UNIT 9 ENERGY

Structure

9.1 INTRODUCTION

You are familiar with the term energy. You have studied about it in the very first course of this programme. In the newspaper you may have often read about various sources of energy, solar energy, hydropower etc. Technically, energy is a term used to describe or measure the amount of work done for any activity. Suppose you have to lift a bucket (10 litres) of water from a 10 metre deep well or from the ground floor of a house to its first floor. To lift the water, you have to do work, and energy is required to do this work. Similarly, suppose you have to boil one litre of milk. What will you do? You will heat the milk until it boils. How will you heat it? You will use cooking gas or kerosene oil, firewood or electrical heater, etc. This means that all of them have the capacity to heat milk. They are called as **energy sources.**

You are familiar with electrical energy, which is used for providing heat and light as well as running motors and pumps. Heat, light and electrical energy are various **forms of energy**. Without going into too many technical details about energy, in this unit we focus on the various issues involved in the management of energy as a resource, particularly with reference to agriculture.

We draw your attention to the energy needs of the agricultural sector and how these can be fulfilled without polluting the environment. In this context, the renewable energy resources have an important role to play. In rural areas, the issue of energy is not purely a technological issue. It has a socio-economic dimension that you should be aware of. Finally, we consider strategies of conserving and managing energy. In the next unit, we consider the issues and challenges we face in the management of off-farm inputs.

Objectives

After studying this unit, you should be able to:

- describe the energy needs of the agricultural sector;
- discuss the renewable energy resources viz., solar energy, biomass energy, bio-fuels, wind energy;
- explain how best renewable sources of energy can be used in agriculture; and
- discuss various strategies for energy conservation and methods to achieve higher efficiency in energy use in agriculture.

9.2 THE ENERGY SCENARIO IN AGRICULTURE

Agriculture is basically a process of conversion of energy. In this process, solar energy is converted to chemical energy, as plants make their food in the presence of sunlight. Plants use the solar energy to convert it into chlorophyll, the green substance in leaves that gives them their colour, in a process called **photosynthesis**. Modern agriculture enhances production of biomass by increasing photosynthesis through better plant types, use of irrigation water, fertilizer, pesticides and other growth promoters.

Agriculture is both a producer as well as a consumer of energy. Some energy inputs in agriculture are commercial like animal power, diesel, fertilizer, irrigation water, seeds, etc. while some are provided free of cost by nature like solar energy for photosynthesis, rain water, microbial activities in soil, etc. Let us study both these aspects of agriculture in relation to energy.

Units of Power and Energy

The S.I. unit of power is watt whereas S.I. unit of energy is joule.

Since S.I. unit of time is second, we may say

1 joule = 1 watt $\times$ 1 second. The familiar unit of electrical energy is kWh (kilowatt-hour).

Hence,

1 kWh = 1000 W $\times$ 3600 seconds = 3600,000 joules = 3600 kJ or 3.6 MJ
1 kJ(Kilojoule)=10^3 J,
1 MJ(Megajoule)=10^6 J

9.2.1 Agriculture as a Consumer of Energy

Crop production (from preparing the land, sowing seeds, managing crops to harvesting the produce and post harvest operations), livestock management, fisheries, poultry, and many other agricultural systems need energy for their various processes/practices and productivity.

Traditionally, human beings and animals have been the main sources of energy in agriculture in South Asian countries. If you remember your school physics, you might find the information given in Table 9.1 interesting. *Otherwise, you may skip it.*

Energy requirement in the agricultural sector depends upon the size of cultivated area, level of technology, cropping pattern, water availability etc.

Table 9.1: Energy norms for various inputs

Input	Unit	Energy (MJ)
Adult men	Man-hour	1.96
Adult women	Woman-hour	1.57
Children	Child-hour	0.98
Medium Bullocks	Pair-h	10.10
Buffalo	Pair-h	15.15
Mule	Animal-h	4.04
Camel/horse	Animal-h	10.10
Diesel	Litre/ Kg	56.30 /63.27
Petrol	Litre	48.23
Kerosene	Litre	41.30
Coal	Kg	32.7
Fuel wood (dry)	Kg	20.0
Saw dust	Kg	18.0
Dung/dung cakes	Kg	18.0
Rice straw	Kg	12.5
Fertilizer N	Kg	60.0
Fertilizer P_2O_5	Kg	11.1
Fertilizer K_2O	Kg	6.7

Different agricultural operations require energy. As examples, let us see how much energy is required for rice transplanting, wheat harvesting and soybean cultivation and how it can be met by human power or machine power:

Examples of Energy Requirements

Rice transplanting: For covering one hectare rice planting (including nursery raising, uprooting, washing and transport), we require 212 man hours (=15.82 kWh). Energy required for a rice transplanter of 3.73 kW will be 67 man hours and nine hours of machine operation (Total 38.57 kWh). This shows that energy required by machines is 2.44 times more as compared to human beings.

Wheat harvesting: For harvesting one hectare cropped area, manual method requires 125 man hours, which is equivalent to 9.33 kWh. If the same job is done by machines, e.g., a 26.11 kW tractor operated with vertical conveyor reaper, it would require 42 man hours and 3.226 of machine hours equivalent to 84.22 kWh and 3.13 kWh for human labour to operate the machines. The total energy consumed in the second method is 9.3 times more than the manual one.

Seed bed preparation and sowing of soybean in black soil: For one hectare area ploughing (once) will require 40 hours of a pair of bullocks equivalent to 29.84 kWh and harrowing (twice) will require 16 hours of a pair of bullocks equivalent to 11.94 kWh. Seeding will require 5 hours of the bullock pair, equivalent to 3.73 kWh. The total energy consumed will be 45.51 kWh. The same operation when done by a 26.11 kW tractor will consume 6.75 hours equivalent to 306.79 kWh of energy. The machine energy is 6.7 times more than the animate energy.

The above three examples clearly show that the work output per unit energy is more in animate energy as compared to commercial energy. However, the increased cropping intensity, production and productivity of land require more and quick input of energy which cannot be met alone by animate energy. The use of tractors, pumping motors have also become necessary and all sources of energy have become complementary to each other.

