

Block

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ENERGY AND MINERAL RESOURCES

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BLOCK 3 ENERGY AND MINERAL RESOURCES

This is the third block of the course 'Ecosystem and Natural Resources'. In this block we will make an attempt to understand importance of natural resources, resource management, types of energy resources, non renewable and alternative resources, mineral resources and sustainable issues related to energy and mineral resources.

Unit 1 gives you an information about the natural resources and their importance, global availability of resources, consumption pattern of all natural resources and, in particular, non-renewable resources.

Unit 2 presents you of the various types of energy sources, problem of utilizing various non-renewable and alternative sources of energy and various ways by which our energy demand could be minimized.

Unit 3 provides you an insight about the pattern and causes of mineral demand, the factors affecting mineral exploitation, classify mineral resources, generation and management of different types waste due to mining activity. The ecological, environmental and social impacts of mining are also presented in the unit.

Unit 4 presents the resource use pattern, sustainable use of a resource, various links between resource use depletion, environmental degradation and the sustainability issues related to mining, drilling and other harvesting practices by providing alternative strategies for sustainable energy and material future.

UNIT 1 RENEWABLE AND NON-RENEWABLE RESOURCES

Structure

- 1.0 Introduction
- 1.1 Objectives
- 1.2 Value of Natural Resources
- 1.3 Concept of Resource and Waste
- 1.4 Type of Resources and the Concept of Renewability
- 1.5 Renewable Resources: Supporting Capacity and Assimilative Capacity
- 1.6 Resource Management and Sustainable Yield
 - 1.6.1 Problems of Past Resource Management Practices
 - 1.6.2 Maximum Sustainable Yield (MSY) and Optimum Sustainable Yield (OSY)
 - 1.6.3 Dealing with Resource Crisis and Environmental Degradation
- 1.7 Exploitation of Resources and Issues of Sustainability
- 1.8 Resource Right and Resource Flow
- 1.9 Let Us Sum Up
- 1.10 Key Words
- 1.11 References and Suggested Further Readings
- 1.12 Key to Check Your Progress

1.0 INTRODUCTION

Life on this planet earth depends upon large number of goods and services provided by nature, which are known as natural resources. In a broad sense, they refer to all the living and nonliving gift of the earth. Traditional usage confines the term to naturally occurring resources and systems that are useful to humans under ordinary technological, economic, social, and legal circumstances.

Thus air, water, soil, minerals (fuel and non-fuel), forests, crops and wildlife are all examples of natural resources. This not only includes the products but also the services provided by them, including the waste assimilative capacities of all parts of the environment etc. Many of the natural resources are essential for our survival while others are used for satisfying our wants. A natural resource can be a substance, an energy unit or a natural process or phenomenon. e.g., land, soil, water, grassland, forests, energy sources, etc. Some of the resources such as soil, water etc. are important components of life supporting system. The natural resources are not only sources of food, fodder and shelter, they also provide recreational opportunities, solace and even inspiration to mankind.

The nature of resources varies from society to society. The variation is related to the culture, the level of development and the nature of work of society. Natural resources have been exploited by human beings since the beginning of civilization or even before. However, since the resources were abundant than the demand, no significant depletion occurred. But due to considerable increased consumption during the last century, serious destruction has been caused to the natural resources.

So, keeping these things in our mind the main objective should be to conserve our natural resources and to utilize the natural resources in a sustainable manner.

1.1 OBJECTIVES

After reading this unit, you will be able to:

- define the concept of renewability and non-renewability of a resource and its sustainable harvest;
- underline the resource potential wastes; and
- select sustainable patterns of resource use.

1.2 VALUE OF NATURAL RESOURCES

There are at least five values called as the five E's of natural resources namely, ethical, emotional, esthetic (aesthetic), economic, and environmental services. Out of these, the first one is an intrinsic value and the rest four are considered as extrinsic values. The ethical value is the value of a resource onto itself, regardless of its value to humans. The intrinsic value or ethical value gives right to the existence to a mountain, forest, stream, plant or a worm. Intrinsic values are "ecocentric" (environment-oriented). Extrinsic values are values that are external to a resource's own right to exist. It refers instead to the resource's ability to provide something for humans. Such values are "anthropocentric" (human-oriented), more utilitarian, or practical, than intrinsic values and therefore political and economic debates on resource management discusses them more widely. Esthetic (aesthetic) value is the role of a resource in making the world more beautiful, more appealing and pleasant to the senses. The value one places on a cool breeze and fresh air on a summer morning, the peace and calmness in a natural setting are some of the examples. This may bear no value for some whereas, indispensable for some others. Emotional values include the value of a resource beyond sensory enjoyment e.g. emotional bonds of some people for certain natural setting, plants or animals. This is sometimes called a "sense of place". Many psychologists consider nature to be important for mental health, especially for children.

Economic values are associated with tangible products such as food, timber, energy, and so on. These values are influenced by market forces and can be of short as well as long term in nature. Society needs to focus more on long-term economic values, which actually provide more income over the long run. The value of resources for tourism, native fruits, or other such products is ultimately much greater than the value of their destructive uses. Environmental service values are the values of resources in providing intangible "services" that allow humans (and other life) to exist on Earth. Plants help purify air and produce oxygen, and plant roots and soil microbes purify water; ultimately, all food relies on a variety of environmental services.

Logging, mining, and other types of harvesting that destroy the resources are called direct values. Most environmental problems arise when resources are appreciated only for their direct values which are generally short term in nature and in turn artificially "discount" their true value to society and to future generations. Except economic values, the other 4 Es come under **indirect values**.

For reflecting a resource's true value, environmental cost needs to be taken into account.

1.3 CONCEPT OF RESOURCE AND WASTE

A resource is a means for satisfying human and social requirements in a given space and time. Technically the term "Resource" is a naturally occurring solid, liquid, or gaseous material in or on the earth's crust in such form, concentration and amount that economic extraction of a useful commodity is currently or potentially feasible. The resources are classified into two broad categories: a) identified and b) undiscovered resources. This feature is more appropriate to use with the mineral kingdom as for biological resources, there is no meaning about "undiscovered resources" for technical reasons. "Identified Resources" are those resources whose location, grade, quality, and quantity are known or estimated from specific geologic evidence. They include economic, marginally economic, and sub-economic components.

A natural resource need not always have a direct economic link. The indirect services like fresh air, clean water, recreational pleasure etc. that we get from the nature bear a lot of value but may not have an economic tag. These resources are in fact vital for life to sustain. Can one evaluate the benefits that one get from having a good physical and mental health due to these natural resources? In turn, the formation of a healthy society depends upon a healthy person.

Our daily activities can give rise to a large variety of different wastes arising from different sources and have their effect on health, the environment or aesthetics. Household rubbish, sewage sludge, wastes from manufacturing activities, packaging items, discarded cars, old televisions, garden waste, old paint containers etc. are some examples. According to Basel Convention waste can be defined as: "Substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law". Wastes may be generated during the extraction of raw materials, the processing of raw materials into intermediate and final products, the consumption of final products, and during other human activities i.e. wastes in many cases are byproducts of a product or process.

Waste is a resource that is misplaced, mistimed, or misproportioned. Or in other words a waste can become a resource, if it is placed in a proper place at a proper time and in appropriate amount or proportion. For example, an agricultural residue if burnt becomes a waste but if composted become a resource. The extra amount of fertilizer that is applied to any field than the requirement of the crops is a waste. Similarly most of the external material applied to a crop field unsynchronized with the requirement of the plants goes waste. Use of drinking quality water for purposes, say gardening etc. where low grade water can be used is wastage of the valuable resource. Water in the reservoir or supply system is a resource but when flows into drain become waste. Like that, a drug in proper proportion, adequate dose and administered to the patient in right time is a lifesaving medicine, but otherwise it becomes a poison.

On the basis of physical state waste is of 3 types: 1) solid waste, 2) liquid waste and 3) gaseous waste. Different types of waste that get generated due to our everyday activity or from manufacturing units of different types of industries (small scale, cottage, or big industries) driven by our demand add up to a huge

amount. Different examples of waste are: municipal waste (including household and commercial), industrial waste (including manufacturing), hazardous waste, construction and demolition waste, mining waste, waste from electrical and electronic equipment (WEEE), biodegradable municipal waste, packaging waste, end-of-life vehicles (ELVs) and tyre, agricultural waste and so on. These varied and voluminous wastes have to arrive at a final resting place somewhere. The steady flow of these varieties of wastes including domestic garbage and yard wastes of industrial, commercial and construction refuse is termed as **waste flow**. Many of the materials in our **waste stream** would be valuable resources, if they were not mixed with other garbage. Here again, the recyclable wastes or decomposable wastes which could have become resources by processing, remains a waste and contributes to the volume of flow in the waste stream.

1.4 TYPE OF RESOURCES AND THE CONCEPT OF RENEWABILITY

On the basis of availability, resources can be divided (figure 1.1) into exhaustible and inexhaustible. These again can be divided on the basis of exploitation as:

- a) Perpetual (solar energy, wave and tidal energy, wind energy etc.).

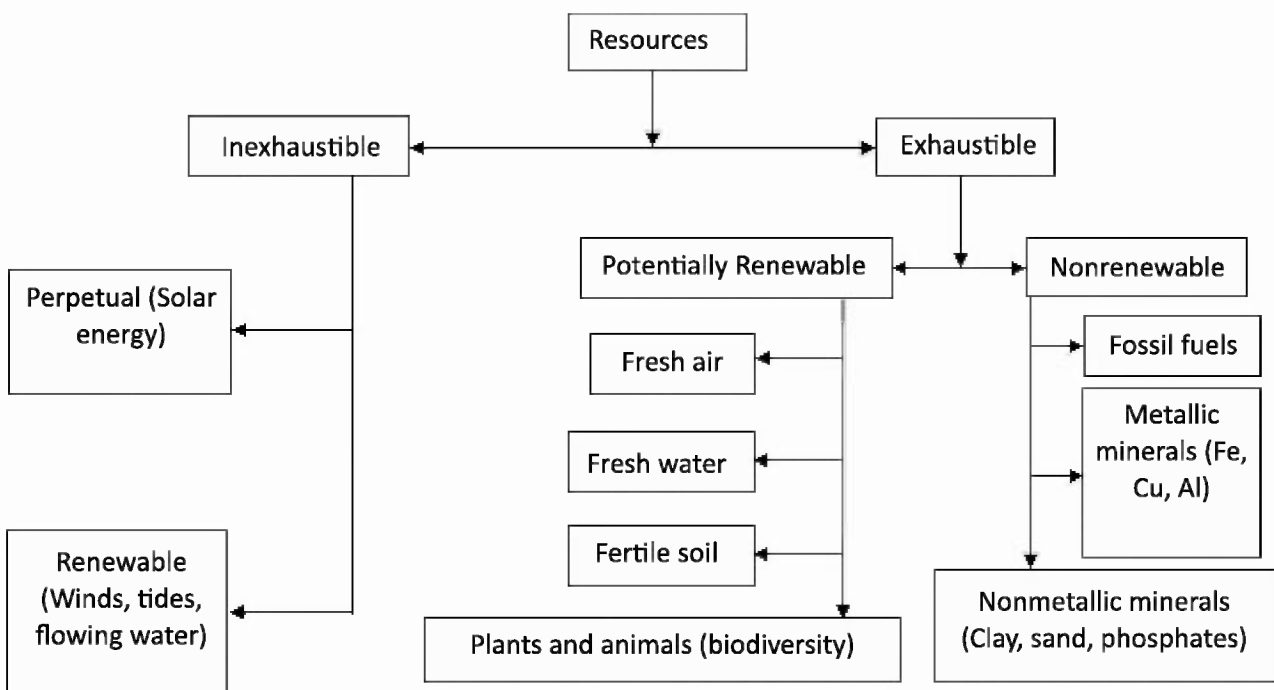


Fig. 1.1: Major types of natural resources

- b) Renewable (Wind, tides, flowing water etc.).
- c) Potentially Renewable (water resources, forest resources, wild life resources, range lands, agriculture or food resources, livestock, aquaculture, energy resources such as biomass energy, biogas, geothermal energy, and atomic energy).
- d) Nonrenewable (mineral resources, land resources, soil resources, natural gas etc.).

Renewable Resources: Solar energy is called as a perpetual resource. On a human time scale and magnitude of use, it is essentially inexhaustible. It is expected to last at least 6.5 billion years while the sun completes its life cycle.

Renewable resources have the capacity to reappear or replenish themselves by quick recycling, and replacement within a reasonable time. Soil, water, wind, tides, waves, flowing water, ocean thermal energy, geo-thermal energy etc. are examples of renewable resources and living beings (i.e. plants, animals and micro-organisms) are potentially renewable resources.

A potentially renewable resource can be renewed fairly rapidly (hours to several decades) through natural processes. Examples of such resources include microbes, forest trees, grassland, grasses, wild animals, fresh lake and stream water, groundwater, fresh air, and fertile soil.

One important potentially renewable resource is biological diversity, or biodiversity, which consists of the life forms that can best survive in the variety of conditions currently found on Earth. As discussed in previous block kinds of biodiversity include (1) genetic diversity (variety in the genetic makeup among individuals within a single species), (2) species diversity (variety among the species or unique forms of life found in different habitats of the planet, and (3) ecological diversity (variety of forests, deserts, grasslands, streams, lakes, oceans, wetlands and other biological communities that interact with one another and with their nonliving environments of matter and energy). We know that this rich variety of genes, species, and biological communities give us food, wood, fibers, energy, raw materials, industrial chemicals, and medicines. Earth's vast inventory of life forms and biological communities also provides free recycling and purification services.

Several types of environmental degradation can change potentially renewable resources into nonrenewable or unusable resources. Topsoil is now eroding faster than it forms. Salt buildup has reduced the yields on one-fourth of all irrigated cropland. Water logging has affected at least one-tenth of such croplands. Coral reefs are being destroyed or damaged in 93 of the 109 major locations. Each year overgrazing by live-stock degrades a large area of land. Almost half of the world's tropical forests have been cleared. In the developed countries, many of the remaining diverse, old growth forests are being replaced with single-species tree farms or with much less diverse second growth forests. Such practices reduce bio diversity. If habitat destruction continues at current rates, millions of species could disappear within a few decades, a drastic loss in vital **Earth capital**. These examples help in explaining the fear of most environmental scientists, that over the next few decades, the danger of degradation and depletion is greatest for potentially renewable resources, not nonrenewable resources (except for petroleum and perhaps a few scarce minerals for which we can't find economically and environmentally acceptable substitutes).

Nonrenewable Resources: Resources which are not regenerated because they do not have a life cycle or are not recycled are termed non renewable (or exhaustible) resources. These are the resources that exist in a fixed quantity in Earth's crust, and thus theoretically can be completely used up. On a time scale of millions to billions of years, such resources can be renewed by geological processes. However, on the much shorter human time scale of hundreds to thousands of years, these resources can be depleted much faster than they are formed. Mineral deposits are formed slowly over millions of years and once used cannot be generated, e.g. fossil fuels, such as petrol and coal. Since the formation of soil takes thousands of years and is not renewable in the life span of

many generations, it is thought of as nonrenewable resources. These resources provide food, fodder, fuel, medicine and clothes for man, and hence sustain life on this planet.

These exhaustible resources include energy resources (coal, oil, natural gas, uranium), metallic mineral resources (iron, copper, aluminum), and nonmetallic mineral resources (salt, clay, sand, phosphates, water, and soil). A **mineral** refers to any hard, usually crystalline material that occurs naturally. We extract more than 100 nonrenewable minerals from Earth's crust and convert the raw materials into many items to be used, reused, discarded or recycled. The availability of nonrenewable resource refers to their **reserves**: known deposits from which a usable mineral can be profitably extracted at current prices. Reserves can be increased when new deposits are found, or when price rises make it profitable to extract, identified deposits, that were previously considered too expensive to exploit.

In practice, we never completely exhaust a nonrenewable mineral resource. However, a mineral resource becomes economically depleted when the costs of finding, extracting, transporting, and processing the remaining material exceeds the amount earned from them. At that point, we are left with choices like recycling or reusing the existing supplies, wasting less, use less, trying to develop a substitute, or finally doing without them and wait millions of years for more to be produced.

Recycling involves collecting and reprocessing a resource into new products. For example, glass bottles can be crushed and melted to make new bottles or other glass items. Reuse involves using a resource over and over in the same form. For example, glass bottles can be collected, washed, and refilled many times. Similarly, copper, aluminum etc. can be recycled or reused to extend the supplies. Nonrenewable energy resources, such as coal, oil, and natural gas, can't be cycled or reused. Once burned, the useful energy in these fossil fuels is gone, leaving behind waste heat and polluting exhaust gases.

The growth and reproduction of living beings can be successfully managed so that these resources continue to regenerate. On overexploitation not only their quality becomes affected, they may even totally exhaust. They are maintainable. The highest rate at which a potentially renewable resource can be used indefinitely without reducing its available supply is called its **sustainable yield** or the **supporting capacity**. If a resource's natural replacement rate is exceeded, the available supply begins to shrink: a process known as **environmental degradation**. Some resources do not have a life cycle but can be recycled, for example water. But purely exhaustible resources like fossil fuels and some minerals are non maintainable.

Check Your Progress 1

Note: a) Use the space given below for your answer.

b) Compare your answers with those given at the end of the unit.

1) Mention different values of natural resources.

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2) Define waste. In what way do we contribute to the flow in waste stream?

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3) Write a note on renewability and non-renewability of resource.

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1.5 RENEWABLE RESOURCES: SUPPORTING CAPACITY AND ASSIMILATIVE CAPACITY

For any biological resource (biodiversity) to remain renewable it is very much essential to harvest its produce within the supporting capacity of the ecosystem. **Supporting capacity** of a natural ecosystem, is the maximum number of consumers (or the quantity of harvest) it can support ensuring a continuous supply of the resource(s) to fetch the optimum requirements (or consumption). In other words, the rate of consumption or harvest remains below the rate of regeneration. If the resource consumption or harvest exceeds the supporting capacity of the resource base, the stock will start declining, resulting into lower yield. If the practice of over exploitation still prevails, then the cycle of less stock and lesser yield will continue, and the system will collapse. For example, in case of aquaculture (say fisheries) if sufficient number of organisms are not left in the system after the first year (season) of harvest and sufficient time is not given to regenerate, the assessable stock by the next harvest will have a reduced yield. The decreasing trend will follow afterwards but the rate of decreasing harvest will go on increasing and at a certain point of time either the ecosystem will collapse, or the cost of harvest will become prohibitive. Other examples are: harvest of timber from forest, non-timber forest produce, grazing in the grassland etc.

