An Assessment of Technology for Local Development

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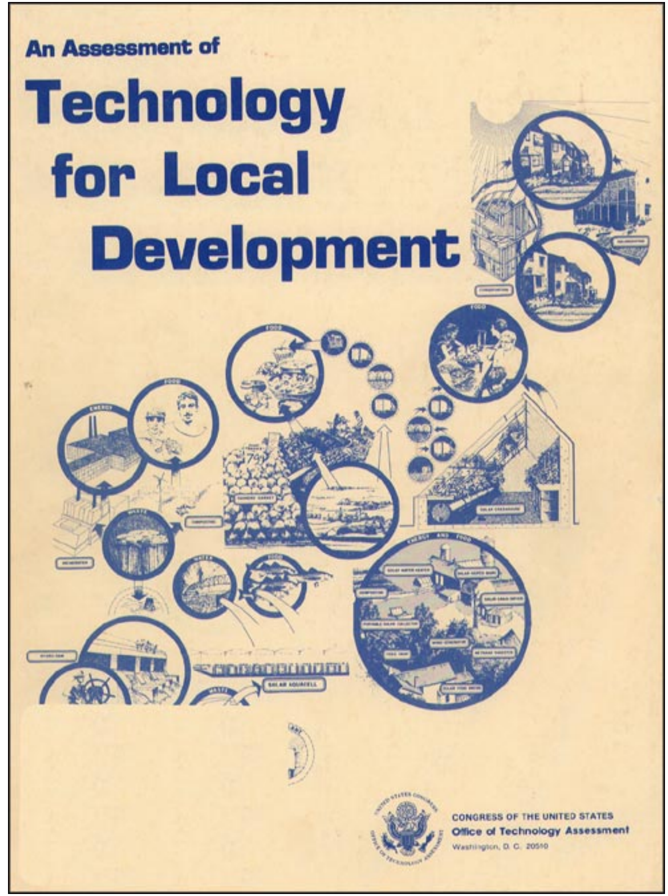

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Foreword

The late Dr. Pearly F. Ayre, a sociologist who spent several decades working with people in Appalachia, finally became disenchanted with the long-term effectiveness of many of the Federal development programs aimed at that region. He is remembered for his memorable observation in praise of local initiative: “We must do for ourselves, or be done for.”

This OTA study addresses the question of local development and the opportunities for–and appropriateness of–various technologies that can help local people to take advantage of local resources in meeting the needs of their own communities. In many instances there are also close connections between local and national needs; as a result, these local solutions can sometimes add up to national solutions.

OTA has made extensive use of case studies to assess a variety of community projects. One clear conclusion that emerges from these cases is that individuality, ingenuity, and initiative are far from lacking in the United States. It is also evident that many communities are strongly attracted to the principles of local reliance and self-sufficiency. When a community evaluates and chooses a technology for local development, it should take into account nonmarket goals and priorities, as well as purely market factors. In many cases this broader perspective–the attempt to find and develop an “appropriate technology” (AT)–can greatly influence the overall utility of the project.

OTA found that neither “big” nor “small” technologies are consistently more attractive or effective. The historic progression toward larger scale is not universally optimal; indeed, some large-scale projects can result in a diseconomy of scale. Recent developments in science and technology have created an increasing number of opportunities for economic activities on a smaller scale, as well as on a decentralized basis.

Because AT by definition reflects local goals and values, as well as local resources and conditions, the broader adoption of AT may well lead not only to a more diverse and resilient economic system, but also to one that better serves the social and human needs of communities throughout the Nation.

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CHAPTER 1
Executive Summary

Appropriate technology (AT) involves an attempt to tailor the scale and complexity of a technology to the job it needs to do. AT has been proposed by some of its advocates as an answer to many of the social and economic problems created by large-scale, centralized technology in both the industrialized countries and the Third World. Through greater diversity and decentralization, they argue, it is possible to achieve a "technology mix" that makes more effective use of limited capital and is better adapted to, and less disruptive of, the social and natural environment. Large-scale approaches may be necessary for some tasks, but for others it is possible to scale down existing technology or, in some cases, to replace it with more traditional methods that have been improved on through the application of advanced materials, designs, or techniques. Ideally, AT emphasizes resource efficiency, environmental soundness, community control, and labor rather than capital intensiveness.

AT proponents cannot always agree on exactly what the concept entails, however, and its emphasis has changed and broadened over the last 10 years, depending on where and when it was applied. In one of its earliest forms, AT was proposed as an alternative approach to economic development in the Third World. Observers like British economist E. F. Schumacher noted that when an advanced, capital-intensive technology is introduced into a developing nation, it sometimes crates as many social and economic problems as it solves. What is needed, Schumacher suggested, is an "intermediate technology" that is far more productive than traditional methods but is still more labor intensive (and less capital intensive) than the sophisticated, large-scale technologies of the industrialized nations.

In the past few years, on the other hand, a growing number of appropriate technologists have come to view themselves as pioneers, operating "at the frontier" in several areas of applied science. They argue that much of what is called AT is in fact a particular kind of advanced technology, one designed for changing resource conditions. In response to the current economic environment, for instance, a number of relatively sophisticated technologies have been de~'eloped that are efficient users of energy and material resources. In this view', the main challenge is to integrate numerous applications of AT in efficient, sustainable systems in the local community.

OTA's exploratory study is not intended to be comprehensive. Nevertheless, the AT projects examined in this study exhibit a great diversity in size, complexity, and location. They range from attached solar heating greenhouses built by individual homeowners in New Mexico to a plant that converts municipal waste to steam heat for downtown Akron, Ohio; from a heat-retentive house designed for low-income families in Alaska to a cooperative market for small-scale farmers in Louisiana; and from an innovative sewage treatment plant in California to a pair of recommissioned hydroelectric projects in New England.

Congress has frequently taken the lead in promoting the development of AT. This interest was demonstrated by the creation of the National Center for Appropriate Technology by the 94th Congress and the Office of Small Scale Technology within the Department of Energy (DOE) by the 95th Congress. In June 1978, OTA was asked to conduct an exploratory study to:

- assess the conceptual base for AT;
- assess technologies which are appropriate for local community development; and
- collect information on promising new technologies now being innovated in energy, waste disposal, housing, agriculture, and health that may provide an alternative and possibly more effective approach to community and regional development.

The request for the OTA study came from Senators Ribicoff, Percy, Javits, Humphrey, Leahy, Brooke, McIntrye, McGovern, and Hart, as well as Representatives George Brown, Scheuer, and Udall.

Findings

The projects examined in this study had widely varying objectives, and their significance can be quite different when viewed from the national perspective instead of the local. Thus, no simple judgment of "success" or "failure" can be applied: each case must be examined from both points of view.

Viewed broadly, local development is not always simply a question of economic growth as conventionally measured. Efficient and cost-effective municipal services—the goal of several of the projects—are a necessary underpinning to local development, as is the availability of health care and the affordability of housing.

Creating employment and new industry was not the principal objective of the projects examined. Nevertheless, one project saved local jobs that otherwise would have been lost, and other projects provided help in severely depressed areas by creating temporary jobs and by providing marketable training and work experience. Some of the projects helped to improve the viability of existing enterprises (small farms), and others could create significant opportunities for small business (notably in the construction and home-improvement sector).

From the local perspective, the primary significance of these projects *is their potential for reducing—or at least stabilizing—the real costs of community services.* The following are some examples taken from the case studies:

1. *Waste management and resource recovery.—*
   - reduce the operating costs of secondary wastewater treatment;
   - use municipal solid waste as a fuel to generate steam for use in the downtown area;
   - recover materials from municipal wastes, including compost and water as well as aluminum, glass, iron, and steel;
   - reduce the volume of sludge and other residues that must be disposed of; and
   - reduce the air, water, and land pollution associated with waste management.
2. *Energy.–*
   - reduce the energy consumption of wastewater treatment facilities;
   - develop new sources of energy for municipal services and local industrial use; and
   - recommission abandoned or underutilized energy-generating facilities for local use.
3. *Health care and* social *services.—*
   - *increase the* availability of primary health care;
   - reduce the cost of medical services; and
   - provide community activities for the elderly and the handicapped.

On the national level, projects also address several important and vexing problems that will face the United States during the next 20 *years.* If these and similar efforts are replicated on a nationwide basis, the results could be significant in the following areas:

- greater *energy* conservation in *the* residential sector—which currently accounts for over 20 percent of U.S. energy consumption—could make an important contribution to achieving the national goal of independence from imported oil;
- new Production and marketing techniques *for* small-scale *farmers may* contribute to the retention *of the* Nation's farmland-which is being converted to nonagricultural use at the rate of 1 million acre/yr;
- alternative wastewater treatment technologies could reduce the cost of expanding and upgrading the Nation's *sewage* treatment facilities—an enormously costly process that might otherwise be beyond the available resources of Federal, State, and local governments;
- installing *new* generating *capacity at existing* damsites--many of which are abandoned or underutilized, could greatly increase the Nation's supply of hydroelectric power; and
- community health centers *and prepaid health plans could lead to significant savings in the cost of health care—which* now consumes almost 10 percent of U.S. gross national product.

Given these potential national benefits, the process by which the technologies were adopted and the potential barriers to their replication by other communities become important considerations. Close attention to local needs, goals, and resources was found to be an essential factor in most of the successful projects. In some cases, a significant barrier to transferability was the availability of reliable information on the design, cost, and performance of the technologies themselves. In other cases, the barriers were institutional: opposition from commercial interests; reluctance on the part of engineers, builders, or lending institutions to accept innovative designs; and insensitivity in the application of building codes, waste management guidelines, medical practice laws, and other regulations by various levels of government.

Existing Federal policies and programs have been relatively effective in encouraging the development and adoption of AT projects like those examined in the case studies. Based on these case studies, *there appears to be no justification for a new, centralized Federal effort to promote such projects; existing programs could, however, be improved in four specific areas:*

- *gathering reliable data* on the design, cost, and performance of the technologies, either through modified project design, redirected research, or expanded Federal monitoring efforts;
- *information dissemination,* both through regional "demonstration projects and through the encouragement of networking and other informal, local mechanisms for information exchange;
- *technical assistance,* including both community workshops for individuals and planning aids for municipalities; and
- *financial assistance,* such as tax credits or cost sharing for individuals and risk sharing for municipalities.

The Case Studies

Resource-Efficient Residential Architecture

In 1977, energy consumption for heating and cooling in the residential sector totaled 17 quadrillion Btu, or almost one-quarter of total U.S. energy consumption. Rising energy prices and potential supply shortages have forced architects and builders to develop residential housing designs that are less dependent on fossil fuels. Some houses being built today require less than one-fifth as much energy to maintain acceptable inside temperatures as typical housing stock built in the 1970's. A few new heat-retentive designs promise to all but eliminate the need for backup heating. Several alternatives are discussed in five case studies:

- solar heating greenhouses in New Mexico, which collect heat from the sun for use in both the greenhouse and the house to which it is attached, and which can be built by individual homeowners at a low cost, often with scrap or salvaged materials;
- the "Ark II, " a passive solar-heated house designed by Solsearch Architects for the Cooley family of Washington, Corm., and built by the Cooleys, which incorporates the patented "solar staircase" roof and a number of advanced building materials;
- the "Conserver Home" on Prince Edward Island, Canada, also designed by Solsearch Architects, a low-cost house that uses "Arkansas framing," thick insulation, and other design features to retain the heat given off by the occupants and their activities, thereby greatly reducing the need for supplemental heating;
- the "Bethel House," designed and built by the faculty and students of Kuskokwim Community College in Bethel, Alaska, another low-cost heat-retentive design that uses superinsulation and a number of innovative design features that conserve building materials as well as energy in a demanding climate; and
- the "thermal envelope" house, built by Tom Smith near Lake Tahoe, Calif., which consists of a "house within a house" that combines a solar greenhouse, convection currents, and a buffer space to produce a house that is less expensive to heat in the winter and cool in the summer.

These and similar designs promise considerable energy savings for individual families, but the costs of the solar and thermal-envelope houses are such

Photo credit: Office of Technology Assessment

Bethel House, Bethel, Alaska

that they are being built primarily for the middle- and high-income custom housing market. The attached solar greenhouse offers a low-cost retrofit that can be applied to existing homes in many locations, and the Conserver, Bethel, and other heat-retentive designs show considerable promise for new low-income housing. At present, however, there is a lack of reliable data on the cost and performance of some of the designs, and no "preferred" solutions have gained general acceptance from financial institutions or the building industry.

Food-Producing Solar Greenhouses

Solar greenhouses have two features of special interest: they can provide a year-round source of fresh, locally grown produce, 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 may be able to reduce the food budgets as well as the energy budgets of individual families, community groups, and the Nation as a whole.

The 5,000-ft^2 Cheyenne (Wyoming) Community Solar Greenhouse is the largest freestanding solar greenhouse in the United States. Funded by grants from the Community Services Administration, the project was notable for the degree of community participation in the planning, construction, operation, and management of the greenhouse. It has also provided job training for students, alternative service for youth offenders, educational opportunities for children, and activities for elderly and handicapped members of the community. Produce grown in the greenhouse is distributed to low-income and elderly volunteers who work there and through local meals programs.

The project has been less than successful when evaluated strictly as a food-producing enterprise. It has encountered a number of design and operation problems, crop yields have been low, and it has yet to become self supporting. Although the project was successful in delivering social services, there has been no study of whether this kind of project is the most cost-effective way to deliver those services.

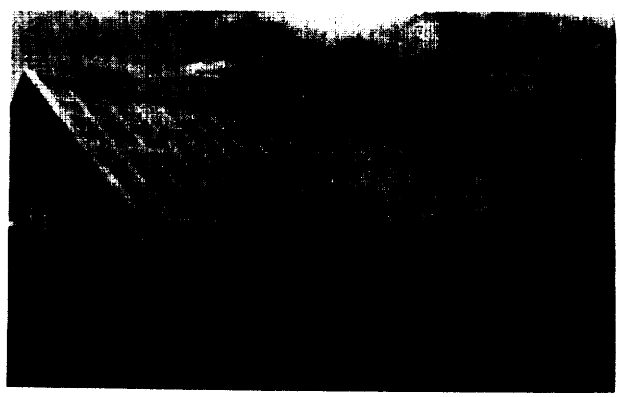

Photo credit: Office of Technology Assessment

Cheyenne Community Solar Greenhouse, Cheyenne, Wyo.

Small Farm Systems

The three major operating costs associated with farming–feed for livestock, fertilizer for fields, and fuel for machinery and buildings–have all been affected by rising petroleum prices. These factors have endangered the economic viability of the small family farm. The New Life Farm (NLF) and Small Farm Energy Project (SFEP) are two attempts to reduce the energy costs and increase the self-sufficiency of small-scale agriculture in their regions.

NLF is developing a "system" of alternative energy sources and energy-conserving farming techniques suited to the needs of low-income farmers in the Ozark Mountains of Missouri, a region of thin and badly eroded topsoil. Their principal innovation has been the biogas digester, in which the anaerobic decomposition of manure or plant wastes produces a gas that is 60 percent methane. This gas can then be burned to heat the farmhouse, to generate electricity, or to distill alcohol as a fuel for farm machinery.

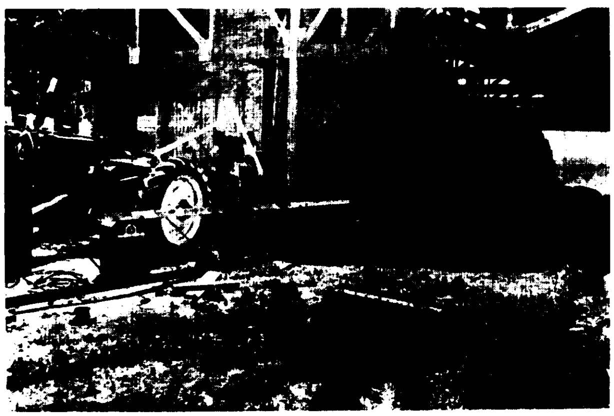

Photo credit. New Life Farm

Digester building, New Life Farm, Drury, Mo.

SFEP, in Cedar County, Nebr., is a 3-year program to demonstrate how far a group of low-income farmers can progress toward energy self-sufficiency when provided with technical and cost-sharing assistance. The farmers were introduced to proven, primarily solar technologies through a series of seminars, hands-on workshops, and lectures by farmers from other areas who had undertaken similar projects. They were then allowed to select the projects that would best suit their farming operations. About half of the projects involved conservation measures, a few involved improved farming methods, and a third involved applications of renewable energy sources, including a wind generator, a portable solar collector, two solar grain dryers, and a solar-heated farrowing barn.

Both of these projects promise considerable benefits to the small-scale farmer, but SFEP had a far greater impact on the local community, largely because it made a greater attempt to involve the community in the planning and execution of its programs. Self-selection by the innovating farmers was a particularly valuable feature, and the project seems to have had a considerable effect on non-participating members of the community, many of whom undertook similar conservation steps.

Farmers' Markets

Cutting production costs is one way to improve the profitability of small-scale agriculture; another is the time-honored practice of marketing produce directly to the consumer. Case studies of six farmers' markets–in Rutland, Vt., Morehouse Parish, La., Ravinia, Ill., Boston, Mass., Baltimore, Md., and Seattle, Wash.—show that this food-marketing technology can still benefit farmer and consumer alike. The markets were organized by a variety of local groups, including farmers, consumers, businessmen, municipal governments, and local extension agents. All of them, however, depend vitally on the participation of farmers and local consumers, and when the needs and convenience of these groups were given greater attention the success of the market was more assured.

Most of the farmers' markets contributed to local development, primarily by expanding the local market for fresh produce or creating markets where none had existed before. The profitability of direct marketing led local farmers to diversify their crops and improve their farming methods, and several of them said that the farmers' market had influenced their decision to keep their land in production. Nationwide, the availability of similar local markets may help to prevent the further "paving over" of farmland near urban centers.

