GHG emission. It was implemented in 1975 to replace price soaring imported oils. The fuel (sugarcane ethanol) is sold virtually in all petrol pumps in the country. This seems inevitable, as engines that strictly run on gasoline are no longer available in the country. The Brazilian bioethanol programme is based entirely on sugarcane, as the country is world's largest sugarcane producer. As for China, more than 30 per cent ethanol is produced from grains such as corn, cassava and rice; about 10 per cent from sugar; 6 per cent from paper pulp residue and the rest from ethylene via synthetic process.

In Europe and US, as well in several developing countries there is a move towards cultivation of energy crops for production of biomass as a fuel. As fossil fuels become scarce and expensive with their carbon emission level being of great environmental concern, there is huge potential for biomass in energy production. In addition, bioethanol is a renewable source and its combustion adds no net CO_2 in the atmosphere thereby reducing threat of global warming. Biofuels and food crops may in the long run compete for land. However, this debate of food vs. fuel can be addressed by efficiency improvement like better land and water uses, agriculture management, industrial production, adequate social policies for job reallocation and international trading.

At the home front, the Government of India (GoI) constituted the Committee on the Development of Biofuels (CDB) within the planning commission in July 2002 (CBD 2003). The committee recommended adoption of biofuel programme in the country based on ethanol produced from sugarcane (molasses) as a substitute to petrol (gasoline) and bio-diesel produced from the oil bearing seed of jatropha as a substitute to High Speed Diesel (HSD). In view of this, the GoI has recognised biofuels as a major player in the nation's energy scenario.

It is clearly visible that the biofuel mission is gaining momentum across the globe for obvious reasons. A cross section of both developing and developed countries are investing on technology improvement for biofuel production which clearly indicates the future status of biofuel.

7.7 Enhancing Efficiency of Devices and Optimising Energy Utilisation

Saving energy is a cheaper and environmentally friendly option to increased energy production to meet the growing energy demand. Efforts to enhance energy efficiency contribute greatly in lowering the energy intensity of developing countries like India thus strengthening the national energy security. Increased energy efficiency reduces stress on energy production and transport infrastructure and contributes to a healthier environment through decreased emission of greenhouse gases and other pollutants.

According to the thermodynamic definition, energy gets transformed from one form into another form. A device is used to facilitate such a transformation process. For example, an energy end-use device converts the input energy into useful energy as desired by the consumers. To further elaborate on this, consider the example of an incandescent bulb (an end-use device), which transforms electrical energy into light energy. From an efficiency perspective, the relevant issue here is to find out how much of electricity actually gets transformed into light energy. This determines the efficiency level of the device and improvement or enhancement of efficiency of devices is possible when quantity of input energy required can be reduced without affecting level of useful energy (e.g., same level of lighting with reduced quantity of electricity).

Following figures 7.7a and 7.7b (Keulenaer, HD, Belmans, R, Blaustein, E, Chapman, D, Almeida, AD, Waehter, BD, Radgen, P, "Energy Efficient Motor Driven Systems", European Copper Institute, Brussels, Belgium; http://re.jrc.ec.europa.eu/energyefficiency/pdf/HEM_lo_all%20final.pdf) clearly establishes the fact that how same level of energy service can be obtained with reduced input of energy, through efficiency improvement. The figures show two types of water pumping systems, the first one a conventional pumping system with a total efficiency of 31 per cent and the second one an energy efficient pumping system with a total efficiency of 72 per cent. Both the pumping systems give a useful output power of 31 kW each. However to deliver this level of output, the conventional pumping system needs an input power of 100 kW whereas the efficient pumping system needs only 43 kW. This results in a saving of 57 kW of input power. We may observe from the figures that this level of savings in energy input is made possible only through enhancement of efficiencies of individual devices in the pumping systems. For example, the motor used in the conventional system is a standard one with an efficiency level of 90 per cent whereas high efficiency motor with an efficiency level of 95 per cent is used in the energy-efficient pumping system.

It is said that nearly all energy using devices and systems are less energy efficient when compared with their theoretical maximum efficiency. There is always potential for improvement. Thus, few things are truly "energy efficient" and it is a relative term. A device or system can only be more or less energy efficient than the available alternative devices at a given time and in a given situation. Thus, the technical potential of energy efficiency can be defined as the achievable savings resulting from the maximum energy efficiency improvement available at a given time.

There are many ways of enhancing efficiency of end-use devices. Typically, technical improvements are made depending on the requirements in order to enhance efficiency levels. The possible ways of improving energy efficiency of devices can be broadly classified as follows.

- Those that are applicable only to new devices, that is, when replacing the old device with a more efficient new one.
- Those that are due to retrofitting of an existing device with new part. Example could be replacing worn out parts with better quality new parts.
- Those that are due to modifications and refinements that are carried out during minor or routine maintenance.

