Energy Management

Unit

9

Unit 9
Energy Management

Introduction

'Energy management' is a term that has many pronged implications. However, our focus will be directed at saving energy in businesses, public-sector/government organisations and homes.

What is ENERGY-SAVING?

With respect to energy saving, energy management is the process of monitoring, controlling and conserving energy in a building or organisation. Characteristically, it is inclusive of the following steps:

- Metering energy consumption and collecting data
- Discerning ways and options to save energy and estimating how much energy can be saved by managing to do all of this.
- Analysing meter data to determine, quantify routine energy waste, and investigate energy savings that you could make by replacing equipment (e.g. lighting) or by upgrading your building's insulation are examples of energy management.
- Taking action to target the opportunities to save energy (i.e. tackling the routine waste and replacing or upgrading the inefficient equipment). You would typically commence with the best opportunities first.
- Tracking progress by analysing meter data to see how well your energy-saving efforts have worked.

Energy Management

Many people use 'energy management' to refer specifically to those energy-saving efforts that focus on making better use of existing buildings and equipment. Strictly speaking, this limits the scope of energy management to behavioural aspects of energy saving, although the use of cheap control equipment such as timer switches is often included in the definition as well.

Fundamentals of Energy Management

The term 'energy management' does not pertain to saving energy in buildings alone it is also employed in other fields:

- Energy management is undertaken by energy suppliers (or utility companies) in order to ensure that their power stations and renewable energy sources generate adequate energy to fulfil demand (the amount of energy that their customers need).

- Energy management is used to allude to techniques for managing and controlling one's own level of personal energy.

- It also has relevance in aviation, as energy management is a skill that aircraft pilots learn in some shape.

Home Energy Management

Most people desire that the home energy-management system should afford description of the amount of energy being consumed, techniques to make their home energy efficient or tools to manage their energy needs without compromising on quality. A good home energy-management system should possess the following qualities:

- **Simplicity:** Many people want the system to demonstrate daily energy consumption. They want to know how much energy they will conserve by switching off major home appliances like refrigerators, heating and air-conditioning systems. A simple and effective device is thermostat software to automate heating and cooling. This lowers the bills while maintaining the desired level of comfort.

- **Utility-free:** Some home energy management systems only work when they can be integrated with power meters installed by electric utilities. However, there are devices, which can be used without being attached to any meter. These are plug in devices which can be used for household and commercial establishments and save as much as 30% electricity. These devices optimise voltage and current demands thus reducing active power demands and thereby saving electricity.

- **Rule setting:** There are web-based interfaces, which enable control of home energy use. A consumer can allocate and declare a certain amount of money he wants to pay for electricity. The energy management system manages the power flow between various appliances and directs power to the appliance, which is doing important functions at that time. For example, more power is directed to lighting system during the night and so on.

- **Remote control:** Controlling home appliances remotely is the latest drift in home energy management. It is now possible to leave an appliance on and the energy management system will switch it off at the appropriate time. For example, the washing machine can be loaded before one leaves the house and it will be automatically switched off. Switching on the AC or heater before one reaches home can be done remotely. Mobile applications, which allow one to switch on and off the appliances from the phone, are being designed.

- Simple measures like adding insulation, tinting of window glass, using skylight for illumination, CFL bulbs, solar heaters conserve huge amounts of energy.

Why Is It Important?

Energy management is the answer to energy conservation and economical use of money. Keeping in view the global need to save energy, energy conservation at home is of great importance. This global need affects energy prices, emissions targets and legislation, all of which lead to several compelling reasons why one should save energy.

Controlling and reducing home energy consumption is important because it enables:

- **Reduction in costs:** This is gaining importance as energy costs rise.
- **Reduction is carbon emissions and environmental damage:** This mitigates environmental damage as well as the cost-related implications of carbon taxes and so on. Organisations can reduce their carbon footprint to promote a green, sustainable and healthy environment
- **Reduce risk:** The more energy is consumed, the greater the risk that energy price increases or supply shortages could seriously affect the day-to-day working of the household. With energy management, one can condense this risk by reducing demand for energy and by controlling it to make it more predictable.

The Global Need To Save Energy

The term 'energy management' has come to the forefront because of a global immediate need to save energy. The environmental damage that this consumption is doing is tremendous. The main reasons for energy conservation are as follows: Globally, we need to save energy to achieve the following:

- Reduce the damage to the planet that ensues owing to human activities. Earth had limited supply of resources and it is important to make these resources last.
- Reduce our dependence on fossil fuels that are becoming increasingly limited in supply.

Controlling and Reducing Energy Consumption in Organisation

Energy management is the means of controlling and reducing your organisation's energy consumption. This is of pivotal importance since it enables organisations to achieve the following:

- **Reduce costs:** This is becoming increasingly important as energy costs are on the rise.
- **Reduce carbon emissions:** It is necessary to reduce carbon emissions owing to the environmental damage that they cause. Another aspect of increased carbon emissions is cost-related implications of carbon taxes.. Organisations look forward to maintaining a minimal carbon footprint in order to promote a green, sustainable image, which would help that organisation achieve better social acceptance.
- **Reduce risk:** Energy consumption is directly proportional to risk or rising prices and inversely proportional to supply. Moreover, if there is risk of increase of energy price or shortage of supply, it could have a negative impact on profitability. It may even put the future of the business/organisation in jeopardy. With energy management, you can reduce this risk by reducing your demand for energy and by controlling it in order to make it more predictable.