Resource Recovery From Municipal Solid Waste

The United States generates over 135 million tons of municipal solid waste (MSW) each year, and its disposal is a rapidly growing problem in many areas. Conventional methods, such as open dumping, landfill, incineration, and ocean burial, are either too expensive or environmentally unacceptable. Interest is also growing in methods of recovering valuable resources of MSW, which contains two-thirds of the national consumption of paper and glass, one-fifth of the aluminum, and over one-eighth of the iron and steel. In addition, the combustible portion of this waste could, if burned, provide almost 2 percent of the Nation's annual energy consumption. Improved resource recovery technologies could, therefore, contribute not only to inexpensive and environmentally sound waste management but also to energy conservation and the more efficient use of material resources.

In Akron, Ohio, the steam that heats many of the downtown buildings is now being provided by the Recycle Energy System (RES), a centralized recovery facility that uses combustible MSW as fuel and also recovers ferrous materials for sale. The project has contributed to the revitalization of the previously deteriorating central business district. To assure itself of an adequate supply of MSW, however, the city was forced to pass a controversial ordinance requiring private haulers to dump at the RES site. The ordinance is currently under legal challenge, and if the decision goes against the city it may jeopardize the future of the project.

Photo credit: Teledyne National

Recycle Energy System, Akron, Ohio

In New York City's South Bronx, the Bronx Frontier Development Corp. has established a comporting operation that converts vegetable wastes from a nearby produce market into humus, an essential soil conditioner. Some of the humus is sold commercially, but most of it is donated to various community groups that are turning rubble-strewn lots into parks and gardens. The project has encountered some difficulties with State sanitary codes and with funding; it may, however, be able to become self-supporting if it increases its tipping fees and its commercial sales.

Both projects demonstrate promising alternatives for resource recovery from MSW, but they also demonstrate the problems associated with the control of the "waste stream' '—RES with an adequate quantity of waste and the Bronx project with waste quality. Federal initiatives may be required to resolve this issue.

Community Wastewater Treatment

The General Accounting Office has recently concluded that, due to the scope and enormous costs of upgrading the Nation's sewage treatment system, it is imperative that lower cost approaches be found for providing this community service. The Solar AquaCell treatment facility in Hercules, Calif., is one such alternative. The facility consists of a series of lagoons, enclosed in a greenhouse cover, in which wastes are consumed by water hyacinths, duckweed, small marine animals, and bacteria. The system is still too new to make a definitive evaluation, but it promises to use less energy and chemicals than conventional systems. The biological components of the system are fairly hardy, which may also give the facility increased flexibility in adapting to varying types and concentrations of wastes.

The AquaCell facility was a municipal undertaking with relatively little community input, but

Photo credit: Office of Technology Assessment

Solar AquaCell Treatment Facility, Hercules, Cal if.

it has subsequently received widespread support from local citizens, many of whom have taken steps to reduce their water consumption. The city's unique revenue base made development possible without Federal funds, and this has freed Hercules from the constraints on its growth that might otherwise have been imposed by regional sewage planning. However, it also raises questions about the transferability of the technology to communities that lack similar financial resources, although the Environmental Protection Agency's (EPA) Innovative and Alternative Technologies Program has made some funds available for this purpose.

Community Energy Generation

Hydropower, which represents 13 to 15 percent of U.S. electrical generation, is currently the most widely used renewable source of energy in the United States. Price increases for fossil fuels, as well as environmental considerations, have made hydroelectricity increasingly attractive over the last 10 years and have stimulated interest in developing the Nation's hydropower potential. A recent survey by the U.S. Army Corps of Engineers suggests that current capacity could be greatly increased simply by upgrading current facilities or by installing generators at existing damsites that do not currently produce electricity. Small-scale dams, with their lower capital costs, are particularly attractive for this purpose; about two-thirds of these dams are located in New England.

Woonsocket, R. I., is converting an existing dam to generate electricity. The project was undertaken at the encouragement of the State Energy Office and was initially supported by a feasibility study grant from DOE; the voters subsequently approved a municipal bond issue to fund the major part of the construction. Electricity from the dam will be used to run the regional sewage treatment plant and the city waterworks, surplus power will be sold to the local utility company. A similar project in Wareham, Mass., has run into trouble because of the city's insistence on funding the project entirely through grants, Wareham plans to sell all of its power to the local utility company.

The Wareham project demonstrates the difficulties that can arise from dependence on the grant's economy, but both projects illustrate the benefits

Photo credit: Elizabeth Pezzoli

Tremont Dam, Wareham, Mass.

of developing underutilized local resources. Power from these and similar projects elsewhere can be applied to local energy needs, either for cutting the costs of municipal services, for sale to the local utility company, or for attracting industry to the area. Both projects received general support from local residents, although widespread misconceptions about the size and uses of the projects existed in both communities.

Community Health Care Systems

The Hyde Park-Kenwood Community Health Center was organized by local residents as an alternative to the fragmented and often inadequate health services on Chicago's South Side. Initial funding was provided by a Federal grant and the sale of $110,000 in debentures to members of the community. The center is currently operating in the black. Located on the second floor of a rehabilitated building, it provides primary health care for three types of patients: private patients who pay on a fee-for-service basis; those who are covered by medicare and medicaid; and those who belong to prepaid health plans through their employers or unions.

The center is managed by a board of directors elected by its dues-paying members, but Illinois law requires a separate medical group; as a result, the issue of community control is still unresolved. The center has increased the availability of primary health care and reduced its costs, however, and its programs of preventive medicine and health education could help to improve the gener-

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al health of the community. Widespread creation of similar health maintenance organizations in other communities could have a significant impact on the enormous cost of health care in the United States. However, the human and financial resources found in Hyde Park-Kenwood would not be available in most inner-city areas, and entirely different approaches will probably be required in rural areas.

Critical Factors

The uniqueness of some of the projects, which might limit the transferability of the technologies to other communities, was largely the result of special conditions or resources—human, financial, or material. Nevertheless, a number of lessons were learned about those factors most likely to affect the success or failure of individual projects and their transferability to other communities.

Public Perception and Participation

Public participation was not a major factor in the municipal projects, although greater citizen involvement might have encouraged the consideration of alternative approaches in the planning stages. Participation by local residents was more important in projects undertaken by community groups, such as the health center and the various farmers' markets. A high degree of public interest and involvement was essential—almost by definition—in individual projects like the small farm systems and passive solar houses.

Technical Information and Expertise

The availability of technical information and expertise was found to be essential for the successful planning, construction, and operation of all of the projects. In the larger projects, city planners and engineers demanded reliable data on the capital costs and technical performance of the technology; where this information is lacking, professional resistance and financial difficulties can be expected. In the less complicated community undertakings, the need for information can often be met through "networking" among groups that have similar interests. In the individual undertaking, on the other hand, the greatest need is for personal hands-on experience in design and construction; community workshops and individualized technical assistance were successful in transferring these skills and information.

Essential Resources

The availability of essential resources–material, capital, and institutional—was most commonly found to be unique to the community and therefore most likely to affect the transferability. An apparent lack of resources was often overcome by determined and imaginative organizers working from within the community. Some of the most promising technologies—the manure digester, for instance—were based on what might to outsiders seem to be the least promising resource base.

Financing

The forms of financing used by the projects were almost as varied as their financial needs. Grants were most effective as initial seed money, either to attract conventional financing or to allow the projects to become self-supporting; projects that continued to depend on grants, contracts, or subsidies were less successful. Cost-sharing assistance and grants for community workshops were effective mechanisms for encouraging widespread adoption of some of the small-scale technologies, such as farm energy systems, solar greenhouse retrofits, and residential conservation strategies. Large-scale municipal projects, on the other hand, may require Federal intervention to reduce financial risks and attract conventional financing.

Institutional Factors

Some of the projects encountered resistance from commercial interests, who feared competition, or professional interests, who were leery of innovative but unproven approaches. The development of the AquaCell was impeded by the current state of the venture capital market. Financial institutions generally were hesitant to underwrite innovative projects. Some of the projects also experienced opposition or insensitivity from regulatory and other government agencies. Building codes, waste management guidelines, and medical practice laws were a particular source of difficulty.

Options for Federal Policy

A variety of Federal policies have contributed, directly or indirectly, to the development and adoption of these technologies, and existing Federal programs, for the most part, have seemed effective. However, a number of criticisms have been raised concerning their extent, coordination, and management. There appear to be four principal areas in which Federal programs for local development might be modified and improved:

- data gathering;
- information dissemination;
- technical assistance; and
- financial assistance.

Data Gathering

The technologies examined in the case studies were at varying stages of development, but most of the projects would have profited from more reliable data on the design, cost, performance, and/or reliability of the technology itself, as well as on the experience of other communities in applying it. Some of the case studies, however, involved technologies that were being applied for the first time in a full commercial- or municipal-scale facility; in other cases, the local development project involved an innovative application of a proven technology. The future dissemination of both types of technologies could be assisted by comprehensive evaluation and comparison with more conventional approaches.

There are a number of steps that can be taken by Federal funding agencies and local project organizers to ensure that adequate data-gathering is in fact carried out. These steps include, but are not limited to, the following:

- *modify project design* to include a strong data-gathering component, where possible, by providing additional funding or earmarking a portion of the project's funds specifically for data gathering;
- *redirect existing research* to gather not *more* data but a different *kind* of data, particularly where human behavior is a significant variable (e.g., solar-heated houses and resource recovery); and
- *support and expand cur-rent Federal monitoring programs,* like 'those undertaken by the National Center for Appropriate Technology, to provide assistance in assessing the performance of existing projects for energy-efficient housing and agriculture.

Information Dissemination

Even when a technology is fairly well developed in one project, its diffusion can be impeded if other potential developers are unaware of the project or unable to obtain detailed data on design, costs, and performance. In some cases this will cause communities to overlook a promising alternative, in other cases it will result in resistance from engineers and financial sources who consider the project too risky, and in a few cases it might cause the failure of a project because its organizers were unaware of the problems, and solutions, that have been discovered in similar projects elsewhere. This problem can be compounded if Federal activities in the field of AT are not explicitly identified as such.

The problem of information dissemination can be addressed through a number of measures—local, regional, and national–including but not limited to the following:

- *encourage networking* between local and regional groups with related interests. This was effective in organizing farmers' markets in Boston and disseminating information on small farm systems in Nebraska. Federal agencies, particularly those like the Agricultural Extension Service and the Community Services Administration that have extensive local representation, are in a good position to encourage the establishment of such networks throughout the Nation;

- *establish regional demonstration projects,* which were particularly effective in stimulating public interest and promoting further adoption of proven, cost-effective technologies by local residents in Nebraska, Wyoming, and New Mexico; and
- *encourage information exchange* between different levels of government, and between government and private industry, by creating and funding a more extensive program of regional panels, seminars, and workshops at which interested parties could be exposed to recent developments in their fields; both EPA and the Federal Home Loan Bank Board have established such programs.

Technical Assistance

Even when reliable design and performance data are available, the development of a particular project will not be possible unless an adequate skill base exists, or can be developed, in the local community. This can be a problem even with the simplest of the projects, although the skills needed for planning and building an attached solar greenhouse, for instance, can be taught rather easily. In the case of the larger municipal projects, even the expertise needed for planning the project or determining its feasibility may be beyond the means of a given community.

There are a number of approaches to this problem. Direct, project-related technical assistance usually involves greater Federal involvement and greater expense; skill transfer and other indirect assistance usually cost less and benefit the community more, since the skill base they develop will remain in the community after the completion of the project. The following represent a range of options for technical assistance:

- workshops were highly effective for the simplest of the projects, particularly those that are to be built by individual homeowners or farmers, and were also successful in demonstrating the technology in the local community and stimulating additional installations;
- *training programs and seminars,* like those of the Small Farm Energy Project, can expose local residents to a wide variety of potential applications and provide valuable skills;
- *one-on-one technical assistance* from organizers and outside experts was useful in helping farmers to build solar installations in Nebraska and organize a farmers' market in Louisiana; the existing extension program of DOE and the U.S. Department of Agriculture could be used as a mechanism for this form of assistance;
- *computer models and other planning aids* allow small communities to conduct low-cost site evaluations and feasibility studies for small-scale hydropower projects, farmers' markets, and community health care centers; similar technical and organizational guides for energy-efficient housing and farm systems, resource-recovery systems, and wastewater treatment facilities would allow other communities to conduct their own evaluations and planning, without the need for extensive Federal involvement or funding; and
- *expert assistance panels,* like the teams of technical, financial, -marketing, and institutional specialists provided to State and local governments through EPA's Technical Assistance Panels Program, might be useful in promoting the consideration, adoption, and construction of local projects for wastewater treatment, energy generation, and health care.

Financial Assistance

Some of the technologies had the virtue of low cost, which allowed them to be developed by local communities. In several of the case studies the costs of the project were minimal and the project rapidly became self-supporting. This was particularly true of the farmers' markets and some of the energy-saving retrofits for residential and farm buildings. Some of the large projects, however, involved initial investments or economic risks that could be too great for some communities to bear without governmental assistance. Given the potential expense of these municipal services and the potential benefits to the Nation of developing innovative methods of delivering them, it might be appropriate that the Federal Government intervene to reduce the financial risks and burdens they might impose on local communities.

Several of the projects examined in the case studies could be replicated by other communities without Federal financial assistance. However, where assistance is necessary there are several ways in which the Federal Government can help hold down the cost to the local community and encourage adoption. These measures include, but are not limited to, the following:

- *technical risk reduction,* through efforts to gather and disseminate reliable information on the technologies (particularly cost-benefit and lifecycle cost data), can reduce the financial risks of the projects and prevent costly planning errors;
- *financial risk sharing,* including risk guarantees for the correction of facilities that do not work properly (available under EPA's Innovative and Alternative Technology Program) or tax-free bonding for municipal projects, might encourage the consideration of alternative technologies;
- *tax credits and other incentives,* such as the Residential Energy Credit, might encourage the adoption of several of the smaller technologies (current Internal Revenue Service guidelines do not allow credits for attached solar greenhouses; extension of credits to include farm installations might also promote the more rapid adoption of biogas digesters and onfarm solar installations);
- *investment tax credits and accelerated depreciation* might encourage the commercialization of some of the technologies and the creation of small local businesses to produce and/or install necessary equipment; and
- stimulating markets through Federal procurement guidelines, like those for recycled steel, might ensure a market for locally grown produce or for materials recovered from municipal waste.

Options for direct Federal financial assistance include the following:

- *provide short- and medium-term loans and grants* for long-term planning and front-end costs (i.e., feasibility and market studies);
- *provide long-term financing options* for community projects with favorable lifecycle costs, projects that might otherwise have to be financed with short- and medium-term debt: and
- *establish financial intermediaries,* authorized to make direct loans to community-based AT projects, in order to spread risk and reduce information and transaction costs.

Chapter 2

Introduction

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CHAPTER 2
Introduction

Concepts of Appropriate Technology

For his different purposes man needs many different structures, both small ones and large ones, some exclusive and some comprehensive . . .

* * *

What scale is appropriate? It depends on what we are trying to do.

–E. F. Schumacher, Small is Beautiful[1]

Appropriate technology (AT) involves an attempt to tailor the scale and complexity of a technology to the job that needs to be done on the basis of human as well as purely economic values; it tries to be sensitive to the needs, desires, and resources of the people who will use the technology; and it is sometimes offered as an alternative or supplement to the centralized technology of the industrialized West. Any attempt to define AT precisely is likely to end in frustration, however: the proponents of AT cannot always agree among themselves on exactly what the concept entails, and its emphasis has changed several times in the last 10 years, depending on where and when it was applied. What follows, then, is a sample of the positions held by various AT advocates and groups at different times. It is not a definitive treatment, but rather a summary illustration of the many threads that have come together in the AT movement. This movement's beliefs are distinctive but not always strictly coherent—this to some degree may be inevitable, since AT embodies the principles of diversity and selectivity in its response to varying local conditions and priorities.

In one of its earliest forms, AT was proposed as an alternative approach to economic development in the Third World. Observers like British economist E. F. Schumacher noted that, when advanced technology (particularly the capital-intensive kind employed by industrialized societies) was introduced into a developing nation, it sometimes created as many social and economic problems as it solved. What is needed, Schumacher suggested, is an "intermediate technology" that is far more productive than traditional methods, but still more labor intensive and less capital intensive than the sophisticated technologies of the industrialized nations. In the agricultural sector this might be a metal plow, for instance, as opposed to a hoe at one extreme and an air-conditioned tractor at the other. In the Third World, then, AT is usually associated with small-scale, decentralized industries that make extensive use of an abundant resource—unskilled labor-and are more sparing of resources that are less abundant-energy, investment capital, and skilled labor. An example in the manufacturing sector might be a village foundry that produces and repairs the metal plows: such a project would provide training and jobs in the countryside; its product would improve the yields and lives of local farmers; and multiplied by hundreds of villages, it would lay the foundation for an advanced but decentralized iron and steel industry. An "intermediate" technology, in short, is often more appropriate than an advanced technology to the needs and the resources of a developing nation. AT proponents claim that, if it does the job better, it represents the economically sensible choice both for the Third World and for the industrialized nations who are aiding its development.

In the United States, by contrast, AT was originally associated with the environmentalist and "back to the land" movements of the late 1960's and early 1970's. Its early proponents were influenced by Rachel Carson's *Silent Spring (1962)* with its prophecy of an ecological catastrophe,[2] by the

[1] E. F. Schumacher, *Small is Beautiful*: Economics as *if People Mattered* (New York: Harper and Row, 1973), pp. 61-62.