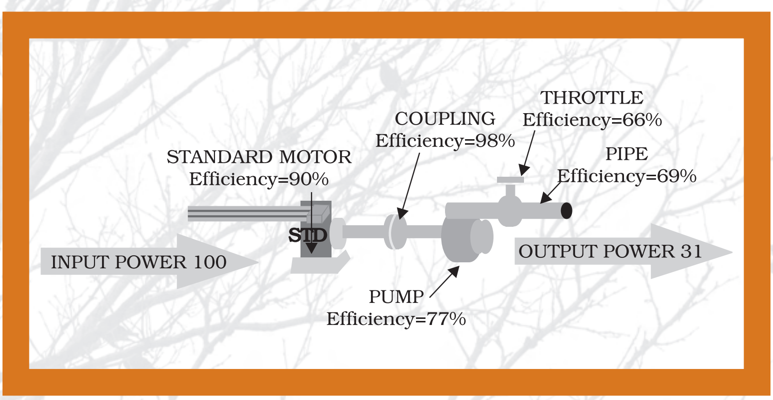

Fig. 7.7a: Conventional pumping system (total efficiency = 31%)

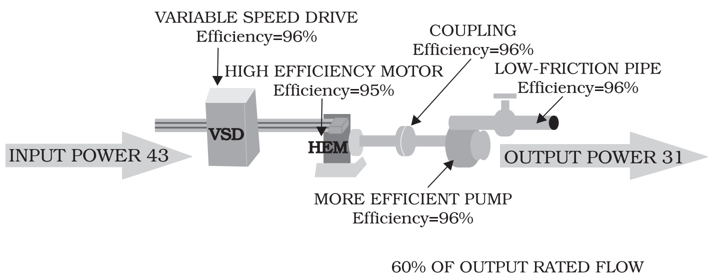

Fig. 7.7b: Energy-efficient pumping system combining efficient technologies (total efficiency = 72 per cent)

- Those that are because of replacement or addition of new parts that can be conveniently added when making major renovations or expansions.

It is not just enough to improve energy efficiency without bothering about the purpose of the energy use. It is equally important to be knowledgeable about what end-use services are being obtained using the energy carriers. Thus, a perfect match between quality of energy carrier and quality of energy service is a desirable outcome. Some of the mismatches that typically happen are:

- Using high quality electrical energy for obtaining low quality service of heating water for bathing purpose.
- Using the air conditioner for cooling the room where the requirement is comfort of the person occupying the room.

Expensive petrol being used for moving the car where the requirement is mobility of the person. Measuring efficiency in terms of fuel consumption per kilometer per person may be more relevant than fuel consumption per kilometer, which is normally used.

These examples clearly show that it is not only the efficiency of energy use which is important, it is equally important to ensure its optimal utilisation. To ensure optimal utilisation of energy, it is essential to focus on the efficiency enhancement of overall system through installing efficient devices, matching the qualities of energy input and service output and ensuring effectiveness of processes occurring at both the upstream and downstream of end-use devices. Following are some of the issues which need to be taken care of in order to ensure optimal use of energy:

- Distribution losses downstream of end-use devices like an energy efficient furnace feeding leaky ducts yielding expensive delivered comfort.
- Undesired or useless services, such as leaving a device on all the time even when it serves no useful purpose.
- Misused services, such as space-conditioning rooms that are open to the outdoors.
- Conflicting services, such as heating and cooling the same room simultaneously. These are wasteful even if they are provided efficiently.
- Misplaced efficiency, such as using a device, however efficient, to a task that does not need it – say, cooling with a mechanical chiller when groundwater or ambient conditions can more cheaply do the same thing.

7.8 Modern Information Communication Technology Revolution and Environment

The Environment sector has been a significant beneficiary of the Information and Communication Technology (ICT) revolution. The availability of powerful computers at affordable prices, advances in space technology, the emergence of the Internet and the availability of innovative software have all contributed to strengthen monitoring, management and conservation of the environment. Some key technologies are discussed here.

Satellite Remote Sensing

Data available from remote sensing satellites has revolutionised environmental monitoring. Satellite data collected using sensing devices on board earth observation satellites like the Indian Remote Sensing Satellite (IRS) is communicated down to earth stations. The orbital arrangement of satellites is such that the same area of earth is repeatedly imaged at set time intervals (like 24 days for the IRS P6 Satellite) permitting detection of changes in ground conditions. Users in India can order satellite data from the National Remote Sensing Agency (NRSA), Hyderabad providing location details of the area of interest. The satellite imagery of the area is sent to the user on CD and the user can analyse the data to extract environmental information using image processing software (Fig. 7.8a). Satellite data is being used to monitor deforestation, ozone hole, status of air and water pollution, manage solid waste, locate and track forest fires, determine sea surface temperatures and monitor effects of climate change just to name a few.

Fig. 7.8a: IRS Satellite imagery of Bhopal showing Bhopal lake with sediment load. Areas in red are vegetation.