The energy requirements do not end with agricultural operations. The transport of produce is a major issue in most South Asian countries. Animal and human beings are extensively used in rural transport system in the developing countries. Bulk of the harvested produce is transported as head loads from field to threshing floor and then to storage areas or trucks or bullock carts etc. as it is convenient and economic. The firewood from field to house and small quantities of fruits, vegetables, grains etc. are transported as head loads or by animal driven carts etc. for short distances under field conditions and *kachcha* roads.

Fig.9.1: Energy needs in rural transport

However the use of commercial energy is increasing as shown for India in Table 9.2.

Table 9.2: Energy used in Indian Agriculture

Energy source	**1970-71**	**1975-76**	**1980-81**	**1985-86**	**1990-91**	**1992-93**
A. Diesel energy						
In agriculture (000' t)	153.5	527.6	1034.5	1339.7	2113.9	2186.4
For crop production (000' t)	61.4	211.0	413.8	535.9	845.6	874.6
High speed Diesel, kg/ha	0.37	1.23	2.39	3.0	4.55	4.72
MJ/ha	23	78	148	190	288	299
B. Electrical energy						
Electricity, GWh	4460	9592	14489	23422	50321	63328
kWh/ha	27	56	84	131	271	342
MJ/ha	322	668	1002	1563	3233	4080
Total mechanical energy, MJ/ha	345	746	1150	1753	3521	4379
C. Animate energy						1059*
Animal energy, MJ/ha	1606	1485	1404	1293	1101	1059
Human energy, MJ/ha	1331	1363	1401	1348	1409	1434
Total energy in agriculture, MJ/ha	3282	3594	3955	4394	6031	6872
Share of commercial over total energy,%	11	21	29	40	58	**64**

Note : 1. *Estimated
2. Capacity: Diesel, 63.27 MJ/Kg: electricity, 11.93 MJ/KWH.
3. Bullocks pair, 10.10 MJ; human, 1.84 MJ (male, 70% and female, 30%).
4. 40% of the total diesel used in rural sectors assumed for crop production and remaining for transport and other agro-industrial activities.

Source : "Data Book on Mechanization and Agro-Processing Since Independence" by Dr. G. Singh, **Director, CIAE, Bhopal - 462038, Dec 1997.**

Table 9.2 shows the trend of increasing use of commercial energy in the form of electrical and diesel energy. The share of animate energy is declining. Why? This may be due to the problems associated with using animate sources of energy.

- Expenditure on the purchase, upkeep and maintenance of animals, irrespective of work.
- Less annual utilization of animal energy. For example, the current annual utilization in different parts of India ranges between 350-1250 hours as against the ideal utilization of 2400 hours.
- Under-utilization of the potential.
- High unit cost of energy as compared to commercial energy.

The question you may like to raise is: **How can we increase the efficiency of the animate sources of energy?**

This is because the use of animate sources of energy will continue in agriculture in South Asian countries and it is necessary to improve the efficiency of animate sources of energy.

Improving the Efficiency of Animate Sources

Efficiency of human energy can be improved by using efficient and matching equipment for various operations done by human beings. The existing equipment should be improved or redesigned keeping ergonomic considerations in view, by scheduling rest under various modes of weather conditions to get maximum output.

The animate energy efficiency can be improved by the following measures:

- By improved breeds of animals and their health care to suit climatic conditions of the area.
- By increasing draft availability of animals by use of improved yokes and harness and designing equipments based on mechanics of animal traction.
- By increasing their annual utilization by developing equipments for those periods when they are not being utilized presently.
- By using them for stationary operations like grinding, oil extraction, chaff cutting, water lifting etc. and by designing matching equipments.
- By utilizing milch and pack animals for draft purposes.

Energy management in agriculture requires an understanding of not only the needs but also how agriculture itself is a source of energy. But before you learn about this aspect of agriculture, you may like to attempt an exercise.

SAQ 1

Although the energy consumed in machine operations in agriculture is more as compared to animate energy, explain why there is a growing preference for mechanized agriculture in developing countries.

9.2.2 Agriculture as Producer of Energy

Though agriculture requires energy inputs, both commercial and natural, its output energy is generally more than inputs. We get back energy in the form of food, fibre, fodder and crop residues. There are other benefits as well, e.g., we get oxygen from plants during photosynthesis. The stored energy in food (cereals, pulses, fruits, vegetables, milk, eggs, fish, flowers, sugar etc.) is many times more than that used as energy inputs.

There are many crops, which can be exploited for bio-fuels – like ethanol or diesel. Such crops are also called **energy crops**. Jatropha and Karanj seeds can be used for extracting bio-diesel, which can be blended with petroleum diesel. The time is not far when we will have to depend upon these type of energy sources. Our governments should promote these schemes of bio-fuels by giving several incentives to farmers to grow such crops in wastelands.

You can get a quantitative idea of energy produced by various sources from Table 9.3.

Essentially, in the plants and trees around us, we have an energy producing biochemical factory that can help us meet our energy needs and leave a surplus too. We discuss this aspect in detail in Sec. 9.3.3 on biomass.

So far we have given you a brief overview of the energy scenario in agriculture. The challenge is to meet the energy needs through environment-friendly methods and improve the efficiency of energy use. Agriculture itself is a source of biomass, which can be used to provide energy.

Table 9.3: Energy of various outputs

Output	Energy (MJ) per kg	Output	Energy (MJ) per kg
Cereals (dry)	14.7	**Fruits**	
Pulses	14.7	High value Grapes, Tamarind	11.8
Oilseeds	25.0	Low value Guava, Mango, Apple, Peach	1.9
Sugarcane (cleaned)	5.3	Fibre crops: Cotton, Jute	11.8
Vegetables		Fodder crops: Berseem, Oats, Maize, Millet	18.0
High food value-Potato, Tapioca	5.6	Cotton seed	25.0
Medium food value-Colocasia	3.6	Milk (Buffalo)	4.9
Low food value-Carrot, Radish, Onion	1.6	Milk (Cow, Goat)	2.8
Fruit or seed vegetables; Beans, Ladyfinger	1.9	Eggs	7.5
Gourd family Cucumber, Papaya, Tomato	0.8	Meat Poultry	4.5
Leafy vegetables: Cabbage, Spinach, Mustard leaves	1.2	Meat Mutton	4.9

The next issue we take up is: What are the resources that can provide us energy without adversely impacting the environment? This is where the renewable energy resources have an important role to play.

9.3 RENEWABLE ENERGY RESOURCES

We begin with the question: What is the difference between **renewable** and **non-renewable resources** of energy?

