Alternative Energy Center

Overview

The Tour
Those who toured the former Alternative Energy Center became aware of what you saw was based on very fundamental laws of science.

The Law of Conservation of Matter
The first principle is that we cannot create or destroy matter; we can only change it from one form to another. Everything that we think we have thrown away is with us in some form or another; there is no away. Hence, it behooves us not to create or use toxic pollutants that build up in the food chain and in our bodies. There is really no such thing as waste in nature since the wastes of one species is food for another. We thus try to reuse and recycle all matter within our local system.

The Law of Conservation of Energy
The second principle involves energy flow. We cannot create or destroy energy; visitors witnessed only change it from one form to another. At the AEEC, we can witness many transformations of energy between forms, putting this law into practice.

Second Law of Thermodynamics (or Entropy Law)
Concentrated or high quality energy is useful and can do many things. Other energy is low-quality and not very useful. As we convert energy from one form to another, energy quality is always degraded. In other words, energy once degraded cannot be recycled to do useful tasks. Thus, our fossil and nuclear fuels, once used, can never be used again. The only energy source that is truly sustainable in the long-term is from the sun. In addition, the use of non-renewable fuels creates toxins in the air, water and soil for which there is no "away." The Second Law tells us that after we disperse these pollutants, it will be practically impossible to remove them from the environment. Therefore, pollution is essential.

Laws of Ecology
There are also several laws of ecology that tell us that humans are interconnected and interdependent with everything else on the earth, that we cannot do just one thing, and that we must not interfere with earth's natural biogeochemical cycles in ways that destroy our life-support systems. That is, in our use of resources and energy, we must be careful not to destroy the basis for all other forms of life upon which we are ultimately dependent. In this tour, we will see some of the ways that these various principles and laws may be put into practice.

As we see the various options for reducing the negative impact of our resource consumption on the planet, it may seem that one person can have little effect. However, you must keep in mind that there are 6 billion people on the earth today, and that number is expected to grow to 12 to 14 billion in the next 50-100 years.

Remember that each positive thing we do has a multiplier effect. Saving water saves energy and also reduces pollution. Recycling an aluminum can reduces the need to mine more ore, process it, transport it, and produce the can. All along the chain, energy and pollution is reduced. Humans must achieve a balance with the earth's resources and life-support systems that is sustainable or suffer severe consequences. The concepts that we see in this tour can play a major part in helping to achieve long-term stability or sustainability.

History

The Alternate Energy and Environment Center (AEEC) was begun in 1975 by a group of students and faculty at Ramapo College in response to the energy crisis of the 1970's. It's goal was to provide a student-built environmental education facility that demonstrated alternative methods of producing and using resources, particularly energy, food, and shelter, that were not heavily based on depleting and polluting sources of fossil fuels.

It was hoped that the technologies and methods developed would provide some insight into how to provide people with the necessities of life, food, shelter, heat, electricity and water that would be ecologically sustainable [able to be provided in the long-term without depleting the life-support systems such as pure air, water, soil, microorganisms and biodiversity of life that are essential for our long-term survival]. At the same time, the AEEC also sought to model social and community sustainability, represented in the full participation of people in a climate of equality and mutual and environmental respect, in the process of achieving personal self reliance and collective survival. The center demonstrated both technological approaches and social/community approaches to understanding and seeking sustainability.

The Center
At the Center, visitors saw various integrated technological systems, most relatively simple, that used local resources such as soil, water, and the sun to provide for human needs.

In one integrated system, a three-season bio-intensive organic garden provided nutrients from composting and from animal manure, water from a solar-powered water-pumping windmill and storage tank.

A solar greenhouse provided seedlings for the garden, extended the growing season, and allowed winter food production.

A relatively simple energy efficient passive solar building (the solar schoolhouse) had its heating, cooling, electricity and hot and cold water provided for by the sun, wind, and biomass (wood).
Some of the methods and technologies have been around for some time, while some (small-scale bio-intensive gardening methods, PV's, small efficient wind generators, solar pumps) are on the cutting edge of today's modern technologies.

The Center was not a demonstration of exactly how we should live, but it offered examples of many technologies and ideas that could easily be incorporated into your current household and lifestyle. These included:

* small-scale production of food
* yard and organic waste composting
* energy efficiency
* minimizing use of all resources
* recycling
* maximizing the use of the sun to provide energy for many purposes

These approaches to providing basic needs can make people more self-sufficient, help extend resources and save money, and reduce pollution.

These technological demonstrations did not exist as isolated examples, but rather as part of a set of interrelated relationships between people and their natural support systems. The nature of these relationships is qualitatively different than the normal ways that people rely upon technological systems to meet their environmental needs.