With over exploitation, as the supporting capacity of the ecosystem or the community decreases, its capacity to bear environmental stress or pollution also goes on decreasing. This capacity of neutralizing environmental stress or pollution of an ecosystem or a community is called as **assimilative capacity**. An optimum size of population or community structure is required to maintain their microclimate and other biological (mainly behavioral) activities. Similarly, at ecosystem level, the assimilative capacity depends upon the ecosystem health. When this assimilative capacity decreases below its resilience or homeostasis, the system starts collapsing. Whereas, supporting capacity refers to sustainable harvest, assimilative capacity refers to stress bearing capacity of the community or ecosystem. The capacity of a plant community with high population density (e.g. forest) to bear stress of drought, wind, cold or fire is higher than that of a community with low population density. Similarly, a healthy soil has a higher stress bearing capacity and is more productive than a soil that is affected by salinity or alkalinity.

We must adopt life styles and development paths that respect and work within nature's limits". Environmental sustainability requires conservation of the two dimensions of Natural Capital resources and sinks. More specifically, the exploitation rates of resources should not exceed their regeneration or substitution rates while the generation or emission rates of wastes or pollution should not exceed the assimilative capacity of the environment. Overshooting the limits will eventually deplete or degrade the Natural Capital, and thus compromise the ability of future generations, as well as the present one, to meet their needs.

1.6 RESOURCE MANAGEMENT AND SUSTAINABLE YIELD

Viewing the natural environment as a resource is a very narrow anthropocentric approach to nature. Sometimes the concept of resource management is thought to be a human arrogance. From ethical view point, it is questionable whether humans have a right to "tamper" with nature, and if so, how much is justified. Ethics aside, the assumption that humans are able, as a practical reality, to effectively manage nature is not shown in human history.

In spite of these valid concerns, the need for resource management is inescapable. As human populations and technologies grow, pressures to exploit the environment will increase inevitably. The only thing needed is change in the approach where you have a concern for other organism and integrity of the natural systems as a whole. Proper management can help minimize environmental damage. Careful planning of water use, for instance, can fulfill our needs without disturbing the integrity of different natural ecosystems. Furthermore, management can help undo past damage. Thus, although resource management is not an attractive concept, in some ways it is preferable to the alternative, which is uncontrolled resource exploitation.

1.6.1 Problems of Past Resource Management Practices

Society can respond to a diminishing supply of a resource in two ways: (1) intensifying efforts to extract more of the resource or (2) reduce the need for the resource. Until recently, the first response was much more common. The usual result was a **bubble pattern** (i.e. a bell shaped curve) as depletion accelerated

when supplies ran low. The mining of lower grade, high volume materials also led to pollution problems. Nevertheless, two influential concepts were advanced to justify these past intensification efforts: Net yield of nonrenewable resources and maximum sustainable yield of renewable resources.

Intensified extraction of nonrenewable resources is based on the concept of **net yield**, which holds that a resource can continue to be extracted as long as the resources used in extraction do not exceed the resources gained i.e. the unit cost of material is under the purchasing power of the market and no other option available. As the energy used in extraction and processing increases exponentially after certain point and the amount of over burden and pollution also increases exponentially with depletion of high grade deposits, the miners switch over to low grade deposits. This greatly increases the available supplies because nearly all nonrenewable resources are characterized by an inverse quality curve: higher-grade deposits of coal, oil, minerals and other resources are much rarer than lower grade deposits. The net yield driven resource exploitation often encounters the bubble pattern of resource depletion.

The past pursuit of net yield has incurred great environmental costs by accelerating both depletion and pollution. Depletion accelerates because of growing demand and that increasingly lower grade ores must be mined and more energy and other resources must be expended to extract the ores. Pollution accelerates because increasing amounts of waste are produced in mining and processing of lower-grade ores. Mining may have to be curtailed due to the pollution generated by metal extraction rather than because the ores are actually depleted.

1.6.2 Maximum Sustainable Yield (MSY) and Optimum Sustainable Yield (OSY)

Maximum sustainable yield (MSY) holds that the optimum way to exploit a potentially renewable resource is to harvest as much as possible, up to the point where the harvest rate equals the renewal rate. As an example, a person could withdraw as much groundwater as needed up to the point where the withdrawal rate equaled the recharge rate from rainfall. Taking less is desirable and taking more would lead to depletion.

MSY is particularly very useful for management of potentially renewable biological resources such as commercially important fishes, wildlife, different forest products etc. The basic principle is that, fishes, game, and other populations could be harvested up to the point where the population's ability to reproduce itself is impaired which are governed by many factors like finding a mate, behavioral changes, the ability to counter natural forces etc. On the other hand, some part of the population should be harvested because, if population abundance becomes too high, further population growth is inhibited by overcrowding and competition. Thus, MSY aims at a balance between too much and too little harvesting to keep the population at some intermediate abundance which ensures maximum growth rate of the population. MSY population is usually about one-half of the carrying capacity.

Although it is widely practiced in regulating wildlife, forests, and fishing, MSY has been heavily criticized by ecologists and others for both theoretical and practical reasons. An important theoretical shortcoming is that MSY does not take large environmental fluctuations into account which could reduce the

population unpredictably. More important perhaps are the many practical problems: the actual population size, calculation of the MSY point, calculation of the point where population faces natural competition etc. Indeed, in many cases such as marine fishes, animals in wilderness etc. just calculating the population size is even difficult. Of course some statistical modeling can do some estimation. Still, the decline in commercial fishing in many areas indicates that humans are harvesting far more than the MSY. A variation on the MSY concept known as the **optimum sustainable yield (OSY)**, which takes into account many factors such as, how the harvest will affect other species and functioning of the ecosystem, how it will affect other human uses of the ecosystem (like recreation), and such other benefit cost questions.

1.6.3 Dealing with Resource Crisis and Environmental Degradation

It is recognized, that less resource use can ensure reduced environmental and health costs and long term economic benefits. There are three basic options that resource management can apply to minimize resource use: preservation, conservation, and restoration. **Preservation** refers to nonuse. A “preserved” national park, or wilderness area is an ecosystem that is set aside and (in theory at least) protected in its pristine, natural state. **Conservation** (input reduction) attempts to minimize the use of a natural resource. Use can be minimized through efficiency improvements, recycling or reuse, substitution of other resource, increasing cost, use of services that is meant for masses than individual arrangements, and the most important is getting satisfied with the minimum that is possible. Finally, **restoration** seeks to return a degraded resource to its original state e.g. the restoration of mined areas, lakes etc. Preservations and conservations are more cost effective than restoration, which can be extremely expensive. Restoration is most effective at the landscape level rather than a part of it. Ensured restoration of an acidified lake affected by acid mine drainage can only be effective by restoring the whole landscape to restrict acidic runoff than the lake individually. Similarly, reintroducing wolves into a small forest is unlikely to be successful unless the natural ecosystem for entire region is prepared to support them.

1.7 EXPLOITATION OF RESOURCES AND ISSUES OF SUSTAINABILITY

One of the most sensitive questions posed in the context of world’s natural resource is “How long and under what conditions can human life continue on earth?” The stocks of *in situ* resources are finite (especially the mineral fuels), and the rate of consumption of these stocks are accelerating. That’s why the exponential reserves are much shorter than static reserves. Under the condition of reducing stocks there will be growing dependence on “increasingly low quality reserves” of natural resources. However, poorer the ore quality, more will be the consumption of resources (energy, labour etc.), more will be the process waste, overburden of mining and the pollution. At a point of time, the energy requirements (and other resources) may become prohibitive, and the pollution pressure on environmental components may become too intense to bear. Again, under such conditions the place of major consumption differing from the location of reserves will have a strong geopolitical implications leading to conflicts. The over dependency on non-renewable resources has created a great disturbance in

the biosphere; one major example being green house gases induced global climate change. The awareness about these facts is inducing a shift to increase the dependency on renewable and potentially renewable resources. However, in doing so, the raw material requirement and pollution generated should be taken into account, particularly while dealing with the potentially renewable resources as their renewability is conditioned to exploitation and environmental conditions. In determining how resources will be managed over time, market processes have a great role to play and hence have the duty to act in a socially responsible way. The wisdom of past patterns of resource utilization could rationally guide our present approaches. More importantly, the role and importance of natural resources and environmental services need not be forgotten; else, they may not be freely available for the future generations. It should be remembered that “the environment is not a waste pool” and “the carrying capacities of environmental systems are limited”.

1.8 RESOURCE RIGHT AND RESOURCE FLOW

Like human beings, all other organisms also have the right to live. They are also an integral part of nature. One must understand that every living and non-living entity on this globe is directly or indirectly contributing to the resource pool. Or in other words, the world in its totality is a resource for every living organism. This means that the integrity of whole biosphere is essential for maintaining the resource pool. The integrity of biosphere is essential for sustenance of every individual in a narrow scale and for the existence of life in a broader scale. From ethical point of view, the resource requirement of other organisms for sustenance of life in this earth cannot be denied. The essential elements like air, water, food (comes from a healthy ecosystem and not from a polluted one) of life are their rights. Nobody is entitled to create any kind of disturbance in getting their life supporting requirements. However, the irony is that *homo sapiens* with their selfish motive and a disregard for this integrity (of which they also are parts) of biospheric resource pool are creating disturbance in the fine balance. If the resource right of other life forms are diluted or denied, the ultimate result of collapse of the system will be borne by the whole biosphere. At this point of time one should not forget about the rights of the lives that are yet to take birth on this earth.

Thus the totality of bio and nonbio diversity of the globe contributes to our resource pool. However, the biological resource pool is dependent on the non-biological resource pool for sustenance both in natural ecosystems as well as in human engineered bio systems. Out of these two, the man engineered bio systems are highly dependent particularly on nonrenewable resources like mineral elements and fossil fuels. These systems are again not stand alone systems. They are equally dependent on the biological diversity which is responsible for pollination (bee, insects, birds etc.), nutrition (VAM fungi, rhizobium, nitrosomonas, etc.), disease resistance and stress tolerance (genes from wild varieties), high productivity, control of parasites pests predators, etc. for productivity and existence. Therefore, to ensure the sustainability in flow of resource from such systems one need to sustain the stock of nonrenewable resources as well as the potentially renewable resources. Since, unlike the perpetual and renewable resources the nonrenewables are limited and the renewability of potentially renewable resources is conditioned to its rate of

exploitation we have to adopt a multi pronged approach. The approaches could be: first, reduction of the demand; second, shifting the dependence on nonrenewable resource to potentially renewable resources; third, adopting strategies which maximize the utilization of perpetual and renewable resources.

Check Your Progress 2

Note: a) Use the space given below for your answer.

b) Compare your answers with those given at the end of the unit.

1) Differentiate between supporting and assimilative capacity with examples.

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2) Write a note on resource management practices.

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3) Explain how the current trend of resource exploitation is unsustainable.

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4) How are resource right of life forms and resource flow in nature are related?

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1.9 LET US SUM UP

- Technically the term “Resource” is a naturally occurring solid, liquid, or gaseous material in or on the earth’s crust in such form, concentration and amount that economic extraction of a useful commodity.
- On the basis of availability, resources can be divided into exhaustible and inexhaustible.
- These again can be divided on the basis of exploitation as:
 - a) Perpetual (solar energy, wave and tidal energy, wind energy etc.)
 - b) Renewable (Wind, tides, flowing water etc.)
 - c) Potentially Renewable (water resources, forest resources, wild life resources, range lands, agriculture or food resources, livestock, aquaculture, energy resources such as biomass energy, biogas, geothermal energy, and atomic energy)
 - d) Nonrenewable (mineral resources, land resources, soil resources, natural gas etc.).
- There are three basic options that resource management can apply to minimize resource use: preservation, conservation, and restoration.

1.10 KEY WORDS

- Assimilative Capacity:** The capacity of neutralizing environmental stress or pollution of an ecosystem or a community.
- Conservation** : It attempts to minimize the use of a natural resource.
- Ethical Value** : The value of a resource onto itself, regardless of its value to humans.
- Extrinsic Values** : The values those are external to a resource’s own right to exist, instead referring to the resource’s ability to provide something for humans
- Five E’s** : Ethical, Emotional, Esthetic (aesthetic), Economic, and Environmental services.
- Intrinsic Values** : It is the value of a resource due to its existence and is not concerned with its beneficial value to others.
- Preservation** : refers to nonuse.
- Restoration** : It seeks to return a degraded resource to its original state.
- Sustainable Yield** : The highest rate at which a potentially renewable resource can be used indefinitely without reducing its available supply.

1.11 REFERENCES AND SUGGESTED FURTHER READINGS

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- McKinney, M. L and Schoch, R. M. 1998. Environmental Science: Systems and Solutions. Jones and Bartlett Publishers, Boston. 639 pp.
- Miller, G Tyler Jr. 1996. Worldviews, Ethics, and Sustainability. In Belmont, CA (Edt). Living in the Environment. Wadsworth Publishing Company.

1.12 KEY TO CHECK YOUR PROGRESS

Check Your Progress 1

- 1) Your answer must include the following points:
 - Definition of natural resources.
 - 5 E's of natural resources
- 2) Your answer must include the following points:
 - Resource and waste
 - Types of waste and reasons that contribute to waste stream
- 3) Your answer must include the following points:
 - Characteristics of renewable and non-renewable resources
 - Vulnerability of potentially renewable resource to become non-renewable.

Check Your Progress 2

- 1) Your answer must include the following points:
 - Supporting capacity
 - Assimilative capacity
- 2) Your answer must include the following points:
 - Resource management and net yield
 - Maximum and optimum sustainable yield
 - Dealing with resource crisis.
- 3) Your answer must include the following points:
 - Pressure of resource base
 - Geopolitical and global environmental issues
 - Traditional wisdom
- 4) Your answer must include the following points:
 - Life as an integral part of nature
 - Dependence of biological resources on abiotic resource pool

UNIT 2 ENERGY RESOURCES

Structure

- 2.0 Introduction
- 2.1 Objectives
- 2.2 Types of Energy Resources
- 2.3 Non Renewable Energy Resources
 - 2.3.1 Oil
 - 2.3.2 Natural Gas
 - 2.3.3 Coal
 - 2.3.4 Nuclear Energy
- 2.4 Alternative Energy Resources
 - 2.4.1 Solar Energy
 - 2.4.2 Hydropower
 - 2.4.3 Wind Energy
 - 2.4.4 Tidal Energy and Wave Energy
 - 2.4.5 Geothermal Energy
 - 2.4.6 Ocean Thermal Energy
 - 2.4.7 Energy From Biomass (Biofuels)
- 2.5 Energy Storage
 - 2.5.1 Electrical Energy Storage
 - 2.5.2 Heat Energy Storage
- 2.6 Future Alternative Energy Sources
- 2.7 Let Us Sum Up
- 2.8 Key Words
- 2.9 References and Suggested Further Readings
- 2.10 Key to Check Your Progress

2.0 INTRODUCTION

Philosophically, *Saba* (matter) and *Shakti* (energy) coexist and together form *Siva* (the universe). Scientifically, energy has a strong association with the matter as suggested by Einstein's famous equation of matter-energy conversion ($E=mc^2$). As you are aware, energy is very fundamental for any kind of activity. Energy is the ability to do work. Energy comes in different forms such as heat (thermal), light (radiant), motion (kinetic), electrical, chemical, gravitational and nuclear. In a broad sense, there are two types of energy, namely, stored (potential) energy and working (kinetic) energy. Energy sources are divided into two groups, namely, inexhaustible (an energy source that can be easily replenished) and exhaustible (an energy source that is limited by its stock or capacity of regeneration).

About 99% of the energy used to heat Earth, drive all other natural processes of earth comes directly from the sun. Without this energy input, Earth's average temperature would be -240°C . Solar energy also helps in recycling of the carbon, oxygen, water and such other vital chemicals of life. Solar energy includes both the perpetual energy and other renewable forms of energy produced indirectly

by the sun's energy i.e. wind, falling and flowing water (hydropower), wave energy and biomass (solar energy stored in chemical bonds of organic compounds of biomass). The remaining 1% of energy that we generate to supplement the solar input is either '**commercial energy**' sold in market place or '**noncommercial energy**' used in the form of fuel wood, dung, and crop wastes. Most commercial energy comes from extracting and burning mineral resources in Earth's crust, primarily nonrenewable fossil fuels. Developed countries uses commercial energy to a great extent, but developing countries largely depend on the noncommercial energy.

The energy policy of India is largely characterized by trade offs among four major drivers such as:

- Rapidly growing economy, with a need for dependable and reliable supply of electricity, gas, and petroleum products;
- Increasing household incomes, with a need for affordable and adequate supply of electricity, and clean cooking fuels;
- Limited domestic reserves of fossil fuels, and the need to import a vast fraction of the gas, crude oil, and petroleum product requirements, and recently the need to import coal as well; and
- Indoor, urban and regional environmental impacts, necessitating the need for the adoption of cleaner fuels and cleaner technologies.

While choosing an energy source, its ability to do useful work (**energy quality**) is an essential factor. The organized or concentrated energy is known as **high-quality energy**, and can perform a great deal of useful work. Examples of high-quality energy are electricity, fossil fuels, concentrated sunlight, nuclear power, and matter at high temperature. By contrast, **low-quality energy** is disorganized or dispersed and has little ability to do useful work. An example is, heat dispersed in the moving molecules of a large amount of matter (such as the atmosphere or large body of water) so that its temperature is relatively low, although the energy on sum up can result into very high amount of energy. Thus, matching the quality of an energy source with the quality of energy needed to perform a particular task is essential to saves energy.

2.1 OBJECTIVES

After studying this unit, you will be able to:

- list the various types of energy sources;
- state the promise and problem of utilizing various nonrenewable and alternative sources of energy;
- recognize the various ways by which our energy demand could be minimized;
- define the various approaches of energy conservation; and
- discuss various alternative fossil fuel energy solutions for domestic, industrial and commercial establishments in order to mitigate the energy problems in the country.

2.2 TYPES OF ENERGY RESOURCES

As described under the unit natural resources (unit-1 of this block), the energy resources can be similarly divided into inexhaustible and exhaustible on the basis

of availability and exploitation (see figure 2.1). Then, inexhaustible can be divided into perpetual and renewable. Similarly, exhaustible energy sources can be divided into potentially renewable and non-renewable.