You know that most of the energy we use today is being obtained from coal and petroleum. We also have nuclear power plants. But these energy sources are limited as only finite quantities of coal, petroleum and gas exist underground or in oceans. The present reserves of coal and petroleum, if consumed at the current rate, may be exhausted after a certain period.

Nature would take thousands of years to produce them. Thus, as far as human life times are concerned, once exhausted, they will not be available for use. This is why these are called **non- renewable sources of energy**.

On the other hand, there are some sources of energy, which can be used repeatedly without exhausting them, such as, energy from the sun, energy from a water-fall, wind energy, tidal energy. Biomass energy and energy from plants can be obtained by growing plants. Hence, we call such resources of energy as **renewable resources,** i.e., those that are continuously restored by nature. The challenge today is how to tap these energy resources efficiently and economically.

Renewable energy and farming are a winning combination. Solar, wind and biomass energy can be harvested forever, providing farmers with a long-term source of energy and income. Renewable energy can be used on the farm to replace other fuels. It can also be sold as a “cash crop”.

We now discuss each of these sources.

9.3.1 Solar Energy

Sun is a unique source of energy. It also indirectly controls other sources of energy like wind, tidal, hydro-energy, biomass energy etc. The sun radiates continuously and the earth receives 4.4×10^{15} kWh of solar energy every day. This means that solar energy falling on the earth per day is sufficient to meet the energy needs of the world for 15 years. In comparison, the total energy available in the form of coal, petroleum and other reserves is equivalent to just 27 days of solar energy.

Today, solar energy is accepted world wide as the energy of future society. It is said that by 2020, solar electricity will be cheaper than conventional electricity. Developed countries are planning to produce 20% of their energy through renewable sources by 2020, because the existing oil reserves will last only for 50 more years. It is also projected that the cost of production of conventional electricity will increase further while the cost of producing solar electricity will decrease.

Unfortunately, as of now, we are not able to tap even a small fraction of this vast energy. Scientists and technologists are working hard to develop various appliances and conversion devices to utilize this vast and freely available energy. Many devices and appliances like solar cookers, solar geysers, solar stills, solar photovoltaic cells etc. are in use, but all of them put together still utilize a very small fraction of solar energy.

The major advantage of solar energy is that it is clean and unlimited. Capturing the sun's energy for lighting, heating, providing hot water and electricity can be a convenient way of saving money. On the farm, solar energy can be efficiently used for drying crops, powering a water pump or heating buildings. The use of solar energy in agriculture helps in saving money, increasing self-reliance, and reducing pollution. Green houses are quite common.

Solar energy can be basically converted through two pathways:

- Solar energy to thermal energy through *solar thermal devices*.
- Solar energy to electrical energy through *solar photovoltaic devices*.

Solar Thermal Devices

More than 3 lakh solar cookers have been sold in India. The cost of ISI approved solar cookers is in the range of Rs. 900-1100. To promote the use of solar cookers state governments are giving subsidy and soft loans. The Bureau of Indian Standards in consultation with Ministry of Non-conventional Energy Sources of India has set up national level testing centres for solar cookers.

Solar thermal devices convert solar energy into thermal energy. This is generally achieved using a black metallic surface, which acts as a heat absorber. This surface is enclosed in an airtight box, which is covered by insulating materials from all other sides except the one, which is used to receive the sunlight. The top cover is normally made of transparent glass sheet. Some of these devices are: **Solar cooker, solar water heating systems**, **solar dryers** and **solar still**. We briefly describe them below:

Solar Cooker: The box type solar cooker (Fig. 9.2) is capable of cooking various types of food like rice, vegetables, pulses, chicken, fish, etc. It can also be used for steaming, roasting or boiling, etc. It works as an airtight box with double glass covers. A reflector is also used over it, which boosts the incoming sunlight. The temperature rises depending upon duration and intensity of sunlight. These cookers have special vessels in which food is kept. Some cookers have space for four such vessels, in which rice, pulses, vegetable etc. can be cooked at the same time. Due to their simplicity and easy operation, these cookers have become popular even in urban areas.

Fig.9.2: Solar cookers

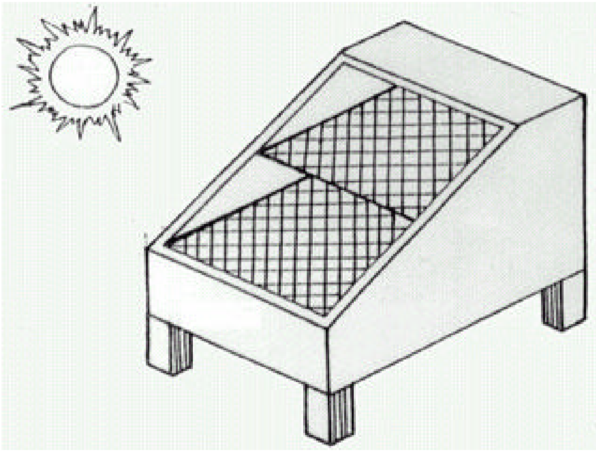
Solar Water Heating Systems: Solar water heaters (Fig. 9.3) also have flat plate collectors with built-in water channels attached to the absorber sheet. With black paint or coating on flat plates and tubes, water can be heated up to 60 to 90°C. With special coating, the temperature can be raised up to 100°C. These solar water-heating systems are being used for domestic, commercial and industrial applications. For domestic heating, a temperature of 60°C is sufficient. For hospitals, hotels, milk dairies, textile mills etc, a little higher temperature is used. These water-heating systems are commercially available from 100 litres per day for domestic uses to even 20,000 litres per day capacity for huge establishments.

On a farm, solar water heaters can provide hot water (low- to medium-temperature) for cleaning of cattle pens. Dairy operations can use solar heated water to clean equipment and to warm and stimulate cows' udders. For homes or farms with electric or propane water heaters, solar collectors can save hundreds of rupees per year.

Fig.9.3: Solar water heating systems

Solar dryers: Solar dryers (Fig. 9.4) are very useful for agricultural processing and drying of produce. Various types of solar dryers are available for drying vegetables, fruits, grains, fish, etc. These are also being used in some industries. There are reports that these are very successful in the seasoning of wooden panels and timber.

The basic principle is that the plates absorb heat and then ambient air is blown over the heated surface, which gets heated, and then it passes over the material to be dried. There are some direct dryers also where the subject material gets solar heat and gets dried like surface drying. The only difference is that heat losses that occur in open surface drying are reduced.