Rather than reducing nature to a storehouse of resources to be exploited by humans, the AEEC suggested that people can meet their needs successfully by acting with and through nature, not against it. Thus, a relationship of stewardship and participation characterized the activities at the AEEC.

People engaged in growing their own food, they directly felt the warmth of the sun that heats their buildings, they pumped their water up from the ground or un-leased the force of gravity to drop it down from the storage tank, they placed organic wastes in the compost bins and then stirred the piles, becoming agents of the composting process.

In all these things, they created and built and experimented with nature as a guide---as the ultimate teacher. But they also saw the cyclical relationships of nature---how compost fuels plants that are eventually composted. And, thus, they viewed nature as a learning process, of response to feedback, that creates highly variable and adaptive systems.

In a world in which our needs are met by mindless switching on of circuits, at the AEEC, there was the possibility of discovering an intelligence far different from the automated virtual reality we have surrounded ourselves with.

Participant learning followed Barry Commoner's ecological rule that "nature knows best." It is incumbent upon the individual and the social system to provide the skills for observing, understanding and collaborating with nature. What are some of the lessons to be learned?

Benefits

The Recycling Center
The structure that greeted the visitor to the AEEC was a largely open ramada structure. As the result of the foresight and hard work of two environmental studies at Ramapo, this building was constructed in the 1970's as a model community recycling center. A wide range of materials encompassing the household waste stream was collected, even including waste car oil.

Materials were processed at the recycling center and sold to support the AEEC. People from Ramapo as well as the surrounding communities used the center through the mid-1980's. At that time, under New Jersey's model state recycling law, ownership of the recyclables passed to the Township of Mahwah, which created its own recycling center. For a time, Mahwah operated the center at the AEEC, but eventually consolidated operations in its own facility. As a new use of the recycling center evolved, it stood as a remembrance of how two Ramapo College students took the initiative to create a model recycling program at a time when relatively little recycling was occurring. Today, seeing the ecological and social destruction that the era of waste disposal created, it is easy for us to realize the importance of the three R's of waste management: reduce, reuse and recycle. If we avoid waste creation, give already manufactured products and materials a longer use life and recapture the resource values of spent materials, 90% or more of the at least six pounds of waste we generate daily can be averted. As we have already learned, everything goes somewhere and there is no "away." Waste begets pollution.

Tree Nursery and Potential for Permaculture
A small tree nursery was also been established at the AEEC, serving eventually as a source of trees to grace the Ramapo campus. Elements of a permaculture also existed at the AEEC. Permaculture makes use of perennial or self-seeding food plants that require little care and supply an edible landscape.

The Garden

Modern industrial large-scale agriculture produces a lot of food, but it also has a lot of negative impacts. In the U.S., about 1/5 or 20% of all our energy use goes into our food system (farm, processing, transportation, storage and preparation), tremendous amounts of artificial fertilizers, pesticides and herbicides are used (using fossil fuel resources and creating pollution), land degradation is accelerating (from erosion and salinization), water use for irrigation is not sustainable in many regions, and natural ecosystems (grasslands and forests) are being destroyed. Yet very large amounts of food can be produced on a small scale without these negative effects.

The garden was based upon French intensive biodynamic principles developed in the late 19th and early 20th century and coupled with modern technologies. This method is based on intensive spacing of plants, enriching the soil with natural organic fertilizers and nutrients, extended three-season planting and growing techniques, and providing natural pest control (for insects, plant diseases and animals) through cultural methods, mechanical and biological controls, and safe use of natural chemicals. Direct use of fossil fuels is minimized. By extending the season, many vegetables and fruits can be eaten fresh without processing or storage. Transportation costs and associated energy consumed is nil. No toxic pollution is created, in the air, water or soil, or on the food. Indeed, the garden becomes a joint human/nature endeavor which is beneficial for many species of life. Each of the simple techniques and methods used supports and enhances the others so that the system becomes more productive than the sum of each technique alone (the principle of synergy). Let's look at several components.

In the garden you would have noticed the raised beds and the walkways. Visitors were asked never to step on the beds! Ordinary agriculture plants crops in rows several feet apart and compacts the soil next to plant roots by machinery or walking. Raised beds (typically 3-4 ft wide and any length) allows the plants to be grown close together, maximizing the space for plants and minimizing the walkways. This is called intensive spacing. Working with raised beds has other advantages. Nutrients may be concentrated in the beds where the plant roots can absorb them. Loose un-compacted soil favors good drainage, deep root penetration, and good root air exchange or aeration. Raised beds dry out quicker in spring, allowing earlier planting. Plant roots do not sit in water if it very wet. By concentrating production of certain crops in small areas, protective devices for insect control, summer shading, or cooler weather protection may be more easily applied. Mulch such as newspapers, hay, leaves, grass clippings or other organic material may be applied to the walkways to eliminate weeds, and to the beds around the plants to reduce weeds and hold moisture in the soil.