[2] Rachel Carson, *Silent Spring* (New York: Houghton-Mifflin, 1962).

publication of The *Limits to Growth* (1972) with its prediction of the "overshoot and collapse" of world industrial growth,[3] and by a spreading disenchantment with an advanced technology that, despite its material benefits, was felt to be an overbearing and sometimes destructive presence. Some of these early advocates concentrated on reviving traditional techniques like organic farming and log houses, but for others the emphasis on smallness and simplicity became what Witold Rybczynski has called "a cheerless reaction against the excessive optimism that had been prevalent in the industrial nations.'" For a few of them AT represented a negation of the values of advanced technology and other large-scale social institutions, and their attacks became so extreme that E. F. Schumacher came to regret the title of his influential *Small is Beautiful,* which he feared was becoming a simplistic dogma. Others dismissed the AT movement at that time as "antitechnology" and a retreat to more primitive standards of living.

Over the last decade a broader and more pragmatic concept of AT has emerged side by side with the first. A growing number of observers have pointed out that, while small may be "beautiful" in many ways, it is not always sensible. For some jobs it is possible to scale down or decentralize a large technology, but impossible or undesirable to do away with it entirely. In this view, AT embodies the principle of selectivity in assigning (or developing) a "mix" of large and small technologies to meet specific tasks and conditions:

> In the ideological view, AT is an antidote to the past trends in Western technology, particularly those of the last twenty-five years . . . .
>
> The alternative view stems from a more pragmatic definition of AT and leads to the conclusion that the whole AT movement is simply a manifestation of an increasing tendency toward diversity' and pluralism in today's world. Thus, it is argued, AT will occupy an increasing number of ecological niches in the global technology but only in places where it is adapted to its environment . . . . [The] special characteristics of smallness of scale and susceptibility to community control are less important than the overall measure of adaptation to the social and natural environment, which may imply large scale and centralized control in some instances, small scale and decentralized control in others, or some symbiotic combination of the twos

This ecological metaphor is apt, since environmental compatibility remains a major criterion in this selection process. In the past few years, however, a growing number of appropriate technologists have come to view themselves as pioneers operating "at the frontier" in several areas of applied science. They argue that much of what is called AT is in fact a particular kind of advanced technology designed for changing resource conditions. In adapting to the current economic environment, for instance, AT has led to a number of relatively sophisticated technologies that are efficient users of energy and material resources. In this view, the main technical challenge is to integrate AT applications in community systems that incorporate resource-efficient architecture, integrated aquiculture-agriculture systems, water conservation and wastewater reclamation, new domestic applications of computers and communication technologies, and the like,

There appear to be four major areas of concern in which AT can make a specific, productive contribution:

- problems of economic growth;
- problems of international equity;
- problems of domestic equity; and
- problems of regulation and participation.

[3] D. H. Meadows, et al., *The* Limits to Growth: A Report/or the *Club of* Rome's Project on the Predicament *of* Mankind (New York: Potomac Associates/Universe Books, 1972).

[4] Witold Rybczynski, "After Appropriate Technology," paper presented to the American Academy for the Advancement of Science annual meeting, Washington, D. C., Feb. 15, 1980, See also his Paper Heroes: A Review *of* Appropriate Technology (New York: Anchor, 1980),

[5] Harvey Brooks, "A Critique of the Concept of Appropriate Technology, " in Appropriate *Technology* and Social Values—A Critical Ap*praisal,* edited by F. A. Long and A. Oleson (Cambridge, Mass.: Ballinger, 1980), pp. 55-56.

Problems Addressed by Appropriate Technology

Problems of Economic Growth

AT proponents may not be able to agree on just how much economic growth the world and Nation can sustain, but most of them conclude that there has to be some middle path between headlong expansion and no growth at all. Continued indiscriminate growth would contribute to further pollution of the environment, depletion of energy resources and other raw materials, inflation and supply shortages so severe as to threaten the economic system, and increasing social and political tensions. No growth at all—a position attributed to the AT movement by some people—would have catastrophic effects on the international and domestic economies and, by betraying the hopes and expectations of the less fortunate, might lead to widespread social unrest.

There are a number of positions in the AT dialog over growth: some proponents feel that the United States is "misdeveloped" and that there must be a change to more frugal lifestyles and an end to the ever-increasing consumption of materials; many feel that some growth is possible, but only in selected sectors or at a slower pace; still others believe that the wise application of technology (e.g., the careful use of energy, particularly through conservation measures and the development of renewable sources) could make growth possible and sustainable, although perhaps not at the rate of the past 25 years. Most observers, however, see the search for solutions to the problems of growth as a monumental challenge to human ingenuity, as well as an opportunity to redress some of the perceived errors and wrongs of the past.

Five major themes emerge from this dialog:

1. A *human definition of growth*.–The quality of life is as important as the quantity of material outputs; increased consumption of raw materials is not a satisfactory measure of human progress.
2. *Sustainable growth.*—Mature industrial economies must make the transition from production processes that exhaust resources and produce undesirable wastes to processes that use renewable or recyclable resources and, where possible, use the wastes of one process as raw material for another.
3. *Environmentally sound growth.*—Attempts to put "filter tips" on existing industries should be only a transitional stage in the development of technologies that procure and process materials with fewer and less harmful wastes.
4. *Decentralized growth.*–More care should be taken *to* adjust the scale and geographical distribution of technology to the actual distribution of needs; this can also cut costs (e.g., transportation) by taking advantage of the human and material resources available in the local community or region.
5. *Diversified growth.—There* is a need for a diverse "mix" of technologies from which to pick those that are (or can be) best tailored to the job and the location.

Problems of International Equity

The poorest nations, by and large, are staying poor. The Third World, where 90 percent of new babies are born, is less able than the industrialized West to cope with inflation and rising energy costs, and less able to accumulate needed capital. Schumacher and others have argued that the indiscriminate development of capital- and energy-intensive technology is bound to run into trouble under these conditions. It can lead to higher unemployment, the social and economic destruction of rural areas, and mass migrations to the urban slums. As Congressman Clarence D. Long, a proponent of AT in U.S. aid programs, has noted:

> As I think back on the role of professional economists in foreign aid, as an economist, I simply have to blush. Economists were ignoring the principles of economics that they taught in their own classrooms, namely that the factors of production could be combined in proportions appropriate to their relative abundance and scarcity . . . .
>
> Anyone who looks at the sidewalks of Bombay or at the countryside outside the cities in any poor country can see that heavy capital development strategies have, if anything, created extreme concentrations of wealth in poor nations while at the same time disemploying, or failing to employ, thousands and millions. Our foreign aid, originally

thought of as a way of heading off communism, may well have been a boost to communism by increasing the already glaring disparities between the rich and the poor.[6]

Schumacher argued that AT would allow a "bottom up" form of development. It would establish more work places for a smaller capital investment, and by creating more jobs it would benefit more people. These ideas were not universally popular. For years, many economists had held that developing countries would move up through the "stages of economic growth" by adopting the capital-intensive technology of the West. When the nation would reach a "take off' point, it would evolve toward modern mass production and consumption patterns, and the benefits would "trickle down" to the vast poorer population.[7] This economic program, however, seldom came to pass, and the benefits of development have been further delayed or diverted by recent rises in energy costs and by the mounting costs of caring for rapidly growing populations.

Appropriate technology has also been criticized as a "second rate" technology, not as "good" as the technology used by the developed countries. This attitude is based in part on the notion that AT is antitechnology and antiprogress. AT advocates counter that an intermediate technology is a "first step" technology, one that improves upon traditional methods and lays the foundation for an equitable form of development by promoting the skills and expertise that will be required by the advanced technologies that can, if desired, be developed later.

More recently, AT proponents have introduced ideas and techniques which might properly be called "advanced appropriate technologies. " They are relatively sophisticated but easy to use, and they fit into the traditional village way of life. Examples include several renewable energy technologies, small-scale industries, and the use of solid-state communication technologies for education and village health care. Advocates of these new technologies think they would help some nations leapfrog the Industrial Revolution and avoid the problems that currently face the industrialized West.

[6] Hon. Clarence D. Long, *Congressional Record*, Feb. 8,1977.

[7] See W. W. Rostow, *The Stages of Economic Growth: A Non-Communist Manifesto*, 2d ed. (Cambridge, England: Cambridge University Press, 197 1).

Problems of Domestic Equity

The thrust of industrial and technological growth over the past century has been to substitute energy and capital for labor, thereby increasing worker productivity. Most nations, however, are now beginning to encounter scarcities of both capital and cheap energy, making this approach less satisfactory. AT advocates point to a number of inequities that seem to be created or exacerbated by highly centralized advanced technology:

- the increasing concentration of wealth in a few national and multinational corporations;
- unemployment, underemployment, and worker unrest from stultifying or nerve-wracking jobs;
- lack of satisfying social roles for the elderly, the young, women, and minorities;
- disproportionate hardships for low- and fixed-income people coping with rising energy costs and other effects of inflation; and
- undermining of self-respect produced by the "welfare orientation" toward the unemployed and the poor.

AT advocates fear that failure to deal decisively with the problems of growth will make these problems worse, and they offer three basic approaches to solving the problems of domestic equity:

1. Replace highly capital- and energy-intensive technologies with small-scale, decentralized technologies that will create new jobs in more numerous locations.
2. Combine the factors of production in a proportion that responds to changing patterns of abundance and scarcity: when both unemployment and energy prices are rising, it might make better sense to substitute labor for energy–not wheelbarrows instead of trucks, but better maintenance (and improved efficiency) of existing trucks.
3. Emphasize a "community development" approach to the problems of poverty by using appropriate technologies as a basis for public projects and local enterprises that will develop local skills, provide jobs for the young and

productive activities for the elderly, and create opportunities for small local businesses.

Problems of Participation and Regulation

Most AT advocates believe that increases in Government regulation have occurred in response to the increasing size and impact of advanced technology. They point out that this "Government explosion" has occurred in every industrialized nation, regardless of ideology:

> We seem unwilling to come to terms with the fact that each increase in the order of technological mastery and managerial control leads to a concomitant order of magnitude of government coordination and control. . . . [Advanced] industrialized societies . . . generate a bewildering increase in unanticipated social costs: in human maladjustment, community disruption, and environmental depletion. . . . The cost of cleaning up the mess and caring for the human casualties of unplanned technology . . . mounts ever higher.[8]

By contrast, the social philosophy of the AT movement tends to favor a shrinking of Government. The investors and small businessmen who are attracted to AT complain that Government regulation inhibits technological innovation and diversity; social activists complain that growing technical, organizational, and regulatory complexity leaves the ordinary citizen powerless to understand or influence the choices that will affect him. AT proponents therefore offer three approaches to the problems of regulation and participation:

1. Develop new ways to foster active citizen participation in evaluating the technological choices that affect their communities.
2. Develop technologies that allow individuals and communities to reduce their dependence on large, remote institutions, no community can be totally self-reliant, but a reduction of scale could result in a reduction in the level of Federal involvement and regulation.
3. Develop inherently low-impact technologies, which will not only ease the problems of growth but will also require less regulatory control; a truly advanced technology should have few unintended side effects.

Implications for Politics

AT appears to offer no specific prescriptions for action, no hard and fast rules of the road. It does, however, offer a distinctive way of analyzing the needs and resources of a community, as well as a broader context in which to judge the suitability of the various technologies' solutions to the community's problems. It has also drawn greater attention to the issue of how the character of a technology can influence the character of a society. AT advocates warn that, by continuing single-mindedly along the path of centralized technology, society will be led into worse problems that will only become more difficult and more expensive to remedy in the future. They argue that we must instead choose a different path, a technology more appropriate to human values and goals, one that treads more softly on nature and leaves more options (and fewer problems) for future generations.

[8]Hazel Henderson, Creating *Alternative* Futures (New York: Berkeley, 1978), p. 84.

Congressional Interest in Appropriate Technology

Background

Congress has frequently taken the lead in encouraging the development of AT, but although a number of bills relating to small-scale solar technologies and energy conservation were introduced as early as the 1950's, the specific phrase "appropriate technology" is not found in any action of any Congress before the 93d (1973-74). Three of the four major existing Federal programs in appropriate technology were initiated by the 94th Congress (1975-76):

- the National Center for Appropriate Technology (NCAT);
- the appropriate technology program of the National Science Foundation (NSF); and
- A.T. International, Inc. (ATI).

The fourth major program was initiated by the 95th Congress (1977-78):

- the Appropriate Technology Small Grants Program of the Office of Small-Scale Technology (OSST) within the Department of Energy (DOE).

The 95th Congress also passed a number of measures related to AT, including the Energy Extension Service, the Agricultural Solar Energy Research, Development, and Demonstration Act of 1977, and the Food and Agriculture Act of 1977. Federal funding for these AT programs is growing but still small. In 1978, when total Federal R&D funding amounted to approximately $26.3 billion, of which about $2.8 billion was spent on energy R&D, only 1 percent ($30 million) was spent on Federal AT programs. (For a more detailed breakdown of Federal legislation and funding for AT programs see table 1.)

93d Congress

The 93d Congress passed two major pieces of solar legislation that prepared the way for the more extensive work on AT that was to follow. The Solar Heating and Cooling Demonstration Act of 1974 (Public Law 93-409) established a joint program in the National Aeronautics and Space Administration (NASA) and the Department of Housing and Urban Development (HUD) to develop solar heating and cooling devices and to encourage their commercialization. The aim of the program, as implemented, was to promote the development of large-scale, advanced solar systems; it gave little attention to small-scale, dispersed ap-

Table 1 .—Federal Legislation and Appropriations Related to Appropriate Technology

Public Law (bill)	Title	Date enacted	Committees	AT sections	Total authorized or appropriated (millions)	AT authorized or appropriated (millions)
Public Law 94-1611 (H.R. 9005)	International Development and Food Assistance Act of 1975	Dec. 20, 1975	Senate Foreign Relations House International Relations	306	$1,363	$20 (total for fiscal years 1976, 1977, and 1978
Public Law 94-187 (H.R. 3474)	Authorized & appropriated—ERDA (FY 76)	Dec. 31, 1975	Senate Interior & Insular Affairs House Science & Technology	101(a)(2)	$3,658.7	$97.1 (for solar energy development; not all AT
Public Law 94-439 (H.R. 14232)	Depts. of Labor, HEW Appropriations Act, 1977	Sept. 30,1976	Senate Appropriations House Appropriations	None; in report language	$511.2 (for CSA)	$0.4 (for NCAT)
Public Law 95-39 (S. 36)	Authorized & appropriated for ERDA	June 3, 1977	Senate Interior& Insular Affairs House Science & Technology	101(7)(h) Title V	$1,640	$7.5 (for DOE AT small grants program) $18 (for Energy Extension Service)
Public Law 95-88 (H.R. 6714)	International Development & Food Assistance Act of 1977	Aug. 3, 1977	Senate Foreign Relations House International Relations	Title I 114	$2,502 (title 1)	$18 (for FY 78)
Public Law 95-113 (S. 275)	Food & Agricultural Act of 1977	Sept. 29, 1977	Senate Agriculture House Agriculture	1420 1452	Indeterminate	$60 $20
Public Law 95-205 (H.J.Res. 662)	Continuing Appropriations, 1978	Dec. 9, 1977	Senate Appropriations House Appropriations	—	Indeterminate	$1.5 (for NCAT)
Public Law 95238 (S. 1340)	Department of Energy Act of 1978—Civil Applications	Feb. 25, 1978	Senate Energy & Natural Resources House Science & Technology	Title 1, 101(16) 101(17)	$6,081	$8 (for Energy Extension Service) $8 (for AT small grants)
Public Law 95-424 (H.R. 1920)	Foreign Assistance& Related Programs Appropriations Act, 1979 (title 1)	Oct. 6, 1978	Senate Foreign Relations House International Relations	107, 111	$2,478	Indeterminate
Public Law 95-482 (H.J.Res. 1139)	Appropriations for FY 1979—Continuance	Oct. 18,1978	Senate Appropriations House Appropriations	—	Indeterminate	$1.8 (for NCAT)
Public Law 95-434 (H.R. 11400)	National Science Foundation Authorization Act	Oct. 10,1978	Senate Human Resources House Science & Technology	2 (8)	$930	$0.2
Public Law 96-44 (H.R. 2729)	National Science Foundation Authorization Act for FY 1980	Aug. 2,1979	Senate Labor & Human Resources Senate Science & Technology	2(b)(l), 2(c)(3)	$998	$2.75

SOURCE: Joe Belden of Roger Blobaum & Associates.

placations of solar technology. The Solar Energy Research, Development, and Demonstration Act of 1974 (Public Law 93-473) had a similar emphasis. The Energy Research and Development Administration (ERDA), created by another Act of the 93d Congress, eventually became the lead agency for the solar program, with HUD remaining responsible for residential applications.

94th Congress

Three of the four major Federal programs in appropriate technology were products of the 94th Congress.

National Center for Appropriate Technology.–Congress urged in report language that the Community Services Administration (CSA) fund NCAT. In September of 1976 CSA approved an initial $400,000 grant to fund the Center, which is headquartered in Butte, Mont., with a staff that now numbers about 60. NCAT was organized to make the benefits of AT developments available to low-income individuals and communities throughout the United States. Its program includes three basic areas:

- a small grants program for low-income groups to fund field demonstrations in energy, housing, agriculture, and recycling;
- technical research and evaluation; and
- national and regional outreach through publications, conferences, field workers, and an information service.

Many NCAT projects are closely associated with CSA's network of community action agencies, but the Center also publishes bibliographies and technical research papers and sponsors regional conferences and technical workshops. It has come under some criticism for poor communications—due, in part, to its location in Butte, Mont.–and some AT proponents believe that NCAT is too narrowly focused to serve as a truly national AT institution, Despite their reservations, however, AT advocates tend to be highly supportive of NCAT's work.

