Chapter 4

Food-Producing Solar Greenhouses

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CHAPTER 4

Food-Producing Solar Greenhouses

Introduction

In the last chapter, solar greenhouses were discussed as passive solar collectors that could supply part of the space-heating load of the houses to which they were attached. In this chapter they will be discussed as a technology for producing food for the individual family and for the community. In this capacity, solar greenhouses have two features of special interest: they can provide a source of fresh, locally grown produce year-round, even in the coldest climates; and, unlike conventional greenhouse production or the mass distribution of remotely grown winter vegetables, they do not require large quantities of oil or other fossil fuels. By combining these two benefits, solar greenhouses can reduce the food budgets and energy budgets of individual families, community groups, and the Nation as a whole.

According to the estimates of the U.S. Department of Agriculture (USDA), per capita consumption of vegetables in the United States was 223 lb in 1975. As nutrition becomes a more important concern, this figure is likely to rise, and with it the demand for locally grown produce. A recent report on the Community Food and Nutrition Program observes that:

> The focus on quality promises to be the overriding concern of Federal nutrition research for the 1980's. This concern, which first surfaced within the Federal Government in a major way when the Senate [Select Committee on Nutrition and Human Needs] released its "Dietary Goals for Americans" in 1978, has now penetrated the Federal bureaucracy. In the very near future, it is expected that USDA and HEW [now the Department of Health and Human Resources] will jointly issue a set of nutrition guidelines calling on all Americans to consume less sugar, salt, and fat and eat more vegetables, grains, fruits, and fiber-rich foods . . . . The concern for improving the quality of the American diet is reflected in the increasing interest shown by Congress in the labeling of foods and in nutrition education.[1]

[1]Community Services Administration, "A Preliminary Report to Congress on the Community Food and Nutrition Program of the Community Services Administration, "Jan. 15, 1980, pp. 30-31.

Locally grown vegetables, if properly grown, have a higher nutritional value simply because they reach the consumer faster. They usually require less processing, packaging, and transportation—factors which account for as much as 85 percent of the cost of supermarket vegetables. This has led to heightened private and public interest in alternatives to conventional, energy-intensive technologies for the mass production and distribution of fruits and vegetables.

Community gardening has received the most attention from government agencies at all levels:

> City lot projects, youth gardens, employee gardens, and gardens for retired people and the handicapped have sprung up throughout the country. High food costs caused in part by resource shortages is the major reason why so many have become involved in community gardening . . . . For low-income people in urban areas, gardens are an opportunity to reduce fuel and food costs simultaneously.[2]

The next two chapters will discuss steps that have also been taken to develop low-cost energy sources for small-scale farmers (ch. 5) and local marketing systems for their produce (ch. 6). Both are methods by which the viability of small farms and quality of produce may be improved, and the costs of both reduced.

This chapter will examine a community project in which produce is grown on an energy-efficient basis year-round while at the same time providing job training, employment, and a basis for local economic development.

[2]Ann Becker, "Appropriate Technology and Agriculture in the United States," background paper for Appropriate Technology in the United States, prepared by Integrative Design Associates, Inc., for the National Science Foundation, Research Applied to National Needs, grant No. 76-21350, 1977, p. 13.

Conventional Greenhouse Technology

Greenhouse food production is not a new idea. Europeans cultivated pineapples and oranges in hothouses in the 1600's, using troughs filled with charcoals to keep the tropical fruit warm during the northern winter. The present-day greenhouse structure with glass walls and roof made its appearance about 1700, and by 1800 was sometimes attached to the south sides of houses, opening onto the parlor or salon through folding doors. These glassed-in rooms, called "conservatories," were quite fashionable in Victorian England and enjoyed a brief vogue in the United States, as well. They were not used to grow food crops, however, and because so many were poorly designed or built, their popularity faded by 1900.

Conventional greenhouses—freestanding structures, glassed in on all sides and heated by oil, natural gas, or electricity—are not customarily used to grow a variety of common garden vegetables. Their inefficient designs and high operating costs make them economical for high-return horticulture, such as flowers, tropical plants, and exotic or out-of-season produce. The last category includes the three crops that are the mainstay of the limited commercial greenhouse production of vegetables: tomatoes, lettuce, and cucumbers. Research on greenhouse vegetable yields has focused on these three commercial crops; typical annual yields are shown in table 7. Factors that influence yields include:

- light levels;
- growing temperatures;
- transpiration rates (the rates at which the plants lose moisture into the air);
- carbon dioxide (CO_2 levels;
- structure of growing medium and availability of nutrients; and
- pest and disease control.

Commercial growers control all of these factors carefully in order to achieve the highest possible yields under very dense planting conditions. Because of the all-glass design, much of the light that enters the structure goes out again through the north wall, so supplemental lighting is common. The glass walls and roof allow a great deal of heat to escape from the greenhouse, especially at night, so operators must use *a* standard space-heating system to maintain stable temperatures. To keep transpiration rates low, greenhouse humidity is kept high and many operators install automatic misting systems. It is also common for greenhouse air to be enriched with additional CO_2, and chemicals are almost always used for fertilizers and for disease and pest control.

Table 7.—Typical Yields of Commercial Vegetables in Conventional Greenhouses

Crop	Annual yield[a] (ton/acre)	Annual crops	Average yield[b] (lb/ft^2/month)	1980 value (cents/lb) Wholesale	1980 value (cents/lb) Retail
Tomatoes	120	2	0.46	60-80	70-120
Lettuce	140	5-7	0.53	45-75	60-100
Cucumbers	175	2	0.67	35-100	60-110

aMarketable yield after removing culls.
bYields vary greatly by season; e.g., spring tomatoes yield about three times as much as fall crops, and spring cucumbers yield about 2.2 times as much as fall crops.

SOURCE: Personal communication from William Bauerle, associate professor of horticulture, OARDC, Wooster, Ohio.

Solar Greenhouse Technology

Solar greenhouses are not yet in widespread use for commercial vegetable production. As presently constructed, they have a more highly variable growing environment than is permitted in conventional greenhouses, and as a result crop yields are unpredictable. On the other hand, home and communit y solar greenhouses can be used to grow a much wider variety of vegetables, many of which have a limited history as greenhouse crops in the United States; and their resource-efficient design, combined with the innovative horticultural methods, can lead to lower operating costs.

Design

The simplest forms of resource-efficient greenhouses are the cloche, originally a bell-shaped jar or bottomless glass jug, and the cold- or hot-frame, a small seedbed enclosed in a glass-topped box. These traditional small-scale methods of protecting individual plants or rows, which have been used since the 1600's by European peasants and market farmers, have been improved on in the modern, energy-efficient solar greenhouse. These modern applications are the *attached* greenhouse (examined inch. 3), which can supply part of the space-heating and food-producing needs of a family home, and the larger *freestanding* greenhouse, which is more appropriate to the needs of a community gardening project and is potentially adaptable to low-cost commercial production. The discussion that follows focuses on the freestanding solar greenhouse.

Three principal features of solar greenhouse design and construction account for its energy efficiency:

- sun-catching design,
- **insulation, and**
- heat storage.

The south-facing translucent roof is the primary receptor of the Sun's light and heat. Because heating needs are greatest during the winter months, the slope of the roof is angled to be perpendicular to the Sun's rays when it is lowest on the horizon; the farther north the greenhouse, the greater this slope. The north roof is angled to allow sunlight to strike the rear interior wall, and the east, west, and north walls—since they are not needed to admit solar energy—are made of well-insulated wood, masonry, or other materials. Several features allow the greenhouse to capture the greatest amount of light and heat: the peak of the roof is about as high as the building is deep; the structure is at least twice as wide (east to west) as it is deep, and the inside surface of the opaque walls and north roof are painted white or lined with reflective materials. These features can combine to deliver up to 33 percent more light to the plants during the winter.[3]

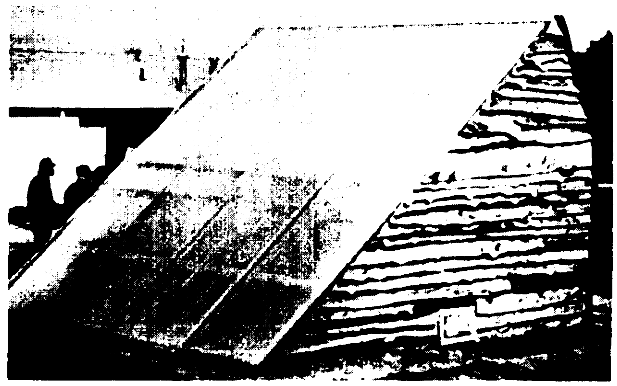


Photo credit: Office of Technology Assessment

Representative model of small freestanding greenhouse

To retain the solar heat that enters the greenhouse, it is heavily insulated. The south roof is double-glazed with glass or, increasingly, fiberglass

Photo credit: Office of Technology Assessment

Heavy insulation retains heat that enters greenhouse

[3]Jack Ruttle, "The Solar Greenhouse That's Right for You," Organic Gardening, vol. 25, No. 8, August 1978, p. 51.

and clear plastic. Triple-glazing might be necessary for tropical plants or for extreme climates, but a night curtain is usually more effective than a third layer of glazing. The north roof and opaque walls are insulated according to climate, with the insulation extending into the ground below the frost line on all four sides. Figure 13 shows the recommended amount of insulation for different regions of the United States. All seams and joints are caulked and weatherstripped to prevent drafts and heat loss.