Inexhaustible energy sources are unlimited as far as human consumption is concerned whereas **exhaustible energy** sources are prone to depletion depending upon the exploitation. Exhaustible energy source are source, whose rate of replenishment is either very very slow or is dependent on the state of the parental stock. Solar energy is the only **perpetual** source of energy and indirectly is the source of most of the other forms of energy. **Renewable** sources of energy are those which get renewed continuously by inputs mainly from sun in addition to gravitational forces, geothermal and geomagnetic forces. This group of energy includes energy of wind, flowing water, wave, tide, geothermal, ocean-thermal etc. Another group of energy (solar driven energy) those remain renewable as long as their rate of exploitation is below their rate of regeneration are called **potentially renewable energy resources**. On overexploitation (exploitation beyond their regeneration capacity) they become non-renewable. This includes the muscular energy of animal world and chemical energy content of the organic substances (liquids, solids and gaseous) produced by the diverse biological world. Another group of energy resources occurs in limited stocks on Earth's crust which theoretically can be completely used up and thus are called **nonrenewable energy resources**. This includes the mineral fuels such as coal, petroleum, natural gas, nuclear ores etc. Some of the nonrenewable energy resources (like petroleum) are in continuous making but the rate of formation is extremely less than the rate of consumption.

On the basis of limitation of stock and pollution all of the above energy resources can be grouped together into nonrenewable and alternative energy sources. Except nonrenewable resources, all possible resources of energy that are being exploited presently or whose exploitation will be possible in future are included under **alternative sources of energy**. The main emphasis in choosing alternative resources are: minimum pollution, renewability or perpetuity of the stock and least overall environmental impact. Another way of classifying energy resources is to consider them in terms of conventional and non-conventional every resources. Conventional resources of energy include coal, oil and natural gas, thermal power, firewood (fuelwood), hydro-power, nuclear power. Similarly, non-conventional energy sources include urban waste, agriculture waste, energy plantations, animal and human waste, solar energy, wind energy, tidal energy, geothermal energy etc. These are pollution free, environmentally clean and socially relevant.

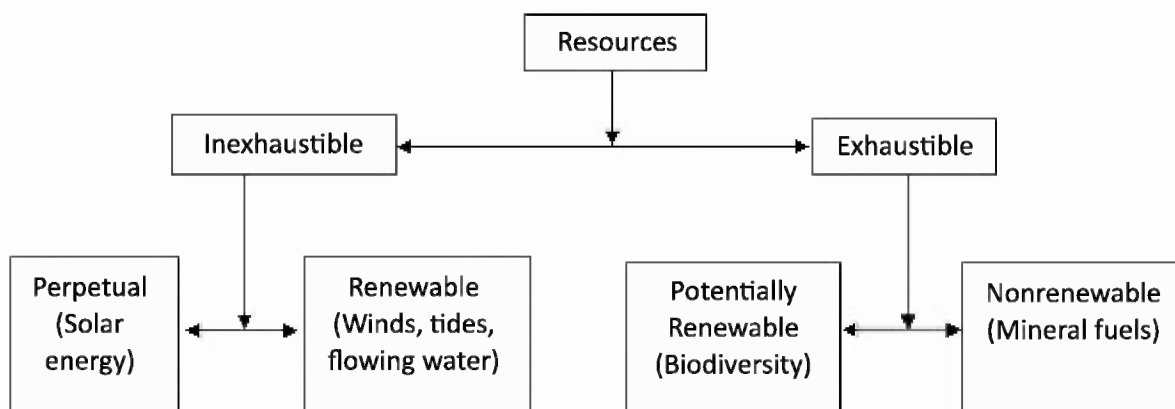


Fig. 2.1: Classification of energy resources

2.3 NON RENEWABLE ENERGY RESOURCES

2.3.1 Oil

Crude petroleum oil is a viscous liquid consisting mostly of hydrocarbon compounds, with small amounts of oxygen, sulfur, and nitrogen compounds. They are formed from biomass in millions of years by biogeo physico-chemical processes. Crude oil and natural gas are often trapped together deep within Earth's crust dispersed in pores and cracks in rock formations.

Primary oil recovery involves pumping out the oil that flows by gravity into the bottom of the drilled well. On reduction of flow some of the remaining **heavy oil** could be forced to flow by injecting water into nearby wells, a process called **secondary oil recovery**. Primary and secondary recovery together could remove only about one-third of the oil. On price rise about 10% of the remaining heavy oil could also be recovered by **enhanced** or **tertiary oil recovery**. The different fractions of petroleum such as gasoline, heating oil, diesel oil, asphalt, residual oil (boiler fuel) and other components are obtained by fractional distillation in the refineries. Some petrochemicals are used as raw materials for industrial chemicals, fertilizers, pesticides, plastics, synthetic fibers, paints, medicines, and many other products. Another source of heavy oil is **Oil shell** which is a fine-grained rock that contains a solid, waxy mixture of hydrocarbon compounds called **kerogen** which on vaporization underground or aboveground (after mining) followed by condensation form a heavy, slow-moving, dark-brown **shale oil**. **Tar Sand**, a mixture of clay, sand, water, and **bitumen** (a gooey, black, high-sulfur heavy oil) is another source. This is usually removed by surface mining and heated with pressurized steam until the bitumen fluid softens and floats to the top. The bitumen is purified and chemically upgraded into a synthetic crude oil suitable for refining. To date, it is not technically or economically feasible to mine underground deposits of tar sand or to extract bitumen under the ground.

Oil can be easily transported within and between countries, and when extracted from easily accessible deposits it has a high net energy yield (energy spent in extraction is taken into account). Including all fossil fuels oil is associated with release of carbon dioxide and other pollutants to the environment. Marine pollution is sometimes associated with it. Shale oil has a low and tar sand has still lower net energy yield compared to conventional oil. Processing of tar sand and shale oil are associated with much higher environmental impacts than conventional oil. There can be leaching of salts, cancer causing substances, and toxic metal compounds from their processing site.

2.3.2 Natural Gas

In its underground gaseous state, **natural gas** is a mixture of methane (50-90% by volume), ethane (~ 6%), propane (~ 4%) and butane (~ 2%). It also contains some impurities such as hydrogen sulfide, carbon monoxide, and carbon dioxide. **Conventional natural gas** lies above most reservoirs of crude oil. **Unconventional natural gas** is found in sources such as coal seams, Devonian shale rock, deep underground deposits of tight sand, and deep zones that contain natural gas dissolved in hot water. It is not yet economically feasible to get natural gas from unconventional sources. Propane and butane gases are liquefied to use as LPG. The rest of the gas (mostly methane) is cleaned of water vapour, hydrogen

sulfide and other impurities to use directly. The purified gas can also be used as liquefied natural gas (LNG) and as compressed natural gas (CNG).

Natural gas is cheaper and cleaner fuel than oil, coal and nuclear fuel in terms of extraction, processing and emission. It can be transported easily, has a high net energy value and high energy content. The economically recoverable conventional deposits will ensure supplies for at least 80 years, at the current rate of consumption, and on addition of nonconventional deposits, supplies may last about 200 years. Processing for LNG (liquefied natural gas) is expensive, dangerous and reduces the net energy yield by one-fourth.

2.3.3 Coal

It is a solid fuel formed in several stages as plant and animal remains are subjected to intense heat and pressure over many millions of years in the Earth's crust. It is a complex mixture of organic compounds, varying amounts of water, and small amounts of nitrogen and sulfur. Three types of increasingly harder coal are there: lignite, bituminous and anthracite. Peat, formed in the first stage, although not a coal has low heat content. Anthracite is the best coal due to its high heat and low sulfur content. Bituminous has the highest sulfur content among the three. Solid coal can also synthesize **synfuels** (synthetic-fuels) by gasification into synthetic natural gas (*Syngas*) or by liquefaction into methanol, synthetic gasoline etc. The net energy yields of these fuels are low due to conversion inputs. **Town gas** similarly is a manufactured gas, originally produced from coal. In the UK, **suction gas** which specifically means a fuel gas made from coke, anthracite or other carbonaceous material are in use. The syngas, town gas, suction gas including wood gas (from gasification of cellulosic biomass) are grouped as **producer gas**. Coal supports 39% of world's electricity generation and 75% of its steel making.

Coal is the most abundant but also the dirtiest fuel among the fossil fuels. Identified world reserves of coal should last at least 220 years and that of unidentified ones for 900 years at current usage rates. Coal mining is dangerous because of accidents, (land disturbance, soil erosion, water pollution and black lung disease. Nearby streams and groundwater can get severely polluted with acids and toxic metal compounds from leachates. Coal produces more air pollution (SO_x , NO_x etc.) per unit of energy than any other fossil fuel. It also releases particles of radioactive materials (e.g. isotopes of uranium and thorium).

2.3.4 Nuclear Energy

Unlike the fossil fuels where the bond energy of chemicals is converted into other forms, here some mass of the radioactive matter is converted into energy ($E=mc^2$). Enormous amount of energy can be produced from a small quantity of radioactive materials. For instance one ton of U^{235} (Uranium-235) provides as much energy as by three million tons of coal or 12 million barrels of oil. This energy in the form of heat is used directly and/or by converting into electricity in nuclear power plants, marine vessels, spacecrafts etc. Inside a nuclear reactor enormous heat is produced (by the controlled reaction of radioactive matter) and is exchanged with water to generate steam for driving the turbine of electric generator. Nuclear fusion for energy generation is also a very good option (energy generation is much higher than fission reaction), but it is only in research stage. The fissile material used are U-235 and Pu-239 which also can be enriched from fertile materials like U-238, U-233 and Thorium.

In evaluating the safety and economy of nuclear power, the entire cycle and not just the nuclear plant should be taken into account. The spent fuel rods are temporarily stored in large concrete lined pools in water at plant site. The widely practiced method for disposal of high level radioactive waste is recovery of long half-life components (e.g. Pu-239) and then deep burial underground. The recovery reduces the storage period to about 10,000 years from 240,000 years (ten times the 24,000 years half-life of Pu-239), and provides a fissile material. Low level radioactive wastes are dumped in ocean in steel drums in addition to underground burial (need not be very deep). The entire fuel cycle including mining, processing, power plant operation, waste reprocessing, storage and disposal of waste etc. contributes about one-sixth the amount of green house gas as coal produces per unit of electricity. Water pollution and land degradation are low to moderate. In case of accidents as in the power plants of Chernobyl, Russia (April, 1986) and Three Mile Island, US (March 1979), hazards of exposure are far reaching than any other pollutants. Weapon grade wastes may be misused for making nuclear weapons.

Check Your Progress 1

Note: a) Use the space given below for your answer.

b) Compare your answers with those given at the end of the unit.

1) Enumerate different types of energy resources.

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2) Write notes on the non-renewable energy resources.

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2.4 ALTERNATIVE ENERGY RESOURCES

2.4.1 Solar Energy

Solar technologies are broadly characterized as either passive or active depending on the way they capture, convert and distribute sunlight. Active solar techniques use photovoltaic panels, pumps, and fans to convert sunlight into useful outputs. Passive solar techniques include selecting materials with favorable thermal properties, designing spaces that naturally circulate air, and referencing the position of a building to the Sun. Active solar technologies increase the supply of energy and are considered supply side technologies, while passive solar

technologies reduce the need for alternate resources and are generally considered demand side technologies.

a) Solar thermal energy for air conditioning of houses and water heating:

Building and water can be heated by solar energy both actively and passively. A **passive solar heating system** captures sunlight directly within the structure and the thermal energy of sunlight heats up the space. The sun facing **energy-efficient windows, green houses and sunspace** perform such action. **Thermal mass** (heat storing capacity), in the form of walls and floors or concrete, adobe, brick, stone, salt treated timber, or used tires are good heat storage structures and they release the heat throughout the day and night. Roof mounted **passive solar water heaters** such as thermo-siphoning Copper Cricket, can supply all or most of the hot water for a typical house. These arrangements save around 30-40% of the energy needs for such requirement in a long run although they may need some 5-10% extra cost for construction. Automation can add higher efficiency in the operations.

In an **active solar heating system**, specially designed collectors absorb solar energy, and supply heat to the required part of a building by a fan or a pump. Collector(s) usually mounted on a portion of the roof ensuring maximum exposure to the sun captures heat of which a part can be used directly, and the rest can be stored in insulated tanks containing rocks, water, or a heat absorbing chemical for release later as needed. **Active solar collector** (solar water heater) can also supply hot water. It consists of an insulated box painted black from inside and having a glass lid to receive and store water heat. The most common types of solar water heaters are evacuated tube collectors and glazed flat plate collectors generally used for domestic hot water, and unglazed plastic collectors used mainly to heat swimming pools. Solar energy for low-temperature heating of buildings is almost cost free, and the net energy yield is moderate (active) to high (passive). The operations of these techniques are pollution free and causes minimal land disturbance. However, owners may need “solar rights” laws to prevent others from building structures that block access to sunlight.

Natural cooling of buildings can also be done by using super insulation and super insulated windows. Passive cooling can also be provided by blocking the high summer sun with deciduous trees, window overhangs, or awnings. Earth tubes can also be used for cooling as at a depth of 3-6 m the soil temperature stays at about 5-13°C in colder regions and about 19°C in warmer regions throughout the year. For a large space, two or three **geothermal cooling fields** could be used. Initial construction costs are high but the running costs are extremely low. **Solar powered air conditioners** have also been developed. **Solar assisted evaporative air conditioners** are suitable in dry climate. Air circulation in the buildings can be promoted by use of **solar chimney** (a passive solar ventilation system). Performance can be improved by using glazing and thermal mass materials.

b) Electricity and High temperature heat from solar energy:

Solar thermal techniques collect and transform radiant energy of sun into thermal energy (heat) at high temperature, which can be used directly or converted to electricity. In **heliostats**, a huge array of computer controlled

mirrors, track the sun and focus sunlight on a central heat collection tower. Another arrangement could be focusing sunlight by curved solar collector to a centrally running oil filled pipe. This concentrated heat energy can be used for industrial processes and for generating electricity. Similarly, a **solar pond** which is a pool of salt water (usually 1–2 m deep) with a density gradient that collects and stores solar energy (90 °C in its bottom layer) can be utilized for electricity generation (~2% efficiency) and other purposes. A **non-imaging optical solar concentrator** is a promising approach which has a capacity to concentrate the incident solar radiation by some 80,000 times. These are used for steam generation (in power plant), for hydrogen gas generation, to desalinate water, in liquefaction, gasification or other type of processing of dirty fuels (coal, oil etc.), or in treatment of hazardous wastes. Similarly, solar furnace can produce as high a temperature as 3000°C by arranging thousands of plane mirrors into a concave reflector. The solar thermal power is very cheap and causes very low level of air and water pollution. The land requirement is high (same as nuclear power) but comparatively much lower than thermal and hydropower.

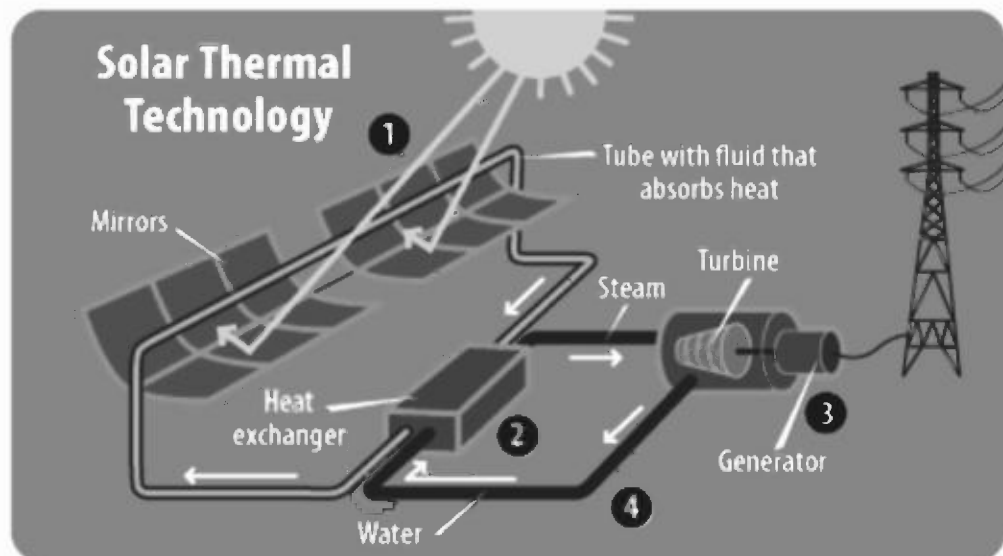


Fig 2.1: Solar Thermal Technology

Solar cookers use sunlight for cooking, drying and pasteurization. They can be grouped into three broad categories: box cookers, panel cookers and reflector cookers. A basic box cooker (90–150°C) consists of an insulated container with a transparent lid. It can be used effectively with partially overcast skies. Panel cookers use a reflective panel to direct sunlight onto an insulated container and reach temperatures comparable to box cookers. Reflector cookers use various concentrating geometries (dish, trough, fresnel mirrors) to produce a temperature of around 315°C and above. **The solar bowl** is a concentrating technology employed by the Solar Kitchen in Auroville, Pondicherry, India, where a stationary spherical reflector focuses light along a line perpendicular to the sphere's interior surface, and a computer control system moves the receiver to intersect this line to produce steam (150C) for using in kitchen. Similarly, **Scheffler reflectors** (developed by Wolfgang Scheffler in 1986) use polar tracking to follow the Sun's daily course and the curvature of the reflector is adjusted for seasonal variations in the incident angle of sunlight. These reflectors can reach temperature of 450–650°C and have a fixed focal point, which simplifies cooking. The

world's largest Scheffler reflector system in Abu Road, Rajasthan, India is capable of cooking up to 35,000 meals/day.

c) **Solar cell electricity**

Sunlight can be converted into electricity using photovoltaic cell (PV cell), concentrating solar power (CSP), and various experimental technologies. **Solar cells** are made of thin wafers of semi-conductor materials like silicon and gallium (gallium arsenide, boron or cadmium sulphide provides high efficiency). A potential difference of 0.4-0.5 volts with some milli amperes of current can be produced by a single PV cell of 4 cm² size. Different number of solar cells can be grouped together in a definite pattern to form solar panels of different size delivering the desired amount of electricity. The solar cells are widely used in calculators, electronic watches, street lighting, traffic signals, water pumps etc. They are also used in artificial satellites.

Solar cells can have a life of around 30 years, if properly protected and maintained. Its major component, silicon is the second most abundant element in Earth's crust. Installation is quick, easily expandable and movable. It can work even in diffused light and does not need special space for installation. It involves no moving parts. It requires occasional washing. Air and water pollution during operation and manufacturing are very low and land disturbance is also very low. The net energy yield is fairly high and is increasing with new design. In laboratory condition an energy conversion efficiency of 31% has been recorded.

d) **Water distillation and disinfection with solar energy**

Solar distillation can be used to make saline or brackish water potable. Individual still designs include single slope, double slope (or greenhouse type), vertical, conical, inverted absorber, multi wick, and multiple effect systems. These stills can operate in passive, active, or hybrid modes. Double slope stills are the most economical for decentralized domestic purposes; while active multiple effect units are more suitable for large-scale applications. **Solar water disinfection (SODIS)** involves exposing water filled plastic polyethylene terephthalate (PET) bottles to sunlight for several hours (minimum of six hours to two days). Solar energy may also be used in a waste stabilization pond to treat waste water without supplying any chemicals or electricity. Algae grow in such ponds consume carbon dioxide and the produced biomass could be used for biofuel production or other purposes.