National Science Foundation.–The House Science and Technology Committee, in a report accompanying the NSF budget authorization bill for fiscal year 1977, urged NSF to support work in appropriate technology. NSF's Research Applied to National Needs program commissioned an inquiry into the nature and extent of AT activities in the United States and published three reports in 1977: *Appropriate Technology in the United States–An Exploratory Study, Appropriate Technology-A Directory of Activities and Projects,* and *Appropriate Technology and Agriculture in the United States.* In January 1978, NSF held a national workshop to bring together scientists and innovators in AT, and the recommendations of this conference were also published.

Again at Congress' urging, NSF conducted seven regional public forums in September and October of 1978. The resulting recommendations were incorporated in a program proposal that included the following project areas:

- AT and urban innovation;
- small-scale industrial technology;
- recycling, resource recovery, and conservation;
- AT, rural revitalization, and the small family farm;
- food and nutrition; and
- AT's role and impact on society, the economy, and technological development.

Although NSF sought no funding to implement the plan in its fiscal year 1980 budget request, Congress authorized $2.5 million for the program—$1.8 million for applied research and $700,000 for education and information.

A. T. International, Inc.—ATI was established as a private, nonprofit corporation by the International Development and Food Assistance Act of 1975, which authorized $20 million over a 3-year period for:

> . . . activities in the field of intermediate technology, through grants in support of an expanded and coordinated private effort to promote the development and dissemination of technologies appropriate for developing countries.

Headquartered in Washington, D. C., ATI's staff includes specialists on Latin America, Asia, Africa, and the South Pacific; its basic objectives emphasize field projects in developing countries rather than conferences or other activities in the United States. ATI has deliberately experimented with new approaches to development assistance, including support for AT extension, resource centers, and the encouragement of private-sector involvement in AT. Some AT proponents have expressed disappointment that ATI's initial Board of Directors contained few actual practitioners of AT, and an AID review noted a variety of program weaknesses, the most important of which probably is that ATI's approach has been poorly focused. Despite these criticisms, however, ATI remains the principal manifestation of official U.S. support for private-sector AT efforts in the world arena; its creation reflects a significant change in the nature of U.S. development aid.

95th Congress

Interest in AT continued to increase during the 95th Congress, which held the first congressional hearing to deal exclusively with AT. The 95th Congress also created DOE, which continued to work on solar energy and began a very small AT program under OSST.

Office of Small-Scale Technology.–The Appropriate Technology Small Grants Program was initiated in the first year of the new DOE at the urging of several members of Congress. Administered by OSST within DOE, the program began in 1977 as a pilot effort in the Federal Pacific Southwest Region; the success of that demonstration led to an expansion of the program to the national level, although the program's regional basis has been retained.

The Small Grants Program offers awards of up to $50,000 for development and demonstration of ATs and up to $10,000 for concept development. As of June 22, 1979, 12,876 proposals had been received nationwide, asking for a total of $343 million; the OSST staff estimates that about 20 percent of proposals are good to excellent. Projects completed under the program have included efforts in solar thermal, heat recovery, conservation, biomass, wind, geothermal, hydro, aquiculture, integrated systems, and education.

The successes or failures of the DOE Small Grants Program have yet to be measured. Judging by the large number of applicants, the AT Small Grants Program is one of DOE's most popular programs, but enthusiasm at policymaking levels of the executive branch is less apparent.

The Energy Extension Service (EES) was established by the fiscal year 1978 ERDA authorization act to encourage smaller consumers of energy to reduce their energy use and adopt renewable resources. EES began as a 2-year pilot program in 10 States, with projects aimed at homeowners and small businesses. It is now being expanded to include all of the States, on the model of the Agricultural Extension Service of the U.S. Department of Agriculture (USDA).

The Agricultural Solar Energy Research, Development and Demonstration Act of 1977, enacted as a subtitle of the Food and Agriculture Act of 1977 (Public Law 95-1 13), broadened USDA's involvement in AT as well. The Act recognized the present agricultural system's dependence on energy-intensive machinery, fertilizers, pesticides, and herbicides, and called for the development of an "alternative farming technology" that uses solar and renewable energy sources to reduce the farmer's vulnerability to fossil-fuel shortages and price increases.

The Innovative and Alternative Technology Program, established by the Environmental Protection Agency (EPA) in October 1978, provides risk guarantees and an increased Federal share in the funding of wastewater treatment projects. Qualifying projects involve either proven technologies that are not yet in extensive use or developed but unproven technologies that show potential for improved reliability and efficiency or for reduced energy use and lifecycle costs. This program had funded 212 such projects by the midpoint of its initial 3-year authorization and has also established an extensive information and training network.

96th Congress

The major AT-related legislation enacted by the 96th Congress was the Energy Security Act (Public Law 96-294), which created the Solar Energy and Energy Conservation Bank. The Bank is authorized to- provide grants and subsidized loans for the installation of solar and conservation technologies, with particular attention to conservation in existing buildings and solar features in new structures. The funding level of this program is tied to the level of revenues from the windfall oil profits tax. Also passed was the Technology Innovation

Act (Public Law 96-480), which authorizes Federal R&D centers to participate in AT-related activities.

Other AT bills introduced in the 96th Congress include the Energy Productivity Act (an amendment to S. 388), which would authorize $58 billion over 10 years for conservation and alternative energy programs, and the Omnibus Solar Energy Commercialization Act of 1979 (S. 950), which would set a national goal (to be achieved by the year 2000) of at least 20 quadrillion Btu of energy production annually from renewable sources. The latter bill also calls for the establishment of a Solar Energy Development Corp., a lending institution similar to the Solar Bank.

The Scope and Methods of This Report

In June 1978, several Members of Congress asked OTA to conduct an exploratory study of AT, with particular instructions that the study:

- assess "the conceptual base for appropriate technologies;"
- assess "technologies which are appropriate for local community development;" and
- "collect data on promising new technologies now being innovated in energy, waste disposal, housing, agriculture, and health that may provide an alternative and possibly more effective approach to community and regional development."

In response to this request, OTA surveyed a wide, representative range of technology projects undertaken by public and private groups in urban, suburban, small-town, and rural communities. Several factors posed methodological problems:

- lack of agreement on what constitutes an "appropriate" technology;
- variation in the definition of "community" and "community development;"
- the wide range of technologies to be studied;
- the focus on AT as a community initiative; and
- the fact that many ATs are still in the early stages of development and use by the community.

The case study approach, chosen in part to overcome these difficulties, meshed well with the nature of the technologies referred to as "appropriate" because it focused on the experience of specific communities in trying to develop technologies tailored to particular local needs, resources, and constraints. Projects for the case studies were chosen by an ad hoc OTA Task Force on Appropriate Technology (a panel of individuals representing various AT interests) from a list of candidates identified through literature searches, questionnaires, and interviews. Care was taken that the case studies would reflect:

- the basic needs of human settlements (housing, food, and health care, as well as energy, resource recovery, and waste management);
- different types of "community" and different regions of the Nation (a farming county in Nebraska, a village in New England, a small town in California, an industrial city in the Midwest, and so on);
- the various software and hardware aspects of AT; and
- the different ways of financing community projects (some were financed by Federal grants, others by community groups, and a few by individual families).

Five of the case studies were conducted by community teams made up of 10 to 12 local residents, eight were conducted by teams from the Harvard University Workshop on Appropriate Technology; and the remaining case studies were conducted by OTA contractors and staff. This made it difficult to generalize from the data, since each case study had to be treated as a separate entity and there was a wide variation in the study teams gathering the data. An initial set of guidelines was developed to demarcate the major areas of inquiry, and for purposes of comparison the case studies are presented in the following format:

- Community setting (a profile of the community, its needs, and its resources);

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- *development* (the original initiative, the various groups and institutions involved, and the process by which the project was selected, planned, and organized);
- *technology* (a brief discussion of the technology itself and the ways in which it was applied to local uses); and
- *performance* (the problems and/or benefits of the completed facility, but not a full evaluation of its social and economic impacts).

In each chapter, the case study is preceded by an introduction that establishes the context for the technology and, in some cases, by a discussion of the conventional technology it might replace or supplement.

Several "critical factors" encouraged or impeded the process of community adoption. Because they also affect the transferability of the technology to other communities, these factors are discussed in each chapter as a way of framing issues for further analysis:

1. *Public perception and participation.—*
   - the degree of citizen initiative and access to decisionmaking bodies;
   - the extent to which those who will use the technology are actively involved in its development, construction, and management;
   - the degree to which the general public accepts and supports the project; and
   - the extent to which education and outreach activities are able to influence public perceptions.
2. *Essential resources.—*
   - the ability to utilize available resources and raw materials, particularly salvage or "waste" materials;
   - the ability to acquire the needed information, tools, hardware, and facilities; and
   - the ability to acquire or train labor for construction, operation, and maintenance.
3. *Technical information and expertise.—*
   - the availability of reliable, detailed information on the design, costs, and performance of the technologies;
   - the accessibility of this information to potential users; and
   - the ability to locate or develop the needed managerial know-how and skills in the user community.
4. *Financing.–*
   - the ability of individuals, community groups, and municipalities to finance their own projects, either out-of-pocket, through donations, or through general revenues and local bond issues;
   - the availability, size, and effectiveness of tax credits, cost-sharing, grants, low-cost loans or loan guarantees, tax-free bonding, and other incentives;
   - the stability and flexibility of grants and subsidies from both public and private sources;
   - the availability and costs of conventional market financing;
   - the degree to which potential lenders perceive an AT project as a high risk, due to unfamiliarity with the technology or lack of confidence in the credit worthiness and management ability of the borrower; and
   - the degree to which the decisions of potential investors and/or lenders are distorted by considering only initial capital costs, rather than lifecycle costs, in comparing conventional and innovative options.
5. *Institutional factors.—*
   - the degree of opposition from vested commercial, professional, and political interests who feel threatened by AT and community initiatives;
   - the degree to which regulations, such as health and building codes, are either out of date, arbitrarily applied, or prescriptive rather than performance oriented; and
   - the extent to which regulatory requirements and permitting procedures require as much time and money for small-scale projects as for much larger projects.

Because these technologies promise substantial benefits in areas of major national concern, each chapter concludes with a discussion of relevant Federal legislation, existing Federal programs of technical and financial assistance, and the issues and options for possible further Federal action.

Chapter 3

Resource-Efficient **Residential Architecture**

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CHAPTER 3
Resource-Efficient Residential Architecture

Introduction

Shelter has always been one of mankind's most basic needs, but in the past the relationship between shelter and the local environment was much closer than it is today. Buildings were necessarily built with materials that were locally available, and their designs usually responded to the local climate. Steeply sloping roofs in northern New England, for instance, prevented snow from accumulating; similarly, the flat roofs and open breezeways of the Southwest made for comfortable living in a hot, arid climate.

In the last 30 years, however, as climate control systems became more sophisticated, as energy became cheaper, and as building materials became standardized and more easily transported, the need for indigenous styles of architecture declined. It became possible to build similar homes in Virginia and Vermont, and indeed this was often done.

Recent developments are changing this trend. Energy is growing much more expensive, as are building materials and the cost of transporting them over long distances. Once again there is both a need and a demand for architecture that utilizes resources more efficiently in construction and minimizes the energy needed to maintain acceptable comfort. As a result, the development of resource-efficient housing has become a significant movement in U.S. architectural design and construction.

The case studies in this chapter illustrate the great diversity of this movement and the wide variety of energy -saving strategies that it has made available. This progress, which has been achieved through individual efforts in numerous locations, has advanced the goal of residential energy conservation by making a wide range of strategies available (singly and in combination) for achieving the best results in diverse sites and climates. The diversity and adaptability of these technologies seem to suggest that conservation is a strategy that can be successfully pursued in all regions of the Nation.

This chapter discusses the larger context of resource-efficient architecture, its potential benefits and problems, and two major approaches to resource-efficient design and construction: solar heating, which uses the energy of the sun to supplement or replace fossil fuels for space heating; and heat retention, which tightens the "thermal shell" of a house to reduce the total energy needed for space heating. The five case histories present innovative examples of both approaches:

- Solar heating greenhouses in New Mexico, which are attached to houses and collect heat from the sun for use in both the greenhouse and the rest of the house.
- The "Ark II," a solar-heated home designed by Solsearch Architects for the Cooley family of Washington, Corm.
- The "Conserver Home" on Prince Edward Island, Canada, also designed by Solsearch Architects, which requires very little space heating because of its heavily insulated shell and many other heat-retaining design features.
- An energy-efficient house developed by students and faculty of Kuskokwim Community College in Bethel, Alaska, which uses a variety of nonconventional construction techniques to produce a house that is energy efficient and uses few imported materials.
- A "thermal envelope" house in Lake Tahoe, Calif., owned by Tom Smith. The house is literally a "house within a house, " combining principles of solar heating with those of a highly heat-retentive structure.

In this and the following chapters, case studies of individual applications of the technologies will be followed by a discussion of critical factors that may affect their future diffusion and adoption. Each chapter will close with a discussion of relevant Federal policy and issues and options for further action.

Residential Housing and Energy Conservation

Total energy consumed for residential space heating and cooling is estimated to be 17 Quads, or about one-quarter of total U.S. energy consumption in 1977.[1] Typical residences constructed in the 1970's using standard building technology and practice require between 10 and 15 Btu per square foot per heating degree day (Btu/ft^2/dd) to maintain acceptable inside temperatures. Older, poorly insulated or uninsulated residences may require as much as five times this energy input.

Some housing being constructed today requires less than 2 Btu/ft^2/dd input from fossil fuel sources. This low energy consumption is being achieved by a wide range of strategies. At one end of the spectrum are active solar houses, which have standard levels of insulation and airtightness, but to which solar collectors and heat storage have been added to reduce the need for backup energy. Next come the passive solar homes, which are somewhat better insulated and in which the solar collector and storage are integral parts of the structure. These homes also achieve low backup energy needs. The Cooley house described in this chapter is an example of integrated passive design, which also reduces backup energy needs.

At the other extreme are heat-retentive houses, superinsulated structures that reduce the heating load to near the levels of energy released by occupants and their normal activities. The Conserver Home and Bethel House described below are examples of superinsulated structures. The "thermal envelope" house described in the final case study is a hybrid, which combines elements of both solar heating and heat retention with a number of other energy-conserving design features.

As experience is gained, the best aspects of these various strategies are being incorporated into new designs for very energy-efficient houses that can be built and marketed widely by local contractors and builders. For example, the Tennessee Valley Authority has designed and built, and is currently testing 11 different designs for their seven-State service area.[2] The Mid-American Solar Energy Complex (MASEC) is sponsoring a "Solar 80" home design program, through which houses using less than 2.5 Btu/ft^2/dd of fuel energy are being constructed and demonstrated.[3] The program requires that the construction costs of these houses are not to exceed by more than 5 percent those of a similar house without any special energy-conserving features. This cost requirement is possible because the added costs of high-insulation, low-infiltration, and simple passive solar features are largely offset by the reduced size and cost of space-heating equipment, which in some cases may be eliminated entirely.[4]

Reducing the fuel requirements for heating and cooling existing homes present more complex problems. Adding insulation or reorienting window locations, even in recently constructed houses, is often not feasible; and weatherizing older structures, while essential, cannot reduce space-heating loads to the low levels that can easily be achieved in new construction. However, low-cost solar retrofits offer an additional strategy for reducing fuel needs in existing housing. Attached solar heating greenhouses are proving to be a popular and apparently cost-effective solar retrofit.

[1] *Residential Energy Conservation* (Washington, D. C.: office of Technology Assessment, U.S. Congress, July 1979), vol. 1, p. 4.

[2] "Solar Homes for the Valley Project," W. C. Adkins, Chief Architect, Tennessee Valley Authority, Knoxville, Term.

[3] David Pogany and Don Kraft, "Mid-American's passive Homes," *Solar Age*, vol. 5, No. 4, April 1980, p. 107.

[4] R. W. Besant, R. S. Dumont, and G. Schoenau, "Saskatchewan House: 100 Percent Solar in a Severe Climate," *Solar* Age, vol. 4, No. 5, May 1979; and E. H. Leger and S. D, Gautam, "An Affordable Solar House," Proceedings *of* the *4th* National Passive *Solar* Conference, Kansas City, Me., Oct. 3-5, 1979, p. 317.

A Case Study of the Solar Heating Greenhouse, New Mexico[5]

The Community Setting

New Mexico was particularly well suited for the initial development of solar greenhouse designs. The winter in the northern part of the State is cold but very sunny, with an average January solar availability of over 70 percent. Under such conditions, the daily heat gain of even a crude greenhouse will often exceed its heating load. But New Mexico was also suited to greenhouse development because of the human and institutional resources that were available.

During the late 1960's, northern New Mexico was the site of a number of alternative communities. They attracted young people from middle-income backgrounds, many of them college educated, who brought design skills and a sense of adventure to the development of small-scale alternative technologies. One such community was the Lama Foundation in Taos, N. Mex., which (with the help of designers Steve Baer and Day Charoudi) developed a pit greenhouse based on the "biosphere concept."

The pit greenhouse, often called a "grow hole," is simply a hole dug in the south side of a hill and glazed over; they have been used for centuries to extend the growing season. The biosphere concept adds heat storage, in the form of plastic jugs of water and thermal mass in the walls and floors, to keep the greenhouse warm at night and during periods of cloudiness. The result is a freestanding, integrated passive solar greenhouse in which plants can be grown year-round. (See ch. 4 for further discussion of freestanding solar greenhouses.)

In 1973, Bill Yanda from Nambe, N. Mex., also became interested in pit greenhouses. After visiting the Lama Foundation's solar grow hole, he built one for his own family. The following winter was an unusually cold one in northern New Mexice, but to their surprise the plants in their pit greenhouse did not freeze. The design collected solar heat so effectively, in fact, that despite the cold weather the Yandas had to vent excess heat during the day. This led them to the idea of an attached solar greenhouse that produced heat as well as food: "Why not help heat your house with that excess heat, instead of venting it to the outside?"