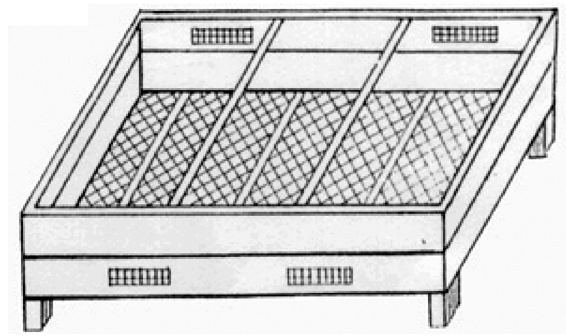


Fig.9.4: Solar dryers

Crop and Grain Drying: Using the sun to dry crops and grain is one of the primitive applications of solar energy. Solar drying equipment can dry crops faster and more evenly than leaving them in the field after harvest, with the added advantage of avoiding damage by birds, pests, and weather. A typical solar dryer consists of an enclosure or shed, screened drying trays or racks, and a solar collector. Natural convection or a fan moves hot air through the crops to dry them. If a farm has a crop dryer already in place, it may make sense to install a low-cost solar heater to supplement a propane or oil heater. The farmer would save on fuel costs while still being able to dry crops in cloudy weather.

The sun's heat can also be used to warm homes and livestock buildings. In confinement operations, a steady supply of fresh air is critical to maintain animal health, but this can result in substantial heating bills. “Active” solar heating systems, which use heat boxes and fans, can warm the air and save fuel. “Passive” solar designs, where the building is designed to take advantage of the sun automatically, are often the most cost-effective.

Greenhouse Heating: Commercial greenhouses often rely on the sun for lighting, but on gas or oil heaters to maintain constant temperatures. A solar greenhouse uses building materials to collect and store solar energy as heat (Fig. 9.5). Insulation retains the heat for use during the night and on cloudy days. To capture maximum sunlight, a solar greenhouse generally faces south in the northern hemisphere, while its northern side is well insulated, with few or no windows. A gas or oil heater may be used as a backup.

Fig.9.5: The sun is a reliable source of heat, light and power for greenhouses

Solar Still: A solar still (Fig. 9.6) can produce 4-6 litres of distilled water for every square meter of basin area during day sunshine of 8-10 hours. The efficiency depends on various factors like ambient temperature, quality of glazing, and temperature of basin water. Fibreglass body basin type stills are commercially available in India with an approximate cost of (Indian) Rs. 2500 per sq.m. of basin area. Concrete-based solar stills will be cheaper. It is estimated that 30-40 sq.m. of land is required for a 100 litres per day water still system.

The solar distilled water can be used for batteries, laboratories and industries. In brackish water areas it can also be used as drinking water.

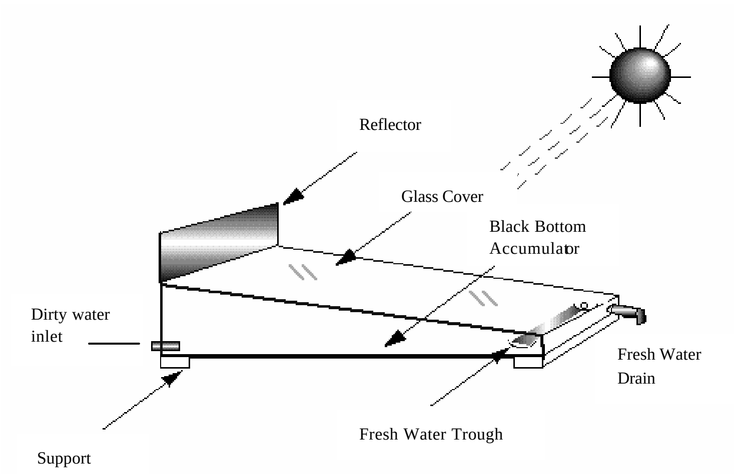


Fig.9.6: Solar Still

Solar Photovoltaic Devices

You may have heard of solar photovoltaic (SPV) technology, which uses photovoltaic cells.

Photovoltaic cells can convert solar energy into electrical energy in an environment friendly manner. You may like to know: **What is a solar photovoltaic cell**?

Solar photovoltaic cells are most commonly made from semi-conductor materials like silicon, the same material which is used for making computer chips. A solar cell is built like a sandwich, with two layers of silicon separated by a thin layer of a transparent insulating material. All the three layers work together to convert the sunlight into electricity. When sunlight falls on the upper surface of the solar cell, it produces a small electrical charge. As in a battery, negative charge is accumulated on the upper layer and positive charge on the bottom layer. If a wire is connected between the two, the charge or current flows, which can be used to power a small bulb, or charge a battery or run a calculator.

A single solar cell can provide only a small current. But if a large number of solar cells are connected together on a multi-cell panel, higher amounts of currents can be produced.

The energy converted by an SPV system can either be used instantaneously or can also be stored in batteries for use in night or in times of need.

Various types of silicon based photovoltaic cells, modules, solar panels and complete PV systems for a variety of applications have been developed in India. Some of the devices based on photovoltaic system are: *solar lantern*, *street lights*, *domestic lights*, *community centre light and power system*, *solar water pumps* and *solar power plants*. We briefly describe them below.

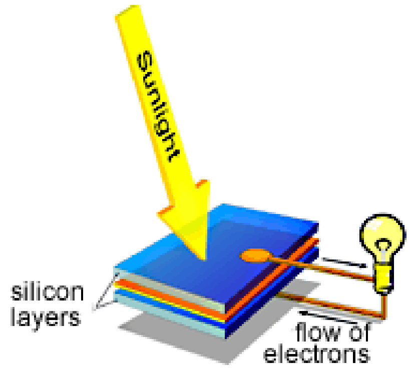


Fig.9.7: Solar photovoltaic cell

Fig. 9.8: Solar Lanterns

Solar lantern: We do not need light during daytime when we have ample sunlight. A PV system also converts solar energy during daytime when we do not need it. We can store that energy in a battery. Solar lantern (Fig. 9.8) is the smallest gadget, which converts solar energy during daytime into electrical energy and stores it in a battery. In other words, it charges the battery during daytime. The battery in turn gives electrical power to a small low voltage lamp during night. These days CFLs (Compact Fluorescent Lamps) are available which consume less energy and provide more light. But as compared to a simple bulb, a CFL will require an inverter circuit and ballast (Choke).