Unlike conventional greenhouses with standard space-heating systems, solar greenhouses are kept warm at night and during periods of cloudiness by warmth released from a heat storage medium such as rocks, water, or thermochemical materials. Water holds heat well and is cheap, drums stacked along the rear wall in direct sunlight are a common design. Heat storage stabilizes temperatures in two ways: it absorbs incoming heat during the day, thus keeping the greenhouse from overheating, and the heat is released slowly as the greenhouse cools, thus keeping it warmer at night. The amount of heat storage will vary with climate (see figure 13), and by adding more heat storage the builders can avoid the need for excessively thick and expensive insulation. Some solar greenhouses

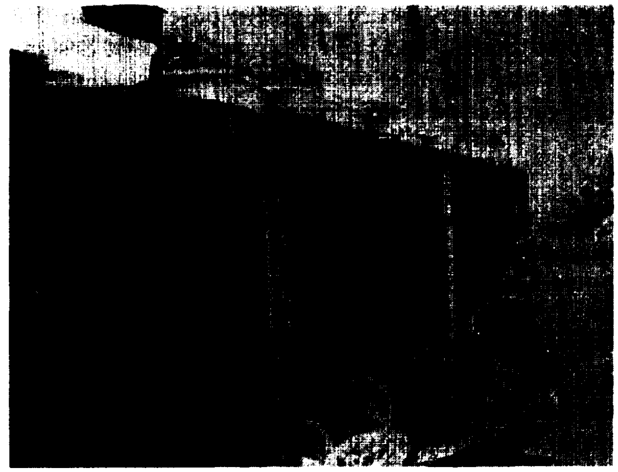


Photo credit: *Office of Technology Assessment*

Single row of water-filled 55-gal drums

also include a backup system to provide heat when outside temperatures are particularly low or during extended periods of cloudiness.

Plant Production

Solar greenhouse horticulture is still in the early stages of development, but a number of innovative methods have been discovered. In keeping with

Figure 13.—Recommended Minimum Insulation and Heat Storage for Solar Greenhouses in the United States

Regional recommendations for minimum amounts of insulation in walls and roof, below ground and of water for heat storage.

Zone 1 wall and roof, R-40
below ground, R-15 to 3 feet deep
heat storage, 4 gallons per square foot of floor

Zone 2 wall and roof, R-22
below ground, R-15 to 3 feet deep
heat storage, 3 gallons per square foot of floor

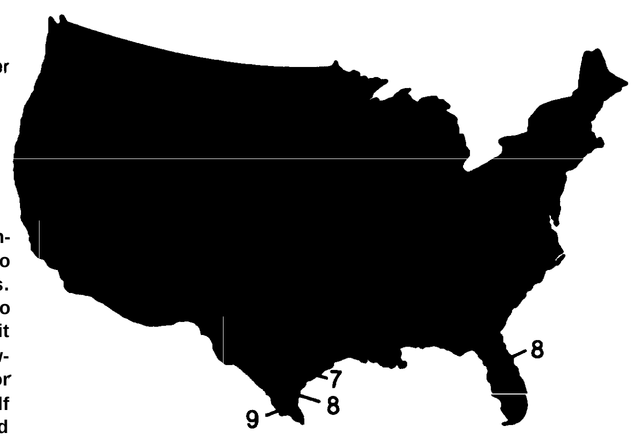
Zone 3 walls and roof, R-12
below ground, R-10 to 2 feet deep
heat storage, 3 gallons per square foot of floor

Zone 4 walls and roof, R-6.5
below ground, R-10 to 2 feet deep
heat storage, 2 gallons per square foot of floor

Zone 5 walls and roof, R-6.5
below ground, R-5 to 1 foot deep
heat storage, 2 gallons per square foot of floor

Zone 6 walls and roof, R-6
below ground, R-5 to 1 foot deep
heat storage, 1 gallon per square foot of floor

Zone 7, 8, 9 These regions need insulation and night curtains, but to much lower insulating values. Greenhouses in these regions do not require double glazing, but it will help. No heat storage or below-ground insulation is needed for minimum performance. About half the north slope of the roof should be glazed.



Source: Organic Gardening and Farming Research Center, In Organic Gardening Magazine, August 1978, p. 54.

principles of resource conservation and environmental safety, these have tended to be organic rather than chemical techniques. Pest control, for instance, can be accomplished with natural predators such as praying mantises or small reptiles. CO_2 can be provided by keeping a compost pile or by incorporating large amounts of organic materials into the growth medium, this will also improve the structure and fertility of the soil.

Unlike conventional greenhouses, where plants are grown in pots on waist-high benches, solar greenhouses usually have 18-inch deep beds on the floor, which both increase the growing area and protect plant roots from the larger swings in air temperature. The variable conditions in a solar greenhouse can also be exploited to meet the growing conditions of different plants in the same space: cool crops can be grown at floor level or near the glazing; crops that need more warmth can be grown in hanging containers or on top of the heat storage. Since home and community greenhouses are used to grow a wide variety of crops, these variations may actually be an advantage.

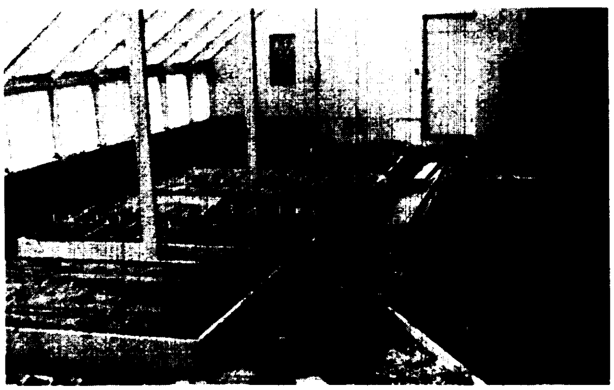


Photo credit: Office of Technology Assessment

18-inch-deep beds on the floor of the Cheyenne Community Solar Greenhouse

The horticulture department at Pennsylvania State University has begun an evaluation of the commercial vegetable production potential of several solar greenhouse designs.[4] Preliminary results showed a rather high degree of variability in time to fruiting and expected total yields (see table 8). The investigators reported that the quality of the produce was generally as high or higher than the quality of the same crop grown in a conventional greenhouse. These preliminary results involve too many variables to be readily comparable with the yield figures for conventional greenhouses given in table 7, but they do suggest that some plant varieties are better suited to solar greenhouses than others. Further research and experience will be required to determine the crop yield potential of solar greenhouses and the best crop varieties and horticultural methods for realizing that potential.

[4] Carla Mueller, J. W. White, and R. A. Aldrich, "The Growth and Response of Vegetables in Sub-Optimum Greenhouse Environments, Proceedings o/ the Conference on Energy-Conserving *Solar-Heated* Greenhouses, Marlboro College, Marlboro, Vt., Nov. 12-19, 1977.

Table 8.—Estimated Yields of Commercial Vegetables in Solar Greenhouses

	Time to first yield (days)				Yield per crop (ton/acre)				Average yield[b] (lb/ft²/month)			
Crop and varieties	#1	#2	#3	#4	#1	#2	#3	#4	#1	#2	#3	#4
Tomatoes												
9102M[c]	70	66	58		24	8	35	36	0.18	0.06	0.27	0.28
"Small Fry"[c,d]	114	116	102	93	55	33	60	36	0.42	0.25	0.46	0.28
Lettuce												
Bibb[c]	101	101	89	87	21	20	20	19	0.24	0.23	0.23	0.22
Buttercrunch[c]	—	—	—	—	**20**	**22**	**18**	**14**	**0.23**	**0.25**	**0.21**	**0.16**
Cucumber												
"La Reine"[c]	**83**	**76**	**51**	**51**	**10.4**	**12.1**	**13.9**	**12.8**	**0.12**	**0.14**	**0.16**	**0.15**

[a] Greenhouse designs:
#1—20 by 20 ft double-barrel vault fiberglass house with heat storage.
#2—Same as #1 but without heat storage.
#3—20 by 20 ft two-ridge gable-roofed house double-glazed with acrylic paneling.
#4—12 by 16 ft traditional single-glazed glass house.
Backup heat was supplied to all houses, but on average temperatures were lower in #1 and #2.

[b] Assuming constant yield at single-crop rate, with two crops/yr of tomatoes, and three crops/yr of lettuce and cucumbers. Figures are at best approximate, since it is not known whether the yield figures reflect spring, summer, or fall crops.
[c] Transplant.
[d] Seed.