Next, visitors were asked to look at the soil. They would have noticed that it was relatively dark, indicating that it had a high organic material content. The intensive planting method is very productive because the soil is high in natural nutrient content. The breakdown of organic matter releases nitrogen at a rate that supports continual growth of the plant. Nitrogen as well as other important nutrients such as potash (potassium) and phosphorous and many important trace elements are provided with the use of compost, animal manures, natural mineral soil amendments, with green manure crops, or by decaying mulch. Such soil is biodynamic in that it contains vast amounts of soil microbes and insects that help break down the organic matter, thus releasing nutrients to plants. The soil has lots of pore spaces that can hold air and water. Such soil holds moisture much better but doesn't saturate with water, and has a crumbly beneficial soil structure that encourages root growth. The ideal soil will have 5% organic matter, 45% mineral matter (mixture of silt, clay and sand), and 25% soil water and 25% soil air space. The goal of an organic gardener is to continually increase the fertility of the soil, leading to better plant growth using intensive spacing, and less problems with disease and insects (healthy plants will usually outgrow the problems).

Visitors looking at the plantings in the beds, would have noticed the diversity of the garden. There were different spacings (different for different crops), interplanting of different crops to best use the available space (both above and below ground, i.e. lettuce and brassicas) and nutrients (heavy feeders vs light feeders, i.e. corn

and beans), succession planting so that there will be a continual harvest over time, companion planting to enhance the growth or diminish the stresses on plants; (i.e. aromatic plants such as basil and French marigolds can mask a crop from pests; others attract pests, keeping them away from the desired crop), mulch to keep weeds from germinating and to keep the soil from losing too much moisture. Many flowers and herbs attract beneficial insects which help keep damaging insects in control. In contrast, large scale agriculture is based on monoculture, thousands of acres of the same crop. This provides a vast food source for insects and encourages the spread of plant diseases. Diversity in the garden provides protection of the harvest. Despite weather fluctuations, drought, insect attack or diseases, diversity ensures that many plants would survive to provide a food source.

The garden provided a variety of foods grown over 3 seasons - spring, summer and fall. Some plants such as peas, brassicas and lettuce prefer cool temperatures; others such as tomatoes, beans, corn and squash are heat-loving. Cool temperature plants may be planted in the spring and again in the fall. In this climate, some crops may be planted as early as March and grow through October without protection. By using solar-based protective devices such as cold frames, row covers, or solar pods, some varieties may be started even earlier. This same devices allow the fall season to be extended until late November or December. There are also plants such as kale, spinach and various greens that are cold-resistant. With some protection, they may be grown or over-wintered in the coldest months. Some crops such as carrots and parsnips may be stored in the garden under mulch throughout the winter. Integration and use of these different crops and methods allows for food production and availability throughout the year, sometimes called 4 season gardening.

In biodynamic organic gardening, various methods were used to control pests (insects, plant diseases and destructive animals) to keep the damage at minimal and acceptable levels. The use of powerful chemical pesticides and herbicides is avoided because they damage the beneficial living organisms in the soil, they kill beneficial insects, they pollute the drinking water, and they leave poisonous residues on food. They also don't work in the long run since insects build up resistance and immunity so that even more powerful and dangerous chemical must be used. Use of such chemicals also exposes us, our pets and our loved ones to poisonous substances.

Pest and weed control in the organic garden was based on a variety of methods including:

* crop rotation - moving crops on a 3 year rotation helps prevent disease and insect buildup
* clean cultivation - removing and destroying diseased plants, removing weeds before they go to seed
* variety selection - choose varieties that have disease and insect resistance
* mulch - to prevent weeds from sprouting
* intercropping - diversity makes it difficult for pest populations to expand rapidly
* companion planting - repels certain insects, provides trap crops, etc.
* biodynamic soil - plants outgrow insects and diseases
* mechanical control - row covers, bird netting, fences, cut worm collars, beetle and slug traps, sticky traps, and hand picking all protect vulnerable crops
* innocuous chemicals - soapy sprays, pepper or garlic-based sprays, or even just spraying water can control aphids or flea beetles; light oil spray coats insect eggs and suffocates certain insects
* biological controls - BT is a bacteria that can be sprayed or dusted on plants which is deadly only to caterpillars, milky spore disease may be used against Japanese beetles, predators such as lady beetles, soldier beetles, parasitic wasps and beneficial nematodes may be used to provide control for certain insects; it has also been found that mulching the garden enhances the spider population which then provides greater insect control.
* organic chemical insecticides - extracts from certain plants contain poisons that kill insects. Pyrethrum, rotonone, ryania, sabadilla and neem are broad spectrum organic insecticides. That is, they kill both destructive and beneficial insects, often may affect birds and fish, and are often dangerous to humans. Most do break down quickly in the soil. It is suggested that these be used only when all other methods fail, and then only sparingly with caution. Their use should be part of an integrated pest management (IPM) regime, in which the use of pesticides is timed carefully to the outbreak of pests.