Energy management is vital since it will help the company at various points. In the present scenario, it is probable that there will be an aggressive energy-consumption reduction target in the near future. An understanding of effective energy management would prove useful in meeting those targets.

Best Ways to Manage Energy Consumption

There are four integral steps to the energy-management process, which have been discussed below.

1. Metering your energy consumption and collecting the data

As a rule of thumb: Extensive and detailed data is most beneficial.

The old school approach to energy-data collection is to take meter readings once a week or once a month manually. However, this poses difficulty since; it is a less efficient way of collecting data as compared to data that is made available easily and automatically from the modern approach. The modern approach to energy-data collection is to install interval metering systems that automatically measure and record energy consumption at short, regular intervals such as every 15-minutes or half hour.

Detailed interval energy consumption data allows one to see patterns of energy waste that would be impossible to see otherwise. For example, weekly or monthly meter readings cannot show the consumption of energy at different times of the day or on different days of the week. In addition, these patterns make it much easier to determine if energy is being wasted or is not being utilised properly in your building.

2. Finding and quantifying opportunities to save energy

The detailed meter data will be invaluable for determining and quantifying energy saving opportunities.

The easiest and most cost-effective energy-saving opportunities typically require little or no capital investment. For example, many companies and private households possess advanced control systems that could and should, be controlling HVAC (Heating Ventilation Air conditioning).

However, the lack of knowledge of the facilities-management staff, may result is wastage of energy while heating or cooling an empty building.

One of the simplest ways to save a significant amount of energy is to encourage staff to switch off equipment at the end of each working day. Examining detailed interval energy data is the ideal way to locate routine energy waste. This can be used to unearth whether the staff and electronic timers are conserving energy. This saves the owner trouble in terms of personal patrolling. This was the employer can establish who or what is causing the energy wastage.

In addition, detailed interval data, is crucial in identifying the amount of energy being wasted at different times. For example, if it is identified that energy is being wasted by equipment left on over the weekends, one can:

- Use interval data to calculate how much energy (in kWh) is being used each weekend
- Estimate the proportion of the energy that is being wasted (by equipment that should be switched off)
- Calculate an estimate of the total kWh that is wasted each weekend

Alternatively, if you are unaware of the proportion of energy that is being wasted by equipment left on unnecessarily, one could:

- Visit the building one evening to ensure that everything that should be switched off is switched off.
- Look back at the data for that evening to see how many kW were being used after you switched everything off.
- Subtract the target kW figure (b) from the typical kW figure for weekends to estimate the potential savings in kW (power).

Multiply the kW savings by the number of hours over the weekend to get the total potential kWh energy savings for a weekend.

3. Targeting the opportunities to save energy

Finding opportunities to save energy is not the sole answer to energy conservation. For those energy-saving opportunities that require you to motivate people to save energy, it is important to comprehend how systems work and how they make the planet a better place to stay in. It may require hard work but if you can convince people, saving energy will be achievable without investing anything other than time.

4. Tracking your progress at saving energy

Once you have taken action to save energy, it is important to take feedback and determine the efficacy of your actions.

- Energy savings that stem from behavioural changes (e.g. getting people to switch off their computers before going home) need frequent attention to ensure that they remain effective and achieve their maximum potential.
- If you have invested money in new equipment, you may want to determine whether the energy savings you predicted have been achieved.
- If you have corrected faulty timers or control-equipment settings, you would need to keep checking back to ensure that everything is still working as it should be. Simple things like a power cut can easily cause timers to revert to factory settings- if you are not keeping an eye on your energy-consumption patterns, you can easily miss such problems.
- If you have been given energy-saving targets, then you will need to provide evidence that you are either meeting these goals or making progress towards these goals.

Managing Energy Consumption Effectively: An Ongoing Process

Continuous monitoring of data is necessary to ensure that there is no hindrance or decline in energy conservation. If consumption is not being monitored accurately, it will not work as energy consumption will not work efficiently and in due course it will lead to an increase in the wastage of energy and more energy: it is to be expected that equipment will break down or lose efficiency and that people will forget the good habits you worked hard on to encourage in the past.

Therefore, at a minimum, monthly or weekly monitoring of energy data is advisable to ensure that nothing has gone wrong. It is unfortunate when easy-to-fix faults such as misconfigured timers remain unnoticed for months on end, resulting in a huge energy bill that could have easily been avoided.

Ideally, the energy-management drive is an ongoing effort to find new opportunities (step 1), to target them (step 2) and to track progress at making ongoing energy savings (step 3). Managing energy consumption does not have to be a full-time job, but will achieve much better results if it is made a part of regular routine.

Fossil Fuel Use

Fossil fuels are fuels formed by natural resources through processes such as anaerobic decomposition of buried dead organisms. The age of the organisms and their resulting fossil fuels is typically millions of years and sometimes exceeds 650 million years. The fossil fuels include coal, petroleum and natural gas, which contain high percentages of carbon.