SOURCE: Carla Mueller, J. W. White, and R. A. Aldrich, "The Growth and Response of Vegetables in Sub-Optimal Greenhouse Environments," *Proceedings of the Conference on Energy Conserving Solar Heated Greenhouses,* Marlboro College, Marlboro, Vt., Nov. 19-20,1977.

Relatively large freestanding solar greenhouses are currently under construction or recently put into operation by cooperatives in Orange, Mass., and Flagstaff, Ariz.; the Cherokee Nation has constructed a number of solar greenhouses which they hope will show profits of as much as $1 million per year after 2 years of operations The case study that follows will discuss a fourth installation, the Cheyenne Community Solar Greenhouse in Laramie County, Wyo.

[5]Bob Hathaway, Cherokee Nation, personal communication.

Solar Greenhouse Horticulture—A Case Study of the Cheyenne Community Solar Greenhouse[6]

The Community Setting

Cheyenne, the capital and largest city of Wyoming, is located in Laramie County in the southeastern corner of the State. The city has a population of approximately 60,000, of which 20 percent are Hispanic and 2.5 percent are black; over 10 percent of the city's residents are 60 years of age or older. A surge of development has been taking place in the area since the early 1970's, with the population of Laramie County growing by 15 percent between 1970 and 1976 after remaining relatively stable in the preceding decade. This growth is attributed primarily to the recent acceleration of domestic energy production, especially coal, and increased mineral exploration in the region.

Rapid expansion, particularly in the outlying fringes of Cheyenne, has focused the city government's attention on its infrastructure (streets, water system, and fire and police protection) and on its management and financial capabilities for dealing with this growth. The mayor has cited the local government's difficulties in responding to all of the city's needs simultaneously, and emphasized that priority must be given to necessary projects and those that can "pay their own way."

Rapid growth has also had some "boomtown" effects, including an inflationary impact on the local economy, particularly on the food, housing, and energy costs for Cheyenne's low-income and elderly residents. The directors of the Laramie County Senior Citizens Center cited nutritional inadequacies, expensive and energy-inefficient housing, limited health services, and physical isolation as the major problems facing the city's elderly residents; the same problems face much of the low-income population.

Photo credit: Office of Technology Assessment

The elderly and low income are recipients of the harvest from the Cheyenne Community Solar Greenhouse

Community Action of Laramie County (CALC), the local branch of the Community Service Administration (CSA), is the largest social service agency in Cheyenne. Its clientele consists

[6]Material in this case study is based on a working paper, "Community Solar Greenhouse," prepared by Katherine Day and Babette Racca for the Harvard Workshop on Appropriate Technology for Community Development, Department of City and Regional Planning, Harvard University, May 15, 1979.

largely of the low-income and elderly segments of the city's population, and it has a history of undertaking innovative community projects. CALC has established an Energy Advocacy Program, which has been used as a forum to examine utility rate hikes; a Foster Grandparents Program, which among other things places senior citizens in the school system to share their experiences and skills with students; and a Weatherization Program, which both provides job training and improves the energy efficiency of low-income housing. Another innovative local agency is Youth Alternatives, a program that places young offenders in public service projects to work off court fines or as an alternative to jail terms.

In 1976, as a part of CALC's efforts to develop innovative and instructive uses for Federal funds, the agency recruited 15 Summer Youth Program participants for a pilot project to design, build, and plant three 10 by 16 ft solar greenhouses attached to the homes of local low-income families. The participants, all from low-income families, ranged in age from 16 to 22 and included several from work-release programs like Youth Alternatives. The summer program was a success and generated considerable enthusiasm in the community. It convinced CALC that solar greenhouse technology was simple and inexpensive, and that it could serve as an imaginative, productive way to train community members in design, construction, and horticultural skills. CALC also recognized the technology's potential as a focus for local development that could encourage low-cost self-help among its low-income clients, provide a meaningful activity for senior citizens, and improve the nutrition of those using the local meal programs. To realize these potential benefits and to encourage the widespread adoption of the technology, CALC decided to pursue a large-scale demonstration project—a freestanding community solar greenhouse.

Development

In the fall of 1976, CALC submitted a grant request to CSA's Community Food and Nutrition Program for $56,000 to fund the construction of the Cheyenne Community Solar Greenhouse (CCSG). It was awarded $42,700 by CSA, which had also funded the pilot project. In December of the same year, initial plans for the design of the greenhouse were developed by 30 local volunteers, ranging from engineers to high school students, who participated in a workshop and training session conducted by CALC in conjunction with the Domestic Technology Institute (DTI) of Denver, Colo. These plans were revised and a final draft prepared by DTI; the extent of their revisions is unclear and the subject of controversy (see below).

After a 2-month search for a site in the city proved fruitless, CALC was able to find a suitable (if somewhat remote) location for the greenhouse

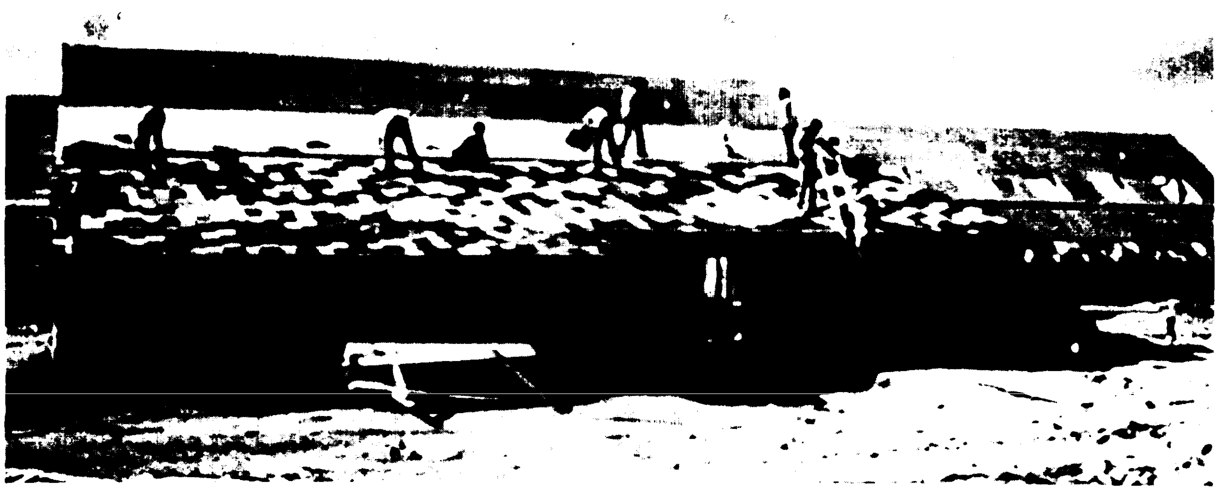


Photo credit: Office of Technology Assessment

Workmen, mostly volunteers, constructing the roof of the Cheyenne Community Solar Greenhouse

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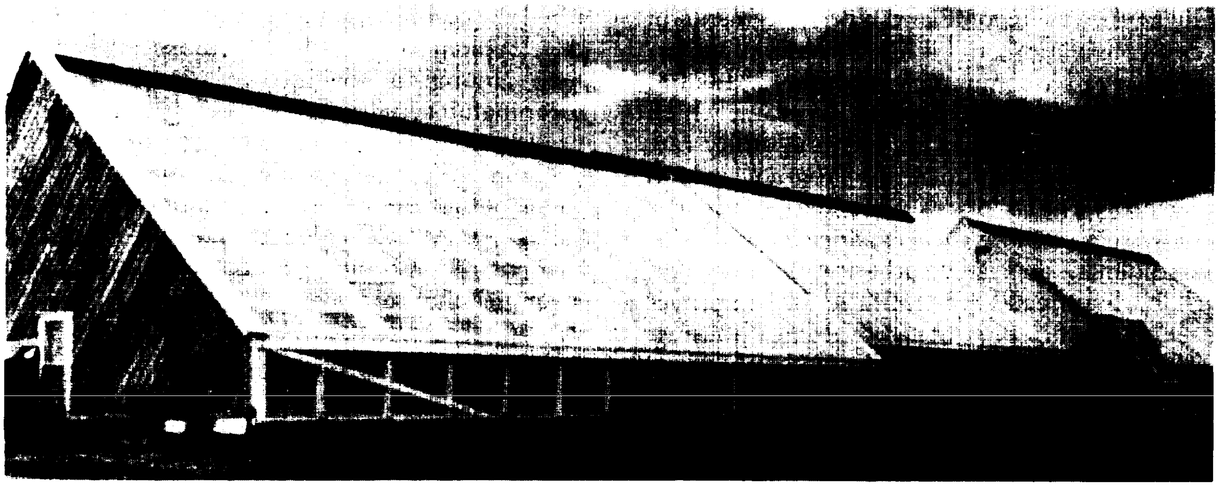


Photo credit: Office of Technology Assessment

Cheyenne Community Solar Greenhouse, Cheyenne, Wyo.

on a 2.5-acre parcel of land on the outskirts of Cheyenne, about 5 miles east of the center of town. The land belonged to a local family, who gave CALC possession of the site for 10 years with the option of extending their use of the land for an additional 10 years thereafter. In return for the use of the site, it was agreed that at the end of the 10- or 20-year period the land and the greenhouse would revert to the owners.