The average person in the U.S. eats about 300 pounds of fruits and vegetables a year(about 1/4 of total food consumed). With some knowledge and a relatively small effort (less than an hour per week for a 100 sq. ft. bed or 33 ft x 3 ft), you could grow a lot of your fruit and vegetables for consumption in a small space in your backyard. From a health perspective, it would be desirable to perhaps double your present consumption of fruits and vegetables.

The Windmill and the Storage Tank

Water Pumping Wind System and Water Storage
Pure water, like pure air and food, is part of nature's life-support system upon which humans depend. Water supply is a potentially renewable resource since the hydrologic cycle evaporates water from the ocean and the winds distribute it over land areas as rainfall. Some of this water is absorbed by the ground and forms a groundwater supply. Other rainfall runs off into rivers, streams and lakes and ultimately finds its way back to the ocean. Both surface and groundwater also can flow into each other. Unfortunately, water can be contaminated from pollutants, and modern agriculture with its massive use of fertilizers, pesticides, and herbicides is one of the major polluters. Water supply itself is a big problems in many parts of the world where rainfall is scarce. In the west and southwest U.S., there are continual problems with water supply. Surprisingly, even in the eastern half of the U.S. where rainfall is abundant (40 inches per year), there are periodic droughts and increasing supply problems. One reason is that massive development pollutes water supplies making them undrinkable. With increasing water scarcity, it is important that water conservation be used to extend our limited supplies.

At the Center, water was needed in the garden and greenhouse for plant growth, and also in the solar school house for human needs like washing. The water supply consisted of a well located underneath the hand pump. The water was mechanically pumped to the surface by a water-pumping windmill where the blade was turned by the wind to provide the up/down motion needed to run a piston pump, or by the mechanical hand pump situated above the well. The well was over 100 feet deep, and the pump is inside a large metal pipe called a casing. The casing is sealed to prevent contamination from surface water. While water directly from the well is safe to drink, the water from the water tower is not (because of pollution from birds, insects, air pollution, etc.).Water-pumping windmills have been traditionally used around the world to provide water for household supply, for cattle, and for irrigation by lifting water from the ground in areas with ample supplies of wind. Since the wind does not blow all the time, it is necessary to provide a water storage tank, a large cedar-built tank that is raised off the ground so that gravity will provide water pressure so that the water will flow to the garden, greenhouse, and schoolhouse. Cedar wood is water and rot resistant, and cedar expands when wet to form a tight seal. The water flows in pipes underground to the greenhouse and schoolhouse. In the winter, care has to be taken to ensure that above ground pipes don't freeze and break. The water in the large tank normally doesn't freeze, and luckily, the need for water is minimal in the winter.

At our homes, we get our water from our own well, or from a municipal water supply (from a lake, reservoir, or groundwater wells). Much of our water supply is wasted unnecessarily. This is expensive since much of our water is treated (typically filtered and chlorinated), pumped, and undergoes waste disposal treatment by energy-consuming technological processes. A lot of water use can be avoided by using toilets that use _ gallon per flush rather than 5 gallons/flush, by using water-conserving shower heads, and by using water flow restrictors in bath and kitchen sink fixtures. It is also possible to reuse greywater (water used in tubs, sinks and by washing machines) for various purposes (outside irrigation or flushing toilets).

In the garden, water can be used much more efficiently as well. Watering should be done early in the morning. This avoids plant diseases since the leaves have a chance to dry in the daytime, and evaporation of water due to the sun is minimized. The use of mulch in the garden keeps the beds moister and prevents evaporative losses. Overwatering should be avoided; most plants need about 1 inch of water per week. Keep track of rainfall with a

rain gauge and water all at once only when necessary. If you use a sprinkler, use a timer to limit the amount to 1 inch in case you forget to move the hose in time. There are a variety of drip irrigation systems that minimize evaporative losses, and provide the water directly to the plant roots. In addition, rainwater runoff from roofs can be collected in barrels and used to water plants.