Fossil fuels range from volatile materials with low carbon: hydrogen ratios like methane, to liquid petroleum to non volatile materials composed of almost pure carbon like anthracite coal. Methane can be found in hydrocarbon fields alone, associated with oil or in the form of methane clathrates. It is generally accepted that they formed from the fossilised remains of dead plants and animals by exposure to heat and pressure in the Earth's crust over millions of years.

Characteristics, Origin, Applications and Effects

Human beings need energy for most of their activities. Energy is needed for domestic, industrial and agriculture use. This is an industrial process, which can be performed using various sources. These sources can be either renewable or non-renewable.

Renewable energy is the energy that can be reutilised by various and can be renewed will therefore not run out easily. However, non-renewable energy sources are limited and there is a threat that they will run out if they are not used sparingly.

Nowadays many renewable energy sources are available for use, for example, solar and wind energy and water power. Ironically, we still gain most of our energy from non renewable energy sources, commonly known as fossil fuels. The non-renewability of these sources collaterally increased the price of these fuels and it is anticipated that such rates prices of fuel will rise to a point where they are no longer economically feasible.

Fossil fuels comprise deposits of once-living organisms. The organic matter undergoes various transformations through the ages and takes centuries to form. Fossil fuels principally consist of carbon and hydrogen bonds. There are three types of fossil fuels, which can all be used for energy provision: coal, oil and natural gas. Coal is a solid fossil fuel formed over millions of years by decay of land vegetation. When layers are compacted and heated over time, deposits are turned into coal. Coal is relatively abundant compared to the other two fossil fuels. Analysts predict that worldwide coal use will increase as oil supplies become scarcer. Current coal supplies could last for 200 years or more. Coal is usually found in mines where it is mined with a great deal of difficulty. Since the middle of the 20th century, coal usage has doubled. Since 1996, its application has been on a steady. Many developing countries have to depend on coal for their energy needs because it is a more economical alternative to oil and natural gas.

a) **Oil:** Oil is fossil fuel formed from the remains of marine microorganisms deposited on the sea floor. Over a span of millions of years, these deposits that lie under rock and sediment turn into oil. This oil can be extracted by large drilling platforms. Oil is the most widely used fossil fuel. Crude oil consists of many different organic compounds, which are transformed into products in a refining process. Oil is used for energy for various purposes like cars, jets, roads and so on. However, oil reserves are not abundant. Many wars have been fought over oil supplies. A well-known example is the Gulf War of 1991. Oil is mainly found in countries like Russia, Saudi Arabia, Nigeria, Venezuela, Iraq, Iran and the USA.

b) **Natural gas:** A gaseous fossil fuel, which is multipurpose, abundant and relatively clean when compared to coal and oil. Like oil, it is formed from the remains of marine microorganisms. It is a relatively new type of energy source. Until 1999, more coal was used than natural gas. Natural gas has now overtaken coal in developed countries.

However, people are afraid that, like oil, natural gas supplies will run out. It is also estimated by some scientists that it may happen by the middle or end of the 21st century. Natural gas mainly consists of methane (CH4). Natural gas is found in highly compressed form in small volumes at large depths in the earth. Like oil, it is brought to the surface by drilling. Natural gas reserves are more evenly distributed around the globe than oil supplies.