Streetlights: Solar photovoltaic -based street light system (Fig. 9.9) is very useful in remote areas. It also saves on cabling .A PV system for streetlights does not require cables from one pole to another. Each pole is equipped with a PV panel, a battery, an inverter, a ballast circuit and a tube-light or CFL. For automatic operation that does not require human intervention, a timer can be included in the circuit, which will switch on or switch off the lights at preset timings.

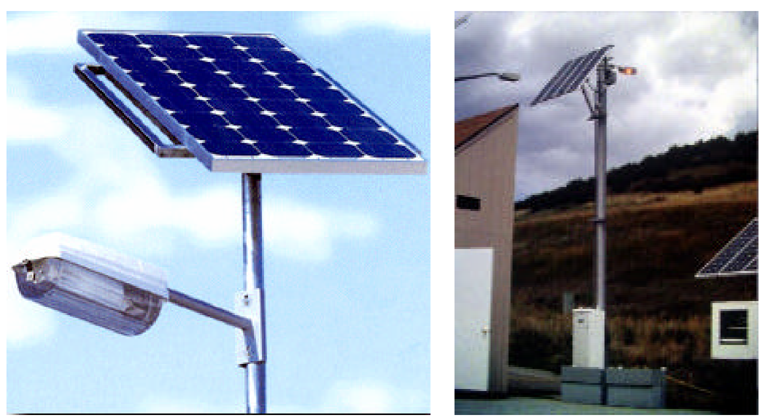


Fig.9.9: Solar street lighting system

Domestic lights: The basic principle is the same as for streetlights. The PV system is placed on the roof of the house. In some typical houses the roofs are made slanting facing towards sun and PV systems are fitted on these roofs. The electrical wires are connected from the PV system to the battery, which is kept in the house. Various circuits are distributed from this battery and an inverter which supplies electrical power during night or in need.

Fig.9.10: Domestic solar lighting

One of the simplest ways to use solar energy is to design or renovate buildings and barns to use natural daylight, instead of electric lights. Dairy operations using "long day" lighting to increase production can save money with skylights and other sun-lighting options.

Community centre light and power system: In remote villages where electrical power lines are not installed or difficult to install, a PV system can provide light and power to run small electrical gadgets like TV or radio. The medium power solar photovoltaic system (300-1000 W) with battery and inverter circuits provide electricity at 220 Volts AC. Villagers can save money on the cost of community based TV/ radio and other common devices.

Solar water pumps: Water lifting pumps can also be operated using solar power (Fig. 9.11). Since these can be operated during daytime, DC motors of matching capacity can be used directly. The photocell current is directly consumed by the motor without any intermediate converter. However, when AC motors are used, an inverter is necessary. Small capacity 360 W PV pump sets are available. These pumps can pump 20-30 m^3 of water on a sunny day from a depth of 4-5 metres.

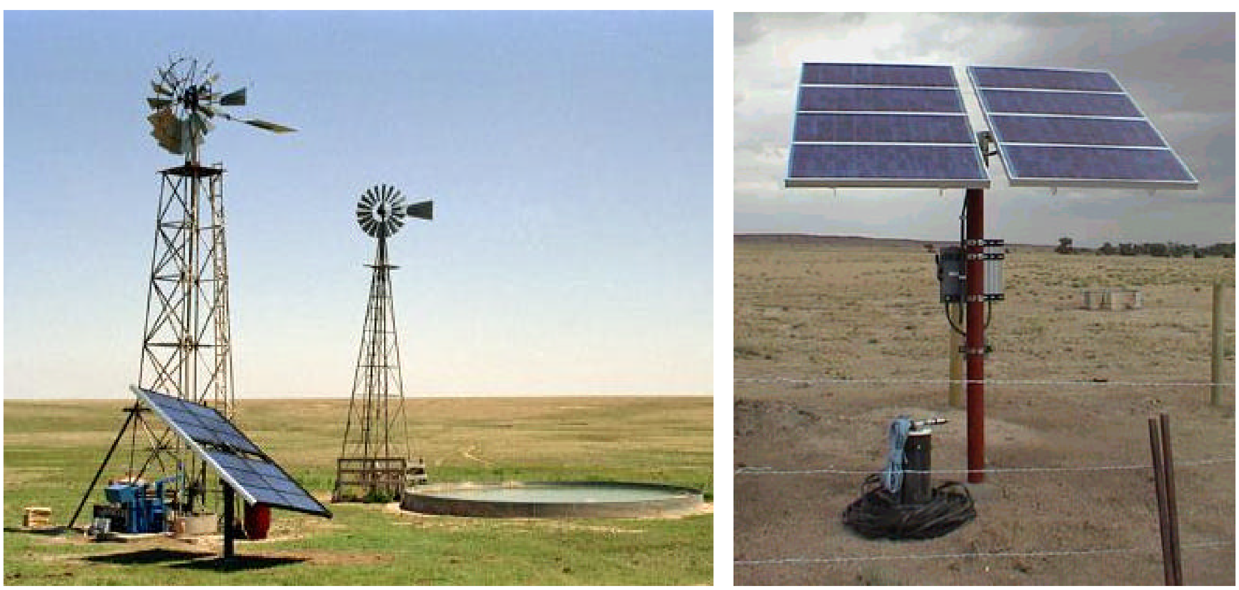


Fig.9.11: Solar water pumps

For higher head pumping, positive displacement pumps can be used, but simple PV panels cannot be used for running them. A small battery is also required to run these pumps.

As the photovoltaic system produces DC power, the use of DC motors is preferred for solar water pumps.

PV based power plants: Village based 2-10 KW capacity power plants (Fig.9.12) based on photovoltaic panels / array of panels are commercially available.

In addition to the main panels, it requires a battery bank housed in a small shed, power-controlling unit, and power distribution lines. The load may be used for lighting, running TV and other low power gadgets. The time may not be far when such power plants will become a common thing (portable generators) in remote /rural areas of South Asian countries.