The Composting Bins

The Compost Bins

In the garden, nutrients were being continually removed as the food was harvested. To keep the soil fertile and at a high production level, we must continually add nutrients. At the same time, each household produces large amounts of organic waste (in this instance, materials derived from living plant organisms) that is often trucked to landfills at enormous cost and energy expenditure. Organic waste is a resource that needs to be recycled back to the garden. Thus, composting is based on the law of conservation of matter, principles of recycling and reuse, and wastes as resources. It also uses principles of energy flow, using solar-based bacteria to recycle organic wastes rather than using artificial fertilizers that degrade high quality fossil fuels and create pollution.

The composting bin process represents one way to recycle organic wastes into a useful soil amendment or fertilizer called compost. The system that was used involved moving the compost 3 times; therefore visitors would have seen 4 compost bins. The first contained the initial raw uncomposted organic materials such as food residues, leaves, weeds, animal manure, etc. These materials are mixed and moistened initially and allowed to decay by aerobic digestion (oxygen consuming bacteria). After a few weeks the pile would have been turned into the 2nd bin. This puts some of the undigested outer materials in the center and keeps the pile decaying at a rapid rate. A few weeks later, it would have gone into the 3rd bin. Larger and less decomposed materials are left in the 2nd bin to decay more. When most decay has occurred and the compost looks like dark fluffy soil, it is placed in the final bin and covered to prevent leaching of nutrients by rain. It is then used as needed as a nutrient-rich amendment to fertilize and top dress plants in the garden.

There are many methods to recycling organic matter back to the garden and many ways to compost. One could just make one compost pile and not turn it at all. It would take longer to compost but it would also be less work.

The general principles for making compost are simple. You want aeration, proper moisture and the right combination of materials. You can think of a compost pile as a lasagna. Put some branches and twigs at the bottom for aeration. Alternate 3 inch layers of high-carbon materials (leaves, hay, dried weeds) with 1 inch layers of high-nitrogen materials (fresh grass clippings, fresh green weeds, vegetable waste from the kitchen or animal manure). Add small layers of soil or previous completed compost on top of the material to provide bacteria. Lightly moisten the pile uniformly as you make it (it should have the moisture of a sponge after it has been wrung out). Small amounts of lime or wood ashes can be sprinkled on to avoid high acidity. Put some larger sticks from the top or side to the center for aeration. A compost pile needs to be at least 3 feet in diameter and 3 ft high. The inside of a working compost pile will get hot after several days, perhaps to 130 degrees F. The height of the pile will decrease markedly as composting occurs. The outside layers may be turned to the center after about 2 weeks to continue the aerobic digestion or the pile may be left to decay over a longer time. Composting occurs most readily in the warmer weather. If there is too much carbon material or too little moisture, the pile will take a long time to breakdown. If there is too much nitrogen material or too much moisture, the pile will smell (ammonia odor). You should never try to compost meat and dairy wastes from the kitchen, just vegetable and fruit wastes.

During the growing season, another way to compost your kitchen waste is to bury it about 1 ft deep in a currently unplanted part of the garden. This composts readily, typically in 2 weeks, and then you can plant seeds or transplants on top. If any animals try to dig it up, just place metal fencing or screening on top. In the winter, you can put all vegetative kitchen waste in a covered garbage can outside. It will not compost much, but in the spring you can bury it in the garden in April and grow your squash on top in early May.

Leaves---which many homeowners have in plentiful supply--- can be added to the compost pile as carbon material or they can be used as mulch in the garden. One method is to use them in the walkways where they will eventually breakdown. For example, you can put down 2 layers of white newspaper, cover it with 6-8 inches of leaves, and then top the leaves with a few inches of mulch hay. No weeds will grow in the walkway, it will not be muddy, and by the fall the materials will have decayed enough so they can be raked onto the beds and incorporated into the soil, providing valuable organic matter. Leaves, hay and grass clippings can also be used as mulch around plants in the beds themselves where they also prevent weeds, maintain moisture levels in the soil, and eventually provide organic material to the soil.

There are many household composters (rotating barrels, etc.) on the market. If they really turn you on, by all means get one. But they are not needed to do composting, and many organic gardeners make a pile, cover it with some hay, and just let nature take its course. They do not worry about composting in the fastest possible time. Remember, leaves in a forest compost all by themselves.

The Composting Privy

On the backside of the Greenhouse, you would may have noticed a composting privy. While funds were sought to replace this unit with an easier to manage one, the privy was still illustrative of some important principles about human waste. We normally think that once we flush the toilet, our wastes just disappear.