Development

Drawing on their personal experience, the Yandas felt that the attached solar greenhouse had sufficiently low cost, in terms of its heat- and food-producing potential, to be a viable approach to solar heating for low-income families.

In the spring of 1974, they applied for and received an initial demonstration grant from the Four Corners Commission, a regional agency funded by Federal and State governments. They built 12 attached solar greenhouses in mountain villages in northern New Mexico, for houses occupied mostly by low-income families of Spanish, Indian, and Anglo heritage. In the spring of 1976, the Yandas received a contract from the State Energy and Resources Board (now the New Mexico Department of Energy and Minerals) to build 12 more attached solar greenhouses throughout the State.

This second project was different from the first because it utilized the workshop process to build the greenhouses. The greenhouse workshop was like a barn-raising: homeowners, neighbors, and friends came together for a long weekend to learn about and build a solar greenhouse. Usually the greenhouses were three-quarters completed at the end of the weekend. According to Bill Yanda, the process had a multiplier effect: "For every workshop, ten more greenhouses were built in the community."[6]

[5]Material in this section is based on the working paper, "New Mexico Solar Greenhouse Study," prepared by the New Mexico Community Study Team (see appendix).

6 S t a t

To date, the Yandas have built 30 solar greenhouses in New Mexico. In 1977, they setup a work group, the Solar Sustenance Team, which has helped facilitate the building of solar greenhouses on a broader scale and by organizing workshops to train people all over the United States. The team supplied leaders for workshops that built community greenhouses for the Wooster (Ohio) Food Cooperative in 1979 and for the Cleveland Hunger Task Force in August 1980.

The workshop concept is now being widely emulated across the country. Although no hard data is available, evidence for the spread of workshops can be seen in the number of reports on statewide greenhouse construction programs. The 1978 National Passive Solar Conference heard only one such report—from the Yandas—while in 1979 there were reports from 5 States: Colorado, Missouri, Ohio, Wyoming, and Arkansas.[7]

Solar Greenhouse Technology

A greenhouse is a glazed structure that admits visible and infrared solar radiation, which is converted to heat by absorption on surfaces within the greenhouse. This heat is trapped in the structure by the glazing materials, most of which are opaque to the long-wave infrared radiation emitted by objects at about room temperature. Simply stated, it is easier for radiant energy to get into the structure than it is for it to escape again. Glazing materials are very poor insulators, however, so heat losses at night and on cold cloudy days can be considerable. For this reason, the conventional "glass houses" are prodigious users of energy during winter months.

Solar greenhouses, on the other hand, are designed to provide adequate light for plant growth, but to limit heat losses and to store sufficient heat to achieve a net heat gain during the heating season. Several design modifications are needed to achieve these results:

- glaze only the south-facing surfaces;
- use two layers of glazing in most northern climates;
- seal the greenhouse shell carefully in order to prevent unwanted air infiltration;
- insulate heavily all nonglazed exterior surfaces; and
- provide sufficient heat storage that nighttime and cloudy day heat losses can be drawn from storage and not from a backup source burning fossil fuels (adequate storage also moderates temperature swings).

The result is a greenhouse that looks quite different from conventional greenhouses, which have low-pitched roofs and all-around glazing.

Although a solar greenhouse may be freestanding (see figure 1), most residential applications of this technology are attached to the house: "lean-tos" built against the south wall of the structure or extended from the east or west walls but facing south (see figure 2). This type of construction reduces costs, permits transfer of excess energy from the greenhouse to the main structure, usually allows access to the greenhouse from a heated space, and often adds an attractive living space to the dwelling.

Glazing materials include glass, fiberglass, and various plastic films. Most plastics, including fiberglass, are damaged by the ultraviolet radiation in sunlight. The plastic material used in greenhouses is protected by ultraviolet inhibitors and has an expected lifetime of 10 to 20 years. Plastics are lightweight, easy to cut, and available in large sheets; for these reasons, many greenhouse-building groups working with relatively unskilled workshop participants use plastics exclusively. Glass is also an excellent glazing material, but it is generally more expensive than plastics, heavier, and more difficult to mount successfully.

Heat storage is usually provided by incorporating thermal mass into the greenhouse structure (such as a concrete floor slab or a rock or gravel bed below the floor) or by placing thermal mass in the greenhouse (such as water-filled 55-gal drums or plastic milk jugs stacked along the north wall, or rocks held against a wall by wire mesh). Thermal mass that is in direct sunlight functions more effectively than mass to which heat must be transferred by air movement or conduction. Because heat storage mass placed in the greenhouse can be added or removed quite easily, adjustment and

[7] *Proceedings of the 2d National Passive Solar* Conference, Philadelphia, Pa., Mar. 16-18, 1978; and Proceedings of the 4th National Passive Solar Conference, Kansas City, Me., Oct. 3-5, 1979.

Figure 1 .—Two Freestanding New Mexico Solar Greenhouses

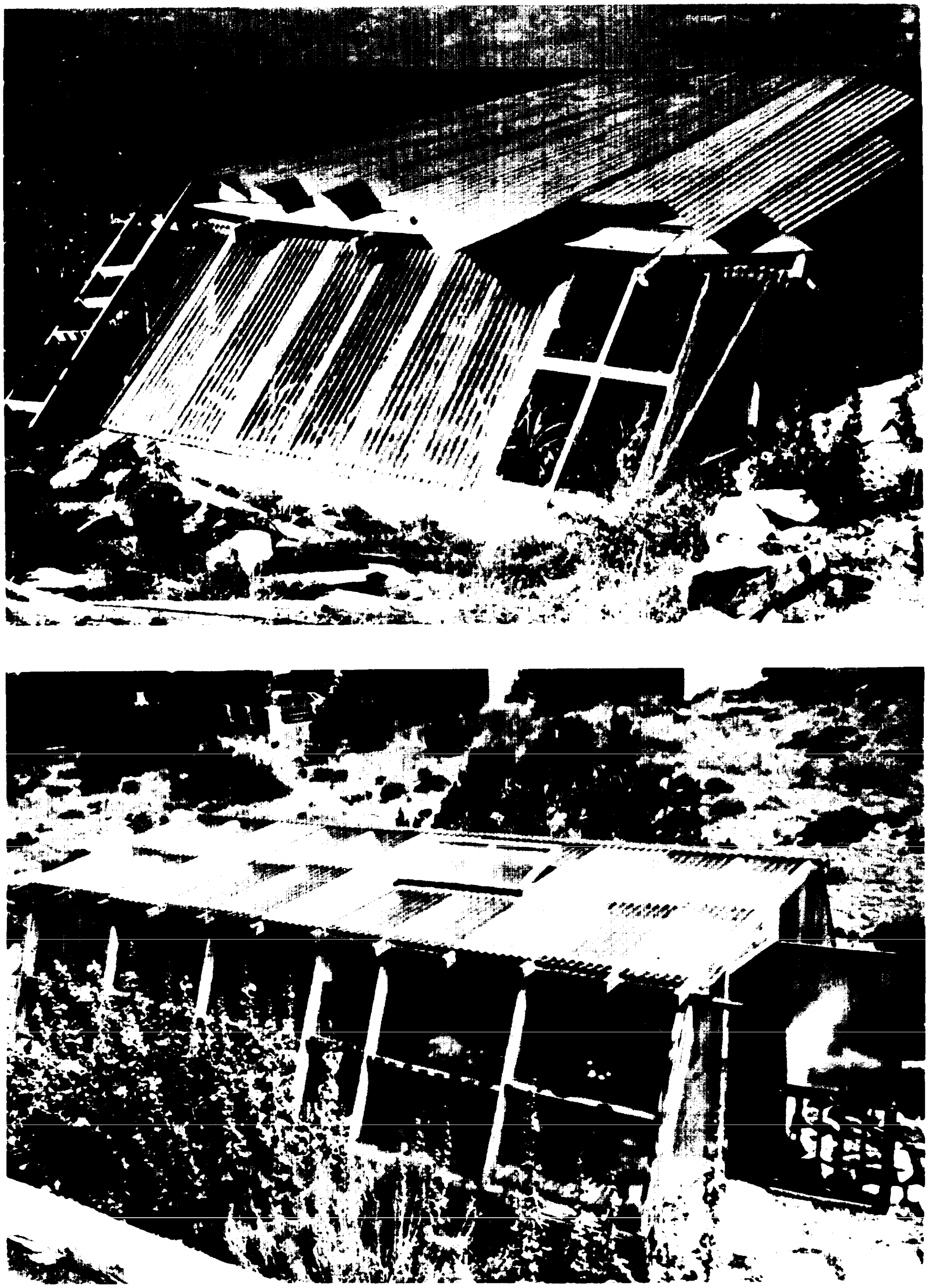


Photo credit: Office of Technology Assessment

Figure 2.—Attached New Mexico Solar Greenhouses

Photo credit: Office of Technology Assessment "fine tuning" is possible; built-in heat storage requires more precise design and construction.

Existing modeling techniques are not adequate predictors of greenhouse thermal behavior, because the interaction of solar input, variable weather, greenhouse heat losses, thermal mass, and heat exchange with the main structure is so complex. Fortunately, the solar greenhouse has turned out to be a rather forgiving and adjustable technology so that relatively crude design procedures are adequate.

Solar Greenhouse Performance and Costs

The thermal performance of attached solar greenhouses as heat producers depends on a number of factors. In areas of high solar availability, such as New Mexico, adequate sunlight will regularly be captured both to charge the greenhouse storage and to provide excess heat for an attached residence. In cloudier areas, such as Ohio, the average monthly gain will still exceed losses in a well-designed and well-constructed greenhouse, but the excess energy available to the residence during December, January, and February will be small. The excess energy can be increased by reducing the thermal mass in the greenhouse, but then freezing is likely on the coldest nights. An insulating "night curtain, " which reduces nighttime losses through the glazing, can greatly enhance performance in poor solar climates.

Thermal behavior has been measured for a number of existing greenhouses, but reports of measured net energy production are not yet available. Tables 2 and 3 give the results of limited measurements of heat delivered by one attached greenhouse in New Mexico and another in Hinesberg, Vt. Table 4 presents theoretical measurements for the performance of the Hinesberg design, extrapolated to 12 major metropolitan areas.

The out-of-pocket cost of building a solar greenhouse varies greatly. In many cases the owner or workshop members volunteer their labor, and they frequently make use of salvaged materials, particularly glass. In most areas of the country, few contractors are prepared to bid on or undertake the construction of greenhouses. Typical material costs, if new materials are used, range between \$8 and \$12/ft^2 (1979 dollars) of floor area. The most important cost variables are the type and number of layers of glazing, the quantity of concrete, and the quality of wood used for the frame.

Only 19 of the 150 New Mexico greenhouse owners interviewed by OTA's community study team had enough data to perform any kind of economic analysis. Those 19 had average costs, including estimated labor costs, of between \$4 and \$17/ft^2, and they estimated their simple payback periods at between 4 and 8 years, based on fuel savings alone. However, unlike solar collectors (whose cost must be justified solely by the value of the net energy they produce), greenhouses are multipurpose devices which can pay the owners back in terms of food production and desirable living space, as well as heat energy production.

Table 2.—Chavez Greenhouse, New Mexico

Performance data

Location	Anton Chico, N. Mex.
Latitude	35°N
Elevation	5,000 ft
Heating dd	3,795
Percent sun winter average	70%

Greenhouse

Orientation	15° East of South
Glazed area	420 ft^2 65°/0 wall, Slope 75° 35% roof, slope 15°
Floor area	432 ft^2 (36 x 12 (dirt floor)
Glazing material	fiberglass outer polyethylene inner
Net transmission	0.65 (estimated)
Thermal storage	Nine, 55-gal water-filled drums 18" thick adobe (house) wall 36' x 9 '
cost	$2.50 ft^2 materials only (workshop constructed)

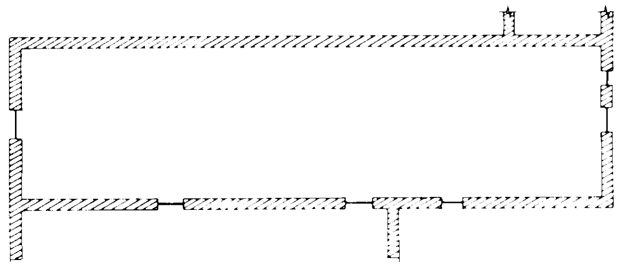
House

Type	Adobe (no insulation)
Floor area	896 ft^2
Annual heating load	51 MMBtu (estimated)
Annual internal sources	13 MMBtu (estimated)
Net load	13 MMBtu

Performance

Annual greenhouse load	**62** MMBtu
Solar energy captured (heating season only)	90 MMBtu
Net available energy	28 MMBtu
Solar fraction (whole house, supplied by greenhouse	**0.73**

SOURCE Sandia Laboratories, "Passive Solar Buildings," report No. SAND 79-0824

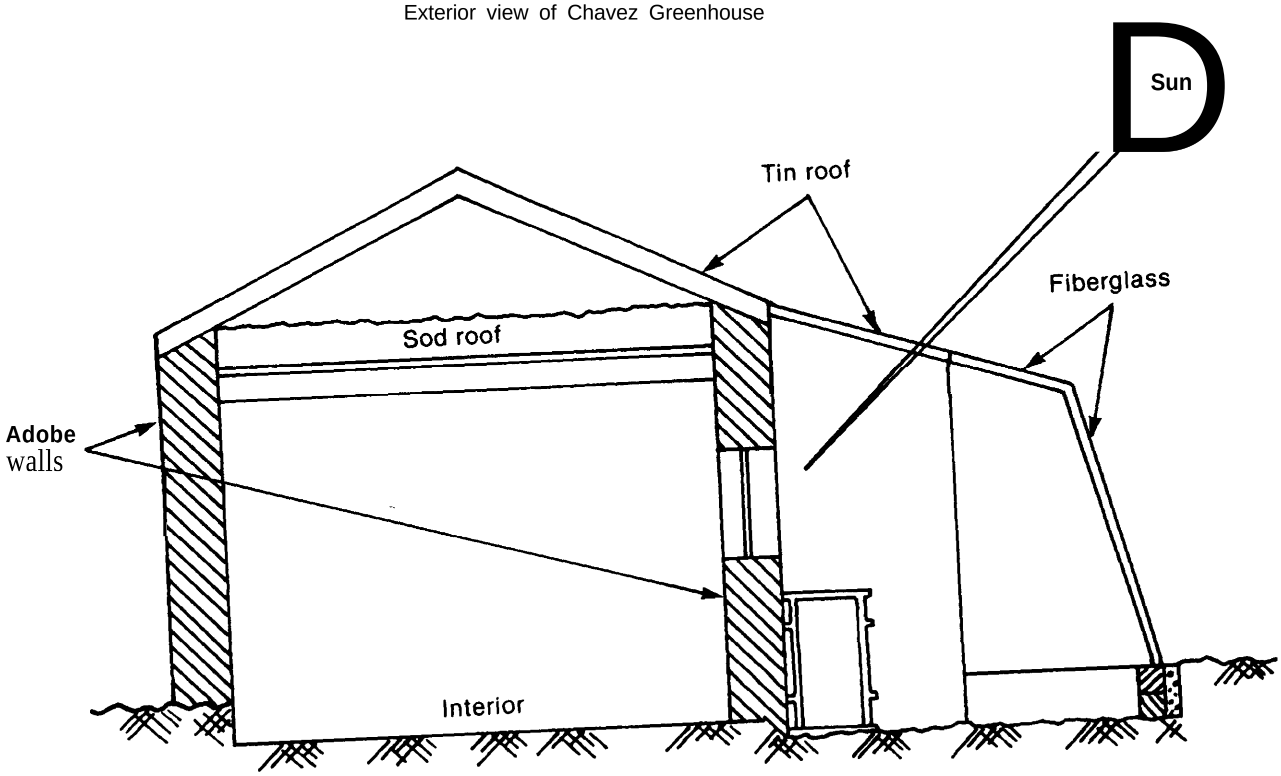


Plan of Chavez House and Greenhouse

Photo credit: Tech Repos, Inc.

Interior of Chavez Greenhouse

Exterior view of Chavez Greenhouse



Thermal Flow Diagram

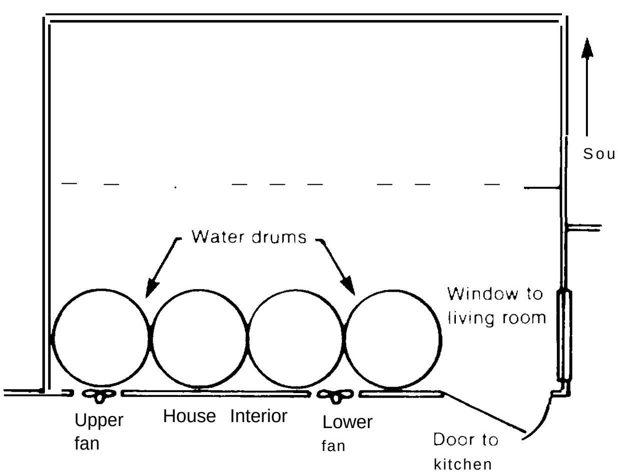
Table 3.—Hinesberg Greenhouse, Vermont

Performance data

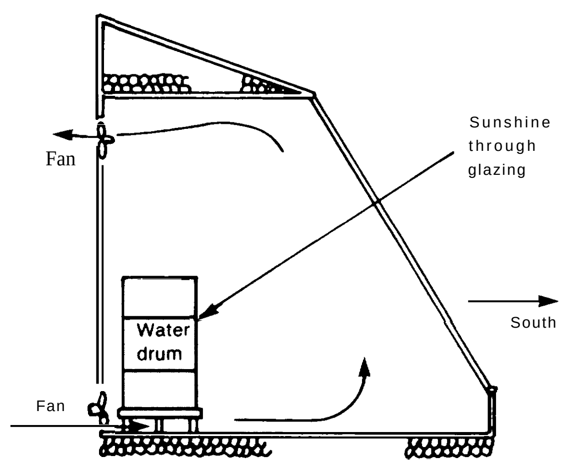
Location	Hinesberg, Vt.
Latitude	44°N
Elevation	150 ft
Heating dd	8,100
Percent sun winter average	36%
Greenhouse	
Orientation	South
Glazed area	96 ft² wall, slope 60°
Floor area	98 ft² (12' x 8')
Glazing material	2 layers fiberglass
Thermal storage	four 55-gal water-filled drums
cost	$9.10 ft² (1976)

House	
Type	Older, frame
Floor area	1,800 ft² (whole house)
Kitchen	360 ft² (estimated)
Kitchen load	26 MMBtu
Performance	
Greenhouse load	10 MMBtu
Solar energy captured	19 MMBtu
Net available to kitchen	9 MMBtu
Solar fraction (kitchen load, supplied by greenhouse)	**0.23**

SOURCE: Sandia Laboratories, *Passive Solar Buildings*, report No. SAND 79-0824.



