

Lecture No.8

Greenhouse heating and distribution systems. Greenhouse utilization - off-season drying of agricultural produce. Economic analysis of greenhouse production - capital requirement, economics of production and conditions influencing returns.

The northern parts of our country experience cold winters, where heating system need to be employed in the greenhouses along with cooling systems for summer. Whereas the southern region greenhouses need only cooling systems since the winter cold effect is not that severe. Greenhouse heating is required in cold weather conditions, if the entrapped heat is not sufficient during the nights. The heat is always lost from the greenhouse when the surroundings are relatively cooler. Heat must be supplied to a greenhouse at the same rate with which it is lost in order to maintain a desired temperature: Heat losses can occur in three different modes of heat transfer, namely conduction, convection, and radiation. Maintenance of desired higher temperature, compared with the surroundings needs heating systems and heat distribution systems. For the purpose of greenhouse heating, apart from conventional systems, solar energy can also be used and the heat can be stored using water and rock storage. Different heat conservation practices are available to effectively utilize the heat energy.

8.1 Modes of heat loss

The heating systems, in a continuous process, should supply the heat just enough to compensate which is lost. Most heat is lost by conduction through the covering materials of the greenhouse. Different materials, such as aluminum sash bars, glass polyethylene, and cement partition walls, vary in conduction according to the rate at which each conducts heat from the warm interior to the colder exterior. A good conductor of heat loses more heat in a shorter time than a bad conductor and vice versa. There are only limited ways of insulating the covering material without blocking the light transmission. A dead air space between two coverings appears to be the best system. A saving of 40% of the heat requirement can be achieved when a second covering is applied. For example greenhouse covered with one layer of polyethylene loses, 6.8 W of heat through each square meter of covering every hour when the outside temperature is 1^oC lower than the inside. When second layer of polyethylene is added, only 3.97 W/m² is lost (40% reduction).

A second mode of heat loss is that of convection (air infiltration). Spaces between panes of glass or FRP and ventilators and doors permit the passage of warm air outward and cold air inward. A general assumption holds that the volume of air held in a greenhouse can be lost as often as once every 60 minutes in a double layer film plastic or polycarbonate panel greenhouse, every 40 minutes in a FRP or a new glass greenhouse every 30 minutes in an old well maintained glass greenhouse, and every 15 minutes in an old poorly maintained glass greenhouse. About 10% of total heat loss from a structurally tight glass greenhouse occurs through infiltration loss.

A third mode of heat loss from a greenhouse is that of radiation. Warm objects emit radiant energy, which passes through air to colder objects without warming the air significantly. The colder objects become warmer. Glass, vinyl plastic, FRP, and water are relatively opaque to

radiant energy, whereas polyethylene is not. Polyethylene, greenhouses can lose considerable amounts of heat through radiation to colder objects outside, unless a film of moisture forms on the polyethylene to provide a barrier.

8.2 Heating systems

The heating system must provide heat to the greenhouse at the same rate at which it is lost by conduction, infiltration, and radiation. There are three popular types of heating systems for greenhouses. The most common and least expensive is the unit heater system. In this system, warm air is blown from unit heaters that have self contained fireboxes. These heaters consist of three functional parts. Fuel is combusted in a firebox to provide heat. The heat is initially contained in the exhaust, which rises through the inside of a set of thin walled metal tubes on its way to the exhaust stack. The warm exhaust transfers heat to the cooler metal walls of the tubes. Much of the heat is removed from the exhaust by the time it reaches the stack through which it leaves the greenhouse. A fan in the back of the unit heater draws in greenhouse air, passing it over the exterior side of the tubes and then out from the heater to the greenhouse environment again. The cool air passing over hot metal tubes is warmed and the air is circulated.

A second type of system is central heating system, which consists of a central boiler that produces steam or hot water, plus a radiating mechanism in the greenhouse to dissipate the heat. A central heating system can be more efficient than unit heaters, especially in large greenhouse ranges. In this system, two or more large boilers are in a single location. Heat is transported in the form of hot water or steam through pipe mains to the growing area, and several arrangements of heating pipes in greenhouse is possible (Fig. 12.1). The heat is exchanged from the hot water in a pipe coil located across the greenhouse or an in-bed pipe coil located in the plant zone. Some greenhouses have a third pipe coil embedded in a concrete floor. A set of unit heaters can be used in the place of the overhead pipe coil, obtaining heat from hot water or steam from the central boiler.

