CHAPTER 14

GREENHOUSE ENERGY AND RESOURCE ALTERNATIVES
"GREENING" THE GREENHOUSE

INTRODUCTION:

* Over the past 50 years, greenhouses have been rather "un-green" endeavors: plastic glazings, tubing and clips; heating using fossil fuels such as natural gas; fans, pumps and computers powered by electricity from various sources including coal… and the cost of fossil fuels continues to rise. Green technologies have been studied and, in Europe for example, have been put into practice. But in most countries, until recently, "greening the greenhouse" has not been a priority.

* Cost can also be calculated in terms of sustainability. As resources become more limited and/or expensive, growers are searching for ways to become more green and more sustainable in the greenhouse.

*This chapter presents some methods for "greening the greenhouse", including ways to conserve energy, alternatives to traditional methods of heating and cooling, using sustainable and/or biodegradable materials, water harvesting, etc.

EMPHASES IN GREENHOUSE TECHNOLOGY & INDUSTRY BEHAVIOR

50 years ago: Moving towards modern CEA & soilless culture production practices (with all its "un-green" technologies & behaviors).

20 years ago: emphasis was in meeting the market demand for consistent, safe, high quality foods & ornamentals, year around.

Today: CEA & soilless culture/hydroponics is an established form of production agriculture. Some are experimenting with sustainable practices.

Future: Development & use of sustainable plant production systems, technologies and behaviors in all greenhouses.

SUSTAINABILITY

* In 1983 the United Nations convened the Brundtland Commission (formerly the World Commission on Environment and Development) to study the accelerated deterioration of the Earth's environment and its natural resources. The report, Our Common Future, was published in 1987 and defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

* 'Our common future' can also not just refer to human nations and peoples but to all life on Earth, as we are all connected and depend on each other for survival.

* Basic needs for all life include food, water, shelter and space. However, many scientists are very concerned about the impact of human society on the Earth. And, given that food, water, the materials to build shelters and space are all limited on this planet, unrestricted growth of all things (including cities, the economy and population) is not sustainable.

*As for agriculture, **sustainable agriculture** must be:

Environmentally sound:

Reduce environmental pollution by re-cycling & reusing resources
Reduce pest & disease infestations, thereby reducing the use of pesticides
Use renewable energies

Economically viable:

Increase yields
Decrease the costs of resources used

Socially supportive:

Provide stable, year-around, employment to people

SUSTAINABILITY: GOING BIODEGRADABLE

* **Clips and string:** currently those used in most greenhouses are made of plastic. Since it is too expensive and time consuming, commercial growers do not remove these at the end of the season. The plant material and plastic all end up in the landfill ! Biodegradable clips & string are available, though they are more expensive than plastic. Hopefully, in the future, biodegradable materials will allow for plant composting rather than filling up the landfills with green waste & more plastic.

* **Growing materials**: Since the 1970's Rockwool has been the standard growing media in the greenhouse and it works very well. But Rockwool is not biodegradable and, has become a problem as it fills up the landfills. Other growing materials, volcanic rock and coconut coir (husk material), are now being used by many growers. All of these can be reused or, in the case of coco coir, composted.

SUSTAINABILITY: MANAGING WATER & NUTRIENT SUPPLIES

* **Water harvesting** from the greenhouses and associated buildings could provide water especially for evaporative cooling. The rain water is free of salts and would keep the pads cleaner than if saltier ground water was used.

* **Water & nutrient recycling** is routinely done by large growers. This requires 1) a sterilization method (to kill possible pathogens in the recirculating solution) and 2) a way to monitor and refurbish the nutrient/water content of the solution coming out of the bags (used solution). Sterilizing and refurbishing the output solution is costly but saves on water and nutrients, which are also very costly.

* **Organic versus "veganic"**. Many soil growers have converted to organic nutrients (from living organisms – bat, chicken or cow manure, fish emulsion, etc.) but they have also had many problems with contamination (*E. coli*, salmonella, growth hormones, etc.). A few growers are using compost teas or compost growing beds derived entirely from plant material (i.e., veganic, with or without the addition of red worms to help decomposition) as a food for their plants. This is being done by Sunizona Family Farm, Willcox, AZ, and by Grimmway Farms, CA.