Plan for the Hinesberg Greenhouse



Thermal Flow Diagram of the Hinesberg Greenhouse

Exterior view of Hinesberg Greenhouse

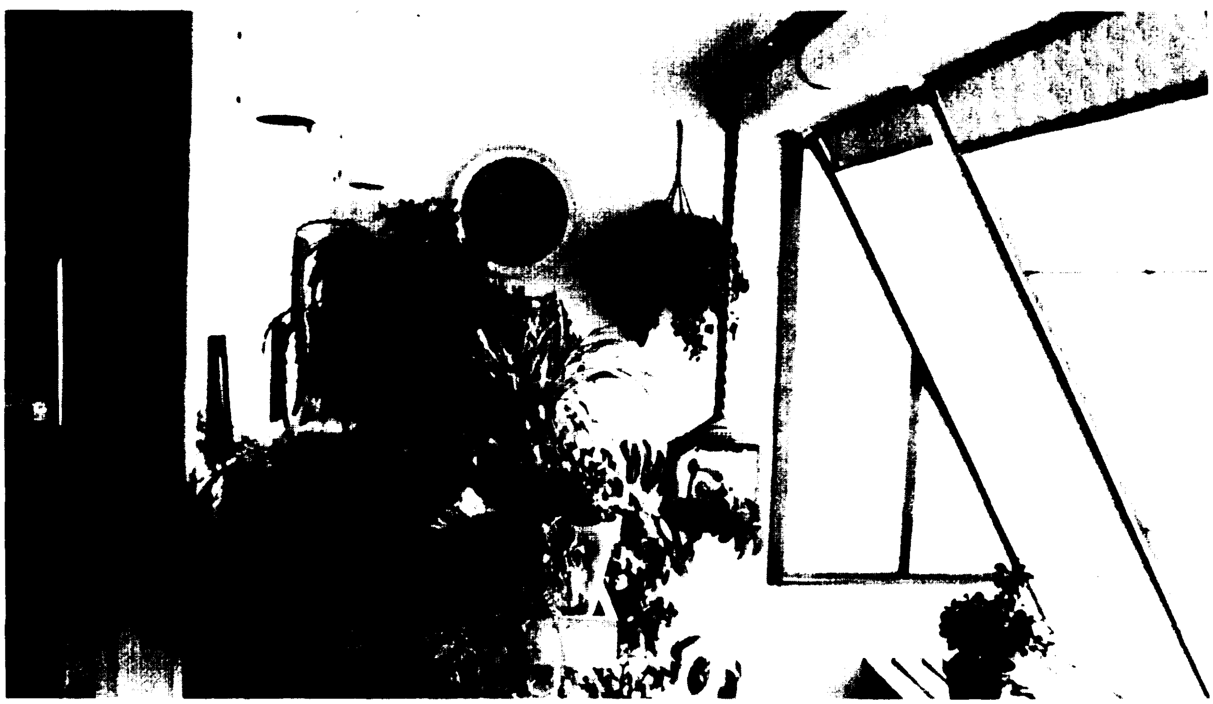


Photo credits: Office of Technology Assessment

Interior of Hinesberg Greenhouse

Table 4.—Theoretical Performance and Fuel Reduction Contributed by an Attached Solar Greenhouse in 12 U.S. Metropolitan Areas

City	Annual degree days (65° base)	Solar heat produced by greenhouses (kWh)	Heat loss[b] of greenhouse (kWh)	Ratio of heat gain to heat loss	Dwelling fuel[c] reduction (%)	Savings[d] ($)
New York, N.Y.	4,871	5,652	2,007	2.8	32.1	$324.85
Boston, Mass.	5,634	5,592	1,856	3.0	28.5	227.90
Burlington, Vt.	7,865	4,476	2,931	1.5	8.4	77.25
Philadelphia, Pa.	5,251	5,452	1,548	3.5	32.0	206.91
Baltimore, Md.	4,654	4,818	1,414	3.4	43.5	156.58
Chicago, Ill.	6,155	4,993	2,159	2.3	19.8	130.36
Springfield, Ill.	4,561	5,754	1,821	3.2	37.0	173.05
Milwaukee, Wis.	7,205	5,965	2,735	2.2	19.2	125.97
Denver, Colo.	6,283	7,897	1,996	4.0	40.3	224.24
Dayton, Ohio	5,597	4,803	2,042	2.4	21.1	99.40
Cincinnati, Ohio	4,870	5,003	1,356	3.7	32.1	124.00
Duluth, Minn.	10,000	6,809	3,968	1.7	12.2	—

aEnergy available after transmission and reflection losses subtracted.
bBased on 55° nighttime setback.
cDwelling is assumed to use 2.33 kWh/dd (base 65°). This quantity of heat is typical of an average U.S. home.
dValue of energy is based on available electrical costs during January 1976.

A Case Study of Solar Architecture-- The Cooley House, Washington, Corm.[8]

Designing and orienting buildings to take advantage of solar energy is an ancient practice. The Remans used passive solar design to warm their baths and public buildings. Native Americans built whole towns in the Southwest based on these principles.

Interest in passive solar architecture, in which solar energy is collected and stored through structural design and orientation, is growing rapidly in the United States. Four national passive solar energy conferences have been held and attended by thousands of engineers, architects, builders, and public officials. Hundreds of passive solar structures have been built during the past 5 years, ranging from the airport terminal at Aspen, Colo., to entire residential subdivisions in California, New Mexico, and Ohio. The Cooley house is one example of this emerging architectural trend.

[8]Material in this and the following case study is based on the working paper, "Energy-Efficient Architecture," prepared by Teresa Canfield and James Greenwood for the Harvard Workshop on Appropriate Technology for Community Development, Department of City and Regional Planning, Harvard University, May 15, 1979.

Development

In 1976, Ruth and Frank Cooley contacted the New Alchemy Institute of Falmouth, Mass., and asked how they could go about leading the kind of energy-conserving self-sufficient life that the New Alchemists advocate. They were referred to the Institute's architectural consultants, Solsearch Architects of Cambridge, Mass. Solsearch designed an integrated solar house for the Cooleys based on the firm's "Ark II" house (see figure 3).

The "Ark II" is a scaled-down, single-family version of the Ark, a $354,000 experiment in self-sufficient living funded by the Canadian Government. The original Ark, which opened in 1976, is intended to house, feed, and provide a livelihood for a family without dependence on outside energy sources.

The Cooleys were active participants in all aspects of the construction of their home. For 6 months they lived in a tent at the building site, where Ruth Cooley acted as the general contractor. She, four college students, and a retired carpenter did most of the carpentry, but she hired subcontractors to perform a number of specialized tasks, such as plumbing and wiring. A neighbor with 40 years of experience as a general contractor helped her to find good subcontractors at competitive prices. The Cooleys moved into their partially finished house in December of 1977, and the house was largely completed by the spring of 1979.

Integrated Solar Technology

The Cooley House has 2,500 ft^2 of living area, 700 ft^2 of which is a daylight basement. The rest is divided among three bedrooms and the main living area. The house is an example of "integrated" design, employing active as well as passive solar principles and advanced technological materials.

The entire south roof is glazed by a patented system called the "solar staircase," which is designed to admit sunlight in winter and deflect it in summer (see figure 4).[9] The system uses multiple layers of glazing: two outer layers of "Acrylite SDP;" the "staircase," which alternates polished aluminium horizontal steps with transparent vertical risers; and an inner layer of "Tedlar" film. The downward facing surfaces of the aluminium "steps" reflect heat and thus help reduce thermal losses through the roof.

Sunlight passing through the roof in winter (rays 2 and 3 in figure 4) is absorbed by the interior, and its heat transferred to the air, in the same manner as in a solar greenhouse (see above). The heated air rises and collects along the roof peak, where it is drawn into ducts by two fans and delivered into a rock bed under the floor of the main living area. The thermal storage contains 100 yd^3 of graded river rock and will store about 65,000 Btu for every 10 F in temperature change. Heat may be recovered from the storage either by radiation from the floor slab above the storage bed, or by fans that draw air through the warmed rock and into the living space. Backup heat is provided by a wood-burning stove.

In summer, as the altitude of the sun increases, the majority of the light (ray 1 in figure 4) is reflected by the aluminum "steps" of the "solar staircase." Excess heat can be vented through a louver along the north end of the roof ridge; a noticeable breeze fills the house when the louver is opened.

Performance and Costs

The major source of solar input is the glazed roof, which has an area of about 1,100 ft^2. However, the effective aperture of this "collector" is equivalent to the sum of the area of the risers, or only about 600 ft^2. This area is enhanced by double reflection from the steps, as is shown for ray 3 in figure 4. Sunlight directly penetrating the roof undergoes transmission losses through four layers of glazing; reflected light has two additional reflection losses. It is expected that an average of 50 to 60 percent of the incident radiation will enter the house.

The heat resistance of the south roof depends on the effectiveness of the reflective staircase in reducing heat losses by radiation. The projected gross heating load is about 8 $Btu/ft^2/dd$, of which solar heat is estimated to provide about 50 percent. Backup heat is provided by a wood stove; the expected auxiliary winter load is about 45 million Btu, or approximately 3 cords of firewood. At $120/cord, these costs would be under $360/yr. Average winter electricity bills are $24/me, including lights, cooking, and the heating system fans.

The Cooley house has already cost almost $81,000 to build, with the solar features (the roof and rock storage bed) accounting for about $7,000, or 9 percent of incremental costs. However, these costs do not include the value of the labor donated by the owners and other volunteers, which in the case of the Cooleys (as in several other cases studied in this chapter) was significant. The Cooleys were forced to sell about half of their 5-acre lot to raise the money that will be needed to complete the house.

Because of a change in Frank Cooley's job, the family will soon be moving to Oregon, where they hope to build a totally passive house that will allow them to become more fully self-sufficient. As they prepared to sell their present house, however, they became aware of three factors that might affect its marketability. First, it may be difficult to

‘The solar staircase was invented by Norman Saunders of the Circuit Engineers Co., Weston, Mass., who allowed the Cooleys the use of this design for $15 on condition that they document its performance. See his "The Overall Solution to Solar Heating," Proceedings of the Conference on Energy Conserving Solar Heated Greenhouses, Marlboro, Vt., Nov. 19-20, 1977, p. 39.

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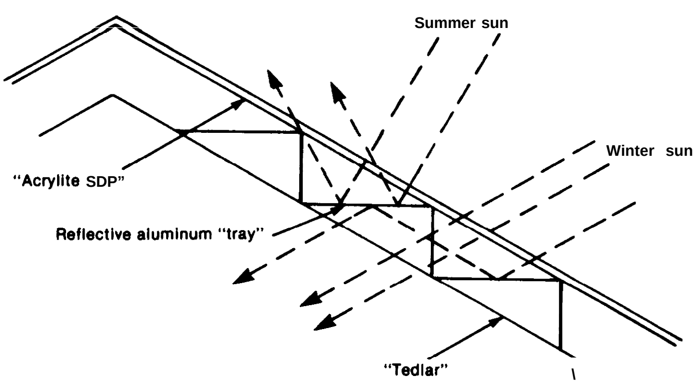
Figure 3.—Solsearch "Ark II" Low-Energy House

Figure 4.-Solar Staircase Roof



Section through the "solar staircase" roof

Photo credits: Office of Technology Assessment

Greenhouse interior

find a buyer (or a lender) willing to take a risk on such a new technology and an unconventional house. Second, prospective buyers may not be willing to tolerate the fluctuations in indoor temperature that are characteristic of this passive design. Third, people with enough money to buy the house may not be willing to perform the necessary operational chores, such as opening and closing vents and feeding the wood-burning stove that provides backup heat. If, for these or other reasons, the full value of the additional solar features cannot be recovered when the house is resold, the difference should properly be considered an additional cost of the house.

A Case Study of Heat= Retentive Homes (l)– The Solsearch "Conserver Home," Prince Edward Island, Canada

Development

Solsearch Architects, the designers of the Canadian "Ark" and the Cooley house in Connecticut (see above), feel that passive solar energy systems work reliably and can be built at a reasonable cost. However, although they welcome the current interest in passive solar architecture, partner Ole Hammarlund has written that solar is not the only way to go. Solar energy may have advantages in terms of the health of the occupants or the esthetics of the house, he writes, but in terms of economics it rates much lower than insulation and other conservation measures. Once a house has been designed with heat retention in mind, "there is no economic justification for [active] solar, since there is no need for any additional solar heat. "[10]

Drawing an analogy to the human body, Hammarlund points out that a person can be warmed by standing in the sunlight or by putting on a coat and relying on the retention of body heat. A house, too, has internal heat sources–people, appliances, lights, and water heater—and Hammarlund contends that with a proper "coat" of insulation the heat from these internal sources can be retained and will provide much of the space-heating needs of the house.

Solsearch developed its Conserver Home to demonstrate this principle, and to show that a design based on heat retention could produce a low-cost, resource-efficient house that would meet the needs of home buyers who want to reduce energy consumption but who cannot afford the relatively high price of more elaborate solar designs. The first two Conserver Homes were built during 1977-78 on Prince Edward Island, Canada, a region of long, cool, and cloudy winters—not an ideal location for a solar house, but a good one for a low-cost, heat-retentive house. The population is largely blue-collar and is primarily employed in mining and fishing. One Conserver Home has been occupied by a local family since September 1978; the second remains unoccupied while its interior temperature and heat loss are carefully monitored by the Canadian Institute of Man and Resources.

[10]Ole Hammarlund, "With Body Heat Who Needs Solar?" unpublished paper, 1978.

Conserver Home Technology

Table 5 shows the estimated heat energy generated by activities inside a house. "Activity" energy is released by people, lights, and appliances; a further increment of solar energy is added by south-facing windows and glass doors, even if the total

Table 5.—Daily Activity Energy for a Family of Four

People	29,000 Btu
Cooking	18,000 Btu
Motors, appliances, lights	59,500 Btu
Water heater losses	10,000 Btu
Activity total	116,500 Btu[a]
Winter average solar input	20,000 Btu[b]
Winter average total nonauxiliary heat available	136,500 Btu

[a]Estimates by other workers for "activity" energy range from 50,000 Btu (Illinois Lo-Cal House) to 90,000 Btu/day (P. S. Lumont's average internal energy estimate for 13 Saskatoon houses plus 29,000 Btu/day for 4 people).
[b]402 Btu/day/ft^2 for 86 ft^2 of south glazing.

SOURCE: Ole Hammarlund.

glazed area is no more than is commonly expected. The challenge for Solsearch was to design a cost-effective and livable home that would use these energy sources as the major source of heat without increasing the complexity or costs of construction.

The Conserver homes use "Arkansas framing," a construction technique that has been widely publicized by Owens/Corning, an insulation manufacturer.[11] This system permits 12 inches of fiberglass batting in the ceilings (R-38), 6 inches of fiberglass batting in the walls (R-19), and a continuous vapor barrier to prevent moisture and air infiltration (see figure 5). In addition, headers over doors and windows are box framed and insulated, as is the band-board. Doors are foamed-filled metal, and windows are triple-glazed on the north, east, and west and double-glazed on the south. The foundation is treated wood rather than concrete, primarily because of high concrete costs ($50/yd^3) on Prince Edward Island, and is insulated to R-10. The total glazed area in the windows and patio door is 135 ft^2, or about 9 percent of the 1,540-ft^2 floor area. (Window area equaling 10 percent of floor area is at the low end of typical current tract housing.) Of this glass area, 65 percent faces south and only 4 percent faces north.

The projected gross heating load for this home is about 5,400 Btu/dd for every 10 F temperature difference between the inside and outside, or about 3.5 Btu/ft^2/dd. Since an estimated 136,000 Btu would be generated each day by the normal activities of the residents and by solar input, these heat sources would support the heating load so long as the average temperature difference between the inside and outside of the house is less than 25^0 F.[12] In other words, no additional space heating will be needed to maintain an average indoor temperature of600 F (650 F day, 500 F night) until the daily average outside temperature falls below about 350 F. The feasibility of the system does not require this low temperature range which was the basis for the designers' calculations: aver-

[11] Owens-Corning, Inc., "Energy Saving Homes: The Arkansas Story," 1977. Arkansas framing was developed by Henry Tschumi (HVAC Engineer), Les Blades (Arkansas Power & Light), and Frank Holtzclaw (HUD design and construction analyst).

[12] (136,500 Btu) ÷ (3.5 Btu/ft^2/dd) ÷ (1,540 ft^2) = 25.32 dd.