In fact, in many homes, they collect in a septic system, where bacteria that consume wastes reduce the volume of solids, essentially along the lines of composting. If the bacterial community are killed off from poisons flushed down the toilet or if too much waste is deposited, the septic may not function completely. Septage sucked from the tanks by "honey dippers" becomes a complex waste for disposal, because of contaminants dumped down the toilet and because of the potential for transmitting human diseases. Contaminated water flushes from the septic tank and moves through a leach field, where soil microbes cleanse the water before it returns to the ground. In communities that have sewer treatment plants, more complex and centralized forms of "treatment" are carried out. Massive amounts of sewage sludge (solids) become part of the waste disposal crisis and sewage wastewater (cleaned to varying degrees by different types of sewer plants) is added to surface waters, with potentially adverse effects.

In both of these processes, water is used to move human wastes through pipes. In this way, extraordinary amounts of drinking water-quality water is wasted unnecessarily. The beauty of the composting privy is that no water is used. Wastes drop directly into a composting chapter, where pressed from above by more wastes, they decompose. If properly vented and ventilated, such privies do not smell, because aerobic bacteria (those requiring oxygen) predominate in the composting process. In such privies, it is common to through organic matter, such as leaves, into the privy after each use, in order to diversify the pile's constituents and speed decomposition. Handling of human wastes must be done carefully. Uncomposted wastes can harbor diseases. However, fully decomposed matter removed from the privy is safe to use as a soil amendment for non-food plantings. Such toilets have their roots in the traditional outhouse, but very efficient and effective technologies for the privy have been developed, particularly in Scandanavia. A modern composting toilet, such as the Clivus Multrum, is an effective tool for reclaiming human wastes as compost while avoiding waste of valuable water.

The Solar Greenhouse

The Solar Greenhouse

The solar greenhouse is a useful but not a necessary part of a home gardening system. The solar greenhouse provides an excellent place for winter growing of certain vegetables. It also is a place to start seedlings before putting them out to the garden. Finally, greenhouses can be used to extend the season for certain crops. Summer crops such as cucumbers, tomatoes and peppers can be grown into late fall and early winter. Spring crops such

as brassicas can be grown earlier in the greenhouse. Of course, some of these same benefits could be obtained with the use of cold frames and season extenders in the garden itself.

But aren't all greenhouses solar greenhouses? No! There are many greenhouses that use fossil fuels for heat and artificial lighting for plant growth. Some people actually have greenhouses on the north side of their house, where there is little or no sun in the winter. A solar greenhouse gets most or all of its heat and light from the sun and avoids consuming fossil fuels.

Solar greenhouses can be free standing, as this one is, or they can be attached to houses on the south, east or west sides. Ideally, a solar greenhouse should face south in order to collect the maximum solar intensity, especially in the winter. There are other features of this greenhouse that enhance its performance in the cold weather. The south glazing is made of Kalwall, a fiberglass reinforced plastic that allows 80% of the sun's rays through and also diffuses the sunlight throughout the building. Glass could also serve as a south glazing. The walls and ceiling are well insulated to reduce heat loss. In order to prevent overheating by day and insufficient heat at night, some storage system is desirable. There are barrels of water painted black which collect the sun's energy in the daytime, increasing in temperature, and then rerelease the energy as heat back to the air at night when the greenhouse cools. Actually, the soil and all materials in the greenhouse do this to some extent, but not as much as the water barrels. This is because water has a very high specific heat; that is, it holds the highest amount of heat of any substance for a given mass and temperature change. Stone and masonry is also good for storing heat, but not quite as good as water. We refer to all substances that store thermal energy for later use as thermal mass. Sufficient thermal mass reduces the overheating problem in the day when the sun's input is largest and shifts the heat gain to the evening when it is needed most. Of course, for optimum plant growth, light as well as heat is necessary. Many surfaces in the greenhouse are painted white to reflect light from all sides, especially the north, so that the plants don't lean to the south or get straggly.

In the spring, summer and fall, the greenhouse also needs ventilation on sunny days to avoid overheating. In the warmer weather, much less heat storage is needed to carry the greenhouse through the night. This ventilation is provided by side windows and vents at the upper north side of the greenhouse. In the summer months, shade netting is also put on the south glazing to prevent too much heat gain.