The third type of system is radiation heating system. In this system, gas is burned within pipes suspended overhead in the greenhouse. The warm pipes supply heat to the plants. Low intensity infrared radiant heaters can save 30% or more, of fuel compared to conventional heaters. Several of these heaters are installed in tandem in the greenhouse. Lower air temperatures are possible since only the plants and root substrate are heated directly by this mode of heating.

The fourth possible type of system is the solar heating system, but it is still too expensive to be a viable option. Solar heating systems are found in hobby greenhouses and small commercial firms. Both water and rock energy storage systems are used in combination with solar energy. The high cost of solar heating systems discourages any significant use by the greenhouse industries.

8.2.1 Heat distribution systems

Heat is distributed from the unit heaters by one of two common methods. In the convection tube method, warm air from unit heaters are distributed through a transparent polyethylene tube

running through the length of the greenhouse. Heat escapes from the tube through holes on either side of the tube in small jet streams, which rapidly mix with the surrounding air and set up a circulation pattern to minimize temperature gradients.

The second method of heat distribution is horizontal airflow. In this system, the greenhouse may be visualized as a large box containing air, and it uses small horizontal fans for moving the air mass. The fans are located above plant height and are spaced about 15 m (50 ft) apart in two rows. Their arrangement is that the heat originating at one corner of the greenhouse is directed from one side of the greenhouse to the opposite end and then back along the other side of the greenhouse. Proper arrangement of fans is necessary for effective distribution in horizontal airflow system for various greenhouse sizes. Both of these distribution systems can also be used for general circulation of air and for introducing cold outside air during winter cooling.

8.2.2 Solar heating system

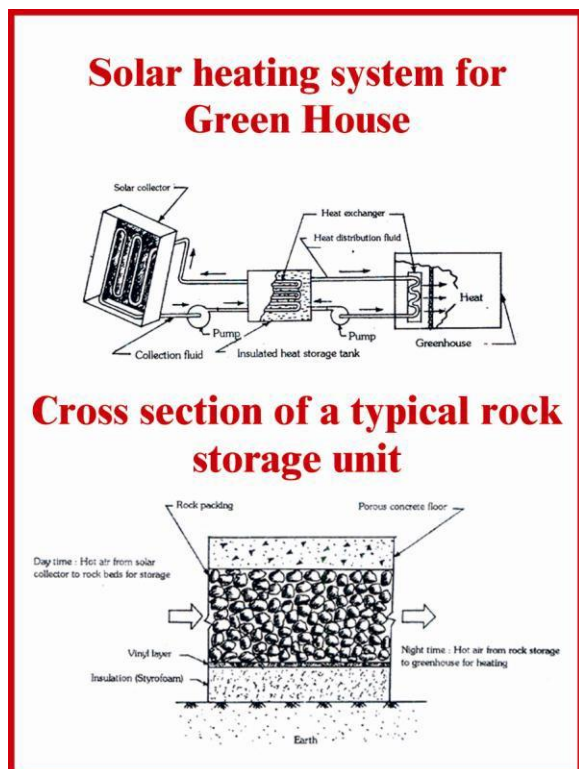
Solar heating is often used as a partial or total alternative to fossil fuel heating systems. Few solar heating systems exist in greenhouses today. The general components of solar heating system (Fig. 12) are collector, heat storage facility, exchange to transfer the solar derived heat to the greenhouse air, backup heater to take over when solar heating does not suffice and set of controls.

Various solar heat collectors are in existence, but the flat plate collector has received greatest attention. This consists of a flat black plate (rigid plastic, film plastic, sheet metal, or board) for absorbing solar energy. The plate is covered on the sun side by two or more transparent glass or plastic layers and on the backside by insulation. The enclosing layers serve to hold the collected heat within the collector. Water or air is passed through the copper tubes placed over the black plate and absorb the entrapped heat and carry it to the storage facility. A greenhouse itself can be considered as a solar collector. Some of its collected heat is stored in the soil, plants, greenhouse frame, floor, and so on. The remaining heat is excessive for plant growth and is therefore vented to the outside. The excess vented heat could just as well be directed to a rock bed for storage and subsequent use during a period of heating. Collection of heat by flat-plate collection is most efficient when the collector is positioned perpendicular to the sun at solar noon. Based on the locations, the heat derived can provide 20 to 50% of the heat requirement.