In spite of the high capital cost, photovoltaic (PV) panels are often a cheaper option than new electric lines for providing power to remote locations. And, because they require no fuel and have no moving parts, they are more convenient to operate and maintain than diesel or gasoline generators. In some areas, the distance from a power source at which PV becomes more economical than new transformers and electric line is surprisingly short – often as little as 50 feet. With the increasing cost of fossil fuel-based electricity and transmission lines and the declining costs of solar-based power plants, the acceptable option will be to go for solar-based power.

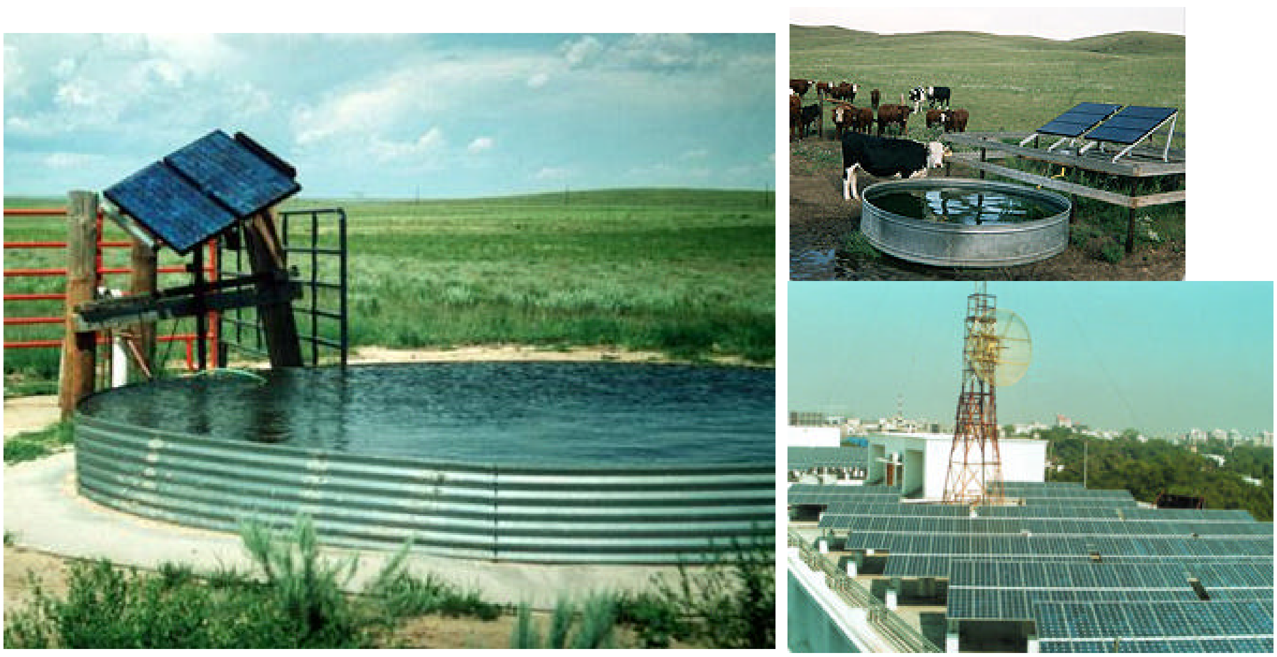


Fig.9.12: Solar powered plants

PV systems are a highly reliable and low maintenance option for electric fences, lights and water pumps. Although current prices for solar panels make them too expensive for most crop irrigation systems, photovoltaic panels are economical for remote livestock water supply, pond aeration, and small irrigation systems. In addition, the cost of PV is projected to decline significantly over time, which will make more applications cost effective.

You may like to stop now and consolidate this information about solar energy.

SAQ 2

a) What do you understand by solar thermal devices? Which of these are appropriate for agricultural operations, and why?

b) In what ways can the SPV devices be used to meet the energy needs of remote and rural areas?

9.3.2 Wind Energy

Energy from wind is free like solar energy. It is also free from pollution of burning fuels. What is more, it is an inexhaustible source of energy. You may know that it was used for sailing of ships in earlier times. The issues involved in the efficient harnessing of wind energy today are:

- Locating a suitable site where sufficient wind velocity is available for most of the time;
- Selection of the most efficient wind mill for that wind velocity and utilization of the wind power directly, and
- Storage of peak time energy to be utilized as and when needed.

You may have come across pictures of windmills used to produce energy from wind (Fig. 9.13). Windmills are ideal for open locations having minimum ground resistance to wind flow. Windmill power can be directly used for water pumping, grain grinding, fodder chopping etc. It can be converted into electricity using a common automobile alternator. The electricity produced can either be used at the same time or can be stored in batteries.

(a) **(b)**

Fig.9.13: a) An ancient windmill; b) windmills used nowadays

Wind speed is a very important factor in harnessing of wind energy. Wind generated power accounts for 4500 MW of installed capacity worldwide. It is also increasingly being used in the developing countries. For example, India has about 1100 MW installed capacity for wind energy generation.

Windmill – Power Plants

Wind farms, which constitute a cluster of grid-connected wind electric generators of 250 kW – 500 kW each, have been found to be a quite feasible method of power generation. The wind power generators should be installed at those locations where the average annual wind speed is at least 18 km/h. This amounts to annual energy content of 2000 kWh/m^2. Wind farms require large open areas (8-10 ha/MW) making the availability of land in windy areas extremely important. However, only 5-10 per cent of land is used for installation of mills and other equipment. The remaining area can be used for crop growing, cattle grazing, etc.

Cost of production

The average capital cost of a wind farm works out to be between (Indian) Rs. 3.5 to 4.0 crores per MW, which is fairly comparable to the capital cost of a conventional power plant. In a conventional plant, we require some fuel like coal, petroleum whereas in wind power the wind is freely obtained from the nature. Also there is zero pollution and zero carbon emission in a wind power plant.

SAQ 3

a) What are the advantages and limitations of using wind energy?
b) In what ways can wind energy be used to meet the energy needs of agriculture?

9.3.3 Bio Energy

Biomass is a term used for the total quantity of living organisms in a given area, e.g., crops, crop residues, animal residues, forests, etc. It is expressed in terms of living or dry weight per unit area.

Energy from biomass is broadly termed as bio-energy. Bio-energy is renewable and produced from biological sources. The food we eat has bio-energy; the milk we drink is bio-energy. Besides the main food crops, there are energy plantation crops, which are used for extracting energy in the form of solid and liquid fuels. Ethanol, a partial substitute of petrol is being extracted from crops like sweet sorghum and cassava. Today we are talking of bio-diesel that can be produced from crops like jatropha.