GPS

The Global Positioning System or GPS is a constellation of 24 satellites that helps users determine their position on the surface of earth in terms of latitude and longitude using a GPS receiver (Fig. 7.8b). This information is invaluable for environmental studies in accurately mapping and navigating to areas of interest on the ground such as sample plots, animal nesting sites, vulnerable habitats, pollution discharge locations and areas facing environmental calamities. GPS is also playing an important role in helping environmental scientists study migration using GPS tracking devices implanted on the animals (Fig. 7.8c) which are then tracked on a computer (Fig. 7.8d).

Fig.7.8b: Hand held GPS Receiver and GPS Image

Fig.7.8c: Elephant with GPS Collar

GIS

Geographic Information Systems or GIS are computer systems that permit maps to be overlaid one on top of the other creating a very powerful

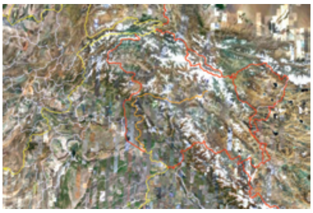

Fig.7.8d: GPS Image

analysis and decision support tool for environmental planning, monitoring and management (Fig. 7.8e). Each map in the stack can be thought as drawn on a transparent polythene sheet such that when two or more maps are overlaid one on top of the other, information on each one of them can be interpreted together. A GIS can integrate environmental data from multiple sources like paper maps, GPS, Remote Sensing data and field data. GIS is being extensively used in areas such as assessing environmental impacts of development projects (highways, dams, industries), wildlife studies, water conservation, biodiversity assessments, deforestation mapping, pollution mapping, monitoring of oil spills, management of hazardous wastes, climate change studies, managing epidemics, disaster management planning and monitoring relief work in areas affected by environmental disasters.

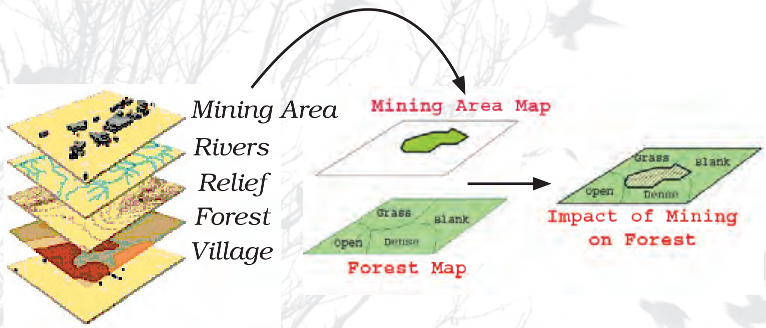

Fig. 7.8e: Stack of Maps in GIS and Map Overlay

The Internet

The Internet is playing a major role in spreading environmental awareness and dissemination of environmental information. The Internet has also been instrumental in catalysing global environmental initiatives by creating virtual communities of environmental scientists through collaborative networking tools. Initiatives such as monitoring global climate change could not have been possible without the Internet. Climate forecast models, that require supercomputers to make sense of huge volumes of climate data, are using donated computer processing time from ordinary internet users through an internet based concept called distributed computing. Data processing capacity matching supercomputers to run climate prediction models is being created by asking internet users to permit the use of their internet connected computers for this purpose when they are not using them (See Things to do box). The Global Biodiversity Information Facility or GBIF which provides information on species is another example of internet based global co-operation (See Things to do box). Initiatives such as Google Earth which provide free access to high resolution satellite imagery of any part of the earth have encouraged the civil society to step up independent mechanisms of vigilance on environmental issues. Internet blogs have redefined environmental reporting empowering common citizens to share their environmental concerns with a global audience on the internet.

Instrumentation

Most instruments used to collect environmental data, which were earlier operated manually, have undergone a generational upgrade due to automation resulting from embedded computer systems. As a result, it is now possible to have unmanned round the clock surveillance on pollution and weather parameters at remote or inhospitable locations and use that data to build early warning system.

Things to do

(Students can be encouraged to explore the following)

Learn more about climate prediction project by visiting their website — *http://www.climateprediction.net* Explore the schools link to join this experiment or access learning resources.

Have you tried Google Earth? Visit the *http://earth.google.com/* and read more about this amazing tool and download the software. Try to see the satellite image of your city.

Try the CO_2 saver is a free programme that manages your computer's power usage when it is idle, saving energy and thereby reducing harmful emissions and greenhouse gases such as carbon dioxide (CO_2) that are released into the atmosphere. Download and try this software from *http://co2saver.snap.com* It also shows how much CO_2 you have saved.

Visit the European Earth Observation Web Site for Secondary Schools *http://www.eduspace.esa.int/eduspace* and learn about environmental applications of remote sensing and Envisat – a satellite dedicated to monitoring our environment. See spectacular images of environmental phenomenon on earth.

Visit the Global Biodiversity Information Facility website at *http://www.gbif.org* and click on the data link followed by countries link and choose India. Place the bounding rectangle on an area on the map of India in the part of country you live in and keep zooming in by clicking on coloured squares to view species data in that area.