8.3 Water and rock storage

Water and rocks are the two most common materials for the storage of heat in the greenhouse. One kg of water can hold 4.23 kJ of heat for each 1°C rise in temperature. Rocks can store about 0.83 kJ for each 1°C. To store equivalent amounts of heat, a rock bed would have to be three times as large as a water tank. A water storage system is well adapted to a water collector and a greenhouse heating system which consists of a pipe coil or a unit heater which contains a water coil. Heated water from the collector is pumped to the storage tank during the day. As and when heat is required, warm water is pumped from the storage tank to a hot water or steam boiler or

into the hot water coil within a unit heater. Although the solar heated water will be cooler than the thermostat setting on the boiler, heat can be saved, since the temperature of this water need be raised as high as to reach the output temperature of water or steam from the boiler. A



temperature rise of 17°C above the ambient condition is expected during the daytime in solar storage units. Each kilogram of water can supply 71.1 kJ of heat, and each kilogram of rock can supply 14.2 kJ of heat, as it cools by 17°C .

A rock storage bed can be used with an air-collector and forced air heating system. In this case, heated air from the collector, along with air excessively heated inside the greenhouse during the day, is forced through a bed of rocks (Fig. 12). The rocks absorb much of the heat. The rock bed may be located beneath the floor of the greenhouse or outside the greenhouse, and it should be well insulated against heat loss. During

the night, when heat is required in the greenhouse, cool air from inside the greenhouse is forced through the rocks, where it is warmed and the passed back into the greenhouse. A clear polyethylene tube with holes along either side serves well to distribute the warm air uniformly along the length of the greenhouse. Conventional convection tubes can be used for distributing solar heated air. The water or rock storage unit occupies a large amount of space and a considerable amount of insulation is provided if the unit is placed outside. Placing it inside the greenhouse offers an advantage in that escaping heat is beneficial during heating periods, but it is detrimental when heating is not required. Rock beds can pose a problem in that they must remain relatively dry. Water evaporating from these beds will remove considerable heat.

8.4 Economics of greenhouse production

Regardless of the type, protected agricultural systems are extremely expensive. The equipment and production cost may be more than compensated by the significantly higher productivity of protected agricultural systems as compared with open field agriculture. The cost and returns of protected agriculture vary greatly, depending on the system used, the location and the crop grown. By design, all protected agricultural systems of cropping are intensive in use of land, labour, and capital. Greenhouse agriculture is the most intensive system of all. The intensity of land use is greatly dependent upon the system of protected agriculture. Year-round greenhouse crop production is therefore much more intensive than seasonal use of mulches and row covers. Coinciding with intensity are yields, which are normally far greater per ha from year round than from seasonal systems. The normal benefit of higher yields of CEA over the open field agriculture depends on the system used and the region of production.

8.5 Capital requirements

The capital requirements differ greatly among the various systems of protected agriculture. Mulching is least expensive while greenhouses require the most capital per unit of land. Total

cost involved in the production is the sum of fixed cost and operating cost (Fig.13). The fixed capital costs include land, fixed and mobile equipment, and structures like grading, packing and office. Fixed costs also include taxes and maintenance. The fixed capital costs for greenhouses clearly exceed those of other systems of protected agriculture, but vary in expense according to type of structure, and environmental control and growing systems. Operating costs include labour, fuel, utilities, farm chemicals and packaging materials. The operating or variable costs and fixed costs are annual expenditures and these can be substantial. Annual costs may correlate to some extent with capital investment. The flow diagram of capital requirements of production is shown in figure.