2.4.2 **Hydropower**

The high potential energy of water behind a dam can be converted to kinetic energy for driving turbines and generating electricity called **hydropower**. In a large scale, high dam across **large rivers** creates vast reservoirs for electricity generation along with other purposes (irrigation, flood control, etc.). Similarly, a low dam with very small or no reservoir across a **small stream** can generate in a smaller scale (microhydel projects, MHD), but the production fluctuates with changing water flow. Alexander Gorlov's technique can be used to harness electricity even from **slow moving rivers** without damming it. Hydropower supplies about 20% of the world's electricity and 6% of its commercial energy need.

Hydropower has a moderate to high net energy yield and fairly low operating and maintenance cost. They generate electricity continuously and have a life span of more than 2-10 times those of coal or nuclear plants. Large dams also help in flood control, irrigation and water supply. However, hydropower especially huge dams and reservoirs destroys wild life habitats, submerges vast area of wilderness and human settlements of upstream regions, uproots people, and decreases fertility of agricultural lands and fish harvest of downstream areas. It also greatly disturbs the river ecology (migration of salmon kind of fish, activity of other life forms, productivity of the deltas etc.). Even small hydroelectric projects can threaten aquatic lives, disrupt the flow of wild and scenic rivers and disturbs recreational activities, and destroy wetlands.

2.4.3 Wind Energy

The horizontal movement of air is known as wind. Winds are caused because of two factors: (1) The absorption of solar energy on the earth's surface and in the atmosphere, and (2) The rotation of the earth about its axis and its motion around the sun. These factors create pressure difference due to alternate heating and cooling cycles and cause the air to move. The rotational motion of the blades of wind mills drives a number of machines like water pumps, flour mills and electric generators. A large number of wind mills installed in clusters in a particular area are called wind farms, which feed power to the utility grid. These farms are ideally located in coastal regions, open grasslands or hilly regions, particularly mountain passes and ridges where the winds are strong and steady. The wind power potential of our country is estimated to be about 20000MW, while at present we are generating about 1020 MW. The large wind farm of our country near Kanyakumari in Tamil Nadu is generating 400MW electricity. Wind energy, is plentiful, renewable, widely distributed, cheap and clean. However, the visual impacts, noise and other such environmental concerns along with the wind speed limit (minimum 15 Km/hr) are some of the drawbacks of wind energy.

2.4.4 Tidal Energy and Wave Energy

Tide is periodic rise and fall of the water level of the sea caused by gravitational forces of sun and moon. These tides can be used to produce electricity known as **tidal power**. When the water is above the mean sea level, it is called flood (high) tide and when the level is below the mean level, it is called ebb (low) tide. A height difference of several meters is required between high and low tide to rotate the turbines. An alternator facilitates rotation of turbine to generate electricity during both entry (high tide) as well as exit (ebb tide) of water of the tidal reservoir. There are only a few sites in the world where tidal energy can be suitably harnessed. The bay of Fundy Canada having 17-18m high tides has a potential of 5000 MW of power generation. In India Gulf of Cambay, Gulf of Kutch and Sunder bans deltas are the potential tidal power sites.

The maintenance costs associated with running a tidal station are relatively inexpensive. The predictable timing of tide in and out makes tidal energy easy to maintain. Maximum energy production is limited to 2.5 terawatts. However, initial costs of installation are very high and it provides power only for around 10 hours a day. The barrage construction can affect some miles upstream and downstream, feeding of birds, some associated ecosystems and the transportation system in water.

The kinetic energy in **ocean waves**, created by wind can also be converted into electrical energy but the suitable sites (e.g. western England) are very less in number or yet to be discovered. Construction costs are moderate to high, and the net energy yield is moderate, but threat to the instruments from salt water corrosion and severe storm is always there.

2.4.5 Geothermal Energy

Geothermal energy can be harnessed for electricity generation by injecting water into one deep well and extracting it from another nearby well, as hot water and steam to drive the electric generating system after cleaning. The mineral containing water is again given back to the injection well. When the water temperature is below the boiling point of water a binary system is used. A low boiling liquid is used to drive a turbine and generator in a closed system. *Dry-steam* (no water droplets) reservoirs are the preferred reservoirs but are rare. *Wet-steam* (steam with water droplets) reservoirs are more common but have low net energy yield. *Hot-water* reservoirs are still more common and its energy can be utilized for systems where low temperature heat is required such as green houses, space heating etc. Other three virtually undepletable sources of geothermal energy are: (1) molten rock (magma found in Earth's surface), (2) hot dry rock zones, and (3) low to moderate-temperature warm rock reservoir.

Geothermal energy is base load power, economically feasible in high grade areas, and has low deployment costs. They run continuously day and night with an uptime typically exceeding 95%. Geothermal power requires locations having suitable subterranean temperatures within 5 km of surface. The reservoirs may get depleted, if not properly managed. Without pollution control, it can cause moderate to high local air, water, noise and odor pollution, and induce local climate changes. Geothermal energy is costly. Some geothermal stations have created geological instability, even causing earthquakes strong enough to damage buildings.

2.4.6 Ocean Thermal Energy

Ocean thermal energy is a marine renewable energy. Ocean thermal energy conversion (OTEC) uses the temperature difference that exists between deep and shallow waters in the same location to run a heat engine. A temperature difference of 20°C or more is required. This temperature difference generally increases with decreasing latitude, i.e. near the equator, in the tropics. The greatest efficiency and power is produced with the largest temperature difference. The warm surface water of ocean is used to boil a liquid like ammonia to produce enough vapour pressure to run the turbine of electric generator. The vapour is condensed to liquid by using cool deep ocean water. Thus the process keeps on going continuously for 24 hours a day. Changes in efficiency of heat exchange in modern designs allow performance approaching the theoretical maximum efficiency.

2.4.7 Energy From Biomass (Biofuels)

The potentially renewable energy, biomass (in solid, semi solid and liquid form) of the diverse biological world can be a continuous source of fuel called **biofuels** if sustainably harvested. Biofuels are a wide range of fuels covering solid, liquid and gases. Biofuels such as biodiesel from land based oils, bio alcohol from

sugar or starch, biogas, producer gas etc. constitute **first generation biofuels** whereas, bio hydrogen, bio oil, green diesel, biodiesel from water based oil like algal oil, bio alcohol from lingo cellulosic materials etc. constitute the **second generation biofuels**. Biomass also includes plant or animal matter used for production of fibers or chemicals. Higher dependence for fuel as well as non-fuel materials from biomass (and waste biomass) saves the non-renewable resources. It excludes organic materials such as fossil fuels which have been transformed by geological processes into substances such as coal or petroleum.

Direct burning of wood, agricultural waste, yard clippings, dung, saw dust, wood chips, garbage and other dry biomass are the major source of energy for household purposes, boilers, small-scale agro-industries and other industries. However, it has limitations of pollution and low energy efficiency. The efficiency of direct burning can be increased by briquetting, pulverization etc. of the biomass and by using improved *chullahs* (15-25% efficiency against 2-10% efficiency of conventional *chullah*). The biomass can be used for production of high calorific gaseous fuels like **wood gas** (in gasifier) which is relatively less polluting. The biomass can also be converted to **bio oil** by *fast* or *flash pyrolysis*. This is a kind of **biomass refining** where several value added chemicals are produced in addition to a consistent quality bio oil. The bio oils currently produced are suitable for use in boilers or in turbines designed to burn heavy oils for electricity generation. Bio oil production and upgradation technology need further research inputs. Although the net energy yield as of now is low, bio oils and its variants are potential source of petro chemicals in absence of crude petroleum. The residues are also resources.

Both the solid and liquid wastes from agriculture, animal husbandry, agro-industries, household activities, municipal sources and other sources can also be processed for a gaseous fuel called **bio gas**. It is a mixture of methane (55-65%), carbon dioxide (20-40%), hydrogen (0-1%) and hydrogen sulfide (0-3%) produced by anaerobic (i.e. in absence of air) digestion of easy bio degradable plant and animal wastes in the presence of water. Woody materials are not suitable for this purpose. The spent slurry is a better source of plant nutrients than conventional compost or farm yard manure (FYM).

The small chain carbohydrate (sugar, starch, etc.) content of biomass can be directly fermented using microorganisms and enzyme to produce alcohol called **bio-alcohol** (methanol, ethanol, propanol and butanol). By the assistance of super-critical fluid technology the lingo cellulosic material can also be converted into easily digestible carbohydrate for fermentation. Ethanol is the most common biofuel worldwide, particularly in Brazil. Biobutanol (also called biogasoline) is often claimed to provide a direct replacement for gasoline. A mixture of gasoline and alcohol called **gasohol** is a good substitute for lead antiknock agent, the major source of lead pollution.

Similarly, the lipid content of biomass can be transesterified with small chain alcohols to alkyl (methyl, ethyl or propyl) esters called bio diesel. It uses edible and non edible vegetable oil (from plants), food processing waste oil, or animal fat (tallow). Biodiesel can be used in standard diesel engines, alone or blended with petrodiesel. However, biodiesel is unable to satisfy many fuel standards in many cases which limit its application. Low storage stability, and high viscosity (increases with decreasing temperature) greatly affects its utility. Yet another

kind of diesel known as **green diesel** or renewable diesel with properties almost similar to petro diesel can be produced by hydro refining of all kinds of edible and non edible oils and fats, waste oils, tallow etc. This diesel overcomes all the drawbacks of biodiesel, but its production is costly.

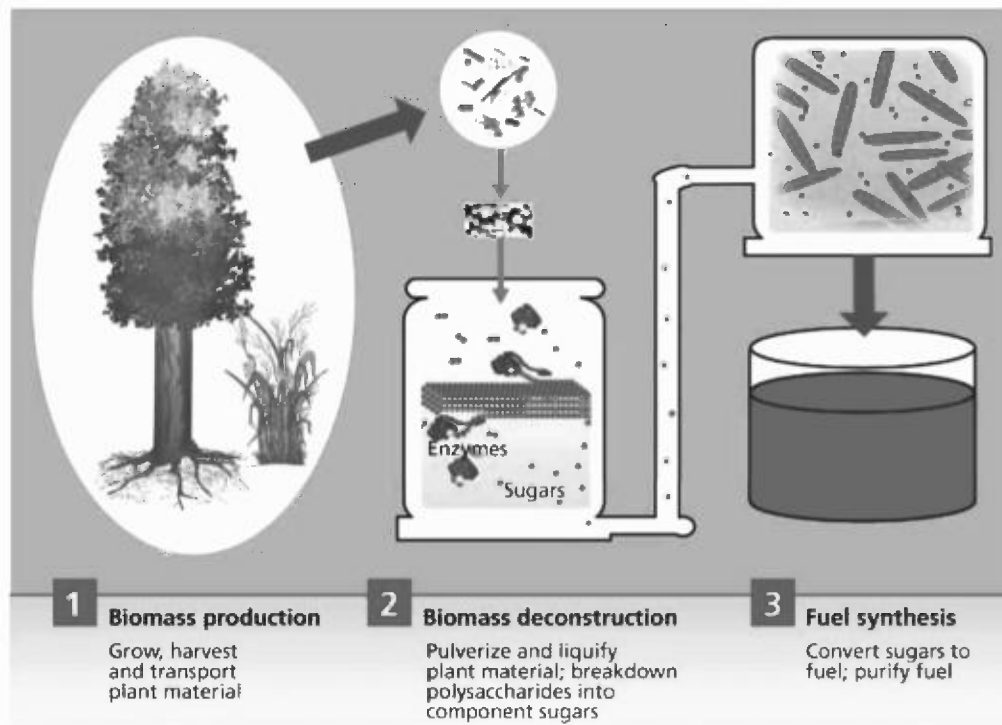


Fig. 2.2: Stages of converting biomass to biofuel, images adapted from DOE Genome Programmes (<http://genomics.energy.gov>)

Bio hydrogen produced via bacterial or algal fermentation of waste organic matter is another potential biofuel. Algal route is in initial research phase. In bacterial fermentation organic acids (acetic acid, butyric acid and propionic acid) are necessary. This does not require glucose as a substrate. The organic acids can be derived from any organic material source such as sewage waste waters or agricultural wastes. Continuous fermentation process is required for high rate of hydrogen production. The fermentation can be a *dark fermentation* (no light), *photo fermentation* (requires light) or a *combined fermentation*.

More than 385 species of plant species which can be used as source of liquid hydrocarbons have been screened. These *petroplants* plants mainly belong to Euphorbiaceae, Asclepiadaceae, Apocynaceae, Urticaceae, Convolvulaceae and Sapotaceae. The products obtained from their latex processed biocrude are gases, naphtha, kerosene, gas oil, heaviers and coke (via hydrocracking). Denuded wastelands can be used for plantation of fast growing shrubs and trees with high calorific value for **dendrothermal energy** (wood based thermal power plant) purpose which requires solid biomass. The petro plantation and dendrothermal plantation including that of corn for bio-alcohol production are called **energy plantation**.

Biomass is abundant on Earth and is renewable. The surplus and waste biomass natural and human engineered systems can be good source of energy and plant nutrient. Alcohols and other bio fuels are clean burning and are feasible replacements to fossil fuels. Biomass is carbon neutral on life cycle analysis because the carbon released in combustion is fixed in primary (plant) and

secondary (animals) production. However, direct combustion of any carbon-based fuel leads to air pollution similar to that from fossil fuels. Intensive energy crop cultivation for bio alcohol, biodiesel or bio oil production uses mineral matter (fertilizer) and energy (for processing of farm requirements, and biomass and fuel processing). It can compete for land and water resources and may lead to destruction of ecosystems by its expanded land requirement.

Check Your Progress 2

Note: a) Use the space given below for your answer.

b) Compare your answers with those given at the end of the unit.

1) Write notes on solar thermal and solar photo-voltaic energy utilization.

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2) Define wind and write a note on harnessing of wind energy.

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3) Write notes on hydro power.

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4) Write notes on tidal energy.

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5) What are the threats associated with harnessing geothermal energy?

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6) Elaborate OTEC. What are constrains related to OTEC?

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7) Define biofuels. Describe in brief on various types of biofuels.

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2.5 ENERGY STORAGE

A major obstacle to the widespread use of many alternative energy sources is the problem of unevenness in time, space, frequency, intensity, and/or magnitude of availability. This problem can be solved to a great extent by using efficient energy storage systems. One of the reasons that the fossil fuels in general, and oil in particular, came to dominate the world energy mix is because of their high energy content, and ease of storage and transportation. Hydrogen gas offers some of the advantages but being bulky and light weight, it is much more difficult to store. Electricity is one of the most versatile energy sources, but it is difficult to store in large quantities and most of it is used immediately after production.

2.5.1 Electrical Energy Storage

Surplus/intermittent electricity from all types of nonrenewable and alternative sources in a mass scale can be stored in a **Pumped hydroelectric storage (PHS)** system which pumps water to a reservoir at high elevation (when demand is low as in night) to use it for electricity generation (when the demand is high). However, the net energy yields are negative and the reported efficiencies are in the 70 to 75% range. It is again associated with capacity limitation and other environmental aspects as in case of big dams. **Compressed air energy storage (CASE)** system is an underground PHS which stores air instead of water, and can be used later on for generating electricity using a modified gas turbine as per the requirement.

Examples of such systems are underground caverns (especially in salt domes), abandoned mines, abandoned natural gas wells, and particularly empty aquifers. The net energy yield is moderate to high. However, the system is neither completely pollution free nor self contained.

The most commonly used form of electrical energy storage is **electrochemical energy conversion** (developed by Alessandro Volta around 1800 AD) system of the **batteries**. Today the most common batteries are of the lead acid variety, utilizing lead plates and dilute sulfuric acid. Various types of miniature batteries and dry cells in common use are nickel-cadmium (Ni-Cd) batteries, Lithium metal hydride batteries etc. Energy density (energy storage per unit weight) and number of charge discharge cycles (normally 500 to 2000) is a deciding factor in using batteries. Newer classes of batteries are under development which uses zinc-chlorine, zinc-bromine, or hydrogen-nickel oxide. These batteries are lighter and long lasting. Another promising line of research involves **high temperature batteries** (300°C) which will be mostly suitable for stationary purposes. Other classes of batteries are the **fuel cells**. The pollution caused by a battery operated automobile charged from any nonrenewable energy source is lesser in comparison to any standard fossil fuel operated engine and is almost none when the charging is done from an alternative energy source. Another device that can be used for energy storage is a simple flywheel (perhaps initially put into motion by an electric motor). The **flywheel**, spinning in mounted case, in a vacuum at a rate of up to 200,000 rpm, stores kinetic energy that can be used as per need. Another technique of energy storage, currently in formative stage is **superconducting magnetic energy storage (SMES)** systems. Extra current is allowed to circulate around a closed superconducting loop of nearly zero resistance and can be used later on. But besides being expensive, it requires very large area of land, and associated with other potential environmental and health problems (mainly electromagnetic).

2.5.2 Heat Energy Storage

The passive heating systems (already discussed) are the major heat storage techniques. When the heat is stored in a material by increasing its temperature without any change in its state it is called **sensible heat storage**. The materials are rock, clay, water, oil, salt water etc. On the other hand, when the energy is stored as latent heat of liquid or gas due to change in phase of the material, it is called as **latent heat storage (LHS)**. The material regains its original state on release of the excess heat. Conversion of wax or ice to liquid and back to solid, conversion of water to steam and back to water etc. are examples of LHS. **Thermochemical heat storage** uses reversible chemical reactions to store heat energy. For instance, methane (CH_4) and steam (H_2O) forms syngas ($\text{CO} + \text{H}_2$). This syngas in presence of catalyst again forms water vapor and methane by releasing the heat. Other pairs of reactants/products include ammonia/nitrogen and hydrogen, and calcium oxide and water/calcium hydroxide.

2.6 FUTURE ALTERNATIVES ENERGY SOURCES

Solar hydrogen revolution, which proposes hydrolysis of water using solar energy to produce hydrogen gas, is one of the future alternatives. In extreme case, with a moderate life cycle environmental impact, hydrogen can be produced using electricity from hydropower, solar thermal, solar cell, biomass power plants, and wind farms. In the initial phase *hythane* (mixture of methane and around

15% hydrogen) can also be used. **Fuel cell** is another innovation with energy conversion efficiency as high as 65% which can minimize the environmental impacts even the consumption of the clean fuels. It is an electrochemical cell that generates electricity through reactions between a fuel and an oxidant, triggered in the presence of an electrolyte (remain unspent). Another variant is a **Microbial fuel cell (MFC)** which uses microbial metabolism in generating electricity. Fuel cells can operate continuously as long as the necessary reactant and oxidant flows are maintained. Unlike conventional electrochemical cell batteries (thermodynamically closed system), fuel cells are thermodynamically open system, as they consume reactant from an external source, which must be replenished. A hydrogen fuel cell uses hydrogen as its fuel and oxygen (usually from air) as its oxidant. Other fuels include hydrocarbons (methane etc.) and alcohols with chlorine and chlorine dioxide as oxidants. The concept has been proven in numerous small scale applications.