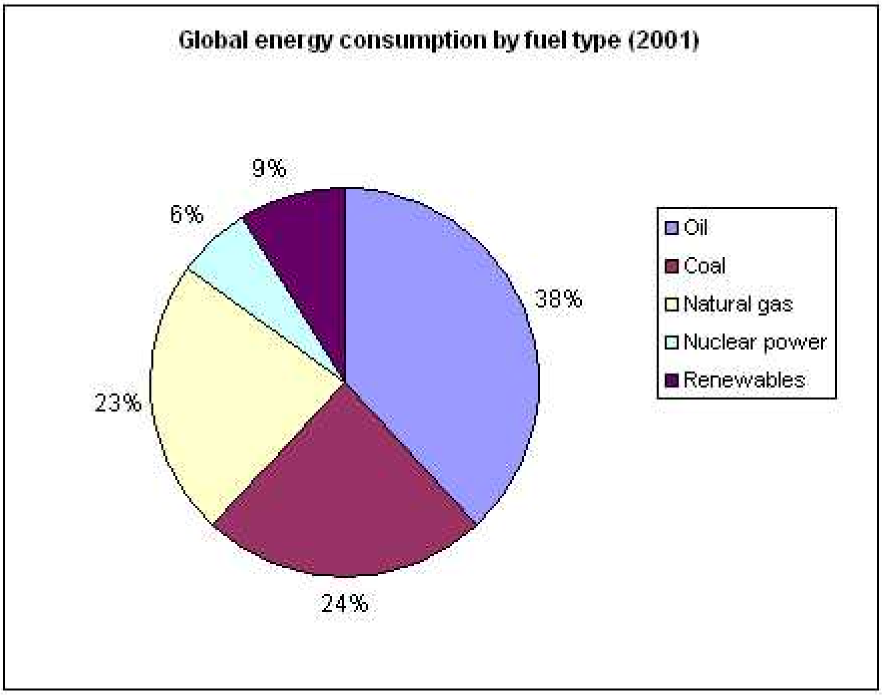

Fig 9.1: Global Energy Consumption by Fuel Type

Energy gained from burning fossil fuels is converted to electricity and heat in commercial power plants. When fossil fuels are burned, carbon and hydrogen react with oxygen in the air to form carbon dioxide (CO2) and water (H2O). During this reaction, heat is released which further amplifies the reaction. Electricity is generated by transforming mechanical energy (heat) to electrical energy in a turbine or generator. Though the investment, in terms of time and money, required to build a power plant is very high, yet the efficiency in converting fuel to energy is very high. It is common for surplus electricity to be created. Electricity demands vary throughout the year and provision must meet the peak load i.e. the highest possible demand within a year. If demands are higher than the supply, it will cause temporary blackouts, as there will be not enough electricity to be supplied throughout the year. An example of this is India, where this is a common occurrence.

Historically, fossil fuels were available in abundance and were easy to obtain and transport. Today, it there is growing awareness that the supply is running out and that it will take centuries to be replenished. Both sources and sinks of fossil fuels are limiting in their use. Sources are deep layers in the earth and sinks are, for example, air and water, which absorb fossil fuel waste products.

However, use of fossil fuels leads to negative environmental repercussion in terms of pollution. Examples are greenhouse gas accumulation, acidification, air pollution, water pollution, damage to land surface and ground level ozone. Sulphur and nitrogen, which are inherent in fossil fuel structures, combine with oxygen during the process of combustion and for noxious gases like sulphur dioxide and nitrogen oxide and so on. When these gases mix with water, they form acids, which is detrimental to human and animal health. It also causes damage to property. 30% of all carbon dioxide emissions in the air are attributed to carbon combustion. Natural gas does not release as much carbon dioxide because of its methane structure. Coal combustion results in the highest number of emissions in the world. Coal may result in underground fires that are virtually impossible to extinguish. Coal dust can also explode. The precarious nature of coal mining makes it a dangerous profession. Oil on the other hand, may end up in soil or water in its raw form, for example, during oil spills or wars. Such oil spills are damaging for marine flora and fauna.

Even with such potentially detrimental repercussions, fossil fuels continue to be used. They are a preferred source of energy, since renewable sources of energy have higher generation and maintenance costs. Renewable energy is very expensive as compared to non-renewable energy and its use can only be sustained if supported by government grants. Some environmental scientists predict that fossil fuel prices will increase in the coming century because of their scarcity. This may cause an ensuing transfer to renewable energy sources. According to Bjorn Lomborg, this situation is inexorable. This is only one of the perspectives on the future of fossil fuel use. Some maintain that fossil fuels cannot be entirely replaced by renewable sources of energy.

Importance

Fossil fuel is accorded immense importance since its combustion produces significant amounts of energy. The use of coal as a fuel predates recorded history. Coal was employed to run furnaces for the melting of metal ore. Semi-solid hydrocarbons from seeps were used as fuel, for waterproofing and embalming. Commercial exploitation of petroleum as a replacement for animal fat in oil lamps began in the nineteenth century.

Natural gas, once flared-off as an unneeded by product of petroleum production, is now considered a very valuable resource. Heavy crude oil, which is much more viscous than conventional crude oil and tar sands, where bitumen is found mixed with sand and clay, is considered an important source of fossil fuel. Oil shale and similar materials are sedimentary rocks containing kerogen, a complex mixture of high-molecular weight organic compounds, which yield synthetic crude oil when heated (pyrolyzed). These materials are yet to be exploited commercially. These fuels are employed in internal combustion engines, fossil fuel power stations and other uses.

Prior to the latter half of the eighteenth century, windmills or watermills provided energy required for industry such as mills and for other uses such as sawing wood, pumping water and burning wood or peat for domestic heat. The wide-scale use of fossil fuels, coal at first and petroleum later, to fire steam engines, enabled the Industrial Revolution. This was accompanied by use of gaslights that required natural gas or coal gas for lighting. The invention of the internal combustion engine and its use in automobiles and trucks greatly increased the demand for gasoline and diesel oil, both made from fossil fuels. Other forms of transportation, railways and aircraft, also required fossil fuels. The other foremost use for fossil fuels is in generating electricity and the petrochemical industry. Tar, a leftover of petroleum extraction, is used in the construction of roads.

Uses of Fossil Fuels

Fossil fuels is the name given to a group of substances believed to have been formed by the decomposition of plant and animal matter under intense pressure and heat over hundreds of millions of years. The key forms of fossil fuels are coal, oil and natural gas. According to the Department of Energy, fossil fuels are used for more than 85 percent of all energy consumption in the U.S.

- **Electricity:** Fossil fuels, particularly coal, are used in power plants for electricity production.
- **Transportation:** While there has been some transition toward hybrid and electric vehicles, the vast majority of vehicles require fossil fuels to operate.
- **Heating:** Most heating needs are met through fossil fuel-based heating oils and natural gas or indirectly through fossil fuel-generated electricity.
- **Cooling:** Like heating, most cooling systems rely directly or indirectly on fossil fuel provided energy.
- **Considerations:** While fossil fuels are the core source of current energy production, they are considered a limited, non renewable and polluting energy source. These factors will ultimately require the development of large-scale alternatives.