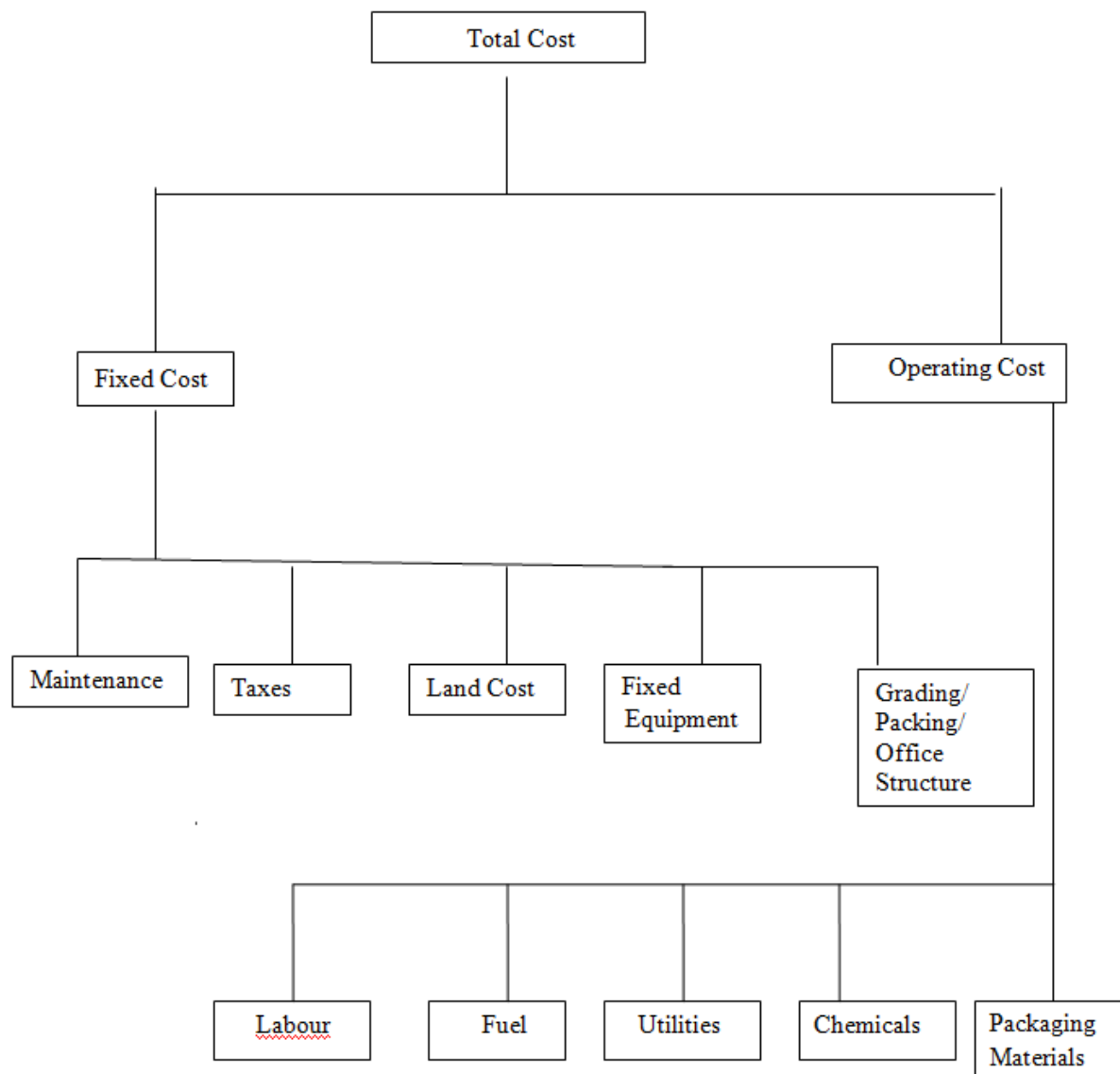
In estimating the capital requirements, the farmer must include the cost of the entire system as well as the mulch. While greenhouse production systems may be far more expensive than open field systems of equal land area, open field systems of protected agriculture are normally more expensive in field area than in greenhouse production. Greenhouses are expensive, especially if the environment is controlled by the use of heaters, fan and pad cooling systems and computer controls.

8.6 Economics of production

Production economics considers the various components of fixed and variable costs, compares them with the income and evaluates the net return, on unit area basis. On an average basis, wages account for approximately 85% of the total variable cost. Wages are the greatest expenditure in greenhouse production, followed by amortization costs and then energy costs, and energy expenditure, when heating is necessary. About two-fifths of the expenses are fixed costs and about three-fifths are variable costs. Depreciation and interest on investment accounts for most of the fixed costs.

8.6.1 Conditions Influencing Returns

A number of variables which may not show up in the yearly financial balance sheet influence the returns to green house operators, such as economics of scale, physical facilities, cropping patterns and government incentives. The size of any system of protected agriculture will depend on the market objectives of the farmer. Most protected agricultural endeavors are family operated. Often the products are retailed directly to the consumer through a road side market at the farm site. In the developed world, greenhouse operations tend to be a size that can be operated by one family (0.4 to 0.8 ha). A unit of 0.4 ha can be operated by two to three labourers, with additional help at periods of peak activity. The labour wages can usually be provided by the owner and his family. Moreover, the owner will pay close attention to management, which is the most important factor. Labour costs may rise significantly if it is necessary to recruit labour from outside the family. Green house owners who hire a highly qualified manager may have to operate a larger greenhouse than family size greenhouses in order to offset the additional salary paid.



The green house system economy can be improved with increased size when:

1. There is a unique opportunity to mechanize certain operations.
2. Labour can be more efficiently utilized.
3. Low cost capital is available.
4. There are economics in the purchase of packaging materials and in marketing.
5. Some special management skills are available.

The physical facilities and location of the green house influence the economics. Another variable that influence the profits from the green house is intensity of production, which is determined by the structures with complete environmental control system facilities year round production and early harvest, thus enabling the grower to realize higher profits. Year –round production offers year round employment to the laborers. It is found that the environmentally controlled green house produced only one- third more revenue than high tunnel structure. With the improved transportation facilities, the new areas of production in combination with the following factors contribute to the lower costs.