There is a vast reserve of methane clathrates in the ocean bed as a source of methane and it is in continuous formation. **Methane clathrate**, also known as **methane hydrate, hydromethane, methane ice** or **fire ice** is a solid where a large amount of methane remains trapped within a crystal structure of water similar to ice. One litre of methane clathrate solid can release 168 litres of methane gas (at STP) on average. However, the technology for economic recovery of this enormous and endless supply of energy is in developing stage. Magnesium energy cycle is also a new area of energy research. Bio alcohol from lignocellulosic material using super critical technology and biooil from biomass need more research inputs. Nuclear fusion of smaller radio nuclei (H) to form an element of bigger nuclei (He) which produces energy even higher than nuclear fission is another possibility. These sources of energies will remain relatively pollution free.

Check Your Progress 3

Note: a) Use the space given below for your answer.

b) Compare your answers with those given at the end of the unit.

1) Mention various types of energy storage systems.

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2) Write a note on future alternative sources of energy generation.

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2.7 LET US SUM UP

- The major demand for energy is in the domestic, commercial, Industry, and agriculture sectors.
- Exhaustible energy source are source whose rate of replenishment is either very very slow or is dependent on the state of the parental stock. Solar energy is the only perpetual source of energy and indirectly is the source of most of the other forms of energy.
- Renewable sources of energy are those which get renewed continuously by inputs mainly from sun in addition to gravitational forces, geothermal and geo magnetic forces. This group of energy includes energy of wind, flowing water, wave, tide, geothermal, ocean-thermal etc.
- Another group of energy (solar driven energy) those remain renewable as long as their rate of exploitation, is below their rate of regeneration are called potentially renewable energy resources.
- Renewable energy obtained from solar heat, wind, biomass, hydro or any other resource has tremendous potential of contributing to meet the energy demand for these sectors to a significant extent.
- India has significant potential for generation of power from renewable energy sources such as wind, microhydro, biomass, sea and solar energy.
- Meanwhile, the Ministry of New & Renewable Energy (MNRE) is taking many initiatives to promote use of renewable energy in our country.

2.8 KEY WORDS

Energy quality	: It is the measure of ability to do useful work.
Solar chimney	: It is a passive solar ventilation system composed of a vertical shaft connecting the interior and exterior part of a building.
Heliostats	: A huge arrays of computer controlled mirrors which track the sun and focuses sunlight on a central heat-collection tower.
Wind farms	: A large number of wind mills installed in clusters in a particular area are called wind farms
Biofuels	: It covers solid, liquid and gaseous fuels of biological origin.
Green diesel	: It is produced through fractional distillation of all kinds of edible and non edible oils and fats, waste oils, tallow etc. Its properties are similar to petro-diesel.
Fuel cell	: It is an electrochemical cell that generates electricity through reactions between a fuel and oxidant in presence of an electrolyte.
Fire ice	: It is a clathrate hydrate in which large amount of methane remain trapped in the crystal structure of water similar to ice.

2.9 REFERENCES AND SUGGESTED FURTHER READINGS

- Miller, G Tyler, Jr. 1996. Worldviews, Ethics, and Sustainability. In Belmont, CA(Edt). Living in the Environment. Wadsworth Publishing Company.
- McKinney, M.L. and Schoch, R.M. 1998. Environmental Science: Systems and Solutions. Jones and Bartlett Publishers, Boston. 639 pp.

2.10 KEY TO CHECK YOUR PROGRESS

Check Your Progress 1

- 1) Your answer must include the following points:
 - Renewable
 - Inexhaustible and exhaustible
- 2) Your answer must include the following points:
 - Oil
 - Natural gas
 - Coal
 - Nuclear power

Check Your Progress 2

- 1) Your answer must include the following points:
 - Solar thermal energy concentration techniques
 - Solar cooker
 - PV cells
 - Advantages and disadvantages
- 2) Your answer must include the following points:
 - Wind farms
 - Advantages and disadvantages with respect to cost, availability, potential, pollution etc. to that of fossil fuels
- 3) Your answer must include the following points:
 - Pollution aspects
 - Operational and maintenance cost
 - Flood control, irrigation and water supply
 - Submergence of land, displacement of habitats and disturbance to river ecology
- 4) Your answer must include the following points:
 - Construction of barrage
- 5) Your answer must include the following points:
 - Injection of water into deep well
 - Ecosystem, seismicity and Pollution view point

- 6) Your answer must include the following points:
- Working principle
 - Efficiency
- 7) Your answer must include the following points:
- First and second generation
 - Various kinds of bio-fuels

Check Your Progress 3

- 1) Your answer must include the following points:
- Electrical energy storage
 - Heat energy storage
- 2) Your answer must include the following points:
- Hydrogen gas generation
 - Fuel cell
 - Methane clathrate
 - Nuclear fusion

UNIT 3 MINERAL RESOURCES

Structure

- 3.0 Introduction
- 3.1 Objectives
- 3.2 Increasing Mineral Demand and Scarcity of Minerals
- 3.3 Mineral Deposits, Ores and Reserves
- 3.4 Types and Grouping of Mineral Resources
- 3.5 Mining: Introduction and Types
- 3.6 Mining Phases and Operations
- 3.7 Types of Waste Generated by the Different Mining Steps
- 3.8 Mining-Waste Management Methods
- 3.9 Impact of Mining on Environment
- 3.10 Mine Restoration
- 3.11 Let Us Sum Up
- 3.12 Key Words
- 3.13 References and Suggested Further Readings
- 3.14 Key to Check Your Progress

3.0 INTRODUCTION

Our life is accompanied by mineral resources at every step. Use of minerals by human beings has been so extensive since the very beginning of human civilization, that some major periods of pre history and history are named after minerals: the Stone Age, Bronze Age, and Iron Age. We currently live in the Iron Age, although some suggest that we have already entered the age of silicon, an important metal in the production of semiconductors, the mainstay of our current electronics. Mineral resources refer to material substances either composed of or extracted from minerals. They include ores, metals, gravel, sand, marble, granite, phosphate rock, and so on. These are usually inorganic compounds; although some deposits may be concentrated or accumulated by life-forms e.g. limestone (composed of the calcium carbonate shells of sea creatures). Minerals find a large number of ways in everyday use in domestic, agricultural, industrial and commercial sectors. Minerals have become essential in: (i) development of industrial plants and machinery (ii) generation of energy e.g. coal, lignite, uranium (iii) construction, housing, settlements etc. (iv) defense equipments e.g. weapons, armaments (v) transportation (vi) communication – telephone wires, cables, electronic devices (vii) medicinal system particularly in Ayurvedic system (viii) formation of alloys for various purpose (e.g. phosphorite) (ix) agriculture i.e. fertilizers, seed dressings and fungicides (e.g. zineb containing zinc, Maneb containing manganese, etc.) (x) jewellery e.g. gold, silver, platinum, diamond.

Mineral wealth as a natural asset can stimulate or enhance economic growth potential and social progress. The reserves of metals and the technical know-how to extract them have been the key elements in determining the economy and political power of nations. The world is facing serious and long term challenges

in the provision of mineral and energy resources. Although, no global shortages of non fuel mineral resources are expected in the near future (According to United States Geological Survey's Global Mineral Resource Assessment Project) a growing number and variety of obstacles have begun to restrict the availability of these resources. These complex issues comprise economic, technical, social, and environmental challenges.

3.1 OBJECTIVES

After reading this unit, you will be able to:

- discuss the pattern and causes of mineral demand;
- define the ecological, environmental and social impacts of mining;
- underline the importance of adopting a multipronged approach for mine restoration; and
- select the mineral resources in accordance with our strict sustainable development standards.

3.2 INCREASING MINERAL DEMAND AND SCARCITY OF MINERALS

Before the nineteenth century, global use of minerals was relatively insignificant compared to the abundance of mineral in geological deposits. Since the Industrial Revolution the associated demographic (demographic plus technological) developments, however, has highly enhanced the rate of mineral resource use. This is evident from the fact that although the world's population doubled, the mineral use has increased by a factor of 10 during 1750 and 1900. The mineral use at present is more than 13 times the amount used during 1900.

The demand for minerals is still extremely high, and will increase further with industrialization in developing countries, replacement of ageing infrastructures and introduction of new technologies. The life expectancy of a stock (how long a stock will last) is not linearly related to the increase in the stock i.e. a 10 to 100 fold increase in the stock does not mean that the stocks will last proportionately. In theoretical situation, assuming that future exploitation will continue at present rate and demand remains the same, the life expectancy of a stock can be linearly related to the increase in magnitude of the stock. In such situation the stock (reserve) is called as a **static reserve**. The demands generally increase exponentially due to increase in population and per capita consumption and the life expectancy of a reserve decreases exponentially. In such situation the reserve is called as **exponential reserve**. Exponential reserves are more realistic as they better reflect the real world pattern of demand. The demand for metals such as tin, zinc, copper and aluminum grows at about 1 to 4% per year. If we assume that demand increase by 3.5% per year, then annual demand will double approximately in every 20 years. A stock having a static reserve of 500 years may last only 83 years when the exponential rate of exploitation is taken into account. If the hypothetical 500 year static reserve is increased to 5000 years, the exponential reserve will increase from 83 years to only 147 years.

The bottom line is that on a global scale, the demand for mineral resources now are so great that even with a conservative or liberal estimate of remaining mineral

stocks, the known supplies of a number of minerals will be exhausted within a few decades. The effects of environmental degradation and associated pollution of mining activities may force us to curtail the exploitation of mineral deposits before they are exhausted. In other words, we need to emphasize the “three R’s” – reduce, reuse, and recycle as well as find substitutes for minerals in short supply (detailed in unit 4).

3.3 MINERAL DEPOSITS, ORES AND RESERVES

A **mineral** is a naturally occurring solid chemical substance that is formed through geological processes and that has a characteristic chemical composition, a highly ordered atomic structure, and specific physical properties. Minerals range in composition from pure elements and simple salts to very complex silicates with thousands of other forms. The study of minerals is called mineralogy. Mineral deposits are formed by natural geological processes. During the rock cycle, weathering may dissolve or physically remove certain elements and minerals, leaving behind a concentrated residue of the remaining minerals. Sedimentary processes can concentrate minerals through precipitation from a solution or by differential settling of grains in moving or still water. Certain minerals may selectively crystallize out of a hot, molten body of igneous rocks. During the formation of metamorphic rocks, elements may be mobilized in the rock, resulting in mineral changes and sometimes giving rise to economically useful mineral concentrations. The high temperatures associated with igneous and many metamorphic processes often result in **hydrothermal processes** (i.e. hot water dissolves, transports and subsequently reprecipitates and concentrates elements and minerals in deposits).

The abundance and distribution of minerals are very uneven. On a global scale a few elements (namely oxygen, silicon, aluminum, iron, calcium, sodium, magnesium, and potassium) are extremely abundant, making up over 99% of the Earth’s crust by weight. Some other elements like copper, tin etc. are very rare. Again, all mineral deposits are not usable and the supplies are practically exhaustible for both abundant and rare minerals. A mineral deposit becomes an **ore deposit** at certain point of time when the mining and processing of the mineral becomes techno economically feasible i.e. a mineral deposit of today may become an ore deposit on some day. Identified but unexploited ore deposits are called as **reserves**. Reserve estimates for a particular mineral will increase as new ore deposits come to existence, as the mining and processing technologies become more efficient and improved, or as price rises allows mining and processing of lower-grade deposits. Reserve estimates will decrease, as known deposits of a particular mineral are exhausted or if market prices fall, to discourage the mining of lower grade deposits.

At current consumption rates, the iron and aluminum in the Earth’s crust could last a million years and a hundred million years, respectively (without recycling). It seems virtually inexhaustible. But at the present rates of consumption, the proven ore deposits of iron and aluminum will last only for a few hundred to a couple of thousand years. Many substances are very rare. For instance, copper has an average concentration of only 55 to 63 parts per million (ppm) of the Earth’s crust, and tin only 2 ppm. There is an upper limit to the quantity of minerals that can be produced, even if energy supply is made unlimited. However, practically, our energy resources are limited. Taking world production,

consumption, and reserves into account, it has been estimated that our *virgin supplies of ores* for copper, tin, lead, zinc, and various other metals will be exhausted within a century.

3.4 TYPES AND GROUPING OF MINERAL RESOURCES

Mineral deposits are diverse in nature and composition, reflecting their origins. Minerals can be divided into different categories such as metallic, non metallic, precious and energy minerals. Metallic minerals include iron, aluminum, copper, zinc, lead, gold, tin, chromium and so on. ***Metallic minerals*** can be ferrous (iron and related metals such as chromium, manganese, nickel, and molybdenum, which are commonly alloyed with iron) or nonferrous (gold, copper, silver, etc.). ***Nonmetallic minerals***, can similarly be divided into *structural materials*, such as building stone, sand, gravel, and other components of cement and concrete, and *industrial materials*, such as fertilizer components (phosphorus and potassium), salts, sulfur, other nonmetals used in manufacturing, asbestos, abrasive minerals (such as emery, or corundum, and industrial diamonds), and so on. The third category is ***precious minerals*** such as gemstones and semiprecious minerals that serve no pragmatic function and are purely of ornamental and aesthetic value. Finally, uranium and fossil fuels (coal, oil and natural gas) are sometimes regarded as a fourth category called ***energy minerals***.

Due to the unequal distribution of mineral deposits around the world and the depletion of once existing deposits, many countries have small or non existent reserves of certain important minerals. Certain minerals which are necessary for the production of essential goods are classified as **critical minerals**. A **strategic mineral** is a critical mineral, that a particular country or countries must import from areas that are potentially unstable politically, militarily, or socially. Problems in these areas could disrupt the supplies of such minerals. Critical minerals may or may not always have substitutes and sometimes the substitutes are rarer than the critical minerals themselves.

In order to have a better understanding of the mineral deposits for effective exploration, they are subdivided into different categories. The classification can be done based on a number of criteria, such as minerals or metals contained, the shape or size of the deposit, host rocks (the rocks which enclose or contain the deposit) or the genesis of the deposit (the geological processes which combined to form the deposit). Based on the major anion group present, a list of minerals is given below and is in approximate order of their abundance in the Earth's crust. The list follows the Dana classification system.

- a) **Silicate class:** The largest group of minerals by far is the silicates. These are composed largely of silicon and oxygen, with some parts of aluminum, magnesium, iron, and calcium. Most rocks are =95% silicates. Examples of some important silicate rocks are feldspars, quartz, olivines, pyroxenes, amphiboles, garnets, and micas.
- b) **Carbonate class:** The major anion here is carbonate (CO_3)²⁻. This includes minerals of calcium carbonate (calcite and aragonite), magnesium/calcium carbonate (dolomite) and iron-carbonate (siderite). Carbonates are commonly found in marine settings when the carbonate containing dead organisms settle

and accumulate on the sea floor. They are also found as evaporite deposits (e.g. the Great Salt Lake, Utah) and also in karst regions, where the dissolution and reprecipitation of carbonates leads to the formation of caves, stalactites and stalagmites. The carbonate class also includes the nitrate and borate minerals.

- c) **Sulfate class:** Sulfate minerals (anion as SO_4^{2-}) are commonly formed in evaporitic settings. Both sulfates and halides are formed at the water-sediment interface by slow evaporation of highly saline waters. They also occur in hydrothermal vein systems as gangue minerals along with sulfide ores. Secondary oxidation product of original sulfide minerals also comes under this class. Common sulfate minerals are anhydrite (calcium sulfate), celestine (strontium sulfate), barite (barium sulfate), and gypsum (hydrated calcium sulfate). The sulfate class also includes the chromate, molybdate, selenate, sulfite, tellurate, and tungstate minerals.
- d) **Halide class:** Halides, like sulfates, are commonly found in evaporite settings such as salt lakes and landlocked seas such as the Dead Sea and Great Salt Lake. It includes the fluoride, chloride, bromide and iodide minerals. This class mainly represents the natural salts such as fluorite (calcium fluoride), halite (sodium chloride), sylvite (potassium chloride), and sal ammoniac (ammonium chloride).
- e) **Oxide class:** The oxide class includes the oxide and the hydroxide minerals. This class is extremely important as in addition to valuable metals they also provide the best record of changes in the Earth's magnetic field. They commonly occur as precipitates close to the Earth's surface, oxidation products of other minerals in the near surface weathering zone, and as accessory minerals in igneous rocks of the crust and mantle. Example of common oxides are hematite (iron oxide), magnetite (iron oxide), chromite (iron chromium oxide), spinel (magnesium aluminium oxide – a common component of the mantle), limonite (iron titanium oxide), rutile (titanium dioxide), and ice (hydrogen oxide).
- f) **Sulfide class:** Common sulfides include pyrite (iron sulfide – commonly known as *fools' gold*), chalcopyrite (copper iron sulfide), pentlandite (nickel iron sulfide), and galena (lead sulfide). The sulfide class also includes the selenides, the tellurides, the arsenides, the antimonides, the bismuthinides, and the sulfosalts (sulfur and a second anion such as arsenic).
- g) **Phosphate class:** It includes any mineral with a tetrahedral unit $(\text{AO}_4)^{3-}$ where A can be phosphorus, antimony, arsenic or vanadium. By far the most common phosphate is apatite which is an important biological mineral found in teeth and bones of many animals. The phosphate class includes the phosphate, arsenate, vanadate, and antimonate minerals.
- h) **Element class:** This group covers native metals and intermetallic elements (gold, silver, copper), semi-metals and non-metals (antimony, bismuth, graphite, sulfur), natural alloys, such as electrum (a natural alloy of gold and silver), phosphides, silicides, nitrides and carbides (which are usually only found naturally in a few rare meteorites).

- i) **Organic class:** This class includes biogenic substances getting concentrated or transformed by geological processes. Various oxalates, mellitates, citrates, cyanates, acetates, formates, hydrocarbons and other miscellaneous species constitute this class. Examples include whewellite, moolooite, mellite, fichtelite, carpathite, evenkite and abelsonite.

Strunz classification is also very similar where the scheme divides minerals into nine classes, which are further divided into divisions, families and groups according to chemical composition and crystal structure. i) elements ii) sulfides and sulfosalts iii) halides iv) oxides and hydroxides v) carbonates, nitrates and borates vi) sulfates, chromates, molybdates and tungstates vii) phosphates, arsenates and vanadates viii) silicates ix) organic compounds.