Fossil Fuel Energy

A. OIL

Oil is a thick, black, viscous liquid that is also called petroleum. It is found deep below the Earth's surface, usually between layers of rock. Oil mining entails digging of oil well, pumping of oil and the subsequent shipping of oil. Oil that is pumped out is carried in pipelines and large tanker ships. A refinery changes the oil into products like gasoline, jet fuel and diesel fuel. It is also burned in factories and power plants to produce electricity. When the oil is burned, it produces gases that make a turbine turn in order to create electricity.

B. NATURAL GAS

Natural gas is lighter than air. It mail component is methane, which is a simple chemical compound made up of carbon and hydrogen atoms. This gas is highly inflammable. Natural gas reserves are found near oil reserves in the ground. The process of extraction of natural gas is similar to that of oil. Natural gas is obtained by pumping it from the ground and transporting it through large pipelines. Natural gas is mixed with a chemical in order to give it a distinct smell- like rotten eggs- as it is not possible to differentiate between the gas and the environment. This is done to ensure detection in instances of gas leaks. This odour infused gas is then utilised for industrial and domestic use. It is also used to generate electricity. Natural gas is burned to produce heat, which boils water, creating steam, which passes through a turbine to generate electricity.

Coal comes in several different forms ranging from hard black rocks to soft brown dirt. There are different grades of coal and a few grades will burn hotter and cleaner than others. Coal is used to create more than half of all the electricity made in the US. In some states, many coal beds are located near the surface. Coal is extracted by mining. It is usually transported by trains to power plants where it is burned to produce steam. The steam turns turbines, which produce electricity.

2. Benefits

One of the biggest benefits of fossil fuels is their cost. Coal, oil and natural gas are abundant today and are relatively inexpensive to drill or mine. In fact, coal is the only fossil fuel that is found everywhere in abundance when compared to other fossil fuels which are not found in most parts of the world. Thus, electricity and fuels for transportation and heating are available to everyone because their costs are contained.

3. Limitations

- **Non renewable Resource:** Fossil fuels are a non renewable resource. Fossil fuels take millions of years to develop under extreme conditions. Once they are used, they can no longer be part of our energy mix.
- **Environmental Impact:** Fossil fuel combustion has a negative environmental impact. Its use has contributed to global climate change, acid rain and ozone problems. There are new technologies under development that could help make fossil fuels much more efficient and cleaner. These technologies could keep fossil fuels in the energy mix for the future.

- **Geographical Considerations:** Controlling fossil fuel resources is of pivotal importance since these fuels play an important role in powering our lifestyles and economy. The
  United States is one of the countries that have large amounts of deposits of coal, which is one of the main fuels for electric generation. The biggest supply of oil is not in the U.S. but in the Middle East. Any disruptions in that supply or increase in the cost of that supply could have huge effects on the daily lives of its citizens. Shipping the oil across the ocean can lead to other risks such as oil spills.

- **Supply and Demand:** The reason fossil fuels are majorly relied on is due to the simple economics- supply and demand. Coal is currently an abundant resource and the US government continues efforts to keep a steady supply of oil flowing to the United States, which has ensured it feasibility for consumers.

Energy Production and Trade

The transformation of energy in an ecosystem begins first with the input of energy from the sun. The process of photosynthesis captures energy from the sun. Carbon dioxide is combined with hydrogen (derived from the splitting of water molecules) to produce carbohydrates (CHO). Energy is stored in the high-energy bonds of adenosine triphosphate or ATP.

All energy available to organisms originates in plants. It is called primary production as it involves the first process of converting the energy from the sun into other forms of energy. This process is termed photosynthesis. Herbivores obtain their energy by consuming plants or plant products, carnivores eat herbivores and detritivores consume the droppings and carcasses of us all.

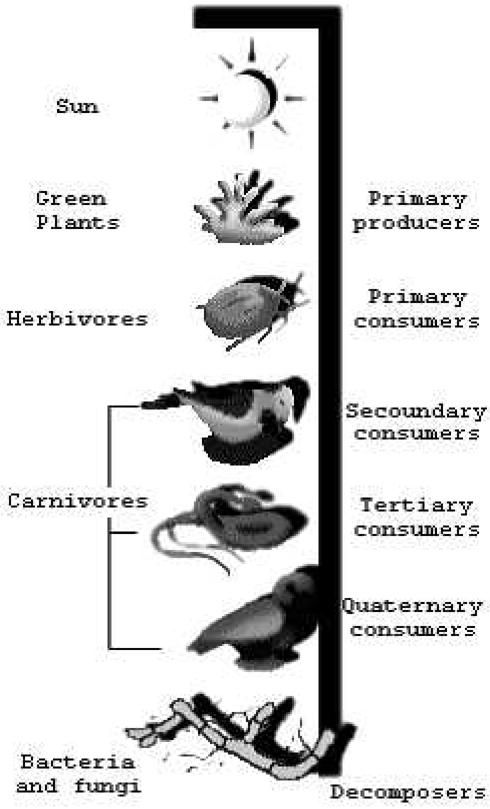

Fig : 9.2 Formation of Fossil Fuel

A simple food chain is portrayed in which energy from the sun, captured by plant photosynthesis, flows from trophic level to trophic level via the food chain. A trophic level is composed of organisms that make a living in the same way i.e. they are all primary producers (plants), primary consumers (herbivores) or secondary consumers (carnivores). Dead tissue and waste products are produced at all levels. Scavengers, detritivores and decomposers then consume such 'waste'. Creatures like vultures and microorganisms like bacteria are responsible for this-- consumers of carcasses and fallen leaves may be other animals, such as crows and beetles but ultimately microbes complete the job of decomposition. Not surprisingly, the amount of primary production varies a great deal from place to place due to differences in the amount of solar radiation and the availability of nutrients and water.