Construction began in June 1977. The construction crew was supervised by two paid carpenters from the community, and consisted of about 50 workers, most of them volunteers, including Summer Youth Program participants, senior citizens, and other local residents. One 60-year-old woman, the first licensed woman plumber in Wyoming, contributed a great deal of time to the design and construction of the greenhouse's plumbing system. DTI also provided occasional technical assistance. Seven months later, in January 1978, construction was completed and planting began. To help cover operating costs, CALC immediately began developing one section of the greenhouse for the commercial production of flowers, seedlings, and starter flats.

The land surrounding the greenhouse was developed as a community gardening site, consisting of 22 plots, each 12 by 30 ft. Low-income residents were given priority in the assignment of these outdoor plots; all of the plots were planted the first summer, with 50 percent of them going to low-income gardeners. Also located on the site are two solar food dryers, comporting bins, an adobe oven used for soil sterilization, and two small geodesic domes.

Photo credit: Office of Technology Assessment

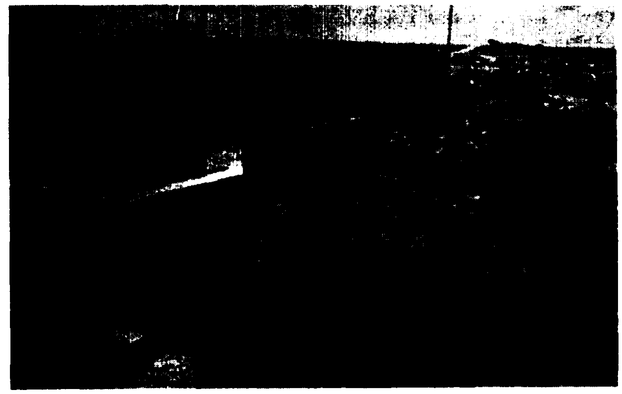
Community gardening plots help reduce family food costs

The CCSG Solar Horticulture Technology

The 5,000-ft^2 CCSG consists of three separate growing chambers of about 1,500 ft^2 each, permitting individual climate and pest control in each chamber (see figure 14). Located at latitude 41 ‘N, its roof has a 450 slope and is oriented 150 west of true south. The roof is double-glazed, with an outer layer of Filon, a corrugated fiberglass, and an inner layer of Monsanto 602, a strong, clear plastic.

The foundation contains 120 yd^3 of concrete and is insulated along the outside with polyurethane foam. The east, north, and west walls are insulated with 8 inches of blown-in insulation; the north-facing roof contains 10 inches of insulation. As further protection against heat loss to winter winds, the north wall is bermed on the outside with step-like layers of compacted earth and wooden beams. All seams and joints have been carefully caulked or weatherstripped to prevent infiltration. Wall studs were placed 4 ft apart to reduce construction costs, and interior walls are paneled with particle board painted white *to* provide maximum light reflection.

Heat storage is provided by 180 water-filled 55-gal drums painted flat black. The drums are placed



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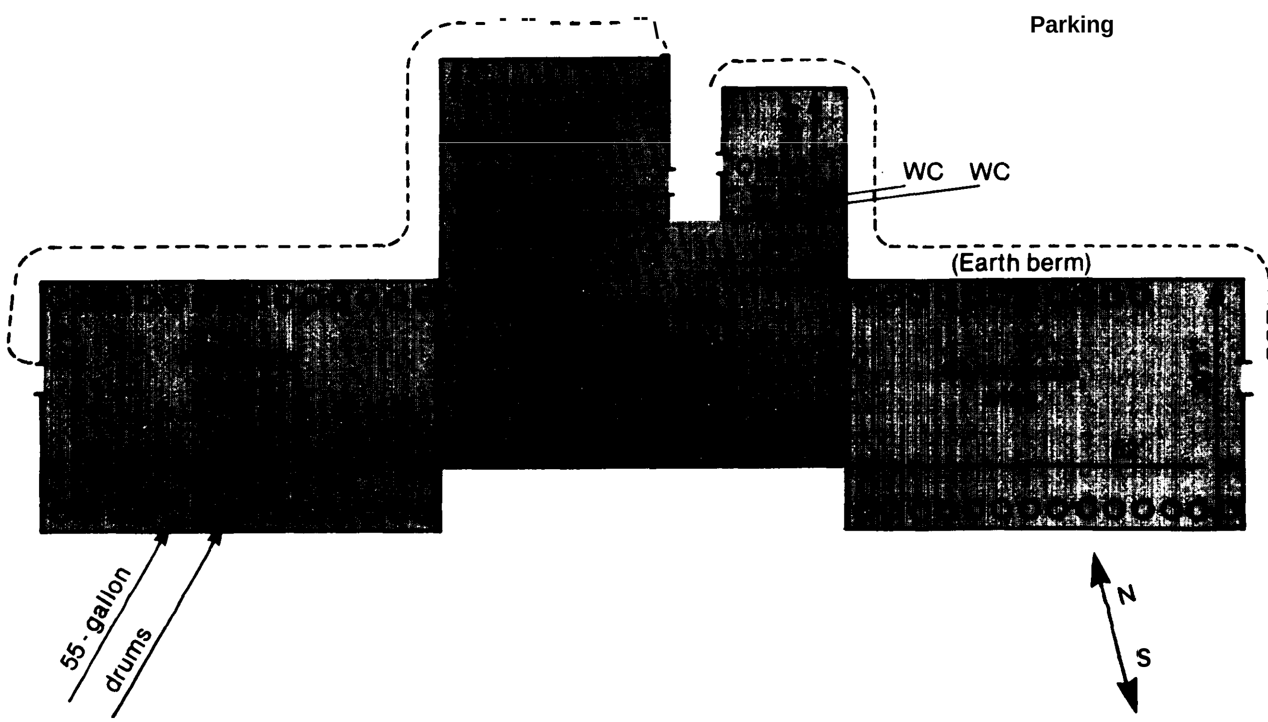
in a single row along the south kneewall and two or three high in a single row along the north wall. Each drum stores about 450,000 Btu/yr; the total heat storage capacity of the greenhouse is estimated to be almost 1 million Btu/yr. Backup heat is provided by two wood-burning stoves that were

Figure 14.—Cheyenne Community Solar Greenhouse Floor Plan



built by a local high school welding class and installed in the east and west wings. Heat loss occurs primarily through the glazing at night, and DTI has recommended installing night curtains; but the staff feels that funding for such an expensive purchase will not be available for some time. However, heat loss is not a serious problem: temperatures rarely drop below *40°* F during winter nights, and the lowest temperature recorded during the first year of operation was 320 F.

During the summer, excess heat is vented by nine wind turbines, three in each chamber, and 13 vents allow cooler outside air to enter through the walls. Five electric fans also assist air intake and circulation. These design features have proven inadequate, however, and serious overheating problems were encountered during the first summer of operation, with peak temperatures of 1160 F. Such heat, combined with the high humidity in the greenhouse, severely restricted the activities of elderly workers and caused tremendous stress on plant life. DTI has recommended the installation of day curtains to keep the unwanted heat from entering the greenhouse, but the staff fears that this would cut light flow too severely and thereby inhibit plant growth; other solutions to the overheating problem are being explored.

Originally, a methane digester (see ch. 5) was included in the greenhouse design to provide backup heat as well as carbon dioxide and fertilizer for the plants. It was found, however, that the design capacity of the digester was far less than claimed—only about 60,000 Btu/day—and that even this level of operation would require CCSG to use a compressor and to obtain additional manure from surrounding farms, as well as diverting valuable staff time to operating the digester. But the greatest obstacle to using the digester was a fundamental design flaw: the methane storage tank and gas burner were placed in the same room, greatly increasing the danger of an explosion. No insurance company will cover such an operation, and for lack of insurance the digester system has never been used. CALC blames DTI, which drafted the final design, and may pursue legal action against the firm.

Paradoxically, the purpose the digester was intended to serve has been satisfied by a far simpler, safer, and less costly alternative: a compost pile. All of the greenhouse's plant wastes are currently being recycled in compost bins, which provide heat, CO_2, and fertilizer. In addition, the water drawn from a nearby well for use in the greenhouse is partially recycled and stored in a gray-water recovery tank until it can be reused for plant irrigation.

Over 100 varieties of plants are grown in the greenhouse. Table 9 lists the major vegetable crops, and bedding plants and a variety of flowers are also cultivated. In keeping with the concepts of resource conservation and environmental awareness, the methods used in CCSG are oriented toward organic rather than conventional (chemical) horticulture. The staff and volunteers also practice a number of innovative horticultural techniques:

Table 9.—Major Crops in Cheyenne Greenhouse

Beets	Green beans	Peppers
Broccoli	Green peppers	Potatoes
Brussel sprouts	Herbs	Radishes
Cabbage	Kohlrabi	Squash
Carrots	Lettuce	Swiss chard
Cauliflower	Okra	Tomatoes
Celery	Onions	Turnips
Cucumbers	Peas	Wax beans
Eggplant		

SOURCE: Office of Technology Assessment.