Check Your Progress 1

Note: a) Use the space given below for your answer.

b) Compare your answers with those given at the end of the unit.

- 1) What factors are responsible for scarcity of mineral resources? Differentiate between exponential reserves and static reserves

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- 2) Classify different types of mineral resources.

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3.5 MINING: INTRODUCTION AND TYPES

The term mining refers to the process of taking out minerals or their ores from the earth. Some minerals can be mined more easily as they are found at the earth's surface, while others lie far beneath the surface and can be obtained by digging deep underground. There are two types of mining A) surface mining B) sub-surface mining.

- A) Surface mining** is adopted when mineral deposits occur at or near the surface of the earth (<300m). Depending upon the type of ore and its place of occurrence surface mining can be done by ways such as open pit mining, dredging or strip mining. In *open pit mining* the minerals are extracted out by removing the materials that cover the deposits. This process forms open pits in the mining site. The minerals like iron, limestone, copper, sand stone, marble etc. are obtained by this method. *Dredging* is the method in which chained buckets and drag lines are used to scrap out the minerals from under water mineral deposits. Finally, in the method of *strip mining* the ores are stripped off by using bulldozers, power shovels and stripping wheels. Phosphate rocks are removed by this method. Strip mining is economical till the stripping ratio (ratio of over burden to quantity of ore recoverable) is low.
- B) Sub-surface mining** is used when the mineral deposit lies deep beneath the earth's surface. In this method, big tunnels are dug in the earth surface to extract out ores from the horizontal ore bodies. The ore extraction capacities of these methods are generally much lower than for surface quarries as well as the quantity of waste produced per unit of ore mined. The ground area of this type of underground mine is considerably smaller than for surface quarrying, except for subhorizontal layers. They are associated with a different kind of mechanical risks (subsurface collapse, structural weakness around shafts and other inclines).

3.6 MINING PHASES AND OPERATIONS

The operations carried out on a mine site to exploit and upgrade a deposit can be divided into three main steps:

- **Preparatory or development operations** providing access to the deposit: the scale of these clearance (or stripping) operations in the case of an open-pit mine and for drilling drifts, shafts or inclines for an underground mine, vary considerably according to the characteristics of the deposit. Opencast pits generally produce about ten times more waste on average than underground mines, which are more selective.
- **Ore extraction operations** (or workings), and crushing or preliminary sorting operations to optimise the transport and grade of crude ore before its transfer to the processing unit.
- **Ore processing** (in many cases for metallic mines) set of operations generally grouped in a specialized unit (called concentrator) used to separate the mineral phases containing the useful substances from the waste gangue. The product of the plant, enriched with useful materials, is called the "concentrate". In most cases, the concentrate is the marketable product.

Mines of so called high assay substances (iron, manganese, bauxite) are rarely found associated with ore processing units on site. In these cases, the ore is exported without processing to distant sites where its metallurgical conversion is more advantageous, particularly in terms of energy. Note also that methods of chemical or sometimes biological processing of the ores are also used in mine sites, in addition to physical and physicochemical methods (gravity separation and flotation). This applies in particular to gold ones (cyaniding), more recently

to copper and nickel oxide ores (heat leaching or autoclave), and even more recently, to copper and cobalt sulphide ores (bioleaching). In some exceptional cases, no physical or chemical process is applicable. A smelter must accordingly be installed nearby and, in these conditions, forms part of the mine (nickel saprolite).

3.7 TYPES OF WASTE GENERATED BY THE DIFFERENT MINING STEPS

Each of the ore mining and processing steps can generate mining waste. This waste generally has different physical and chemical properties, resulting in different potential environmental impacts. The respective volumes of waste produced essentially depend on the type of deposit and the technological alternatives used for mining and for ore processing; stripping of the deposits in strip mined quarries is often one of the steps producing the most waste during ore extraction operations. The chemical composition of the waste varies considerably according to the substance mined and the nature of the geological formation containing the deposit. It is interesting to note that in the most part, these wastes are saleable products, which will be sold if local market conditions are favourable. In addition, both coarse and fine residues are routinely required for site restoration and landscaping.

The main types of mining waste in addition to topsoil and overburden are classified into two categories: waste rock' (mine rock piles) and Tailings (processing waste). Two further types of "waste" because of the need of their environmental management are: temporary stockpiles of ore and slags.

a) *Waste rock*

Waste rock is the unused extraction product that is generally stored indefinitely in a landfill site which, for economic reasons associated with transport costs, is located in the immediate vicinity of the main mining centre. The quantity of mining waste that can be stored at a mining centre varies considerably and mainly depends on the selectivity of the mining method. As a rule, opencast pits and quarries generate much more mining waste than that of underground mine. The main type of waste rock is generated by surface (or barren rock) stripping to expose the shallow ore. This is a rock that is weathered to varying degrees, although increasingly fresh with depth and showing the geological characteristics of the local surrounding material. Its composition is similar to the rocks of the sector. The largest (in tonnage) quantity of barren rock comes from stripping for opencast mines. In underground mines, these barren rocks are generated by the passages (shafts, crosscuts).

b) *Tailings (processing waste)*

At a mine, an ore mill normally abuts on the extraction centre to produce the first marketable products (metallic concentrates, sorted ore, and ingots). The technological processes are very different according to the type of substance mined, and the modernity of the technologies employed (flotation, leaching, and biotechnology). Mill waste is generally referred to as **tailings**, or releases or effluents. For a given mineral, it will have different physicochemical properties according to the conditions in which it has been generated. Its

volume and variety has increased to match raw material demand, combined with the proliferation of upgrading methods and their degrees of sophistication. It is found in solid, liquid and gaseous form as:

- Aqueous solutions from cyaniding.
- Slurries of finely ground particles that have undergone one or more types of physical or chemical treatment, and which contain one or more industrial additives (that have participated in the conversion process) (xanthates, miscellaneous salts, starch, etc.). These tailings are normally dumped in a sort of lagoon or settling basin within an embankment at the exit of the mill.
- Atmospheric releases from sulphide roasting contribute to air pollution.

Through the years, **solid waste** has evolved in line with technological progress, from multi centimetre grain size with a still high content of the desired element (i.e. low tonnage and hence low exchange surface areas to micron grain size with very low chemical contents (i.e. high tonnage and high waste). The release mesh varies from one ore deposit to another, depending not only on the level of technology but also on the geological and mineralogical characteristics.

c) ***Ore stockpiles Ore stockpiles***

Ore stockpiles are intermediate storage of products and may not be considered as waste and are normally temporary dumps of lean ore at the mine site, depending on the cut-off content, which may vary with time. This management requires maintenance on the mine site for a period sometimes longer than a decade. Selectivity of materials corresponds to ores of lower grade than the limit assay. These ores with content lower than the limit content at the time of storage can be used later with advancement in technology or market. It can also be used as a raw material for preparing some other product.

d) ***Slags***

The burning or smelting of ores of Fe, Cu, Sn etc. to remove sulphides produces slags as the waste. These oxidised products are found either accumulated near the mine, if smelting was conducted nearby, or often stacked in heaps near the smelter. Ash produced by cleaning furnaces or smoke stacks is frequently associated with them.

3.8 MINING WASTE MANAGEMENT METHODS

By order of importance, the disposal of tailings is generally done by:

- Terrestrial impoundment (tailings ponds),
- Underground backfilling,
- Deep water disposal (lakes and sea),
- Recycling.

a) ***Terrestrial impoundment***

Terrestrial deposition is the predominant method for tailings disposal. It concerns fine waste and slurries such as mill tailings. The principle of tailings

dams (or ponds) is to dispose of the tailings in an accessible condition that allows their future reprocessing (once improved technology or a significant increase price makes it profitable). Actually, the vast majority of tailings facilities are design as permanent disposal facilities. Tailings are often transported to the impoundment *via* pipelines.

b) *Underground backfilling*

The backfilling of mines is possible only for ore deposits which do not have any contact with an aquifer. Such an operation is usually costly and will be carried out for stability and safety reasons.

c) *Deep water disposal*

The disposal of tailings and solid waste directly into bodies of water although sometimes was used in past operations, is rapidly becoming unauthorised as a standard practice due to the significant pollution effects, it can have on the receiving waters and the possible subsequent impacts on the livelihoods of the local communities. This method requires specific conditions and specific impact assessments. An appropriately designed underwater disposal of sulphidic tailings is an ideal solution from an environmental point of view in the short term with control of the level of water.

d) *Recycling*

Coarse mining waste and especially barren rock is sometimes considered as materials for roads, building foundations or cement factories, depending on its geotechnical and geochemical characteristics. Recycling is not classified as disposal. If a market will emerge later, the rock stored temporarily can be sold as aggregate when environmental specifications are met. With new techniques, the tailings can be reprocessed.

3.9 IMPACT OF MINING ON ENVIRONMENT

Although mining provides a variety of socio-economic benefits, from the exploration to the closing stage, it has serious impacts on ecosystem, biodiversity, environment, health and socio-cultural systems. These impacts come through the value chain activities like prospecting, exploration, site development, ore extraction, mineral dressing, smelting, refining/metallurgy, transportation and post mining activities. The sector is resource intensive in turn generating massive amount of solid and liquid wastes of high concentrations, and sometimes toxic substances. If not well handled, its environmental and social costs can be massive. In general, degradation arising from mining includes air pollution; surface and ground water pollution; land, agriculture and forest degradation; sound pollution; as well as socio-cultural problems such as health, rehabilitation, conflicts, inequality, alcoholism, drug abuse, prostitution and other social unrests. All these have negative implications for various livelihoods and sustainable development and therefore, require urgent attention.

The mining, processing and disposal of minerals have many negative effects on environment. The main harms caused by mining are as follows:

- i) It results in formation of **derelict land** or **mine spoil** due to removal of top soil from the mining area to get access to the deposit disturbs and damages the land causing defacing the landscape.

- ii) It causes ground subsidence, which results in tilting of buildings, cracks in house, buckling of roads, bending of rail tracks and leaking of gas from cracked pipelines leading to serious disasters.
- iii) It disturbs the natural hydrological process and also pollutes ground water as well as surface water. Sometimes radioactive substances like uranium also contaminate the water bodies through mine wastes.
- iv) Extraction and processing of ores emits enormous quantities of air pollutants such as suspended particulate matter (SPM, soot, metal particles etc.).
- v) Miners often suffer from serious respiratory and skin diseases like asbestosis, silicosis, blacklung disease etc, due to constant exposure to the suspended particulate matter and toxic substances.

3.10 MINE RESTORATION

It is the process of creating functional ecosystems (or sometimes industrial or municipal land) from mined land so that the wastes and pollutants no longer available to enter into any ecosystem. It includes material placement, stabilizing, capping, regrading, placing cover soils, revegetation, and maintenance. Rehabilitation management is an ongoing process.

Waste dumps are contoured to flattened and stabilize them against erosion. Sulfide containing ore are usually covered with a layer of clay to prevent its oxidation by rain or air to sulfuric acid. Open pit are backfilled and covered with topsoil, and plantation is promoted to help consolidation of the material. Fencing is often done to prevent access. Tailings dams are left to evaporate, and then covered with waste rock, clay and soil etc. followed by plantation to enhance stabilization. Rehabilitation in case of underground mines is relatively easier and less costly due to higher grade of the ore and lower volumes of waste rock and tailings. In some situations, stopes are backfilled with concrete slurry using waste, so that minimal waste is left at surface. Often in gold mines, rehabilitation is performed by scavenger operations which treat the soil within the plant area for spilled gold using modified placer mining gravity collection plants.

A holistic strategy for restoration of mine spoil must essentially include the following: (i) mechanism to store fertile top soil layer for use in post mining restoration operation, (ii) ensuring least disturbance and protection of the remaining parts of the affected ecosystems, (iii) rainwater harvesting, (iv) assisted soil remediation through addition of pond bed silt and sediment as well as earthworm, (v) assistance to available persistent rootstock, if any, (vi) attracting seed dispersers, (vii) direct seeding, (viii) vegetative cutting, and (ix) plantations, preferably a mixed native vegetation (x) use of microbial population for bioremediation and supplement the easy establishment of vegetation (xi) treatment to adjacent farmlands and streams affected by mining operations, and, (xii) preventive measures to mine induced groundwater pollution. Different market mechanisms could be applied to incorporate the costs of such activities. Policy measures and incentive should also be devised for taking care of such affirmative initiatives and market forces. As far as possible the cultural resources such as local knowledge and skills should be appreciated in addressing the challenge of mine spoil restoration.

A primary succession of vegetation in the mining areas could be catalyzed by natural regeneration of native forest species originating from remnant forests and ancient trees in the vicinity. In combination with direct seeding, it can increase the likelihood of restoration success. The natural process of succession is enhanced by the variety of fauna supported by the remnant vegetation, that help in seed dispersal in the adjacent areas. Sediments of aquatic systems like lakes, ponds, tanks act not only as a rich source of nutrients but also as a seed bank for a variety of grasses, herbs, shrubs and trees. This also stimulates microbial activity and improves the chemical and physical properties of the reclaimed soil. In peripheral dump areas root stocks can be supported to regenerate through a combination of rainwater harvesting. Direct seeding using a mixture of native species has proven to be cost-effective and ecologically viable restoration method. The seed mixture must be carefully selected based on physical and chemical properties of mine spoil as well as ecological, economic and social criteria. The composition includes framework species across taxa, herbs, shrubs and trees, early and late successional species, as well as a few keystone species to accelerate the restoration of a functional ecosystem. **Framework species** are a minimum number of indigenous species having the potential to accelerate biodiversity recovery and enhance natural regeneration to create a self sustaining forest ecosystem from a single plantation event. Similarly, **keystone species** are species which play a critical role in maintaining the structure of an ecological community, affecting many other organisms in an ecosystem and helping to determine the types and numbers of various other species in the community. Direct sowing methods in combination with minimal soil work, provides a large base for choice of species, and ensures high biodiversity per unit area and can also be combined with natural regeneration.

Examples of rehabilitation success of mine spoils in arid regions in India notes the use of a combination of rainwater harvesting, soil amendments and plant establishment methods using trees, shrubs and grasses. Such an approach is also socially acceptable as it enhances productivity of the systems and availability of products to people. Along with direct seeding, planting of large vegetative cuttings, and wherever possible, assistance to persistent root stock has provided effective results in Rajasthan.

Check Your Progress 2

- Note:** a) Use the space given below for your answer.
b) Compare your answers with those given at the end of the unit.
- 1) Write a note on types of mining and operations.

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2) Describe in brief on types of waste generated during mining and their management.

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3) Enumerate various environmental impacts related to mining.

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4) Enumerate different strategies for restoration of mines.

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3.11 LET US SUM UP

- Mineral resources refer to material substances either composed of or extracted from minerals.
- Minerals can be divided into different categories such as metallic, non-metallic, precious and energy minerals.
- The term mining refers to the process of taking out minerals or their ores from the earth. Some minerals can be mined more easily as they are found at the earth’s surface, while others lie far beneath the surface and can be obtained by digging deep underground.
- Although mining provides a variety of socio-economic benefits, from the exploration to the closing stage, it has serious impacts on ecosystem, biodiversity, environment, health and socio-cultural systems.
- Examples of rehabilitation success of mine spoils in arid regions in India notes the use of a combination of rainwater harvesting, soil amendments and plant establishment methods using trees, shrubs and grasses.

3.12 KEY WORDS

- Mineral** : A mineral is an element or chemical compound that is normally crystalline and that has been formed as a result of geological processes.
- Critical Mineral** : These are minerals whose use is necessary for the production of essential goods.
- Hydrothermal process** : Any process associated with igneous activity involving the action of very hot waters.
- Ore deposit** : A mineral deposit at a certain place and time that can be sourced economically.
- Mineral Reserves** : These are the identified ore deposits that are yet to be exploited.
- Tailings** : These are the materials left over after the process of separating the valuable fraction from the uneconomic fraction of an ore.

3.13 REFERENCES AND SUGGESTED FURTHER READINGS

- Miller, G Tyler, Jr. 1996. Worldviews, Ethics, and Sustainability. In Belmont, CA(Edt). Living in the Environment. Wadsworth Publishing Company.
- McKinney, M,L, and Schoch, R.M. 1998. Environmental Science: Systems and Solutions. Jones and Bartlett Publishers, Boston. 639 pp.

3.14 KEY TO CHECK YOUR PROGRESS

Check Your Progress 1

- 1) Your answer must include the following points:
 - Industrial revolution
 - Increased human needs
- 2) Your answer must include the following points:
 - On the basis of their electric conductivity and use
 - On the basis of major anion group present

Check Your Progress 2

- 1) Your answer must include the following points:
 - Depending on place of occurrence and excavation
 - Preparatory operations and Ore extraction operations
 - Ore processing

2) Your answer must include the following points:

- Waste rocks, Tailings and Ore stockpiles
- Terrestrial impoundments
- Underground backfilling
- Deep water disposal and recycling

3) Your answer must include the following points:

- Land degradation
- Air, water, soil and sound pollution
- Health aspects

4) Your answer must include the following points:

- Backfilling and plantation
- Ecosystem perspective
- Holistic strategy

UNIT 4 SUSTAINABILITY ISSUES RELATED TO ENERGY AND MINERAL RESOURCES

Structure

- 4.0 Introduction
- 4.1 Objectives
- 4.2 Environmental Perspectives of Laws of Energy and Matter
- 4.3 Resource Depletion
 - 4.3.1 Depletion of Matter Resources
 - 4.3.2 Depletion of Energy Resources
 - 4.3.3 Bubble Pattern of Resource Depletion
- 4.4 Conservation of Resource
- 4.5 Energy Conservation
 - 4.5.1 Improving Energy Efficiency
 - 4.5.2 Energy Saving Awareness
 - 4.5.3 Role of Government
- 4.6 Dealing with Mineral Scarcity
 - 4.6.1 Expanding the Resource Base
 - 4.6.2 Recycling
 - 4.6.3 Substitution
 - 4.6.4 Durability and Dematerialization
- 4.7 Sustainability Counts Environmental Costs
- 4.8 Earth-Wisdom Society
- 4.9 Let Us Sum Up
- 4.10 Key Words
- 4.11 References and Suggested Further Readings
- 4.12 Key to Check Your Progress

4.0 INTRODUCTION

In this unit, we take an overview of better ways of managing natural resources. Many of the natural resources suffer from depletion, a situation, which occurs when a resource is utilized faster than it is replaced by natural processes. A material resource deposit (mineral or fuel) that took millions of years to form, for example, may be extracted and consumed in just a few years, or a species that took many thousand years to evolve may be driven to extinction in a few years. The ideal goal of resource management is sustainable resource use, which seeks to “conserve” or slow down the rate of resource consumption to the point where the resource can be replenished by nature. Harvest of trees or fishes or other biological organisms are examples. In other case, if the resource is in immediate threat of disappearing, sustainable management must *preserve* the resources where the exploitation is totally stopped, so that the resource get time for regeneration or attain resilience, e.g. endangered species and endangered ecosystem.