FOOD SAFETY/SECURITY

* **Producing our own energy** – Much of our oil comes from other countries and much of our energy is dependent on fossil fuels. These fuels (oil, natural gas, etc.) have been used for greenhouse heating for decades (not to mention in other forms of agriculture - gas/diesel farm equipment, natural gas/fuel oil to heat animal barns, etc.) . As fossil fuel reserves decrease or overseas reserves become inaccessible (due to war, political differences, etc.) the cost of heating a greenhouse with these fuels will rise until it is uneconomical (i.e., many greenhouses failed in the 1970's due, in part, to rising fuel costs brought on by the oil embargo). Also, fossil fuels release gases when burned (i.e., CO_2) which cause heating of the atmosphere. Therefore, other energy sources should be researched and adopted (see below).

* **Producing our own food** – Much of our food now comes from other countries. As transportation costs rise it is costing more for our meals to reach our plates and locally grown food is gaining favor. This is evident with the large number of farmer's markets and the increase in local/urban farms that are springing up in cities all across the country. Also other countries may not have the same regulations concerning the use of pesticides and many people are concerned about pesticide residues on produce. Whether locally grown or not, this is also prompting many people to look for the "organic" label.

* **The problem with population** – Human population was relatively constant for tens of thousands of years reaching ~ 4-5 million 10,000 years ago. The first billion was only reached in the early 1800's whereas now human population is increasing exponentially and is projected to exceed 9 billion by 2050. We must realize that our planet has a finite amount of arable land and that the ever-expanding human population is giving rise to conflicts and war over land and dwindling resources. Also, the increasingly crowded conditions of cities provide the perfect environment for the outbreaks and spread of disease. Finally, large populations give rise to pollution contaminating our waters, soils and air. We must find ways to manage our own population, before we destroy our home!

* **The problem with global climate change** – Many areas of the planet are undergoing desertification, decreasing the amount of arable land. With the warming of the seas and melting of global ice, global sea levels are rising causing inundation of low lying coastal areas. This is creating environmental refugees and forcing

people, who lived in these flooding areas, to higher ground putting more impact on already populated regions and a strain on already decreasing resources. Just a few degrees of temperature change can cause a large change in climatic conditions. An example is the “Little Ice Age”, starting in the 1300’s and ending around 1850. During this time a few degrees reduction of average temperature caused more severe cold resulting in shifts in agriculture, famines, disease and mass migrations. A few degrees of heating are now causing similar problems and these problems must be addressed to secure global food supplies.

ENERGY CONSUMPTION BY ENERGY SOURCES: PAST & PRESENT

*Past: Humans have burned “biofuels” (wood, animal dung) for millennia. Fossil fuels (coal, petroleum, natural gas) have allowed our civilization to expand tremendously. However, the “harvesting” and burning of these bio and fossil fuels have also led to environmental degradation and pollution. Since WWII, nuclear power has increased in use worldwide but not without its problems – there have been at least 100 nuclear power plant accidents (56 in the US) from 1952 to 2011 including Three Mile Island PA 1979, Chernobyl Ukraine 1986 and Fukushima Dai-ichi Japan, during the tsunami, in 2011.

*Present: Since the early 1970’s, alternative/renewable energy sources have been added to our options. Whereas total energy consumption per year has increased about 30% from 1970 to 2013, use of renewable energy sources (see Table 14.1 below) has increased more than 100%... But we still have room for improvement!

Table 14.1: US energy consumption per year, by energy sources, in Quadrillion BTUs. *

DATE	Fossil Fuels:				Renewable Sources:						Total
	Petrol oil	Nat’l Gas	Coal	Nuclear	Hydro electric	Geo thermal	Solar	Wind	Bio mass	Renew total	All energy
1970	29.521	21.795	12.265	0.239	2.634	0.006	NA	NA	1.431	4.07	67.891
2014	34.783	27.592	17.991	8.329	2.469	0.222	0.427	1.734	4.770	9.622	98.460

*From: U.S. Energy Information Administration/Monthly Energy Review, 2014.

ALTERNATIVE SOURCES FOR ELECTRICAL POWER

* **Solar PV (photo voltaic) systems:** The sun’s energy heats the greenhouse. It could also be used to power solar photo voltaic panels that would provide energy to run the fans and pads needed to cool the greenhouse. High light regions of the world would be perfect places for solar PV systems to power greenhouses. Recently, new PV films have been developed for use on or <u>AS</u> greenhouse structures.