- *Biological* pest control.—The CCSG staff has introduced several varieties of natural pred-

Photo credit: Office of Technology Assessment

Staff and volunteers promote maximum productivity while growing over 100 varieties of plants

ators to control insect pests; the lace-wing flies, ladybugs, and praying mantises released in the greenhouse are now establishing self-reproducing populations. In addition, a number of predators native to Wyoming, including three varieties of wasps, the surfid (hoover) fly, and several varieties of spiders, have introduced themselves into the greenhouse through vents and doors.

- *Companion planting.*–Rather than planting a given bed with a single crop, plants with compatible root systems and foliage are densely interplanted. This promotes maximum productivity while reducing susceptibility to the spread of insects and plant diseases through the beds. In some cases the companions (e.g., carrots and onions) repel each other's pests.
- *Multiple-harvest varieties.—To* further boost productivity, experiments are underway to replace plants that can be picked or harvested only a few times with substitutes that can be picked continuously yet continue to grow and produce.
- New varieties.—Experiments are also underway to find plants and plant varieties that will produce satisfactory yields even under the stressful conditions characteristic of solar greenhouses—i.e., high daytime temperatures in summer and low nighttime temperatures in winter. Research is also being conducted to develop and use a range of plants which will grow to greater heights, thereby making more efficient use of the limited floor space in the greenhouse.
- *Optimum timing of planting and harvest.*– Unlike field agriculture (which has one growing season in Wyoming) and conventional greenhouse horticulture (which has virtually no seasons), solar greenhouses are subject to two seasons. "Summer" crops flourish between March and November; "winter" crops are grown between September and March. CCSG's staff is trying to determine optimum planting and harvesting times, as well as the best crops, in order to make most effective use of this cycle in growing seasons.

The CCSG Project

By March 1979, crops had been produced from all three sections of the greenhouse; table 10 presents the quantities of vegetables harvested each month during the first 2 years of operation. This data should be viewed in light of several considerations. First, the east chamber is occupied by bedding plants and a work area and is being developed for commercial use, so most of the vegetables were harvested from the center and west chambers. Of the 3,000 ft2 in these two sections, only about 85 percent or 2,500 ft^2 is actual growing space, the remainder being taken up by the water-filled drums and walkways.[7] Second, yields for the first few months were low because not all of the beds had yet been planted; in addition, the crops first planted in January 1978 and picked in March should have been planted the previous October, which would also have increased yields. Third, yields during the summer months were low due to overheating problems. Fourth, the records for the first year may be imprecise, since it was difficult to ensure that volunteers remembered to record their pickings.

Most importantly, however, the staff and volunteers had little expertise in greenhouse horti-

Table 10.—Cheyenne Solar Greenhouse Monthly Yields During First 2 Years of Operation (in lbs of produce)

Month	Yield	Month	Yield[a]
March 1978	7	March 1979	216
April 1978	80	April 1979	182
May 1978	136	May 1979	167
June 1978	177	June 1979	178
July 1978	266	July 1979	182
August 1978	242	August 1979	506
September 1978	202	September 1979	359
October 1978	305	October 1979	231
November 1978	168	November 1979	297
December 1978	87	December 1979	213
January 1979	88	January 1980	308
February 1979	172	February 1980	215
Total	1,930		3,054

[a]Area use:
Winter—5% carrots, 3% radishes, 40% lettuce, 25% swiss chard, 10% cabbage, 5°A spinach, 5% peas, 2% herbs.
Summer—50% tomatoes, 25% cucumbers, 5% peppers, 5% greens (spinach), 7% squash, 2% herbs, 5% miscellaneous.

SOURCE: Office of Technology Assessment.

[7]The space given over to heat storage is unavoidable, although it could be reduced by substituting more expensive thermochemical or phase-conversion devices. The amount of space given over to walkways is a reflection of CCSG's particular clientele: extra space had to be given over from plant beds to walkways in order to provide ramps between levels and chambers and to remove other architectural barriers that would have made the greenhouse less accessible to the elderly and the handicapped. CALC is currently attempting to increase participation by the handicapped.

culture at the outset, and they also had to make do with whatever seeds were donated. They anticipated that yields would increase as they gained experience and a better knowledge of crop varieties. Figures for the second year of operation, which show a 57-percent increase in yields, would seem to confirm this expectation, preliminary figures for the third year of operation indicate a further significant increase in yields.

During the first year of operation, the vegetables grown by CCSG were distributed as follows:

- *67* percent to volunteers, with first priority to senior citizens and low-income workers;
- 15 percent to local nutrition programs, including Meals-On-Wheels and Needs, Inc., and the Cheyenne Attention Home;
- 9 percent to paid staff and other CALC activities; and
- 9 percent for sale to the public.

Senior citizens reported that they were pleased not only by the produce and exercise the project provided, but also by the chance to do something new and interesting and the opportunity to see their friends and meet new people. Head Start teachers often brought small children to the site, which offers special advantages for learning about natural processes while exploring the greenhouse. Summer Youth Program and CETA participants have had a chance to learn carpentry and other skills, and the director of the Youth Alternatives program reports that the recidivism rate for teenagers working at the greenhouse is much lower than for those who participate in more conventional alternatives.

CCSG provides jobs for two managers (one a horticulturalist from Colorado, the other a local carpenter), a fill-time CETA worker (a horticultural trainee in the Green Thumb Program), and several part-time CETA workers (including students from Cheyenne's alternative high school). In addition, 50 senior citizens and 20 other volunteers worked at the site during 1978. Salaries for the staff totaled $35,000; volunteers considered the produce they received to be compensation for services rendered, rather than a handout. As one elderly volunteer commented, "People should work for their vegetables."

Total capital costs for design and construction were about $64,500, including the purchase of the unused methane digester. The actual costs of construction were borne primarily by CSA, but without the large donations of land, materials, and labor by the local community and paid staff (who worked many hours beyond their contractual obligations) the project would have required additional funding. The same might be said of operating expenses, which total $38,000 per year for salaries, supplies, and electricity for lights and fans. Volunteer work represents most of the labor supplied to the project, which is labor intensive by design; the only capital equipment that might be substituted for volunteer or paid labor would be an automatic sprinkler system to mist the plant beds. Produce distribution is done on an informal volunteer basis, and patrons of the commercial section come to the site to obtain plants, produce, and seeds.

CALC currently covers operating costs through Federal funding and other Government programs like CETA. At its present stage of development, the commercial section of the greenhouse provides little supplemental revenue. CCSG's staff is exploring ways to develop its commercial operation and is investigating the regional market for ornamental plants, seeds, and starter flats for home gardens. No estimates of the size of this market or the anticipated capture rate are available, but the staff is certain that the market would support any amount of commercial products they might offer at current prices. They also think they might develop a certain edge by selling unusual and hard-to-obtain plants, teas, and herbs. However, solar greenhouses present certain problems in full-scale exploitation of seasonal flower markets: Easter lilies and poinsettias, for instance, cannot be raised in solar greenhouses because of the relatively wide temperature fluctuations characteristic of these installations, the same is true of most tropical plant varieties.

Critical Factors

Public Perception and Participation

The idea of building a large solar greenhouse came from the director of CALC, who was encouraged by the success of the pilot project in the summer of 1976 and saw the development of a community-scale project as a means of demonstrating the feasibility of the technology and stimulating its widespread adoption in the community. CALC, the local arm of CSA's Community Action Program, has a history of innovation in designing programs to serve its varied clientele; CCSG is an example of a project in which the public participated in designing the technology to address local needs and achieving local objectives:

- teaching marketable skills;
- involving senior citizens in meaningful activities;
- providing fresh locally grown produce year-round;
- developing a focus for community organization and cooperation; and
- demonstrating a technology relevant to local development.

One distinctive feature of this project was the central role of community volunteers in the design, construction, and operation of the greenhouse. The training session and workshop organized by CALC allowed the planning group to gain some necessary expertise and help ensure that local needs and desires would be expressed and, where possible, incorporated into the plans. The review and revision of the plans by DTI should have ensured that no technical errors remained in the final design, but the methane digester and overheating problems suggest that this was not the case (see below). The actual construction of the greenhouse was also carried out by local labor, including two paid carpenters who supervised the work of trainees from CETA and the Summer Youth Program and the efforts of as many as 50 local volunteers. Similarly, the operation of the greenhouse is carried out by 50 to 100 local volunteers and trainees, supervised by a paid staff.

The operation of the greenhouse is managed by the three paid, full-time staff members, who spend much of their time experimenting with different solar greenhouse horticultural methods. Regular volunteers have certain assigned tasks or responsibilities—the herb garden, for instance—but much of their work is determined by the chores at hand. Key staff decisions on greenhouse horticulture and operations are guided by the Greenhouse Policy Advisory Committee, which in addition to the staff includes several senior citizens and other community representatives. Larger financial and policy issues are decided by the 18-member board of CALC, which includes 6 representatives elected by the low-income segment of the community; 6 representatives of civic and community organizations, such as the League of Women Voters, Kiwanis Club, NAACP, and Latin-American Association; and 6 representatives of local governments, including 3 city and 3 county commissioners or their appointees.