As you know, stopping or slowing down the rate of resource use not only slows depletion but usually has an added advantage of minimization of waste, and thereby reducing pollution. A sustainable society practices “throughput” reduced to the point where exploited resource (inputs) stocks get enough time for regeneration by natural processes, and pollution (output) load remains under the assimilation capacity of the resource base. However, the conventional ways of resource management have not achieved this goal of sustainable use as they are more influenced by short term social, economic, and political gains which emphasize rapid exploitation of resources.

4.1 OBJECTIVES

After reading this unit, you will be able to:

- discuss how resource use pattern is related to sustainability;
- differentiate between over-exploitation and sustainable use of a resource;
- understanding the various links between resource use, depletion, environmental degradation and pollution;
- identify the sustainability issues related to mining, drilling and other harvesting practices; and
- state alternative strategies for sustainable energy and material future.

4.2 ENVIRONMENTAL PERSPECTIVES OF LAWS OF ENERGY AND MATTER

a) Energy

There is no way in which one can get more energy out of a system than the input energy since, in terms of energy quantity the input energy equals the output energy as stated by the **first law of energy** or **first law of thermodynamics** (law of conservation of energy). Similarly, **second law of thermodynamics** or **second law of energy** suggests that we lose some useful energy every time some work is done. But again from first law of energy, we can't lose energy. Then what do we lose? It is the quality of energy, the amount of energy available for performing useful work. When fuel oil is burnt in a machine, it is partly converted into mechanical energy, electrical energy, light energy, chemical energy of exhaust emissions etc., but a major part that is converted into heat energy gets lost into the atmosphere and remains of no use. For example, in an engine only about 10% of the high-quality of energy of fuel-oil gets converted into mechanical energy and electrical energy. Only 5% of this electrical energy lights the bulb. The rest 90% in first step and 95% in the second step are lost as low-quality heat energy into the environment. Thus, when energy is changed from one form to another, some of the useful energy is always degraded to lower-quality, more dispersed and less useful energy being lost in the form of heat given off at a relatively low temperature to the surroundings (environment). The more energy we use, the more low-grade energy we add to the environment. And we can never recycle or reuse high-quality energy to perform useful work. We can heat air or water to bear high-quality energy, but at the cost of more high-quality energy.

b) Matter

According to law of conservation of matter, under ordinary circumstances, matter is neither created nor destroyed (except nuclear reactions) but is recycled endlessly. Matter is transformed and combined in different ways, may get dispersed and go somewhere but it doesn't disappear. As we use more resources to produce more disposable goods, we end up converting high-quality matter into low quality matter. **High quality** matter is generally more organized, concentrated, usually found near Earth's surface, and has great potential for use whereas **low quality matter** is disorganized, diluted, and often found deep underground, or dispersed in the ocean or in the atmosphere, and usually has little potential for use. The fuels, metals, drinking water etc. are high quality matters and the ore, pollutants, impure fuels, impure water are low-quality matters. The useful goods that we produce gradually become low-quality matter depending upon its durability. The fuels (usable-energy rich matters) once used gets converted into low quality matter. When we deal with disposal/treatment of waste we again use more high-quality matter. Again, the low quality matter thus generated has to go somewhere. Many persistent pesticides and toxic metals have the tendency to form the cycle of poison when enters into food chain via polluted habitat. Thus, pesticides (say, DDT) banned at some place and diverted to other (due to selfish business motive) reaches everywhere as residues even across oceans through fallout from air masses. No way, we can get rid of our misdeeds, the results return back to us in one form or the other. As the quality of a matter depends on its usability, recognizing the utility potential (resource) and harnessing may reduce the amount of low quality matter generation.

c) Energy and matter in biological system

In the biological system governing in nature, less than 1% of solar energy is trapped in the process of photosynthesis by the plants. The food that goes to the consumers is only a part of the total photosynthesis, and again only around 10% of the total intake as food gets assimilated by the consumers. And at the last, during the process of conversion of muscular energy into mechanical energy a great amount of energy gets lost. However, the uniqueness of biological system governing in nature is that the energy input is perpetual (solar energy) and they need the chemical elements not in very concentrated form (unlike human and engineered systems). Autotrophs are simply the natural instruments for trapping the perpetual flow of energy.

4.3 RESOURCE DEPLETION

As you are aware, out of the two basic inputs from the environment, matter constantly cycles whereas energy primarily has a unidirectional flow, which is the reason, why matter and energy are depleted differently.

4.3.1 Depletion of Matter Resources

Matter resources are depleted by being "lost" or dispersed. Ore deposits are usually concentrated deposits of minerals that are normally found in more diluted form in the Earth's crust. When the ores are mined out and processed into pure metal and then to different products, the atoms may be eventually dispersed due to wear and tear, or lost to further human use when the products are dispose-off in

landfills and elsewhere. Note that these “**urban-ores**” of a landfill may later be mined for its metal content. Similarly, rapid erosion depletes soil not because the nutrients and minerals in the soil are destroyed, but because the soil is dispersed, ultimately in the oceans. These examples show that when non-renewable resources disperse, molecules of metals and soils stay dispersed unless we spend much energy and money to reconcentrate them. On the other hand, although dispersal of potentially renewable matter resources such as timber also occurs, we can regenerate them relatively quickly. Potentially renewable matter resources are often biological in nature.

4.3.2 Depletion of Energy Resources

Energy resources get depleted whenever they are subjected to conversion to different form. This is the key difference from some forms of “lost” matter, which could be recollected and reconcentrated, if society had enough cheap energy. In contrast, once energy is transformed, it is lost forever; waste heat can never be reconcentrated. If we burn oil or coal to release their chemical energy to drive an engine, that energy can never be reused. We do have a major source of renewable energy, however: the sun. This source of renewable energy could potentially keep society running for many millions of years. Examples of the Sun’s energy include direct solar power, biomass, hydropower, and wind.

4.3.3 Bubble Pattern of Resource Depletion

Unsustainable use of many resources exhibits a bubble pattern of depletion. The best known example is the so-called **Hubbert’s bubble** of oil depletion. This was named after M. King Hubbert, who accurately predicted the bubble pattern of oil depletion in United States, which peaked around 1970 and has been declining since, as the richest reserves steadily depleted. The bubble pattern has two main causes: exploitation and depletion, both are following an exponential pattern, which tend to form a mirror image of each other with exploitation on the left side and depletion on the right side. Resources are exploited very quickly once society discovers their utility. Exponential demographic (population plus technology) growth is the main cause of exponential exploitation, and the exponential phase continues as long as supply exceeds demand. But because all nonrenewable resources on earth are finite, limits to growth eventually occur, and demand begins to exceed supply. During this time, society usually intensifies its efforts to obtain more of the resource through technological applications. However, these efforts usually soon encounter what economists call the **law of diminishing return**, meaning that increasing efforts to extract the resource produce progressively smaller amounts. Production declines exponentially because the most easily extracted concentration of the resource become exhausted. As supplies of the resource decline, price rises, sometimes leading to unemployment and other unpleasant change. In such situation, the normal way is to switch to another available resource (e.g. wood coal oil in England) where again the bubble occurs until the cycle of unsustainable use is broken to switch over to sustainable use.

4.4 CONSERVATION OF RESOURCE

As we are aware now that resources are deleting very fast our approaches need to be changed from a ‘maximizing resource use and short term gain’ to long-

term economic gain and gain of other 4 Es. This can be done in three ways: preservation, conservation, or restoration of what has been degraded. Out of these three, practice of conservation is more important as it can reduce the need of preservation and restoration. Conservation or input reduction by lowering resource use ensures: i) slow depletion of resources, ii) reduced pollution by slowing the flow of matter and energy (throughput), and iii) health and monetary benefits. Until recently, supplies of most resources were so abundant, that little attention was paid to input reduction; as a result, depletion rates were high, and pollution was controlled by scrubbers and other forms of output or as “end-of-pipe,” reduction.

There are three basic ways to conserve, or reduce the need for a resource: efficiency improvement, reuse/recycling, and substitution. However, different resources will require different methods of input reduction. Efficiency improvement is generally most effective and economically cheapest. It is very difficult, for example, to find affordable substitute for water in many of its use, such as agriculture and drinking, so increased efficiency and reuse/recycling of waste water are common. Efficiency improvements occur when the same task is accomplished with fewer resources. Increasing the mileage of an automobile from 30 km/l to 50 km/l is an example of fuel efficiency. Similarly, micro irrigation (using drip irrigation, sprinkler etc.) is efficient than open channel irrigation. Japan in particular and the European countries are leaders in devising technology that improve efficiency. The energy intensity index, which equals energy consumption/gross national product, measures how much energy is used to produce the same unit of wealth. Material efficiency-indices similarly indicate usage of other resources. For example, Japanese technologies convert about 70% of raw timber into finished wood products while in the United States only about 50% is converted.

The relative inefficiency of resource use is a direct result of its historical endowment of abundant resources. When the costs for energy and other resources are low, efficiency seems to be a secondary affair. Ultimately, however, inefficiency is costly to any economy. Money invested in energy-saving technologies would pay more than for itself by reducing energy costs. Increased efficiency leading to conservation of minerals and other resources would achieve similar savings. Besides the economic savings, environmental savings from increased efficiency are also enormous. Less depletion saves more resources for future generations. Less resources extracted means less degradation of the land and less pollution from reduced processing and usage. The pollutants released by the burning of fossil fuels are reduced when efficiency is increased.

Reuse occurs when the same resource is used again in the same form, such as refilling soda bottles. Recycling is similar, but the resource is not reused in the same form. The soda bottles, for instance, may be remelted to make new bottles or other glass containers. Like improved efficiency, reuse/recycling reduces depletion of resources and pollution from resource extraction and use. Reuse/recycling is useful in reducing solid waste, which is important because landfills are being permanently closed at the rate of about two per day. Precycling, which is the reduction of packaging material by manufacturers, is becoming more important. Concentrated foods, for example, can often be packed in smaller containers. **Precycling** is not recycling, but is conservation by increased efficiency; the same task is accomplished but fewer resources are used. Nevertheless, the

technological and economic aspects of recycling can be very complex. A simplified recycling scheme begins with **virgin resources**, which are the original natural resources being extracted. Both extraction, such as mining, and processing during product manufacture usually create pollution. The **recycling loop** begins before the purchased product is discarded; the discard is reprocessed into the same or perhaps another product. As long as the discard is being used in place of the virgin resource, recycling occurs. The recycling loop is closed when someone buys a product containing recycled material. This slows depletion of virgin resources and reduces pollution in two basic ways. Most obviously, it reduces the amount of solid waste that would have been discarded into landfills, incinerators, and other means of disposal. Additionally, recycling reduces the pollution that would have been produced from the extraction of the virgin resources. Unfortunately, the recycling loop is often not closed, usually due to economic reasons e.g. when products made from virgin resources are cheaper. If the costs of products made from virgin resources were increased to reflect their true cost to the environment, the price differential would disappear, and the loop could be closed.

Substitution can also help reduce both depletion and pollution problems. Substitution occurs when one resource is used instead of another. It helps to reduce depletion because when one resource is being depleted, a more common substitute can be used at a cheaper price. For instance, aluminum, a very common metal in the Earth's crust, can be substituted for the much rarer and more expensive copper in making alloys, equipment and other uses. Substitution helps to reduce pollution problems when the extraction, processing, or disposal of the substituted resources produces less pollution. For example, many plastics last for 50 to 100 years in the environment before they significantly decompose. Also, plastics are made of a nonrenewable resource, petroleum, whereas trees are renewable. Such considerations have led to the substitution of paper for plastic in many items, such as drinking cups and food containers. Although it can be useful in reducing resource depletion, substitution is often less desirable than efficiency improvements or reuse/recycling. Instead of reducing overall resource depletion, substitution often simply switches depletion from one resource to another. This can be satisfactory if the new resource is renewable (e.g. paper) or very abundant (as with glass made from sand). Also, substitution often does not reduce pollution, solid waste, or other output problems. For instance, the use of paper products offers many environmental advantages over plastic, but it may do little to solve landfill space problems. Indeed, paper is already the largest component of city garbage.

4.5 ENERGY CONSERVATION

The simplest and cheapest way of minimizing energy crisis and other related problems is **energy conservation**. Here energy conservation talks about the conservation of usable energy and not the energy as a whole, which will be against the 1st law of energy. This can be achieved by decreasing the energy wastage and increasing energy efficiency. Replacing a 100 watt incandescent bulb with a 25 watt CFL (compressed fluorescent lamp) which gives the same illumination is an example of energy efficiency, whereas decreasing the number of bulbs of an over-illuminated place is an example of decreasing energy wastage. Other examples are putting off the fan and light when they are not needed.

Increasing energy efficiency may have a higher initial cost, but the cost saving by lower energy consumption over weighs that. Reduction in energy consumption does not mean a decreased living standard. But use of energy efficient systems may ultimately bring a qualitatively different lifestyle, as energy intensive activities are replaced by labor intensive ones. Decentralization of energy supply and production particularly from alternative resources (e.g. solar and supply) may make the households and business setups partially or fully energy self-sufficient. Energy conservation not only saves the nonrenewable resources it reduces the environmental (pollution etc.) and ecological (habitat loss etc. mainly associated with hydropower) degradations. The shift to alternative energy sources and energy efficient route also ensures carbon efficiency i.e. reduced carbon output per unit of useful work done. The exclusive use of virtually carbon free energy resources would cause the carbon index to approach infinity.

Check Your Progress 1

Note: a) Use the space given below for your answer.

b) Compare your answers with those given at the end of the unit.

- 1) Explain the importance of energy and matter quality in environmental problems.

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- 2) Write notes on depletion of resources.

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- 3) Brief about different approaches for conservation of resources.

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4.5.1 Improving Energy Efficiency

There are many ways of saving energy which is the same as gaining energy. They are, i) not converting energy from one form to another form unnecessarily, ii) reducing the steps of energy conversion, iii) increasing the energy conversion

efficiencies, iv) minimizing transportation/transmission of energy, and v) increasing the efficiency transport/transmission. These steps will reduce the wastage of energy that occurs during conversion (2nd law of energy), and transport/transmission. Decentralized energy production and transport/transmission network, and other planning tools can help saving energy. Energy conversion and transmission can sometimes be made more efficient by simply readjusting and fine tuning old equipment. Use of superconductors (more research and development needed) can dramatically increase the efficiency of all aspects of electrical energy use. **Cogeneration**, which uses the spent (waste) heat of power plants along with the electricity generation, is another way of increasing efficiency. This reduces thermal pollution and the use of waste heat reduces consumption of some other resource. The energy efficiency of many industries can be increased by using recycled materials. In general, recycling saves energy than use of virgin material. Recycle of steel uses only 14% of the energy it would have used for processing raw ore. Similarly, around 95% energy saving is gained in recycling of aluminum. Substantial amount of energy savings in residential and commercial buildings can be done by using super-insulated walls, proper ventilation (for gas exchange and light), passive heating systems, and natural cooling system.

4.5.2 Energy Saving Awareness

By educating people about the individual and environmental benefits of energy savings, use of energy saving practices can be encouraged. In most cases however, the initial investment is high, but the cost-effectiveness of the energy saving systems in the long run and cost cutting on mental and physical health due to better environment are the incentives. In some cases, such as using a public transport system may not always be convenient, however, unless unavoidable, the public transport systems should be used. Similarly, adopting a bicycle culture not only saves a lot of money on energy and maintenance, it promises a good health due to physical exercise and by ensuring a pollution free environment.

The utility companies also can play a great role in energy saving without compromising their profits. They can produce energy efficient and durable products to reduce their investment in production of more electricity and pay for the environmental pollution (directly or indirectly). This is called **demand side management (DSM)**. They sometimes actively promote energy saving by giving some other incentives to the consumers e.g. helping consumer improve the insulation of their homes and use of high efficient CFL while selling high-efficient air conditioner and heaters.

Besides making efforts, communities and individuals must exert intense pressure on elected officials to develop a national energy policy based on much greater improvements in energy efficiency and a more rapid transition to a mix of renewable energy resources.

4.5.3 Role of Government

Some general conclusions by energy experts about the strategy of energy use for a sustainable future are:

- The best shortterm, intermediate, and long-term alternatives are a combination of improved energy efficiency and greatly increased use of locally available renewable energy resources.

- We cannot and should not depend mostly on a single nonrenewable energy resource such as oil, coal, natural gas, or nuclear power
- Because there is not enough financial capital to develop all energy alternatives, projects must be chosen carefully.

The government has to play a major role in encouraging energy saving by influencing the market. A first step is for government to set a positive example by using the most up-to-date energy-efficient technologies. The government can fund and influence private agencies to fund the research and development of new energy-efficient alternatives and then be their first consumer. The use of most up-to-date energy-efficient appliances by government will set a positive example. This can start the production and run the market, and the product can then reach the general public easily at a reasonable price. Government could simply mandate energy efficiency measures within their jurisdiction, although difficult to take such a step. Government should influence the fuel efficiency standards for vehicles, establishing energy-efficiency standards for buildings and appliances, greatly increasing government-sponsored research and development to improve energy efficiency, and giving tax credits and exemptions or government rebates for purchases of energy-efficient vehicles, houses, buildings, and appliances. Tax breaks and subsidies can be given to industries and individuals that are more energy responsible. Consumption of energy from nonrenewable energy sources and use of inefficient appliances may be taxed heavily so as to include the ecological, environmental and health costs (which consumers are now paying indirectly). These taxes will not only discourage such consumption, it increases the funds of the government which can be used for further improvements. Different energy sources can also be taxed differently as per their life-cycle environmental impacts, so that it can shift us to rely more on renewable energy. The public transport vehicles may get fuel/energy at a subsidized rate than the individuals.

Another important way to improve energy efficiency is to modify electric-utility regulations. These changes require utilities to produce electricity on a least-cost basis, permit them to earn money for their shareholders by reducing electricity demand, and allow rate-increases based primarily on improvements in energy efficiency. If utilities are rewarded for *reducing electricity demand* and *cutting their customers' bills*, the goal of the companies would be to maximize production of what Amory Lovins calls Energy and money saving “**negawatts**” instead of megawatts. Replacement of a 25 watt compact fluorescent for a 100-watt incandescent bulb, for example, can be considered as generation of 75 negawatts.”