* **Wind:** Use of wind turbines to create electrical energy is being used more, especially in high wind areas (e.g., North Sea, mountain passes in CA). If a greenhouse was located near a windy area (not the best idea, see Ch 11) or had access to wind energy, one might take advantage of this energy to meet the electrical needs.

* **Anything that can heat something** (i.e., water to make steam) **to run turbines that then generate electricity**. Typically this has been coal, fuel oil, or other fossil fuels. More recently, methane from landfills has been harvested as energy. An alternative is "biomass" which could include pruned plant material from the greenhouse, or other green or brown (wood, cardboard, etc.) waste.

* **Water energy**: This includes hydroelectric power created by damming rivers and using the falling water to turn turbines, a method already being used to produce a significant portion of the world's renewable energy. But "water energy" also includes wave energy. This technology is in the experimental and demonstration stages in Australia, Portugal, England, Scotland, Israel & Oregon USA.

ALTERNATIVE ENERGY SOURCES FOR GREENHOUSE HEATING

***Compost or biomass energy**

The breakdown of plant material in a compost pile generates heat (& CO_2).

Example: Outside temp = 55ºF (~13^0C), temp in the pile = 120ºF (49^0C) !

PVC pipe, with an opening to the outside air, can be put under the pile. Heat from the pile is transferred to air in the pipe which is then drawn into the greenhouse with a small fan. Can add moisture and odors to the air.

Pipes filled with water can also be placed inside the pile and the heated water can be used to heat the greenhouse. This is much better and odor-free.

Sunizona in Willcox, AZ is burning pelletized pecan shells from nut growers to produce heat energy. The shells would otherwise end up in the landfill!

***Solar / fluid energy**

During the day the sun can be used to heat either water or other fluids (glycol). This hot fluid can then be pumped, via pipes, into the greenhouse at night.

However, at present it would take a solar collector at least 500 m^2, or larger, to heat a greenhouse 1000 m^2… but technology is always advancing. Solar/fluid heat collectors are being tested in northern Europe.

Also, solar collectors do not work effectively on hazy or cloudy days. Other types of heat generation would be needed as a back-up.

***Geothermal energy**

Water heated by energy from the Earth's interior is being used extensively in Iceland to heat structures including homes, businesses and greenhouses.

In 2010 the USA was the world leader in geothermal electric production with 77 power plants, most in the western half of the United States, the highest number in California. Geothermal is also being used to heat many greenhouses, producing potted plants, cut roses, cacti, fish, etc.

Problems of using geothermal energy include corrosion and sealing of the pipes, toxic gases such as hydrogen sulfide, mercury, radon, ammonia and boric acid, silica deposition in the equipment, heavy metal contamination and complications with disposal of the waste thermal fluids.

***Waste heat utilization from power plants**

Large industrial units, electrical generating stations and nuclear power plants all produce waste heat mainly in the form of hot water.

During the 1970's and 1980's (last "energy crisis") research was conducted to determine the feasibility of using this waste energy to heat greenhouses.

Facilities were tested in France, England, the United States and other countries.

Most tests showed that the cost of connecting the greenhouse and power plant could be too high and that the resulting heat source might be unreliable during repair and maintenance of the power plant.

However, the current high costs of fossil fuel energy sources could make this alternative energy source more attractive and affordable in the future.

***Co-generation**

Total energy systems which produce both heat and electricity from the same unit.

It consists of an engine which turns a generator to produce electricity onsite. Small units can produce 20-100 kilowatts.

Reject heat from the operation of the engine can be used to heat the greenhouse.

One might also be able to obtain an extra added benefit by tapping the engine exhaust for carbon dioxide for use by the plants in the greenhouse.

ENERGY CONSERVATION MEASURES FOR HEATING & COOLING

* **Introduction:**

In northern latitudes (Canada, England, Holland, etc.) the cost for heating, especially, and cooling a greenhouse has amounted to 70 – 85% of the total operating costs.

In warmer areas (the Southwest United States, Mexico, Spain, Turkey, Israel, etc.) heating and cooling can still be around 50% of the total operating costs.

Therefore, any measures that reduce the cost of or the need for heating and cooling will reduce the overall greenhouse operating costs and will therefore increase profit (the bottom line for a commercial grower, schools and even home gardeners!).