Figure 5.—The Conserver Home

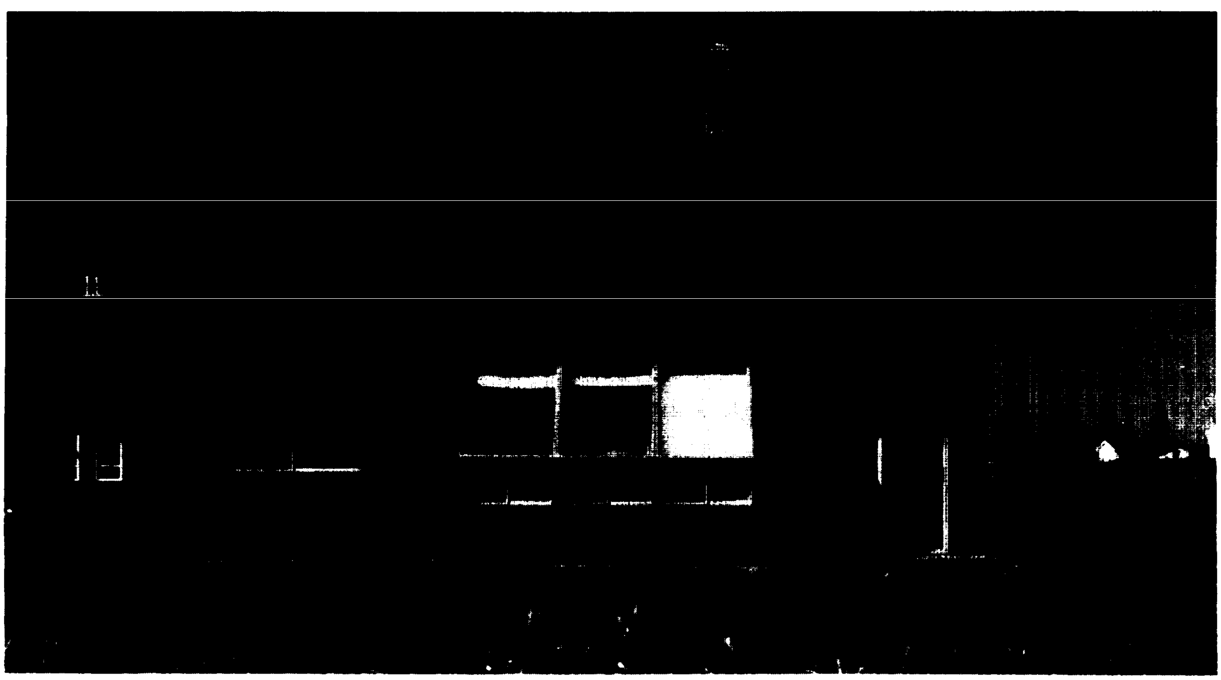


Photo credit: The Institute of Man and Resources, Charlottetown, P.E.I.

age indoor temperatures of650 F (700 F day, 55” F night) can be maintained without auxiliary heating when average outdoor temperatures are 400 F or above.

The house’s low rate of heat loss also means that temperature variations tend to be damped: surplus energy generated during high-activity periods (morning and evening) will be carried over into low-activity hours. The Conserver Home contains no separate furnace; instead, backup heat is provided (through a base-board hot-water system) by a conventional hot water heater. This system, combined with activity and solar inputs, is adequate to meet design heating load requirements of 15,000 Btu/hr. It will thus keep inside temperatures at 600 F even when average outside temperatures falls to – 5°F. [13]

[13] (15,000 Btu/hr) × (24 hr) ÷ (3.5 Btu/ft²/dd) ÷ (1,540 ft²) = 66.79dd.

Performance and Costs

Over the Prince Edward Island heating season of about 8,300 dd, about 50 percent of the expected space-heating load will be met by “activity” energy of the occupants and 20 percent by solar energy. The remaining energy, about 15 million Btu will be drawn from the hot water heater, which is gas-fueled in Conserver I and oil-fueled in Conserver II. At $1/gal for fuel oil, total heating season costs for the Conserver II are expected to be about $150.

Conserver I was commercially constructed and sold for $26,000 in 1978. Conserver II has been sold for $30,000. These low prices, about $17/ft², apparently reflect very economic design (including the wood foundation) and the lower labor costs in the Canadian Maritimes. Current construction costs for conventional homes in the United States range from about $30 to $50/ft².

A Case Study of Heat-Retentive Homes (II)– The Bethel House, Bethel, Alaska[14]

The Community Setting

In contrast to the scenic beauty of much of Alaska, Bethel is a drab and depressing place. Many houses are dilapidated and would be considered substandard by the criteria of the lower 48 States. The land is flat, and there is almost no vegetation. During the spring breakup, when snow and ice are melting, the entire town (except for the two paved streets) is 6 to 12 inches deep in mud. During the summer, the mud turns to dust (see figure 6). There are no roads to Bethel. Everything must be flown or barged in, and therefore everything is expensive. Milk is over $5/gal, propane $16/gal, electricity 37 cents/kWh.

Bethel offers excellent examples of inappropriate applications of housing technology from the lower 48. In villages which have been electrified, housing authorities have equipped many homes with electric stoves and central heating. Many of the houses, however, are designed for California; the cost and difficulty of heating them in the Alaska winter are enormous, and (as one resident reported)”. . . when the power fails, as it often does, the homes are uninhabitable. ” Heat leakage through the thin floors of prefab houses melts the

Figure 6.- Bethel, Alaska

Photo credit: Office of Technology Assessment

[14] Material in this case study is based on the working paper, “Energy-Efficient House Construction, ” prepared by Steven Klein and Richard DeSanti for the Harvard Workshop on Appropriate Technology for Community Development, Department of City and Regional Planning, Harvard University, May 15, 1979.

tundra and causes them to settle. Standard housing is not structurally rigid enough to withstand the forces imposed by seasonal thawing and freezing of the tundra. Thus houses rapidly become out of square, with ill-fitting doors and windows and a dilapidated appearance.

The Bethel House is the result of ongoing efforts within the local community to develop a housing technology appropriate to the resources, economy, and environmental conditions of the area.

Development

Several years ago, the Kuskokwim Community College (KCC) in Bethel began a Maintenance Technology Program. KCC's student body is largely Eskimo, and is drawn from surrounding villages as well as Bethel itself. The original purpose of the program was to train students in repair and construction skills in the context of the hunting and fishing subsistence economy that is still dominant in the villages. The design for the structure that became known as the "Bethel House" evolved over the years as the students (as part of their coursework) built several small prototype houses, which KCC then sold on the private market to recover their administrative expenses and cost of materials.

The ultimate goal of the KCC faculty is to influence the design of subsidized public housing built for Alaska natives by the State Housing Agency and the Bureau of Indian Affairs. However, they are using the private market to test, refine, and demonstrate the soundness of their design. When their latest house, called the "Mark IV" (see figure 7), is completed, they hope to build a small subdivision of houses to be sold in the private market.

In developing appropriate housing for the needs and conditions of Bethel, therefore, KCC designers have addressed five vital concerns:

1. *Energy conservation.*—Sub-zero winter temperatures, combined with the high cost of fuel oil in this remote location, make well-insulated, energy-conserving homes an economic and physical necessity.
2. *Structural* stability.—Bethel is in a permafrost tundra area, which means that a conventional foundation is impractical and that houses need to be engineered for greater solid-

Figure 7.—The "Mark IV" Bethel House

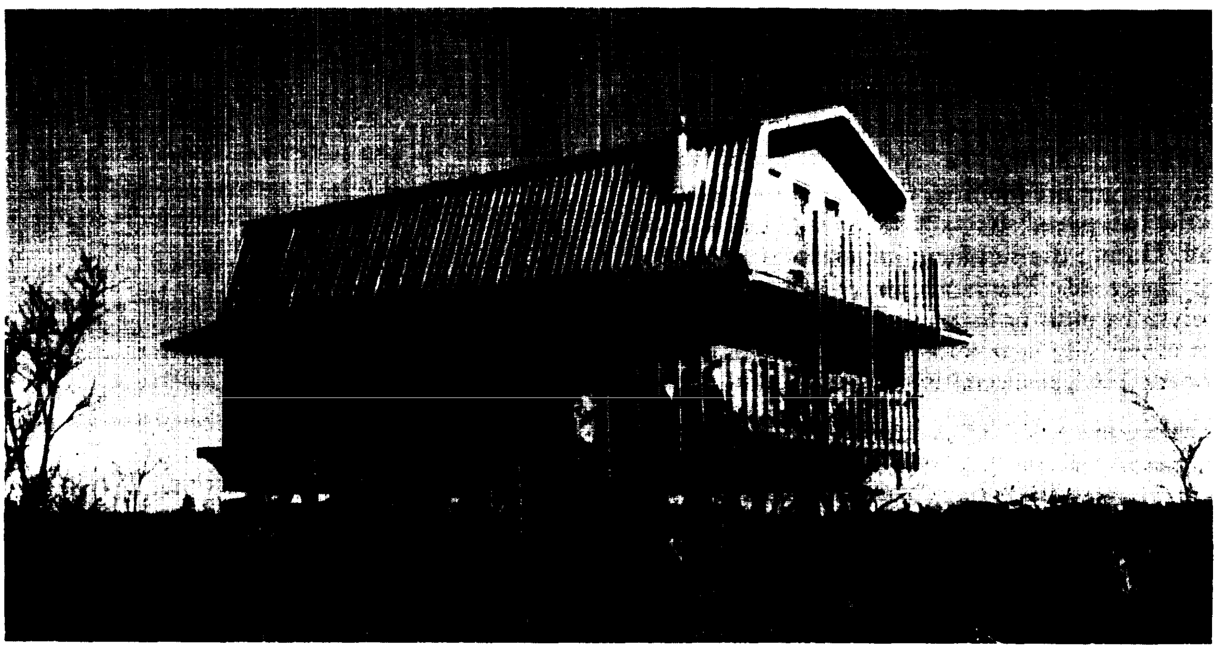


Photo credit: Office of Technology Assessment ity. Typically, heat loss from a poorly insulated house causes the underlying tundra to melt, which in turn causes the house to shift and settle. This can cause walls to separate from floors, windows and doors to fit poorly, and air infiltration to become a major problem.

3. *Materials cost.*–Almost everything in Bethel has to be shipped in from the outside–either by plane, or, during the summer months, by barge from Seattle. This adds substantially to the cost of all products, especially bulky building materials. There is thus a need for a home design that provides improvements over existing structures without increasing the already-high cost of materials.
4. *A pleasant living environment.–Another* goal is to create a house that is roomy and pleasant, in order to alleviate some of the psychological and social pressures of life in an isolated community with few amenities and very long winters.
5. *A regional architectural style.–The* traditional native sod huts have long since disappeared, and Bethel has no typical architectural style. Buildings tend to be an assortment of designs, consisting of whatever was cheapest or easiest to build, or whatever was available from the "lower 48" in prefabricated form.

The Bethel House Technology

The three principal features of the Bethel House design (figure 8) are:

- extensive use of insulation;
- use of structural members made from plywood in many places where a conventional design would use solid wood timbers; and
- use of glue to reinforce joints and create a more solid structure than would result from the use of nails and screws alone.

In addition, KCC designers have developed a number of innovative structural features.

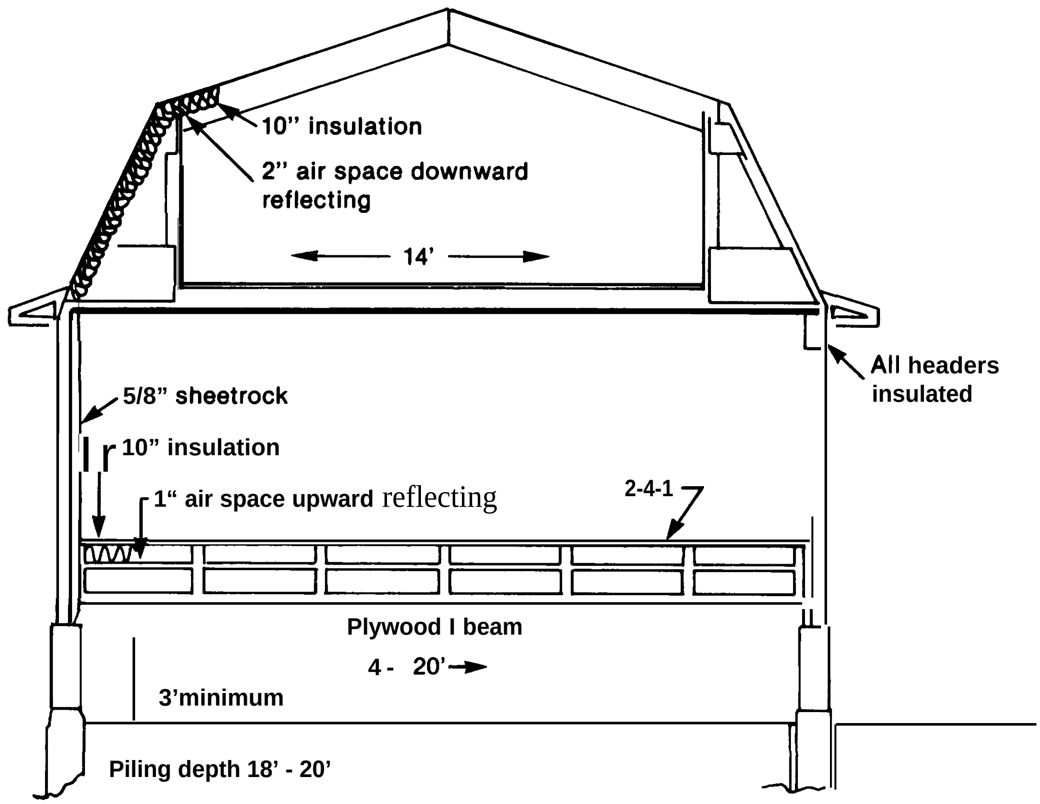
Foundation.–The house is elevated several feet above the ground on a "pad and post" assembly (figure 9), which involves placing pilings into the tundra on pads of sand. This elevated design, plus extra floor insulation, prevents heat from seeping through the floor and melting the tundra underneath the house.

Floor.–In a conventional house, solid 2- by 12-inch timbers (or "joists") spaced 16 inches apart are used to support the floor. These joists account for up to 15 percent of the floor area and account for a substantial heat loss, since solid wood is a relatively poor insulator. The KCC design substitutes a "plywood I-beam" (figure 9) for these solid wood joists. The I-beam is simply a piece of 5/8-inch thick plywood, held vertically between horizontal 2- by 4-inch "spacers" to prevent warping or twisting. Because the plywood sections of the I-beam are only 5/8-inch thick, heat loss through the floor framing is reduced. Because of its shape, the plywood I-beam is stronger than a solid wood beam; only 7 I-beams are needed, instead of 24 conventional joists. Heat loss through floor framing is reduced from 15 percent to only 2 percent, and savings are also realized on the cost of materials.

Similarly, the KCC design replaces solid wood perimeter timbers with plywood "box beams" (figure 9). The box-beams are constructed of four pieces of vertical plywood, 5/8-inch thick, sandwiched between two 2- by 4-inch spacers placed horizontally across the top and bottom. The hollow space within the box-beams can be stuffed with insulation. The result is a very strong insulated beam, which reduces the heat loss and can be constructed with materials costing about one-third as much to ship to Bethel as conventional solid beams. The system also provides a very rigid floor, which requires only 10 support posts instead of nearly 20 for a conventional floor system.

Wall-to-Floor Joint.–In a conventional house, the walls rest on top of the floor. In the KCC house, the I-beams and perimeter box-beams are joined together such that the I-beams project above the box-beams (figure 9). As a result, the walls rest on the perimeter box-beams "outside" the floor, actually extending below it. This design, which is similar to framing techniques used in the 19th century, allows the builders to anchor the walls vertically to the box-beam and horizontally to the I-beams, thereby increasing the rigidity and strength of the house. Second, it also allows them to install continuous insulation through the walls

Figure 8. Cross-Section of the Bethel House



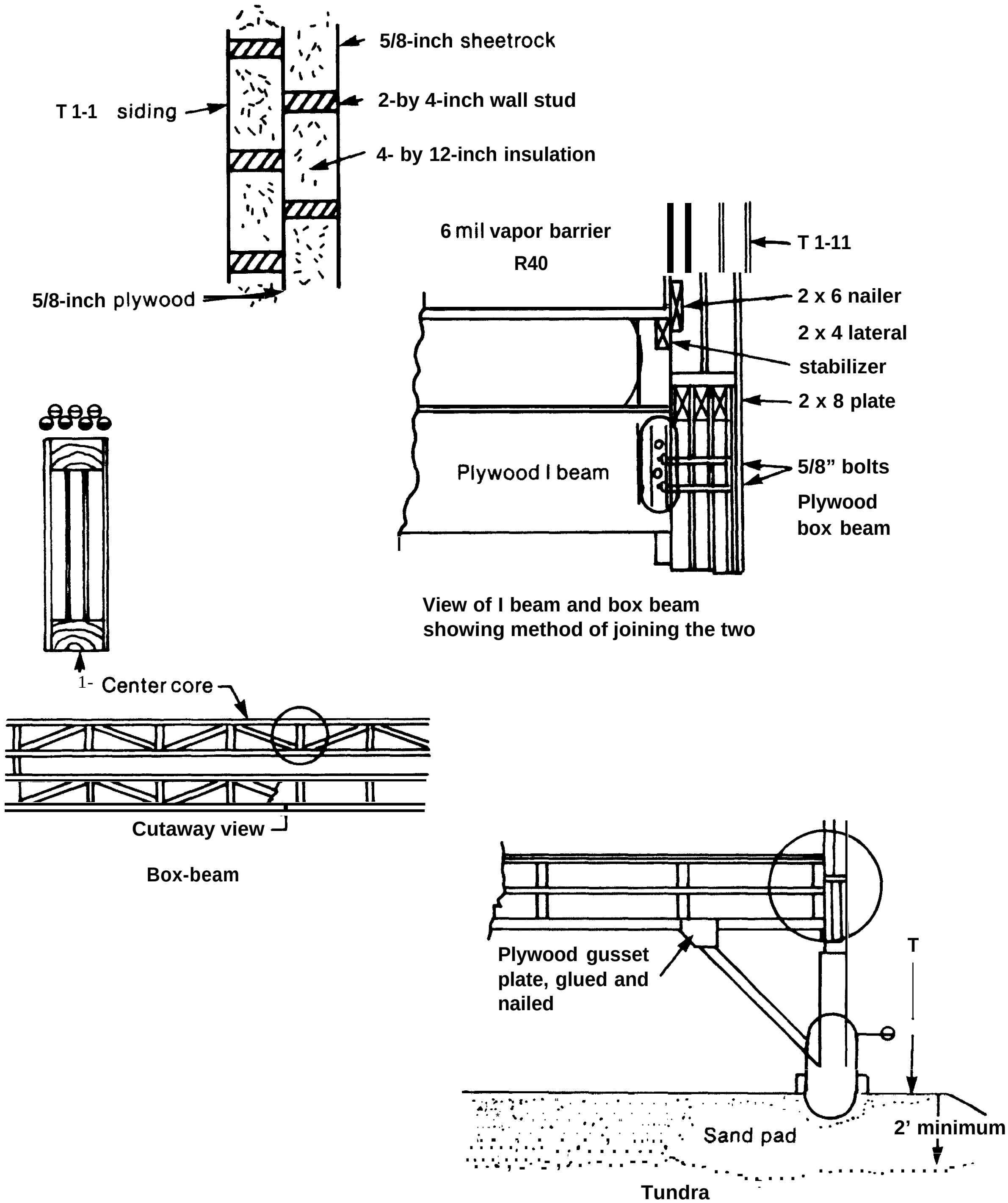
Cross-section of KCC house

and under the floor. In a conventional house, the wall insulation stops at the point of juncture with the floor. In the KCC design, where the walls extend below the floor, it is possible to pull the insulation through and continue it across the bottom of the floor in an unbroken blanket.