Local government apparently favors the project, but thus far has been unable to give it much support because of more pressing demands on its time and resources. General community interest has been high, and the staff has been pleasantly surprised by the interest shown and volunteer labor donated by the wealthier segments of the community. Several hundred local residents visited the site during the first year of operation, and the staff offers tours of the facility as well as outdoor gardening classes and other outreach activities. Several members of the community have built their own attached greenhouses after being involved in the project, including one elderly volunteer who built his at no cost with materials salvaged from the local dump. Other local residents plan to do so, and the staff, encouraged by these spinoffs, have kept in touch with the builders and are currently developing workshops on solar greenhouse operation and food production to stimulate further adoption of the technology.

Nevertheless, although the staff regularly uses radio and other media to publicize the project, many members of the community have never heard of the greenhouse. Interviews with 15 elderly residents at the Laramie County Senior Citizens Center revealed that only one of them had any knowledge of CCSG, and the center's director reported that, although their newsletter reached over half of the area's elderly population, only one article about the greenhouse had appeared in it—and the publication of this one article was at his suggestion, not CALC's. The director expressed an interest in getting more of the center's clients involved in the greenhouse, but noted four major barriers:

- lack of coordination between CALC and the center;
- poor transportation services to the site;
- senior citizens' fears of venturing outside the city limits, away from medical services and friends; and
- lack of interest on the part of some of the elderly in any social activities, even those taking place in a hall adjacent to the center.

Essential Resources

Material inputs for the construction of the Cheyenne greenhouse included land, building materials, labor, and a few pieces of specialized equipment. The 2.5-acre greenhouse site, as mentioned above, was donated by a local family and thus represented no cost; however, at the end of 10 or 20 years the land, the greenhouse, and any other improvements on the site will revert to the owners. This is hardly an ideal arrangement, and other communities might well consider the relative benefits of short-term savings on land against the long-term possession of their entire facility. CALC had no choice in this instance; the terms of the CSA grant did not permit purchase of the property.

Building materials represented a little over half of the capital costs of the project and were purchased with CSA funds and a $2,000 grant from Laramie County. Additional materials were donated by community sources, including the 55-gal drums, which were donated by a local company. Equipment costs consisted primarily of the methane digester, which was purchased with $6,000 from the CALC general fund. Additional equipment was donated or loaned by local sources.

Labor costs included $20,000 for two carpenter/supervisors and $4,500 for Summer Work Program workers. Additional labor was donated by local volunteers and Youth Alternative workers. Detailed records of donated labor, materials, and equipment are unavailable, but the CCSG staff estimates that they were worth about half as much as the recorded development costs.

Raw materials used in the production process costs include soil, water, gardening tools, seeds, a limited amount of electricity, containers for commercial potting, and the natural predators used for pest control. With the exception of the seeds and natural predators, all of these resources were available locally at a relatively low cost. The predators were in some cases purchased from commercial laboratories and suppliers, but no further purchases will be necessary if stable and self-reproducing populations have been established in the greenhouse. Many of the original seeds were donated, and CCSG is now producing some of their seed within the greenhouse from previous crops. The topsoil excavated during the construction of the greenhouse was placed in its planting beds after it was completed, and soil quality has been continuously improved by the addition of compost and nutrients. Water is drawn from a nearby well and partially recycled in the greenhouse for reuse in irrigation. Water usage is dramatically reduced because of reduced evaporation: field-grown tomatoes require 162,500 gal/ton of fruit, compared to 11,700 gal/ton in a greenhouse, a savings of almost 93 percent;[8] this is an important consideration in semiarid areas like Wyoming, which receives an average of only 14.65 inches of precipitation annually. Electricity bills for running the well pump, fans, and lights average between $10 and $20 per month.

[8]James C. McCullagh, cd., The *Solar* Greenhouse Book (Emmaus, Pa.: Rodale Press, 1978).

Technical Information and Expertise

Although solar greenhouse technology appears fairly simple when compared to some of the other technologies studied in this assessment, such as resource recovery (ch. 7) or wastewater treatment (ch. 8), the design and construction of a greenhouse on this scale is fairly complex and may require knowledge and skills that are beyond the reach of many local residents and social service agencies.

CALC's experience with their design consultants, DTI, shows that even with expert advice problems do crop up. Although the training session and design workshop for the planning group was conducted by CALC in conjunction with DTI, and although the firm made the final revision of the plans for the greenhouse, two design flaws seem to have found their way into the final design. The first is inadequate ventilation, which led to serious overheating problems during the first summer of operation. DTI recommended the installation of day curtains to keep out unwanted summer heat, just as it had recommended the installation of night curtains to prevent winter heat loss; both modifications would have required significant additional costs, however, and the CCSG staff feels that day curtains would severely cut light flow and thus inhibit plant growth.

A more serious problem involved the proposed methane digester. DTI claimed that the digester would produce enough methane to provide between 140,000 and 315,000 Btu/day in backup heat. The CCSG staff, after consulting the Solar Energy Research Institute in Golden, Colo., insisted that the maximum design capacity of the digester was only 60,000 Btu/day, and that even this level of output would require the addition of a compressor and the extra cost of obtaining manure from local farms. Furthermore, the operation of the digester would have required an estimated 2 man-hours per day of skilled staff time, which was at a premium, and might have presented insurmountable training problems for volunteers. Under these conditions, both the appropriateness and the cost effectiveness of the digester were open to question.

By far the greatest obstacle to the use of the digester, however, was a fundamental design flaw: as mentioned above, the methane storage tank and the gas burner were placed in the same room, creating a serious danger of an explosion. According to CALC and the CCSG staff, DTI was responsible since it had drafted the final design plans; for its part, DTI has complained that agencies like CALC are unable to deal with technical difficulties. Cooperation between CALC and DTI has ceased, and litigation is being pursued.

A greater degree of technical expertise among the CALC and CCSG staffs during the design and construction phases might have prevented these design flaws and might have provided greater learning opportunities for the members of the construction crew. Nevertheless, public participation in the planning group as well as in the construction and operation of the greenhouse has served to create a pool of community residents who are familiar with the principles of solar greenhouse horticulture and experienced in the design, construction, and operation of the greenhouses. They have been a valuable source of advice for residents who planned to build their own attached greenhouses and have done a good deal to promote the further dissemination and adoption of the technology in Cheyenne.

Experience elsewhere has shown that this grassroots approach to technology transfer can be very effective. CSA, which has funded several solar greenhouse projects, recommends "networking," the sharing of information and experience among local public agencies. Interviews with the owners of attached solar greenhouses in New Mexico (see ch. 3) showed that 88 percent of them had recommended the technology to their neighbors and 55 percent of them knew of other attached greenhouses that had been built as a result. They also stressed the effectiveness of the workshop approach, in which neighbors come together for a weekend to learn about and build a greenhouse, in the dissemination of the technology.

Financing

The CCSG project was financed on a debt-free basis, as were most of the New Mexico attached solar greenhouses studied in the last chapter. But where the New Mexico builders paid for their greenhouses out of pocket, the Cheyenne greenhouse has been financed primarily by Federal grants. Construction costs were met by two grants from CSA (an initial grant of $42,700 in 1976, followed by a continuation grant of $13,800 in 1977) and $6,000 from CALC's general fund (which also comes from CSA), plus a $2,000 grant from Laramie County. Operating expenses for 1978 were paid by another $23,000 from the CALC general fund, an estimated $15,000 in CETA and Green Thumb funds, and about $500 in sales revenues (which was used for incidental expenses such as seeds and office supplies).

An additional, unrecognized source of financing is the volunteer labor and materials donated by local residents and firms. These, too, represent an investment of local resources in the project, and unless they are included the actual cost of the greenhouse is obscured not only from the local developers but also from potential users in other communities. Similarly, no dollar figures were available on the cost savings made possible by CCSG's donations of food to local meals programs or on the intangible benefits of job training, improved nutrition, offender rehabilitation, or activities for the elderly. The adoption of accounting practices which quantify both the investment of nonmonetary resources and the return of intangible benefits would help clarify the financial unknowns and risks involved in such projects.

CALC chose Government grants as its source of financing for three reasons: 1) they were available; 2) they were debt-free; and 3) it was assumed that local banks would not finance a project before its operation began and before its economic viability could be ascertained. Since the "commercial" section of the greenhouse has as yet generated no significant revenue, it appears highly unlikely that financial institutions would invest in it, either. Attached solar greenhouses might be economically feasible for private individuals, particularly if they were given tax incentives; but a mixed social service/commercial project on the scale of CCSG must necessarily resort to a grant, at least for its capital costs. Lack of Government subsidies would bar the development of similar projects unless grant funding could be obtained from private foundations.