Large-scale production of bio-energy would initially require the use of agricultural and forest residues, and eventually dedicated energy crop plantations. The cost-effectiveness in any particular investment situation is likely to depend on site-specific opportunities. The long-term effects of bio-energy exploitation, through dedicated plantations, on soil quality, fertility and biodiversity may be adverse.

Therefore, a balance needs to be struck between the advantages and disadvantages of bio-energy, and this is reflected in both optimistic and pessimistic views regarding the uncertainties about how bio-energy systems can provide cost-effective local and global benefits. These uncertainties have restricted the development and commercialisation of modern biomass technologies.

Among the important **bio-energy sources** are:

Fuel wood, organic residues, dung cakes: For direct burning through improved ovens (*chulhas*).

Biogas plants: For generation of biogas, a clean fuel gas and manure from organic residues like animal waste, domestic waste, crop residues etc.

Biomass-based gasifier systems: For production of thermal and electric power.

Biomass-based fuels: For producing bio-ethanol and bio-diesel.

We now discuss some of these sources.

Biogas Plants

A typical family biogas plant requires cattle dung from about 4-5 adult cows or buffalos (about 50 Kg of wet dung). The fresh dung contains about 18% solids and almost the same volume of water is mixed with fresh dung. Slurry so formed is fed into a digester normally underground. The slurry in the digester undergoes anaerobic fermentation in the presence of methanogenic bacteria, which are present in the cattle excreta. Sometimes used digested slurry is mixed initially to boost the fermentation process. The digester, which is 12-15 feet deep below the ground, gets filled up with the daily feed in about 50-60 days depending upon the temperature. For higher temperatures lower retention time is recommended and vice-versa.

The gas produced in the digester bubbles out and is collected in a floating gasholder. When the gas is produced the holder moves up. The gasholder has outlet connections for gas through valves. When the gas is consumed the holder moves down. The upward and downward movement of gasholder also serves as stirrer for the slurry. The gas pipelines from gasholder to the kitchen are laid down in such a way that the moisture in the biogas is condensed and collected in a trap, which can be cleared from time to time.

The utility of biogas has led to its application to other feed- stocks. Today we have dedicated bio-methanation plants for distillery effluents, industrial wastes rich in organic matter, urban solid waste, fruits and vegetable wastes, kitchen wastes etc. These plants not only produce biogas but also give bio-digested slurry or sludge, which is a substitute of fertilizer.

The clean gas can be used for cooking and lighting. Moreover, the digested slurry coming from biogas plants is very good quality manure. Today biogas is being produced from not only cow dung, but also other wastes like municipal solid waste, distillery waste, crop residues etc. The product, biogas, mainly constitutes methane (60-65%) and carbon dioxide (30-35%). After digestion the remaining slurry can be used as organic manure. The biogas is a clean fuel and gives blue flame if properly burnt with air (oxygen).

Biogas plants in India: A Case Study

In 1939, scientists of Indian Agricultural Research Institute showed that biogas (methane) could be produced from cattle dung using a simple digester and gasholder. It was called the Gobar Gas Plant. In 1951-53, Khadi Village Industries Commission (KVIC) developed its own model (KVIC Model) which was slightly different from IARI model. During the last 40 years about 30 designs of biogas plants have been developed in India to suit the specific requirements of feedstock, water availability, cost reduction and climatic conditions. A major breakthrough took place during the Janata Government's regime in 1977 when a drum-less biogas plant was introduced. It was further improved by various agencies involved in the biogas work. A Deenbandhu model was introduced by AFPRO, which became very popular and cost effective.

Fig.9.14: A biogas plant

Fig.9.15: A gasifier

Gasifier-based power generation systems have been in successful operation in the range of 5 KW to 100 KW at various places in India.

Gasification of biomass – Gasifiers

The gasification technology, which involves a series of interlinked thermo-chemical processes like drying, pyrolysis, oxidation and reduction etc., offers a good scope for use in stationary and mobile operations. The basic advantage of a gasifier is its simplicity in construction and operation. The producer gas produced by a gasifier can operate normal diesel engines after some modification in compression ratio, fuel injection time etc. Up to 70% of diesel can be substituted without any loss of power and efficiency. The gasification technology is full of potential for energizing water pumping sets, rural electrification, thermal applications etc.

So far we have discussed applications of renewable energy resources in agriculture and other sectors of the economy. A natural question that may have occurred to you is: **Why have we not adopted these technologies, especially in rural areas**? This is where we need to examine the socio-economic dimensions of the energy problem. However, before we move on, we would like you to attempt an exercise.

SAQ 4

a) List various ways in which bio-energy can be produced from biomass.
b) How can biomass energy be used to meet the energy needs in rural areas?

9.4 SOCIO-ECONOMIC ASPECTS OF ENERGY IN RURAL AREAS

We now discuss some of the major socio-economic aspects of the energy question in the rural context.

Energy has a key role in economic and social development.

Without appropriate energy services there can be no true economic development, yet around 2 billion people world-wide do not have access to modern forms of energy. Aid in support of national efforts includes a variety of rural energy programmes to improve energy provision, often through rural electrification. Increased access to energy services can help reduce poverty, but much of the effort thus far has focussed primarily on household energy use, with less attention being paid to energy services for rural industries and agriculture.

Energy has a major impact on the global and local environment.

The needs of sustainable development and the use of clean energy technologies are well recognised. Actions at national and international levels to tackle the problems of air quality and climate change are being developed, and these will require new directions for both energy policy and technology and the nature of investment decisions in energy supply and end-use systems.

Insufficient modern energy is available for agriculture and this affects food security.

In agriculture, a wide range of modern and traditional energy forms are used directly on the farm, e.g., as tractor or machinery fuel, and in water pumping, irrigation and crop drying, and indirectly for fertilizers and pesticides. Other energy inputs are required for post harvest processing in food production, packaging, storage, transport and cooking. Direct energy use in agriculture accounts for only a relatively small proportion of total final energy demand in national energy accounts. In developing countries it is between 4-8%.

Energy for agricultural practices in many developing countries continues to be based to a large extent on human and animal energy, and on traditional wood-fuels. Empirical evidence suggests that the potential gains in agricultural productivity through the deployment of modern energy services are not being fully realized in developing countries. This reduces both the quantity of food and quality of food produced. Rural people are sometimes forced to eat either uncooked food or food that can easily be cooked but which may not give full nourishment.