Energy transfer through the food chain is inefficient. This means that less energy is available at the herbivore level than at the primary producer level, less yet at the carnivore level and so on. The result is a pyramid of energy, with important implications for understanding the quantity of life that can be supported.

We usually assume that the food chain comprises green plants, herbivores and so on. These are referred to as grazer food chains because living plants are directly consumed. In many circumstances, the principal energy input is not green plants but dead organic matter. These are called detritus food chains. Examples include the forest floor or a woodland stream in a forested area, a salt marsh and most importantly, the ocean floor in very deep areas where all sunlight is extinguished at depths of 1000metres and above. However, the organisation of biological systems is much more complicated and cannot be represented by a simple 'chain'. They are difficult to understand as well. There are many food links and chains in an ecosystem and we refer to all of these linkages as a food web. Food webs can be extremely complicated, where it appears that 'everything is connected to everything else' and it is important to understand what the most important linkages are in any particular food web.

Controls on Ecosystem Function

There are two dominant theories of the control of ecosystems. The first, called bottom-up control, states that the nutrient supply to the primary producers that ultimately controls how ecosystems function. If the nutrient supply is increased, the resulting increase in production of autotrophs is propagated through the food web and all of the other trophic levels will respond to the increased availability of food (energy and materials will cycle faster).

The second theory, called top-down control, states that predation and grazing by higher trophic levels on lower trophic levels ultimately controls ecosystem function. For example, if you have an increase in predators, that increase will result in fewer grazers and that decrease in grazers will result, in turn, in more primary producers because fewer of them are being eaten by the grazers. Thus, the control of population numbers and overall productivity 'cascades' from the top levels of the food chain down to the bottom trophic levels.

Both the theories are accurate to some extent in various aspects and they sometimes work in tandem with each other. Neither of them works with full authority. Well, as is often the case when there is a clear dichotomy to choose from, the answer lies somewhere in the middle. For example, the 'top-down' effect is often very strong at trophic levels near the top predators but the control weakens as you move further down the food chain. Similarly, the 'bottom-up' effect of adding nutrients usually stimulates primary production but the stimulation of secondary production further up the food chain is less strong or is absent.

Thus, we find that both these controls operate in any system at any time and we must understand that both the systems are important and we should not underestimate the importance of any of them. The relative importance of each control helps us to predict how an ecosystem will behave or change under different circumstances, for example, in the face of a changing climate, how the ecosystem will respond and how adaptations would be made accordingly.

The Geography of Ecosystems

There are many different ecosystems: rain forests and tundra, coral reefs and ponds, grasslands and deserts. Each of these locations has a different geography, system, human interference etc in them. Climate differences from place to place largely determine the types of ecosystems we see. The dominant vegetation influences the appearance of terrestrial ecosystems.

The word ‘biome’ is used to depict a major vegetation type such as tropical rain forest, grassland, tundra etc., extending over a large geographic area. It is never used for aquatic systems, such as ponds or coral reefs. It always alludes to a vegetation category that is dominant over a very large geographic scale and has a wider scope than an ecosystem.

Energy Balance Ecosystem Concepts

Ecosystem

An ecosystem comprises all the organisms living in a particular area, as well as all the nonliving, physical components of the environment with which the organisms interact, such as air, soil, water and sunlight. All these organisms along with the non-living things create a system, which is self-working and self managing. It is all the organisms in a given area, along with the nonliving (abiotic) factors with which they interact; a biological community and its physical environment. The entire array of organisms inhabiting a particular ecosystem is called a community. In a typical ecosystem, plants and other photosynthetic organisms are the producers that provide the food. Ecosystems can be permanent or temporary. Ecosystems usually form a number of food webs.

An ecosystem is a functional unit consisting of living flora and fauna in a given area, non-living chemical and physical factors of their environment linked together through nutrient cycle and energy flow.

Ecosystems can be categorised as follows:
1. Natural
a. Terrestrial ecosystem

b. Aquatic ecosystem
- Lentic, the ecosystem of a lake, pond or swamp
- Lotic, the ecosystem of a river, stream or spring

2. Artificial, environments created by humans

Ecosystem Services

Ecosystem services are 'fundamental life-support services upon which human civilisation depends', and can be direct or indirect. Examples of direct ecosystem services are pollination, wood and erosion prevention. Indirect services could be considered climate moderation, nutrient cycles and detoxifying natural substances.