Institutional Factors

As has been seen, local governments were able to give the CCSG project only limited support, but they did not oppose it. The only opposition came from the owner of a commercial greenhouse, who feared that he would lose part of his market for plants and flowers. Coordination with other social service agencies left much to be desired, but presented no barrier to implementation. Nor did building codes, OSHA regulations, or other local and Federal regulations pose serious obstacles to the development of the greenhouse. Because of the design error with the methane digester, no insurance company would cover the greenhouse without assurances that the digester would not be used; but with a properly designed digester–or in the absence of such equipment—obtaining insurance would probably create few serious problems for a project of this sort.

Perhaps the most significant institutional factor in the development of the Cheyenne greenhouse, and the most important issue affecting its transferability to other communities, concerns the character of CALC itself. This agency seems to be extraordinarily committed to exploring innovative ways of responding to the needs of its constituents. The presence of these same qualities may well be a vital requirement in any attempt to duplicate the Cheyenne experience.

Federal Policy

Background

No existing Federal legislation deals principally or specifically with food-producing solar greenhouses. Nor, it appears, are there any prospects for legislative action on this subject in the near future. The House Agriculture Committee, for instance, is not considering any proposals on solar greenhouses; and if the committee considers them in the future, according to one staff member, they would probably be more interested in their potential for saving energy rather than growing crops.[9] This at-

[9] Gary Norton, assistant counsel, House Committee on Agriculture, personal communication, July 31, 1980.

titude seems to be shared by other congressional committees and Federal agencies, and it appears to result from: 1) an overwhelming preoccupation with the energy crisis and measures to alleviate it, and 2) a greater emphasis on the national economy and international competitiveness rather than local development and the delivery of community services.

Although no legislation directly addresses the subject, however, a number of acts contain provisions, that indirectly or implicitly support the development of food-producing solar greenhouses. These acts include:

- the Economic Opportunity Act of 1964;
- the consolidated Farmers Home Administration Act;
- the Rural Development Act of 1972; and
- the Housing and Community Development Act, as amended in 1978.

These are the primary Acts upon which various Federal agencies have based their programs of funding, information dissemination, and a limited amount of research (much of it aimed at energy conservation) for food-producing solar greenhouses.

The Department of Housing and Urban Development, through its Office of Neighborhood Self-Help Development, gathers and disseminates technical information that will be useful to communities in revitalizing local neighborhoods and providing services and products needed by local residents. The Office has provided funds for a series of publications on energy and urban gardening prepared by the Civic Action Institute, one of these publications, "Neighborhood Food Programs," includes some information on the possible use of solar greenhouses as a part of such programs.[10]

The Department of Commerce, through the Economic Development Administration, has provided funds for the construction of at least one food-producing greenhouse, a controversial hybrid solar/hydroponic project of the Kickapoo tribe in Oklahoma.[11] VISTA volunteers regularly assist low-income groups in the development of alternative energy projects such as solar heaters, alcohol stills, and solar greenhouses; it is unclear, however, whether they have tried to exploit the latter's food-producing potential.[12] The National Science Foundation (NSF) has also sponsored a limited amount of research on the application of alternative technologies to agriculture and urban gardening.[13]

USDA, despite its mandated concentration on food production and its responsibility for administering the many Federal food programs, has no specific programs to investigate or develop food-producing solar greenhouses. This is not to say that USDA ignores greenhouses entirely: its Farmers Home Administration makes loans available for the construction of solar greenhouses, and the Department has a few small research efforts underway, but the focus of both loans and research is on energy savings. This emphasis reflects the source of finding: USDA "mostly takes its marching orders from the Department of Energy" (DOE), which provides the funds for energy research and demonstration projects and then turns many of them over to USDA for management .*4

An indirect but increasingly important source of support for food-producing solar greenhouses, however, has been the Federal food aid programs administered by USDA. Until the 1960's, these programs were relatively small and were directed toward the needs of the American farmer. By the late 1960's, it had become clear that domestic hunger and malnutrition were far more serious than had previously been recognized. In 1967, after a series of national inquiries, it was estimated that "some 10 million to 15 million low-income Americans were suffering from gross malnutrition while millions of others were skirting nutritional collapse due to borderline deficiencies. "[15] Other studies suggested that malnutrition was a major

[10] Matt Andrea, Office of Neighborhood Self-Help Development, Department of Housing and Urban Development, personal communication.

[11] Bob Hathaway, Cherokee Nation, personal communication.

[12] Scot Sklar, National Center for Appropriate Technology, personal communication.

[13] See Ann Becker, "Appropriate Technology and Agriculture in the United States," background paper for Appropriate Technology in the United Stares—An *Exploratory Study,* prepared by Integrative Design Associates, Inc., for the National Science Foundation, Research Applied to National Needs, grant No. 76-21350, 1977.

[14] Bill Hougart, David Feld, et al., Farmers Home Administration, U.S. Department of Agriculture, personal communication.

[15] "A Preliminary Report to Congress on the Community Food and Nutrition Program of the Community Services Administration," op. cit., p. 1.

factor leading to unemployability and chronic dependence on public assistance programs.

In response to these and other findings, Congress created a number of large new nutrition and food aid programs, including the Food Stamp Program (which now costs $12 billion per year) and the School Breakfast and School Lunch Programs administered by USDA. At the same time, Congress also created a relatively tiny program—the Emergency Food and Medical Services Program–to be carried out by the Office of Economic Opportunity, which has since been renamed the Community Services Administration.

Food Production and Solar Greenhouse Programs of the Community Services Administration

The Office of Economic Opportunity was created by the Economic Opportunity Act of 1964 and was renamed the Community Services Administration (CSA) in 1974. A part of President Johnson's "war on poverty," it was originally designed to reach the poor directly by bypassing State and local governments and distributing funds to grassroots organizers. Some 900 community action agencies (CAAs), almost one for every county in the Nation, have been set up to provide jobs for the poor and to provide information and financial support for projects that will lead to local self-sufficiency. These programs are intended to break the cycle of poverty by promoting community independence, employment, and long-term economic development.

Because of its strong grassroots orientation CSA also provided a mechanism for distributing other forms of Federal assistance. According to one CSA official, the CAAs and their respective programs became:

> . . . vehicles for delivering the services of other agencies, such as the CETA programs for the Department of Labor, the weatherization programs of the Department of Energy, and the Head Start program of the former Department of Health, Education, and Welfare. We have the network and the outreach people, other agencies have programs; so we broker the services. We are an action clearinghouse of sorts. That's fine, but it takes us away from our goal and puts us into a welfare slot when we're supposed to be getting people out of the welfare trap.[16]

An example of CSA's emphasis on self-sufficiency and its role as a local "action clearinghouse" is its Community Food and Nutrition Program (CFNP). Originally established as the Emergency Food and Medical Services Program under section 222(a)(1) of the Economic Opportunity Act of 1964, it now operates under the following mandate:

> . . . improve the delivery of food and nutrition services by other agencies, to mobilize other anti-hunger resources both public and private, to coordinate anti-hunger activities at all levels of government, to develop new approaches to the problem of hunger among the poor, and to do all of this in the context of promoting ultimate self-sufficiency for those among the poor who are capable of becoming self-sufficient.[17]

Recent estimates suggest that the average low-income family spends over 50 percent of its income on food, compared with a national average of less than 20 percent; as many as 40 percent of those who are eligible, however, still do not participate in the Food Stamp Program.[18] This and other food aid programs provide significant economic benefits to low-income families by freeing up additional income, but the emphasis of most of the programs is on providing immediate relief and short-term maintenance—"welfare''—rather than investing public and private resources in projects that will lead to long-term economic development and independence. CFNP, on the other hand, tries to promote better nutrition and local self-sufficiency at the same time through its efforts to develop:

> . . . the ability of low-income people to produce, preserve, purchase, or market their own foodstuffs. These foodstuffs may and often do supplement those provided by Federal feeding programs or by private sector institutions . . . . Activities eligible for funding under this [program] include but are not limited to: (1) Conservation, distribution, and utilization of foodstuffs, such as (i) Organizing fam-

[16] Marshall Boarman, Community Food and Nutrition Program, Community Services Administration, personal communication.

[17] "A Preliminary Report on the Community Food and Nutrition Program of the Community Services Administration," op. cit.

[18] Ibid. p. 35; Community Services Administration, "community Food and Nutrition Program, Final Rules," Federal Register, pt. IV, vol. 45, No. 99, May 20, 1980, p, 33798.

ily and community gardens . . . . [and] (iii) Establishing greenhouses, canneries, etc.[19]

Other provisions in CSA's mandate call for providing more assistance to small-scale and part-time growers and for promoting the use of idle Federal, State, and local land for food production, especially by the poor.[20] As a result, CFNP and other CSA programs have promoted community gardens, food cooperatives, pick-your-own farms, and farmers' markets (see ch. 6), as well as solar greenhouses and other relatively sophisticated food-production technologies. While CSA is interested in the technology of projects like solar greenhouses, it is more interested in the jobs that a community greenhouse might provide, the food it could produce, and the subsequent improvements in nutrition, food and energy costs, and general economic well-being that might result from its development.