1. High sun light intensity undiminished by air pollution.
2. Mild winter temperatures.
3. Infrequent violent weather conditions.
4. Low humidity during the summer for cooling.
5. Availability of water with low salinity levels.

Cropping pattern will have bearing on the green house structure. A high –tunnel structure or any structure not fitted with environmental controlled equipment for heating and cooling will be used only on a seasonal basis. It is common to switch over from green house vegetable production to flower production, especially in structures with more elaborate environmental control systems.

Growers through out the world are currently experimenting with alternative crops, such as herbs. As eating habits change, with times and as the consumers are becoming increasingly conscious of diet and the nutritional value of fruits and vegetables, growers must continually look for alternative to existing cropping patterns. Government policies also influence the financial returns from the crops. Government may provide grants or low interest loans, subsidies towards construction costs, fuels, and use of plastics, such as drip irrigation systems, mulches, row covers and covering materials. Such incentives from the Government encourage the growers and stimulate the green house industry.

8.7 Greenhouse utilization in off-season

Drying is traditional method for preserving the food. It also helps in easy transport since the dried food becomes lighter because of moisture evaporation. Drying of seed prevents germination and growth of fungi and bacteria. The traditional practice of drying agricultural produce in the developing countries is sun drying, which is seasonal, intermittent, slow, and unhygienic. To overcome the problems of sun drying, mechanical drying is introduced with the following advantages: (i) fast drying, (ii) large volumes of produce can be handled (iii) drying parameters can be controlled and quality of the produce can be maintained. The energy demand of conventional mechanical dryers is met by electricity, fossil fuels, and firewood are becoming scarce. Solar energy can be an alternative source for drying of food and solar dryers are employed for the purpose. The use of the greenhouse as a dryer is the latest development. The drying capabilities of the greenhouse can be utilized for curing tobacco leaves, while guarding the harvest from rain damage.

8.7.1 Drying of agricultural produce

In an efficiently managed greenhouse CEA, there will not be any time gap between crops. However, for some other management reasons, if crops are not grown in a particular period, the greenhouse can be utilized as a solar dryer. A small amount of 15 to 30% of the incoming solar radiation is reflected back from the surface of the greenhouse, with the remainder is transmitted into the interior. Most of this transmitted radiation is absorbed by plants, soil and other internal surfaces, the rest being reflected. The usage of greenhouse for the purpose of the drying is of recent origin. Papadikas et al., (1981) investigated the usage of greenhouse type solar dryer for drying grapes. Kholliève et al., (1982) developed a greenhouse type fruit dryer cum hot house used as dryer in summer and as a hot house in winter. They were successful in advocating the year round utilization of the greenhouse facility and thus reducing the operation cost per unit output. In general, the produce is spread as thin layers in trays covering the greenhouse area. The trays can be fabricated with sheet metal and wire mesh. Trays should be arranged horizontally on existing growing benches or frames. For better operation, proper ventilation should be provided by either forced or natural ventilation, to remove the moisture liberating from the produce and to control the air temperature inside the greenhouse. The natural ventilation can be enhanced by using a black LDPE chimney connected to the greenhouse.

8.7.2 Curing of tobacco

Tobacco is an important foreign exchange earning commercial crop of India, which provides employment opportunities to lakhs of people. Curing of tobacco is a delicate and vital process in producing good quality leaves. Tobacco curing essentially refers to drying of the harvested fresh

tobacco leaves under controlled temperature, humidity and ventilation in order to initiate the essential bio-chemical processes. The success of curing also depends on the condition of the harvested leaves and their degree of maturity. The usual curing methods are flue, air, pit, fire and sun curing. The open field sun curing is the cheapest method of curing. The drying capabilities of greenhouse can be successfully utilized for curing the tobacco. Different stages of tobacco curing require specific environmental conditions for the best product, which can be maintained easily in a greenhouse. The harvested tobacco leaves are made into bunches of few leaves by knots and arranged serially to form a string with free ends left for fixing it. Scaffoldings should be erected inside the greenhouse and the string of leaves is tied to them, for the tobacco curing process. To increase the capacity, the strings are tied with judicious gap between them and also put in tiers. As curing progresses, the leaves loose moisture and the string will become lighter and the initial sag in the strings can be corrected. For maintaining uniform product quality, the strings can be cycled among the tiers in a specified sequence. Humidity and temperature control by proper ventilation and frequent inspection is important in tobacco curing operations.