Lack of rural energy development programmes

Many energy policies and interventions in developing countries are designed for the needs of industry, transport and urban infrastructures, whilst agricultural energy requirements are frequently overlooked. Although agriculture contributes significantly to economic and social development, often accounting for around 30% of developing country GDP, energy provision in agriculture has not received the attention that the sector deserves. Energy for agriculture needs to have a higher priority in rural policy and technology assessment work in developing countries than has been the case hitherto.

An energy transition is needed in rural areas

Given the spread of technology and general economic development, it can be expected that traditional energy technologies will co-exist, with a gradual improvement. New technologies will accompany the rural development process. There is also the prospect of technological 'leapfrogging', which could give developing countries the chance to commercialise new technologies relatively quickly. But there is a need for more urgent action, due to the low rate of economic improvement in many rural areas and the drift of rural populations to peri-urban and urban areas in developing countries. Agriculture can have a major role in supporting sustainable rural livelihoods through the increased provision of locally sourced bio-energy. Such an approach can assist more broadly in rural development as well as improving food security.

A challenge and an opportunity

An integrated approach, which exploits the synergies and dual role of agriculture as an energy user and an energy supplier, needs to be developed. The links that energy and agriculture can make between sustainable rural livelihoods, local environmental protection and global environmental benefits are important issues to address. In order to mobilize the synergies and develop the energy function of agriculture:

- the role of agriculture in providing both a source of renewable energy which contributes to rural economic development, and a substitute for fossil-fuels should be recognised and exploited in future energy policy formation and technology development;

- The potential of bio-energy and renewable energy sources should be recognised in general to assist both in the provision of energy services in the rural areas of developing countries and in the transition to more sustainable energy systems world-wide.

The solution to the problem of availability of energy depends not only on generating more energy but also conserving and managing energy. What measures can we adopt for energy conservation and better management of energy? This is the issue we are now going to discuss.

9.5 ENERGY CONSERVATION AND MANAGEMENT

There is a saying "Energy saved is energy produced." Similarly, we can say, "Energy conserved is energy produced." The difference between the two statements is that when we say energy saved we mean we do not use energy when it is not required. For example, if nobody is in a room, lights and fans can be switched off.

However, energy conservation more strictly means we use energy efficiently and save energy using efficient devices, which do the same amount of work for less input of energy. We give below some examples of energy conservation in the context of agriculture in India.

Gur or khandsari production

Much of the sugarcane produced in India is processed into *gur* or *khandsari*, i.e., (*unrefined* sugar) in small-scale enterprises.

Improved crushing machines and fuel-efficient furnaces can save a substantial amount of energy. The use of a screw expeller and a fuel-efficient furnace in a *khandsari* mill has reduced the average cost of production per ton of sugar to the extent of about 20%.

Agro-based industries

Co-generation of electricity and process heat from some fuels has been used in many industries (dairy based industries). The heat produced from the engine or turbine is used in the various processes where heat is required. More than 50% of fuel energy can be recovered in the form of heat from cooling water and exhaust gases.

Energy conservation through improved stoves

The energy used for cooking accounts for over 70% of the total energy consumption in the agriculture sector of India. Biomass fuels like wood, crop residues and dry animal dung cakes have been traditionally used for cooking and heating in winter months.

Improved *chulhas*(stoves) are one of the most important energy conservation technologies from India that can be used in the entire SAARC region. The improved *chulha* technology is the latest version of smokeless *chulhas* which besides being smokeless accounts for higher thermal efficiency. The Ministry of Non-Conventional Energy Sources (MNES) of India has developed about 40 models of improved *chulhas* for different feedstocks and applications. These include fixed as well as portable models.

Energy conservation in irrigation pumping systems

The increased number of tube wells and pumping sets is a direct indicator of increased use of energy in this system. When the majority of these pumping sets were installed, due importance was not given to proper selection, installation and operation. As a result of which they are not operating at the desired level of efficiency and causing a huge waste of energy.

If we take the example of Punjab in India, which is cent per cent irrigated today, the average annual consumption of electrical energy per pump set is 5000 kWh (units). The average number of pump sets is around 6 lakhs, consuming about 3000 million kWh. Even if the overall efficiency is increased by 15%, we can save 450 million units of electricity.

There are many other areas in agriculture sector, which consume some energy. Efforts are to be made them efficient so that energy can be saved. Any amount of energy saved is energy conserved.

In this unit, we have acquainted you with various aspects of the issue of energy, with particular reference to agriculture. We now summarise the contents of the unit.

9.6 SUMMARY

- Technically speaking, **energy** is the capacity to do work. The unit of electrical energy commonly used is kWh.
- Agriculture is both a **producer** and **consumer** of energy. The entire range of agricultural operations from preparing the land to sowing and harvesting produce as well as post harvest processing and transport require energy.
- Traditionally, in South Asian countries, human beings and animals have been the main source of energy.
- The **conventional sources** of energy such as coal, petroleum are finite and likely to end in the near future. Moreover, these also cause pollution. Therefore, there have been efforts to tap **renewable sources** of energy, such as solar energy, wind energy and biomass.
- Solar thermal devices convert **solar energy** into heat and solar photovoltaic devices convert solar energy into electrical energy. Most commonly used solar energy devices in agriculture are solar water heaters, solar dryers, greenhouses, SPV panels and solar water pumps.
- **Windmills** can be used for grinding grain, pumping water and chopping fodder as well as for generating electricity.
- **Biomass energy** is easily available in rural areas. Biomass can be converted into usable energy through biogas plants and gasifiers. Bio-fuels are nowadays being used in conjunction with petrol and diesel.
- Energy has a key role in **socio-economic development**. Insufficient energy supply to agriculture affects food production and food security. Fulfilling rural energy needs is a challenge today.
- Along with generation of energy, **energy conservation and management** is needed to improve efficiency of energy use in agriculture.

9.7 TERMINAL QUESTIONS

1. Prepare a report on the energy scenario in agriculture in your region covering the following aspects:

   - Energy requirements,
   - Sources of energy being used,
   - Feasibility of using renewable energy resources.

2. Why should we encourage the use of renewable energy resources? What are the challenges faced in using these resources in South Asian countries?

3. Develop a plan for the efficient use of energy in agriculture in your region for energy conservation and management.