The services and goods an ecosystem provides are often undervalued as many of them are without market value. Some examples include:

- Regulating (climate, floods, nutrient balance, water filtration)
- Provisioning (food, medicine, fur)
- Cultural (science, spiritual, ceremonial, recreation, aesthetic)
- Supporting (nutrient cycling, photosynthesis, soil formation)

Energy transformations and Ecosystem

An ecosystem entails the biological community that occurs in some locale and the physical and chemical factors that make up its non-living or abiotic environment. There are many examples of ecosystems-- a pond, a forest, an estuary, grassland. The boundaries are not fixed in any objective way, although sometimes they seem obvious, as with the shoreline of a small pond. Usually the boundaries of an ecosystem are chosen for practical reasons having to do with the goals of the particular study.

The study of ecosystems mainly consists of the study of certain processes that link the living or biotic, components to the non-living or abiotic, components. Energy transformations and biogeochemical cycling are the main processes that comprise the field of ecosystem ecology. As we learned earlier, when the organisms interact with each other along with the environmental surroundings in which they occur it is called an ecosystem. We can study ecology at the level of the individual, the population, the community and the ecosystem.

Studies of individuals are concerned mostly with physiology, reproduction, development or behaviour. The study of populations usually focus on habitat, resource needs of individual species, their group behaviour, population growth and what limits their abundance or causes extinction. Various research projects try to perceive how myriad organisms interact with each other and work together in either a symbiotic, parasytic or any other relationship. For example, as predators and their prey or competitors share common needs or resources etc. In ecosystem ecology, we study the working system as a complete unit. This means that, rather than worrying mainly about a particular species, we try to focus on major functional aspects of the system. These functional aspects include such issues as the amount of energy that is produced by photosynthesis, how energy or materials flow along the many steps in a food chain or what controls the rate of decomposition of materials or the rate at which nutrients are recycled in the system.

Components of an Ecosystem

The components of the ecosystem can be categorised as 'abiotic' and 'biotic'. Largely, this set of environmental factors is important almost everywhere, in all ecosystems.

ABIOTIC COMPONENTS	BIOTIC COMPONENTS
Sunlight	Primary producers
Temperature	Herbivores
Precipitation	Carnivores
Water or moisture	Omnivores
Soil or water chemistry (e.g., P, NH_4^+)etc.	Detritivores

Table: 9.1

Usually, biological communities include the 'functional groupings' shown above. A functional group is a biological category composed of organisms that perform mostly the same kind of function in the system, for example, all the photosynthetic plants or primary producers form a functional group. Membership in the functional group does not depend very much on whom the actual players (species) happen to be, only on what function they perform in the ecosystem.

Processes of Ecosystems

Energy enters the system in the form of sunlight or photons, which is transformed into chemical energy in organic molecules by cellular processes including photosynthesis and respiration and ultimately is converted into heat energy. This energy is dissipated, meaning it is lost to the system as heat; once it is lost, it cannot be recycled. These ecosystems depend upon sunlight, as a source of energy, for their survival. Without this energy, everything would collapse and quickly shut down. Thus, the Earth is an open system in respect to energy.

Elements such as carbon, nitrogen or phosphorus enter living organisms in a variety of ways. Plants obtain elements from the surrounding environment through water or soil. Animals may also obtain elements directly from the physical environment, but usually they obtain these mainly because of consuming other organisms. Although these materials are transformed biochemically within the bodies of organisms, eventually due to excretion or decomposition, they are returned to an inorganic state. Bacteria become the last part of this process and they are involved in the process called decomposition or mineralisation.

During decomposition, these materials are not destroyed or lost. Thus, the earth is regarded as a closed system with respect to elements (with the exception of a meteorite entering the system now and then). The elements are cycled endlessly between their biotic and abiotic states within ecosystems. Those elements whose supply tends to limit biological activity are called nutrients.

Basic Concepts and their Applications in business

'Energy Management System' is becoming a widely accepted concept with a rise in energy costs, non-availability of quality power and increased awareness about energy management among consumers.

Creating awareness regarding the need for energy management, incentives for best energy-managed companies and power tariff structure suited to encourage energy saving can improve the existing power situation and will help formulate a better planned power supply system.

An integral energy management system for a building for controlling and monitoring of data, requires considerable investment. In addition, neither monitoring nor controlling is an end in itself, there has to be reasons and ultimate objectives in investing considerable amounts of money in this regard.

The investment is contingent upon the type of building, range of parameters to be monitored, utilities to be connected to the system and level of sophistication. Hence, in opting for an energy management system, care should be taken to arrive at an appropriate system with the desired level and range of operation. The monitored parameters should be recorded and studied carefully, in order to evolve necessary steps and maintenance schedules for optimum use of energy.

Industrial Ecology and Recycling Industry

Industrial Ecology (IE) has been defined as a "systems-based, multidisciplinary discourse that seeks to understand emergent behaviour of complex integrated human/natural systems". This field approaches issues of sustainability by examining problems from multiple perspectives, usually involving aspects of sociology, the environment, economy and technology. The name germinates from the idea that we should use the analogy of natural systems as an aid in understanding how to design sustainable industrial systems.

Industrial ecology is the shifting of the industrial process from linear (open loop) systems, in which resource and capital investments move through the system to become waste, to a closed loop system where wastes become inputs for new processes. The main criterion here is to manage wastes and improve efficiency.