CSA does not have a well-developed research program. It is primarily a funding source for self-sufficiency projects, and as such it does not demand the kind of detailed data that an agency like NSF or DOE might require from a research project. Neither has it been able to persuade USDA or the land-grant universities to undertake any significant research on alternative technologies that would be appropriate to these small-scale, self-sufficient projects.[21] CSA has been unable to gather a body of information or experience on greenhouse design or horticultural methods, and a number of the solar greenhouses built by local CAAs have been too small for effective food production or energy conservation. A further criticism has been that when local CAAs build greenhouses they often give little or no training in how to manage and use them and seldom follow up on the project to deal with problems or monitor performance.[22]

CSA is now taking steps to fill in some of the gaps in the technical information about solar greenhouse design and food production. The National Center for Appropriate Technology (NCAT), which is almost entirely funded by CSA, is currently conducting two research programs that will generate data on solar greenhouses. The first is the Solar Utility Economic Development and Employment Program (SUEDE), which is a good example of CSA's function as an "action clearinghouse:" the program was conceived and funded by CSA; the Department of Labor provides workers through the CETA Program; DOE pays for materials; and NCAT is monitoring all of the 15 individual projects, several of which are solar greenhouses. NCAT set the standards for evaluation and is looking at how the projects were constructed, how they perform, and what potential they have for wider application.[23] The second program is the New England Solar Greenhouse Monitoring Program, in which NCAT is gathering data on 18 separate greenhouse projects in order to generate information on:

- indoor and outdoor temperature ranges;
- energy consumption for operation and backup heating;
- reduction in fuel consumption when a solar greenhouse is attached to a residential structure; and
- crop productivity.

NCAT has had difficulty in analyzing the results of the New England program, however, because of the great differences in the designs of the greenhouses and the varying expertise of the people who built and used them.[24] Furthermore, not all of the greenhouses are used for food production, and crop yield data is a low priority.

Issues and Options

Food-producing solar greenhouses have the potential of increasing the availability of locally produced vegetables, which might in turn improve nutrition, lower food costs, and reduce the energy consumed in growing, processing, and transport-

[19] "Community Food and Nutrition Program, Final Rules," op. cit., p. 33791.

[20] Ibid.

[21] Roger Blobaum, AT consultant, personal communication, July 24, 1980. It should be pointed out, however, that the horticulture department at Pennsylvania State University is currently evaluating several solar greenhouse designs for the commercial production of vegetables and flowers, and that a book on the same subject has recently been published by Michigan State University Press (Wittwer and Honma, Greenhouse Tomatoes, Lettuce and Cucumbers, 1979).

[22] Bob Hathaway, Cherokee Nation, personal communication.

[23] Scott Sklar, National Center for Appropriate Technology, personal communication.

[24] Andy Shapiro, "NCAT New England Solar Greenhouse Monitoring Program—Second Progress Report," National Center for Appropriate Technology, Sept. 1, 1980.

ing these vegetables from remote growing areas. The horticultural methods used in these greenhouses also promise to use less chemical fertilizers, less pesticides, and less water than conventional methods; in addition, their solar design may reduce the economic and energy costs of operating the greenhouses. Finally, by achieving all of these goals in a context of self-sufficiency, community greenhouses promise to provide jobs, teach valuable skills, develop the local economic base, and reduce the dependence of elderly and low-income citizens on Government services and assistance programs.

Principal barriers relate to the gathering and dissemination of detailed information on the energy-saving and food-producing features of the greenhouses. Problems also exist in promoting serious consideration of this technology by community groups and the financial community, as well as in providing technical advice and assistance for their development.

ISSUE 1:

Technical Information on the Potential Effectiveness of Solar Greenhouse Technology.

The single most serious barrier to the widespread adoption of this technology is the lack of reliable data on the design of solar greenhouses and on their potential for saving energy and producing food crops. CSA has a mandate to improve programs of community assistance, including small-scale food production. However, DOE, USDA's Extension Service, and the land-grant colleges are doing very little research on the design, performance, and crop yields of solar greenhouses or on the identification and breeding of greenhouse crop varieties. Local CAAs and community groups seldom have the funds, the manpower, or the expertise to undertake formal scientific monitoring programs, but thus far the results have been limited in scale and difficult to assess.

Option 1-A: Designate a Central Clearing. house for information on Solar Greenhouse Technology.–NCAT might be a logical clearinghouse for gathering technical information on solar greenhouse design and horticultural methods. Its present monitoring projects may provide a preliminary data base, and it is already grappling with the difficulties of analyzing data from different designs, conditions, and user behaviors. A simple, standardized format would allow operators to report details of greenhouse design, operation, local weather conditions, and other useful information. Data on crop varieties planted, growing conditions, time to harvest, and yields would also aid in evaluating different plant varieties and horticultural methods. A designated central clearinghouse could disseminate as well as gather information on greenhouse methods and performance, thereby giving technical assistance to present operators and providing necessary information to potential operators and developers.

Option 1-B: Support or Expand Existing Monitoring Programs.–NCAT's current SUEDE and New England monitoring programs will yield useful information, but they are studying a limited number of individual projects. Additional funds might be made available for a more extensive monitoring effort, either by NCAT or by local CAAs.

Option 1-C: Redirect Existing Research.–USDA has recently announced plans to increase funding for research on organic farming methods. Since many solar greenhouses and community gardens use organic methods, Congress may wish to direct USDA to target some of these funds specifically for the investigation of methods and plant varieties appropriate to greenhouse horticulture.

Option 1-D: Fund Additional Research.–It may be productive to investigate the cost effectiveness of community solar greenhouse projects versus that of more conventional food aid and economic assistance programs. Depending on the results, Congress might wish to authorize additional funds for R&D on improved solar greenhouse designs, crop varieties, and effective horticultural methods.

ISSUE 2:

Coordination of Existing Programs of Technical Assistance.

As discussed above, a number of Federal agencies have programs that offer some form of assistance or support for community greenhouses and gardens. These different agencies and their local representatives have not always had adequate expertise in the development of such projects, however, nor has their training and followup performance always been satisfactory. There is at present little coordination between these programs; in addition, their very diversity presents a barrier to local organizers, who often do not know what assistance is available to them or what eligibility requirements they must meet.

Option 2-A: Designate a Lead Agency.– This option is resisted by both the agencies and their clients, primarily for financial reasons. As noted earlier, DOE is the focal point for energy programs which are the likeliest source of funding for solar greenhouse projects. Money is given to DOE, which takes an overhead slice and then forwards the balance to USDA or some other agency for the management of the various projects. Because of travel cutbacks and manpower shortages, however, USDA cannot inspect or monitor the projects directly and must hire contractors to perform these tasks. By the time DOE, USDA, and the contractors have all taken out funds to cover their overhead and expenses, only 50 percent of the original funds may be left for the actual project.[25] In addition, the Government may often Pay more than necessary for the greenhouse construction it does support because of the lack of available personnel who understand both the potential of the technology and the needs and conditions of the local community.[26]

Option 2-B: Designate a Central Clearinghouse for information **on** Federal Assistance.–A designated clearinghouse for the gathering and dissemination of technical information on solar greenhouses (outlined above) could also serve as a clearinghouse for information on the financial and technical assistance that is available through other Federal agencies and programs, since it would already be in contact with both the existing projects and the potential developers. CSA's grassroots network of local CAAs make it the obvious candidate to manage both types of clearinghouses; specific operating responsibility for both technical and assistance information might be assigned to NCAT.

ISSUE 3:

Providing Financial Support for the Development of Community Solar Greenhouses.

As with most other small-scale technologies, even those whose goal is self-sufficiency, there is a shortage of front-end financing for the construction of solar greenhouses. Tax credits exist for residential energy-conservation measures, but none exist for food production; and tax credits are least useful to low-income families, whose need is greatest, because they seldom have access to capital to invest in these measures. Community projects like the Cheyenne greenhouse also lack access to capital from conventional sources. Banks are hesitant to finance such unusual projects, especially when there is little data on the technology involved. The CALC organizers went after Federal grants for their project because they were available and debt-free; they assumed that no other financing would be available, and they may have been correct in this assumption.

Option 3-A: **Increase Tax Incentives.**– Congress could choose to make attached solar greenhouses eligible for residential tax credits or tax deductions; this might be done through directives to the Internal Revenue Service, which at present will not allow claims for solar greenhouses, whether for energy-saving or food-producing purposes. However, this option would probably require an amendment to the Income Tax Code of 1954.

Option 3-B: **Increase** Markets.—Another option for congressional action would be to increase markets for locally grown produce by encouraging Federal food programs and other Federal agencies to procure vegetables and produce from local producers wherever possible, with a special attention to community, cooperative, and other nonprofit producers. This might be accomplished through Federal procurement guidelines similar to those for recycled materials.

[25] Paul Sleusner, U.S. Department of Agriculture, personal communication.
[26] Bob Hathaway, Cherokee Nation, personal communication.