Another innovation in the mostly monopolistic public utility industry is to allow and encourage more competition from independent power producers to build almost any kind of power plant anywhere in the world which can decentralize the generation of electricity and its storage. The concept of **retail wheeling** will support this venture, which allows users to purchase power directly from independent power producers while using the local utility's lines for transmission and distribution. Residential customers can generate their own electricity using new technologies such as small co-generators burning natural gas, hydrogen- or natural-gas-powered fuel cell, and roofs made of solar-cell tiles (already developed by several U.S and Japanese companies). Any excess power they produce could be sold to the other users on their electric grid. In addition, government subsidies for coal and nuclear power should be phased out.

4.6 DEALING WITH MINERAL SCARCITY

Mineral scarcity can be dealt by adopting two strategies: i) *expanding the resource base* (by locating new ore deposits or cycling old materials), and ii) *decreasing the demand for the substance* (by finding alternatives or substitutes for the substance) or simply eliminating the need for it through technological developments and changes in lifestyle.

4.6.1 Expanding the Resource Base

This aims at exploring new deposits of minerals as one deposits depletes. The high grade deposits that remain to be discovered are smaller, less accessible, and more expensive to exploit e.g. under the sea. Once the high grade deposits are depleted, more number of low grade deposits can be explored. However, the quantity of material dug from mines, the disturbance in ecosystem, the energy input, and pollution caused for getting unit pure mineral will increase tremendously. For a few of the geologically common minerals (iron, aluminum, manganese, magnesium, chromium and titanium), higher grade ores are rare, but the lower the grade of the ores, the more abundant they are. Metals such as copper, tin, and zinc occur either in geologically concentrated high-grade, minable deposits or with very low-grade deposits (0.1% - 0.001% of the high-grade deposits) which hardly can be used. So, in such situations the alternate path, decreasing the demand could be followed.

4.6.2 Recycling

Recycling of materials is one way to reduce our demand for extraction of virgin material. It increases the stock of usable material virtually. For instance, a ton of pure metal at a **recovery rate** (percent of original material recovered from recyclable used products) of 80% get stretched into five tons in effect. The recycle-recovery rate is always less than 100% because of wear and tear, rust and corrosion, and other such processes that the finished products have gone through while in use. A recycling recovery rate of 90% is extremely difficult for any metal. In practice, the current recycling efficiency for many common metals is 30% or less. The only metal for which a higher rate of recovery is possible are precious metals, such as gold, that are relatively non-reactive. On the other hand there are still some uses where we lose the totality of material used and recovery is virtually impossible. Such uses are called **dissipative use** where the material get degraded and dispersed. Examples of such material are dyes, paints, inks, cleansers, solvents, cosmetics, fertilizers, pesticide, alloy etc.

Returning used items for collection is not enough. The recycling loop is closed only if collected items are used again to make product that is repurchased. The loop will often go unclosed if products made from recycled materials cost more than products made only from virgin resources. However, widespread recycling is unlikely to occur until it is economically feasible. Simply passing laws requiring recycling is not enough. By charging an extra fee for each barrel of garbage left out for pickup, people can be influenced to sort their waste, and deposit it in recycling containers. This is an excellent example of the key role that economics plays in promoting resource conservation.

A major reason of a frequent high price of recycled material than virgin material is the cost of energy, including the energy of human labor. The cost of embodied

energy, or the energy used in producing a product, is often the main factor determining the product's retail cost. The energy consumed in recycling some materials is much less than the energy consumed in processing virgin material. For example, mining and processing aluminum and many other metals are very energy-intensive. Because recycling aluminum uses much less energy, there is a strong cost incentive to process it and close the loop. In everyday terms, recycling just one aluminum can saves enough energy to run a television set for three hours. This example shows how both the environment and jobs can benefit from recycling.

Recycling other material, such as newspaper and glass, saves considerably less energy than recycling aluminum. However, when costs of human energy, such as collecting and sorting the newspaper and glass, are added on, the slim profit margin may disappear, and the loop may sometimes remain unclosed. The problem of closing the recycling loop has many possible solutions. One option is to appeal to consumers to purchase recycled products, even if they cost more to encourage recycling. To make it on a wide scale, society can levy higher "green taxes" on virgin resources to boost the price of products made from them, so that the recycled product will be cheaper, and the loop will be closed through consumer-demand. Lastly, human ingenuity and innovation may devise new recycling processes that may lower the costs or new products that appeal to consumers. For example, used tires can be recycled to make sandals, tennis shoes and asphalt etc. When products that people want are created, there is an economic incentive to close the loop. Many businesses are finding new uses for plastics, such as stuffing for ski jackets and even "lumber" to build benches, fences, and playground equipment.

Recycling uses energy, water etc. and is also not free from pollution. However, the energy requirement is much less (90-97% in case of aluminum) than the energy use in getting the same amount of material from raw material. Furthermore, even if recycling extends the effective amount of a substance over a number of years the stocks will not sustain forever due to our consumption demand (due to population and per capita consumption). So, at times we may need to switch over to other substance (preferably renewable) for getting the same task done.

4.6.3 Substitution

At a point of time when there is not enough of certain material for coping with our demands the only option remains is finding a substitute for it with similar properties. For example, tin can be substituted with aluminum and steel for different purposes. Substitutes can also be found for many such scarce metals, such as lead, zinc, and mercury. On the contrary, in certain cases finding a substitute is not possible due to unique properties of the material. For example, Platinum and other metals are used as catalysts in chemical process, mercury is the only liquid and densest metal at room temperature, and small but critical amount of certain elements (e.g. copper, zinc, lead, mercury, tin, manganese, chromium, cobalt and titanium) are absolutely necessary in modern metallurgy. There are still certain substances such as phosphorus which don't have a ready substitute and can't be recycled (dispersive use) but is also a fundamental requirement of life (of more concern for agriculture). The practically minable phosphate deposits may last only 100 year in the prevailing situations or more optimistically 1300 years. However in such situation the substitute is to switchover to organic fertilizers. The stocks of the substitute are also subjected to depletion. For example, plastic could substitute a number of metal but most plastics are

derived from petroleum which is a non-renewable, rapidly diminishing resource. In such cases, bio oil or other such source (coming from biomass) could be used for making plastics. That is wherever possible we should find a substitute whose stock is renewable in nature.

4.6.4 Durability and Dematerialization

Another simple way to reduce the demand for mineral resources is to produce durable goods that are designed to last as long as possible. This can be done by manufacturing the best quality of material and designing them in such a way that they could be repaired, rebuilt, modified, refurbished, or used with other products (e.g. interchangeable joints used in glass wares) wherever required. Reuse of materials can save a considerable amount of material, energy, and money. Food and drink packaging is a classic example. The refillable glass bottles can typically be reused dozens of times unlike the aluminum beverage cans.

Another strategy is to reduce the size of products where possible, a concept sometimes referred as **dematerialization**. A smaller, product (say, car) may use less amount of material and energy (life-cycle analysis) for doing the same task than its counterpart. Miniaturization, as in electronics, can also save substantial amount of raw material and energy due to their efficiency in material (small size), time (fast), and energy (consumes very less energy, automation saves wastages). Many a times they are more dependable and more powerful e.g. computer. However, sometimes the dematerialization process brings such complexity in the design of the products and incorporate such materials (various sophisticated alloys) that it may become virtually impossible to disassemble and recycle them when required. This is the case with many modern electronic devices such as transistors, circuit boards and batteries. While going for dematerialization the factor of durability and design for ensuring repair, rebuilding, modification, refurbishment, interchangeable use, reuse and recycling should always be kept in mind.

4.7 SUSTAINABILITY COUNTS ENVIRONMENTAL COSTS

A basic reason why resources are overused is that they are too cheap. The price paid for metals, timber, petroleum, and many other virgin natural resources does not reflect their true environmental costs. These true costs would include all five E's – esthetic, emotional, environmental services and ethical values and long-term economic values. The price paid by consumers for natural resources now usually omits many of these. The price of metal, for instance, rarely includes many of the environmental costs of mining: costs of water pollution of nearby aquatic ecosystems, esthetic loss from a cratered landscape, and so on. Green fees, such as taxes, can incorporate environmental costs into natural resource use. Mining companies, manufacturers, and consumers all respond to higher prices by increasing efficiency, reusing/recycling more, and substituting more. Another way to incorporate long-term and indirect costs is to use basic market principles: consumers can demand sustainable products such as those made with recycled materials. All environmental problems are closely intertwined with economic causes. This is especially true of resources because their extraction and use are directly determined by their profitability. At present, destruction of resources and unsustainable activities are more profitable.

In many cases, sustainable activities produce more jobs than unsustainable ones. Extracting resources are often mechanized and involves fewer jobs. Collecting used material and making furniture, or any item, from recycled or reused material would employ many more people than logging wood etc. Similarly, tourism employs a larger number of persons. Auto repair, which promotes resource efficiency by ensuring consumption of less virgin material for performing the same task, also promotes much higher number of jobs than automobile manufacturing. Indeed designing more durable and repairable products is an important step toward reducing throughput and curing the “throwaway” mentality.

4.8 EARTH-WISDOM SOCIETY

As discussed in the earlier section referring the laws of matter and energy, every individual resource use automatically adds some low-quality energy (waste heat) and waste matter to the environment. Our individual use of matter and energy resource, and the contribution of waste heat, waste matter and pollution to the environment, may seem small and insignificant. But this individual contribution is only one of the ‘inevitable 6-billion plus’ individuals of the globe and each year there is an addition of about 90 million new consumers. Most of today’s advanced industrialized countries are largely **high waste** or **high throughput societies** that attempt to sustain ever-increasing economic growth by increasing the throughput of matter and energy resources in their economic systems (Figure 4.1). These resources flow through the economies of such societies to planetary sinks (air, water, soil, organisms), where pollutants and wastes end up.

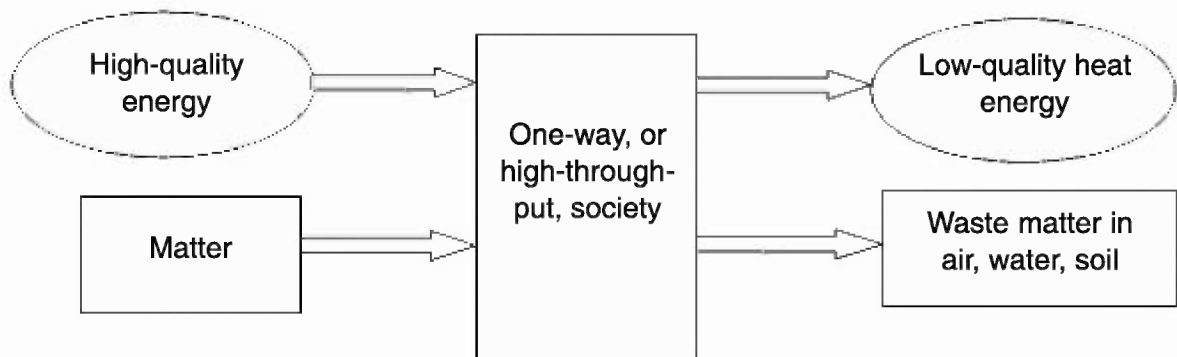


Fig. 4.1: The energy and material flow in high-waste or high throughput societies (figure reproduced from Miller and Tylor, 1996).

If more and more energy and material resources are used and wasted at an ever increasing rate, eventually the assimilative capacity (to dilute and degrade waste matter and pollution, and absorb waste heat) of the local, regional, and global environments will be exceeded. Thus, at some point, high-waste or high-throughput societies (like the modern consumerist ones) become unsustainable. A stopgap solution to this problem is the conversion to a more sustainable **matter-recycling society** from unsustainable high-throughput society. This will allow economic growth to continue without either depleting matter resources or producing excessive waste and environmental degradation. However, it should be kept in mind that even though recycling matter saves energy, always some amount of high-quality energy (which can’t be recycled) is required and adds waste heat to the environment. Along with development of a matter-recycling society, lowering down the population pressure and per capita consumption

pressure on the resource base is highly required for sustainability. Else, we must have an inexhaustible supply of affordable high-quality energy, and an environment with an infinite capacity to absorb and disperse waste heat and to dilute and degrade waste matter. But again, there is a limit to the number of times some materials, such as paper fiber, can be recycled before they become unusable. This shift in resource utilization approach undoubtedly allow us to buy some time, but it is not a solution to more and more pressure on material resource base, even if all of them were somehow perfectly recycled. As suggested by the three scientific laws governing matter and energy changes that the best long-term solution to our environmental and resource problem is to shift to a sustainable **Low-waste society** or **Earth-wisdom society** (Figure 4.2).

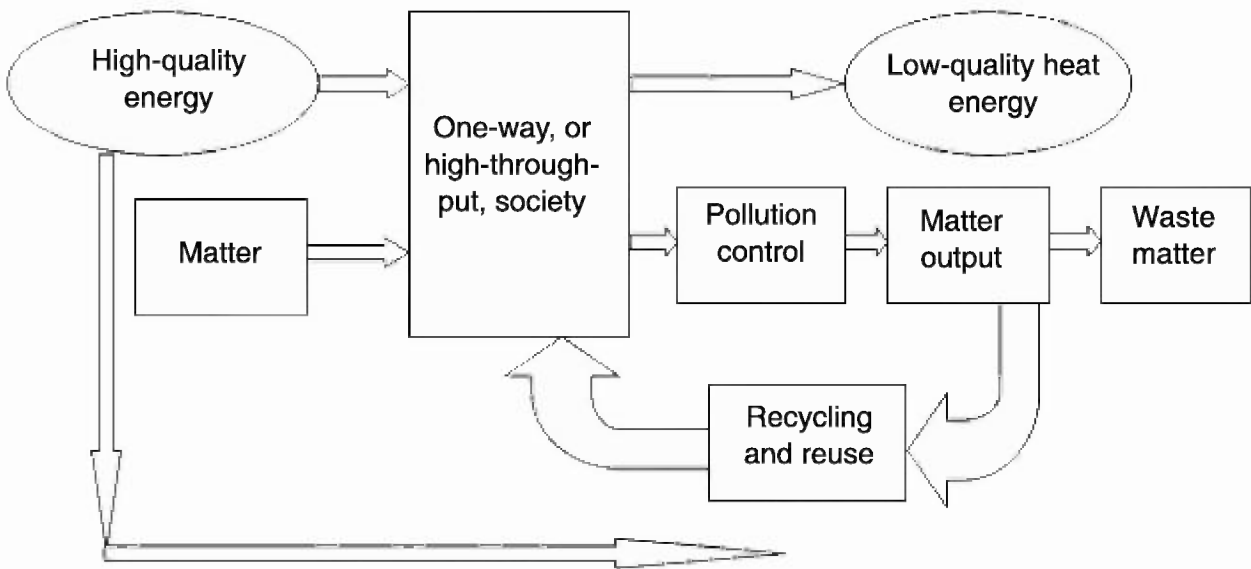


Fig. 4.2: A sustainable low-waste or Earth-wisdom society based on energy flow and matter recycling (figure reproduced from Miller and Tylor, 1996).

Check Your Progress 2

Note: a) Use the space given below for your answer.

b) Compare your answers with those given at the end of the unit.

1) Explain different ways of conserving energy resource.

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2) What are the different approaches of dealing with scarcity of mineral resources?

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3) Explain the importance of including environmental costs in goods and services of the market.

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4) Write the path of transformation of a high-waste society to earth-wisdom society

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4.9 LET US SUM UP

- Sustainable utilization may be considered as meeting the present day needs without reducing the quality of life of future generations.
- Since, in every process we produce some waste (both matter and energy); we need to emphasize more on pollution prevention, waste reduction, and more efficient use of resources.
- This can minimize the conversion of high-quality matter/energy into low-quality matter/energy to a great extent.
- Modern resource exploitation is not even close to being sustainable. Many jobs in the high-throughput society are concentrated at both ends of the flow of materials through society i.e. *in resource extraction* and *waste cleanup*.
- By educating people about the individual and environmental benefits of energy savings, use of energy saving practices can be encouraged.
- Mineral scarcity can be dealt by adopting two strategies: i) *expanding the resource base* (by locating new ore deposits or cycling old materials), and ii) *decreasing the demand for the substance* (by finding alternatives or substitutes for the substance) or simply eliminating the need for it through technological developments and changes in lifestyle.
- Recycling of materials is one way to reduce our demand for extraction of virgin material. It increases the stock of usable material virtually.
- A stopgap solution to this problem is the conversion to a more sustainable **matter-recycling society** from unsustainable high-throughput society. This will allow economic growth to continue without either depleting matter resources or producing excessive waste and environmental degradation.

- In a low-throughput society, sustainable world the virgin resources would be more costly, reflecting their true long-term value and promoting highly efficient use of resources, reuse/recycling, and substitution of more abundant and more renewable resources.

4.10 KEY WORDS

Resource Quality	:	It is the degree of usefulness of a matter or energy.
Urban-ore	:	It is the useful material present in an urban landfill.
Precycling	:	It is conservation of resources by using fewer resources for same task.
Recycling Loop	:	The different paths in which a product can be recycled into different products or different products into a product is called a recycling loop.
Energy Conservation	:	It refers to decreasing the wastage and increasing the energy efficiency.
Dematerialization	:	It is the miniaturization of products or increasing the efficiency of a process so that same job can be performed with fewer amounts of material and energy.
Negawatt	:	It is a concept of saving energy by using efficient appliances and processes.

4.11 REFERENCES AND SUGGESTED FURTHER READINGS

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- Gill, Bruce 2004. Challenges of Change. In Manfredo, M.J., Vaske, J.J., Bruyere, B.L., Field, D.R. and Brown, P.J. Society and Natural Resources: A Summary of Knowledge: 35-46
- McKinney, M.L. and Schoch, R.M. 1998. Environmental Science: Systems and Solutions. Jones and Bartlett Publishers, Boston. 639 pp.

4.12 KEY TO CHECK YOUR PROGRESS

Check Your Progress 1

- 1) Your answer must include the following points:
 - Energy quality
 - Matter quality
 - Energy and matter in biological systems
- 2) Your answer must include the following points:
 - Depletion of matter
 - Depletion of energy resources
 - Bubble pattern of resource depletion

- 3) Your answer must include the following points:
- Importance of resource conservation
 - Principles of resource conservation
 - Practices of resource conservation

Check Your Progress 2

- 1) Your answer must include the following points:
- Energy efficiency
 - Energy saving awareness
 - Role of government
- 2) Your answer must include the following points:
- Expanding resource base
 - Recycling
 - Substitution
 - Durability of products and dematerialization
- 3) Your answer must include the following points:
- Present way of pricing
 - Different environmental costs
 - Benefits of including environmental costs
- 4) Your answer must include the following points:
- High waste society
 - Matter recycling society
 - Earth-wisdom-society