* **Greenhouse orientation:**

-For high latitude ($>= 45^o$) and single bay greenhouses: use east–west orientation. This gives maximum light transmission when the sun angle is low.

-For lower latitudes or gutter connected greenhouses: use north–south orientation for both plant rows and greenhouse for maximum light throughout the day.

* **Use of single bay versus double bay greenhouses:**

Two single-bay greenhouses will each have 2 side walls (4 total) through which cold or heat can enter or leave the greenhouses.

With 1 double-bay greenhouse there will only be 2 side walls.

This reduces the surface area through which cold and heat can move thereby reducing the heating and cooling required to maintain temperature.

***Use of double verses single layer glazings:**

Double layer glazings, with at least a ¼" insulating layer of air in between, can reduce the conductive heat loss by up to 40% over single layer glazings.

Using triple layered glazing or a double layer of polyethylene over glass, can further cut heat loss, but will also reduce solar radiation, so is rarely used.

***Structural considerations – heat conservation:**

Insulating materials can be applied to the foundation of the greenhouse, to the north wall (in the northern hemisphere) and to the walls up to the height of the plants to reduce conductive heat loss, though don't block the light.

Weather stripping and other insulating materials should be added where ever there are gaps in the structure. This includes around doors and vents and where glazing panels meet the structural supports.

If the glazing material is cracked (ripped polyethylene, broken glass panes or cracked poly acrylic or carbonate) replace immediately to reduce heat loss.

***Structural considerations – cooling conservation:**

As with heating conservation, insulation and weather stripping can reduce influx of hot outside air into the greenhouse which will reduce cooling needs.

Damaged glazing materials should also be replaced.

Use tall greenhouses (16-22 ft or 5-7m), since hot air rises away from the crop.

***Retractable heat or insulating blanket or curtain:**

Porous, non-porous and aluminized materials are all used as insulation blankets.

The material can be single or multiple layers: more layers giving more insulation.

The material, placed between the ceiling and the crop, must be secured along the walls to minimize cold air above falling through onto the crop.

These curtains can be used during the day in the summer for shading as well.

These retractable curtains are perhaps the most cost effective.

***Windbreaks to save on heating:**

A wind of only 15 mph can double the heat loss from a greenhouse.

Wind reduces the thickness and therefore the insulating effectiveness of the thin air layer (boundary layer) on the outer surface of the greenhouse. Wind will "suck" heat away from a greenhouse faster than if the air was still.

Windbreaks, in the form of fences, trees, buildings, etc. can slow the wind and reduce heat losses from the greenhouse – best in high wind areas.

Windbreaks help most with older, leaky greenhouses. However, insulating will save far more money in heating costs than can any windbreak.

Place windbreaks far enough away from the greenhouse to avoid shading

*** Infrared (IR) coatings on polyethylene films:**

These IR barrier films allow heat into the greenhouse during the day (requiring more venting/cooling) but reduce heat loss at night by as much as 30%.

With a reduction in heat loss comes a reduction in heating needed to maintain temperature and therefore a reduction in heating costs.

***Other heating/insulating methods – experimental or small scale only:**

Black-painted water-filled drums, used to capture solar energy during the day and radiate it into the greenhouse at night, is applicable for hobbyists. Cheyenne Botanical Gardens uses this method in one of their greenhouses.

Inflatable polyethylene tubes (6-18" in diameter) can be hung from the greenhouse ceiling. When inflated they create an effective insulating barrier to heat loss through the ceiling (up to 40%). The tubes must fit snuggly along the walls. Since polyethylene above the crop will reduce light transmission, tube systems must be retractable or removable during the day. Though effective, these systems are rarely used commercially.

Polystyrene beads have been used by blowing them into the air space between two glazing layers. Energy savings may amount to 60-90% annually but they reduce the light transmission and are not used commercially.

Liquid foam (or soaps) can be blown into the air space between two glazing layers for an energy savings of perhaps as much as 50%. A disadvantage of this is that most foams break down in cold !

***Equipment operation and maintenance:**

Maintain heating/cooling equipment (check for leaks, valve operation, fan motors, thermostats, water pumps, etc.) so that they operate at peak efficiency.

Insulate supply and return hot water/steam pipes. Inspect regularly.

Choose the most efficient and cost effective fuel in your area.

***Passive measures:**

Energy savings can be realized by using shade cloth or paint (see Chapter 13).

REFERENCE MATERIAL

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