During most average winter days, the solar greenhouse will maintain a temperature that is suitable for most cool-loving plants, typically above 40 degrees F. Thus, most of the winter the greenhouse operates in a passive solar mode. By this, we mean that the sunlight enters the structure and its energy is stored and re-released automatically by natural processes without the use of fans or pumps run by electricity. The building itself is a solar collector that collects, stores and releases energy. However, if there is a string of very cold and very cloudy days in the winter, the building has a backup heating system. There is a large bin of fist-sized rocks in an insulated box on the north side of the building. An air-circulating wood stove can circulate heated air into the rock bin with the use of a small fan in a relatively short time, thus heating the rock to a higher temperature and storing heat. With the wood stove off during the evening hours, the small fan, which is thermostatically operated, can re-circulate the heat from the rock back into the greenhouse to keep the greenhouse from getting too cold. On spring or fall sunny days, the fan can be activated to store the excess energy in the daytime without using the wood stove at all. In this mode of operation, we say the system is operating in an hybrid solar mode, because solar energy is collected passively by the greenhouse, but its storage and return is based on the use of a fan. A solar collector on the roof of a house that uses fans or pumps to circulate the sun's heat from the collector to the house or to storage is referred to as an active solar system. Perhaps surprisingly, the solar greenhouse uses very little wood throughout the winter. By growing cool-loving crops, and by using sufficient thermal mass to moderate temperature extremes, the temperature range is adequate for plant survival and growth.

Our solar greenhouse was supplied with electricity from a wind generator on a tower. This system provided the energy to run the fan and also provides extra lighting during the short days of winter. The greenhouse was also supplied with running water from the windmill water system.

By using an attached solar greenhouse, many of the complications of the free standing greenhouse can be avoided. Excess solar energy can be vented directly into the house, thus helping to heat the house in cold weather. By attaching to a heated house, there is no heat loss through the north wall. Structurally, the greenhouse is simpler to build. Some heat can be diverted from the house in very cold weather to avoid freezing temperatures if desired. It is also convenient to enter and leave the greenhouse without going outside. In some cases, simple solar water heaters can be incorporated into the greenhouse to collect solar energy for hot water heating since there is no chance of having the water freeze. Attached solar greenhouses may often be easily added to existing houses.

Passive Solar Design

The building had a lot of south facing glazing to collect solar heat gain. South facing windows are a form of passive solar collector called a direct gain system. The sunlight enters the house, is absorbed by surfaces, and changes into heat. The structure itself is the collector and heat storage system, and it transfers the heat throughout the house without the use of fans or pumps. This is a very efficient way to collect solar energy and each square foot of south facing window typically saves you a gallon of heating oil over the winter heating season. The building has no windows on the north or west sides.

With a lot of south facing glazing, it is important not to overheat the building. In addition, you would like to store some energy for nighttime use. Thermal mass in the form of a concrete slab, masonry, tile, or water barrels absorbs the sun's energy, warms, and reemits the energy later when the house is cooling. If the thermal mass is in contact with the ground, as it is in this building, it is important that it be insulated to prevent heat loss to the ground.

At the far left of the front of the building, you would have seen glazing in front of concrete blocks painted black. There was also openings in the block at the top and bottom to allow warm air to circulate into the building. This is called a Trombe wall (after Felix Trombe, its inventor) or a mass wall. This is an example of indirect solar heat gain since the sun does not penetrate the heated structure as it does in the case of a window. This method of collection and storage puts more heat into the concrete block than if you had a concrete floor in front of the window. The vents allow you to adjust how much of the daytime solar energy enters to the house vs. how much gets stored in the wall itself. This is another example of a passive solar collector since there are no fans or pumps involved in the system.

Another type of passive solar heater, not illustrated in the schoolhouse, is an attached solar greenhouse. This is an example of indirect solar gain since the sun penetrates a separate structure and the heat is transferred to the desired space by vents, doors or windows that lead from the greenhouse to the house. Attached solar greenhouses or sunspaces have many advantages as part of a sustainable house design (see section on the solar greenhouse).

Energy Efficient Construction

It is very important that walls and roofs be insulated properly. Typical houses have R values (measure of heat loss through a surface) of R-11 (3 _ inches of fiberglass) for walls and R-19 (6 " of fiberglass) for ceilings. More reasonable amounts of insulation are R-25 to R-30 for walls and R-40 for roofs. Single pane windows have R-1 and lose a lot of heat. Double pane, as we have in the building, has R-2 and half the heat loss of R-1 windows. Today, it is recommended that R-3 or even higher be used for windows. This is usually obtained by having a clear metallic oxide surface (called a low-e coating) on the outside side of the interior glazing which reflects infrared (heat) radiation back into the house. Houses with large amounts of insulation are sometimes called superinsulated houses. In addition to heat loss through surfaces, houses lose a lot of heat through cold air infiltration. As cold air enters, warm air leaves and the cold air must be heated to room temperature. Air infiltration is stopped by tight house construction which eliminates openings around the sills and where pipes and wires enter the house. Caulking is used to eliminate these openings. Also, it is important to use weatherstripping around openable surfaces such as door and windows to eliminate cracks where air can leak in.