Relation to Evolution

Ecology and evolution are considered sister disciplines of the life sciences. Natural selection, life history, development, adaptation, population and inheritance are examples of concepts that thread equally into ecological and evolutionary theory. Morphological, behavioural and/or genetic traits, for example, can be mapped onto evolutionary trees to study the historical development of a species in relation to their functions and roles in different ecological circumstances. In this framework, analytical tools of ecologists and evolutionists overlap as they organise, classify and investigate life through common systematic principals, such as phylogenetics or the Linnaean system of taxonomy. No clear boundary that distinguishes ecology from evolution and both differ more in their areas of applied focus. Both disciplines discover and explain emergent and unique properties and processes operating across different spatial or temporal scales of the organisation. While the boundary between ecology and evolution is not always clear, it is understood that ecologists study abiotic and biotic factors that influence the evolutionary process.

Relation to the Environment

"The environment of any organism is the class composed of the sum of those phenomena that enter a reaction system of the organism or otherwise directly impinge upon it to affect its mode of life at any time throughout its life cycle as ordered by the demands of the ontogeny of the organism or as ordered by any other condition of the organism that alters its environmental demands".

The environment is dynamically interlinked with ecology. Like the term ecology, the term environment also has different conceptual meanings. To many, these terms also overlap with the concept of nature. Environment includes the physical world, the social world of human relations and the built world of human creation. It describes the physical environmental attributes or parameters that are external to the level of biological organisation under investigation. It includes abiotic factors such as temperature, radiation, light, chemistry, climate and geology and biotic factors including genes, cells, organisms, members of the same species and other species that share a habitat. The physical environmental connection means that the laws of thermodynamics apply to ecology. Armed with an understanding of metabolic and thermodynamic principles, a complete account of energy and material flow can be traced through an ecosystem.

Environmental and ecological relations are studied through reference to conceptually manageable and isolated parts. However, once the effective environmental components are understood, they conceptually link back together as a holocoenoti system. In other words, the organism and the environment form a dynamic whole. Change in one ecological or environmental factor can concurrently affect the dynamic state of an entire ecosystem.

Ecological studies are necessarily holistic as opposed to reductionist. Holism has three scientific meanings or uses:

- The mechanistic complexity of ecosystems
- The practical description of patterns in quantitative reductionist terms where correlations may be identified but nothing is understood about the causal relations without reference to the whole system
- Owing to the above, a metaphysical hierarchy whereby the causal relations of larger systems are understood without reference to the smaller parts

An example of the metaphysical aspect to holism is the trend of increased exterior thickness in shells of different species. The reason for a thickness increase can be understood through reference to principles of natural selection via predation without any reference to the bio molecular properties of the exterior shells.

Ecosystems are primarily governed by stochastic (chance) events, the reactions these events provoke on non-living materials and the responses by organisms to the conditions surrounding them. Thus, an ecosystem results from the sum of individual responses of organisms to stimuli from elements in the environment. The presence or absence of population merely depends on reproductive and dispersal success and population levels fluctuate in response to stochastic events. As the number of species in an ecosystem is higher, the number of stimuli is also higher. Since the beginning of life, organisms have survived continuous change through natural selection of successful feeding, reproductive and dispersal behaviour. Through natural selection, the planet's species have continuously adapted to change through variation in their biological composition and distribution.

Mathematically, it can be demonstrated that greater numbers of different interacting factors tend to dampen fluctuations in each of the individual factors.

- Ecosystems comprise abiotic (non-living, environmental) and biotic components and these basic components are important to nearly all types of ecosystems. Ecosystem ecology looks at energy transformations and biogeochemical cycling within ecosystems.

- Energy continuously enters an ecosystem in the form of light energy and some energy is lost with each transfer to a higher trophic level. Nutrients, on the other hand, are recycled within an ecosystem and their supply normally limits biological activity. Therefore, "energy flows, elements cycle".

- Energy is moved through an ecosystem via a food web, which comprises interlocking food chains. Energy is first captured by photosynthesis (primary production). The amount of primary production determines the amount of energy available to higher trophic levels.
- The study of how chemical elements cycle through an ecosystem is termed biogeochemistry. A biogeochemical cycle can be expressed as a set of stores (pools) and transfers and can be studied using the concepts of 'stoichiometry', 'mass balance' and 'residence time'.
- Ecosystem function is controlled mainly by two processes, the 'top-down' and 'bottom up' controls.
- A biome is a major vegetation type extending over a large area. Biome distributions are determined largely by temperature and precipitation patterns on the Earth's surface.

Recycling

Recycling involves processing used and unwanted materials (waste) into new products in order to prevent wastage of potentially useful materials. It intends to reduce the consumption of fresh raw materials; reduce energy usage, air pollution (from incineration) and water pollution (from land filling) by reducing the need for 'conventional' waste disposal and lowering greenhouse gas emissions as compared to fresh production. Recycling is a key component of modern waste reduction and is the third component of the 'Reduce, Reuse, Recycle' waste hierarchy.

Recyclable materials include many kinds of glass, paper, metal, plastic, textiles and electronics. These materials have to be managed differently. Although similar in effect, the composting or other reuse of biodegradable waste– such as food or garden waste – is not typically considered recycling. Materials to be recycled are brought to a collection centre or picked up from the curbside, then sorted, cleaned and reprocessed into new materials bound for manufacturing.