New construction that is very tight often requires the use of a device called the air-to-air heat exchanger which warms incoming fresh cold air by heating it with outgoing stale warm air.

Construction Material Savings
The post and beam construction was done with recycled beams. One advantage of this method is that it allowed for a large open room without support partitions. It also allowed the heat to circulate freely throughout the house. Most house foundations are made from a large amount of poured concrete or cement block. The foundation for the solar schoolhouse was built on concrete piers which saved a great deal of cement. The floor was insulated from underneath to reduce heat loss. The method eliminated the possibility of flood damage, and eliminates the possibility of radon entering the house from the soil.

Solar Hot Water
On the left hand side of the building on the ground was a batch solar water heater. This was a passive solar system consisting of a 30 gallon metal water heater painted black in an insulated box with a transparent cover. There was reflective foil on the sides and back of the tank so that all the incoming sun's rays hit the blackened tank. On a sunny day in spring or fall, the water is raised from about 50 degrees F to around 110 degrees F, and is then available for nighttime use. Cold water enters the heater from the ground below the water heater directly from the water tower tank by the windmill. As the hot water faucet is opened in the kitchen, the warm water flows under pressure from the solar tank to the faucet. The incoming cold water line is also connected directly to the cold faucet as well as flowing directly to the solar water heater. The system works 8 months of the year. In the winter, the connecting lines (but not the tank itself) might freeze and break unless they are protected. The entire system can be made over a single day, or less if you can get some recycled materials at a cost of only a few hundred dollars. There are both active and passive solar water heaters that can be purchased commercially for about $2000. The payback time varies depending on the form of energy that you currently use to heat hot water. If you use electricity, the payback time is about 5 years and investment is warranted.

Solar Electricity from Photovoltaic Cells and from Wind
On the roof, you would have seen two panels. These were made of photovoltaic or solar cells. Each solar module produced a DC voltage of about 14 volts and about 10 amps in maximum direct sunshine. This electricity entered the building and charged up a set of 12 volt rechargeable batteries. The batteries then connected to a DC-AC inverter that brought the voltage up to 120 volts AC, typical of what is used in U.S. homes. There was also a charge control circuit that diverted excess solar electricity to an air resistance heater once the batteries are fully charged. The entire system was low maintenance and provided electricity to provide lighting and some appliance use. The system used produced about 50 kW-hr a month. A much larger system (about 10x its size) would have been needed to provide an average American home with electricity. However, by getting efficient appliances and lighting, this could be brought down to perhaps 4-5x the current size. The PV panels are expected to have a lifetime exceeding 30 years and their costs have been dropping dramatically over the past two decades and are expected to drop even further. For people who do not want to have an independent system, a synchronous inverter can be used to connect to utility power. This produces 120 volt AC power synchronized with utility power. When the sun is shining and you have excess electricity, it gets sent back to the utility. At night, when you need electricity, you get it from the utility. A meter runs backwards and forwards to determine the net amount of electrical usage. There is no need for a battery storage system which reduces costs considerably.

To the back of the building was a small wind generator called a Windcharger which was donated to the Center. The wind machine produced a maximum of about 100 watts of power (14 volts at 7 amps DC) when the wind exceeded 20 mph. It starts charging at 8-10 mph. The Windcharger also connected to the same batteries and charging circuit as the PV panels so that they were charged by both wind and sun. This is more reliable for producing energy since it is often windy and cloudy at the same time. Wind generators must have fairly large average wind speeds (> 11 mph) to work efficiently since the power and energy produced is proportional to the wind velocity cubed. They also work more efficiently in smooth wind flows. For these reasons, they are often placed on towers that are at least 10 ft higher than any surrounding object within several hundred feet. In many

parts of the country where wind velocities are consistently high, wind power represents the cheapest way to generate electricity, perhaps as low as 4 cents per kW-hr. We pay about 15 cents per kW-hr in the NY-NJ area. In places in California, and in other parts of the country where wind velocities are relatively high, windfarms are growing at a rapid pace. Many other countries are in the process of developing wind energy today.

The Wind Generator

The Wind Generator

The windmill tower may be an important representation of the notion of being off-grid, which the entire center was. Centralized energy grids cross the developed world, bringing electricity from afar and making everyone dependent upon one vulnerable system. Recent blackouts and brownouts in the west illustrate a lesson learned decades ago on the east coast, namely that the grid can go down easily, due to a link weakened by weather, animals, vandalism or sabotage. Off grid applications force the user to see the consequences of power generation and transmission, avoid major penalties due to transmission loses and protect from the vulnerability of the grid. When the grid serves as a backup system to the technologies seen at the AEEC, rather than as a primary source of energy, a greater resilience is achieved.