Walls.–KCC determined that 8-inch thick wall insulation would repay its cost through reducing heating bills in 5 years under Bethel conditions. In conventional houses, however, wall studs comprise about 15 percent of the wall area and offer solid heat-loss paths to the outside. KCC therefore employed a "double wall" construction technique (figure 9). Studs are 12 inches apart, but are staggered on either side of a central sheet of plywood. As a result, a 24-inch wide, 4-inch thick batt of insulation can be placed between the studs on the interior and exterior walls, thus achieving a total 8-inch thickness of insulation in the wall. In addition, since the studs alternate between the interior and exterior walls, there is at least 4 inches of insulation everywhere in the wall and no solid heat-loss paths to the outside.

Roof.—There are three distinctive features of KCC's roof system design. It has a gambrel, or barnlike, roofline rather than the more conventional gable. The gambrel design increases the usable space on the second story of the house in comparison to a typical gable roof, which may reduce by as much as one-fourth the habitable volume of a structure. The second distinctive feature of the KCC roof system is that the wall-to-ceiling joint (like the wall-to-floor joint) is designed so that an unbroken wrap of insulation continues up from the walls and across the roof. Third, the trusses that support the roof are designed to be

Figure 9.— Innovative Structural Details, Bethel House



Box-beam

View of I beam and box beam showing method of joining the two

View of pad-and-post assembly for elevating the house above the tundra partially assembled at the building site before installation, which should make them easier to install without machinery or a large number of people.

Windows and Doors.–Bethel is at latitude 60° N, which means that midwinter solar energy availability is small. However, the climate is fairly sunny and solar availability is quite good from January through May. Most of the windows are located on the south side of the Bethel House to take advantage of solar energy for lighting and heating, and are double- or triple-glazed and tightly sealed.

costs

KCC estimates that the two-story version of the Bethel House, built commercially, would cost $55,000 to $65,000. Construction is more labor intensive—time is required to fabricate building elements such as box-beams and floor framing—but less materials intensive than conventional construction. And in an economy where general costs are very high, $40/ft^2 (1977 dollars) seems hardly out of line (current construction costs in the lower 48 States are between $30 and $50/ft^2.

Clearly, however, if the Bethel House is to penetrate the Government-subsidized housing market, its costs must be brought down. The one-story Mark IV house is an attempt to do this, and KCC estimates the cost of this design can eventually be reduced to about $30,000. By comparison, recent public housing units in Bethel cost only $20,000 to build, but they suffer from all of the problems that the Bethel House is designed to avoid. As a result, they incur much higher maintenance, repair, and heating costs than the KCC design. Detailed lifecycle cost estimates would allow better economic comparison to be made between the Mark IV and the conventional alternatives.

One local builder is currently building six houses that include several–but not all–of the Bethel House principles. His modifications of the KCC design have often been intended to make it more acceptable to his native Alaskan customers, many of whom are skeptical of the kind of technological "fixes" that have been sold to them in the past. This builder may play an important role in the ultimate dissemination of the technology, since he is also the owner of the local lumber yard. He is already convinced enough of the merits of gluing joints that he automatically includes the proper amount of glue with any lumber order from a bush village, whether his customers have asked for it or not.

A Case Study of Hybrid Resource= Efficient Homes—The Tom Smith "Thermal Envelope" House[15]

Development

The original idea for Tom Smith's "thermal envelope" house came from a house in Taos, N. Mex., that was based on passive solar principles. The house was to be built from adobe with cool rooms on the north side and a heating solar greenhouse on the south, a design with strong parallels to the Indian pueblo, the original indigenous architectural style in the area.

In 1977, Smith began making plans to build his own passive solar home near Lake Tahoe in California. He designed the house with several goals in mind: it should use standard construction techniques and conventional, locally available materials; it should also be comfortable to live in, esthetically pleasing to the general homebuyer, and easy to finance through conventional mortgage borrowing; finally, the design should be adaptable to other climates. After consulting a number of experts, he arrived at a design that is now frequently called a double or thermal envelope.

Thermal Envelope Technology

The Smith house (figures 10, 11, and 12) consists of an inner and an outer structure, which share common east and west walls. The inner north wall is separated from the outer wall by

[15] Material in this case study is based on the working paper, "Energy-Efficient Architecture," prepared by Teresa Canfield and James Greenwood for the Harvard Workshop on Appropriate Technology for Community Development, Department of City and Regional Planning, Harvard University, May 15, 1979.

Figure 10.—Thermal Envelope House, Heat-Gain Cycle

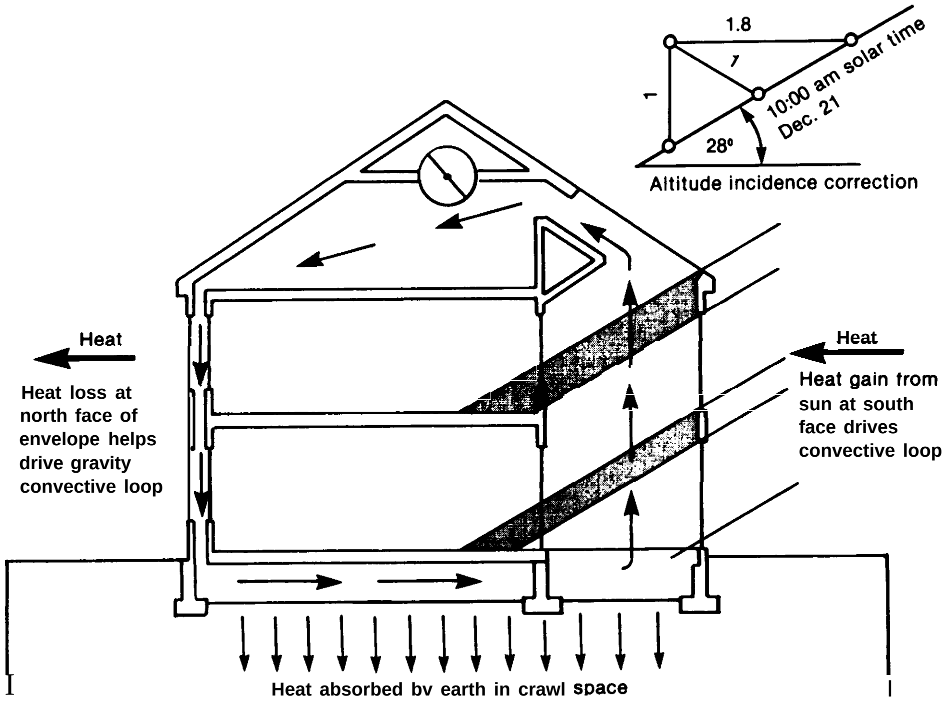


Figure II.—Thermal Envelope "House, Heat"Loss Cycle

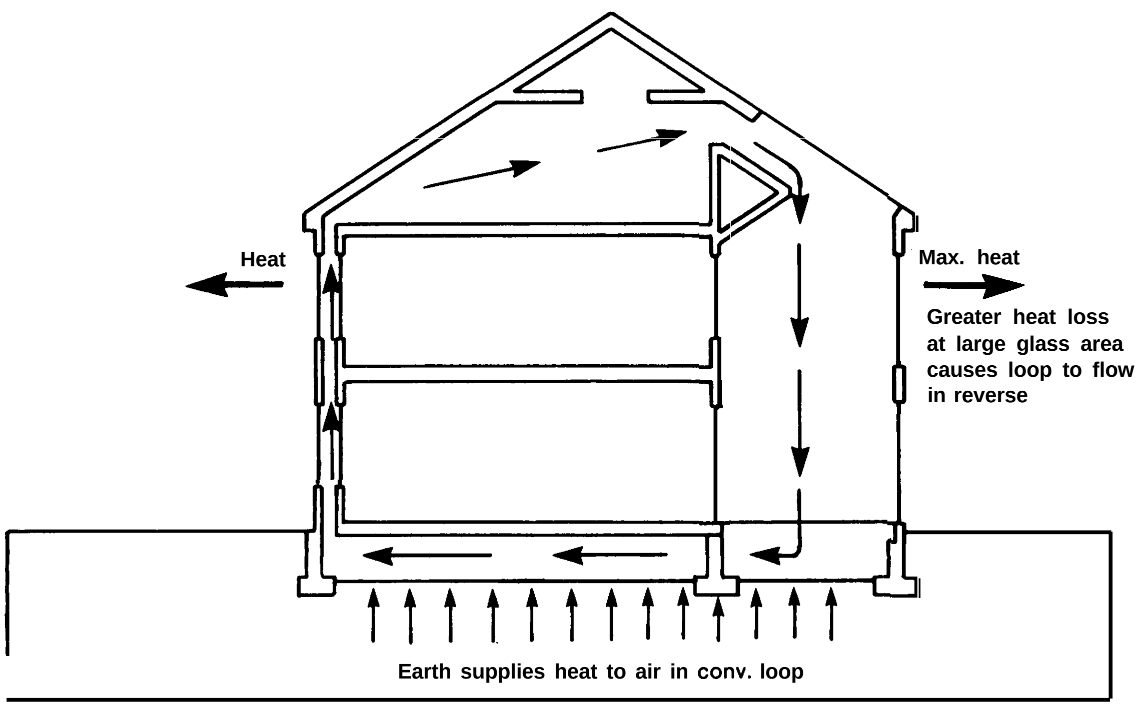
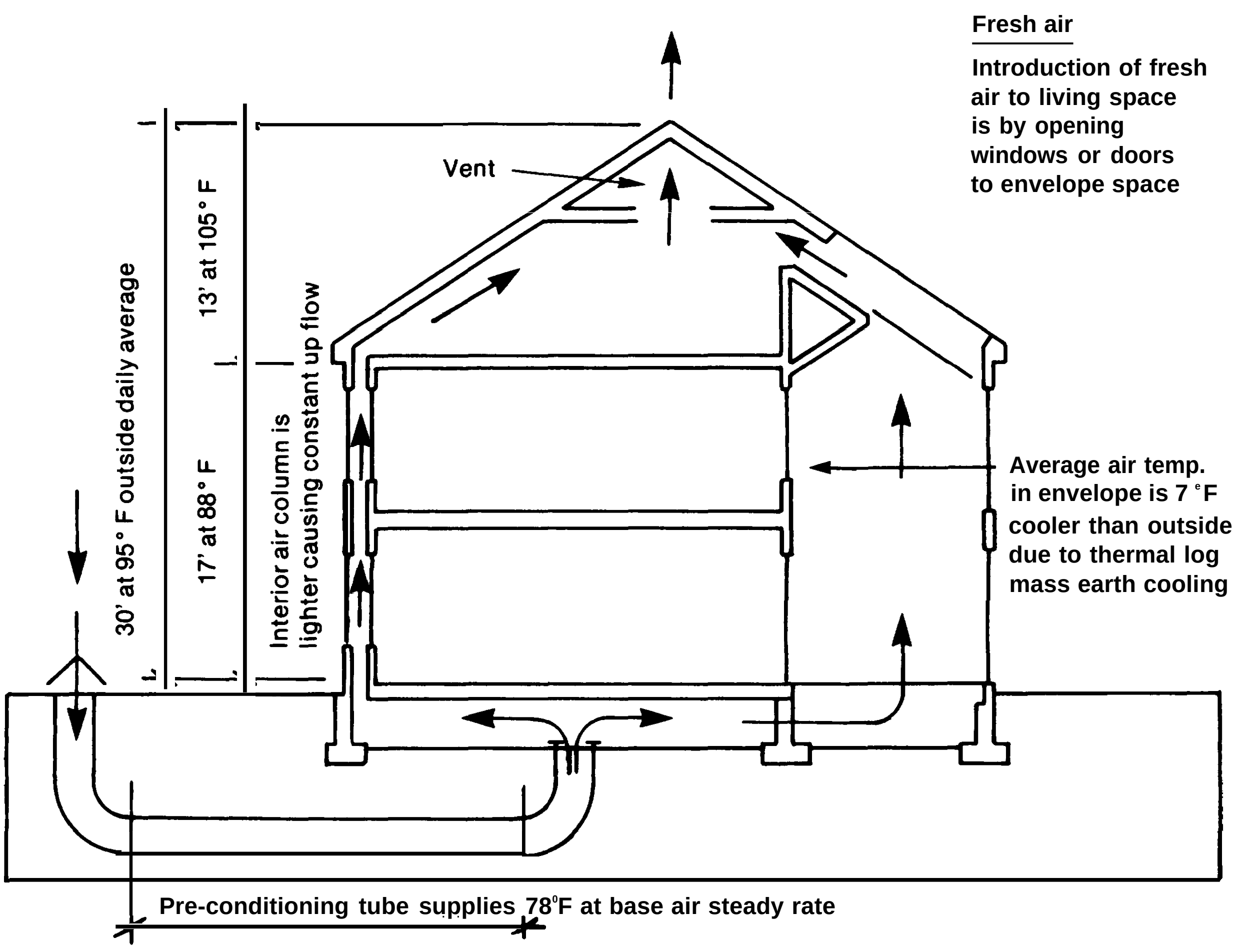


Figure 12.—Thermal Envelope House, Ventilation and Cooling Cycle



about 12 inches This gap is connected to a basement crawl space and the attic plenums, which in turn are open to the floor and ceiling of an attached greenhouse or solarium. As a result, air can pass in a large loop around the inner structure. Both the inner and outer walls of the double envelope are insulated.

The principles on which the double envelope house is designed to work are straightforward. On a sunny day (figure 10) the air in the greenhouse heats up and rises between the inner and outer ceilings, losing heat to both the outside and inside space; as its density increases due to cooling, the air flows down the north cavity and through the crawl space—where it gives additional heat to the earth—and back into the greenhouse through openings in the greenhouse floor. At night or on cold cloudy days (figure 11) when the greenhouse is cooler than the cavity spaces, a reverse cycle occurs: the coldest air gathers at the floor level of the greenhouse, flows through the crawl space where it picks up heat from the earth—and then up the north wall cavity, across the ceiling, and back into the greenhouse. (It should be noted that the greenhouse can be closed off from the inner house to limit direct cooling of the living space at night.)

As a result of these air flows, most of the inner envelope (all except the east and west walls) is buffered from the outside both by the outer shell's insulation and by the convective flows of air heated by the greenhouse or the earth storage. Summer cooling (figure 12) is also enhanced by natural convection: warm air is released through an operable vent in the ceiling plenum and vented from the attic cavity. In the Smith house, replacement air enters through open windows, in some other designs, replacement air is drawn through buried "preconditioning" tubes and the crawl space, to be cooled by the earth before entering the living space.

Performance and Costs

Ultimately, heat loss is governed by the heat resistance of the outer shell and by the temperature difference between the exterior and the air flowing between the shells. The most interesting but least understood aspect of the design is the passive heat exchange between the various elements of the design: greenhouse, living space, and crawl space thermal storage.

That the convective processes described above in fact explain the performance of Smith's or other envelope houses has been questioned. Whatever the precise operation, however, those living in the houses uniformly report very stable temperatures in the living space and very low auxiliary heat requirements, although none have been monitored consistently and few have been occupied for more than one heating season.

Tom Smith built his house in late 1977 with the least expensive materials available at a cost of approximately $30/ft^2$. This figure compares favorably with the average cost of $35 to $37/ft^2$ for conventional new housing constructed in the Lake Tahoe area.

Discussion of Solar-Heated and Heat-Retentive Houses

Performance

Table 6 summarizes performance and cost information for a variety of passive solar, superinsulated, and hybrid houses, including several of those described in the preceding case studies. The reader should be cautioned, however, that the extent and reliability of performance data varies from house to house. The construction of such resource-efficient houses is a very recent phenomenon, and most of the houses have been occupied for less than 5 years, many for only one or two heating seasons. Consequently, although a number of them have been monitored for temperature behavior, few of them have had the kind of rigorous, detailed study that would be necessary to draw firm, experimentally verified conclusions about their precise thermal performance.

In addition, occupied houses are particularly difficult to study, largely because the behavior of the occupants has a significant effect on the thermal performance of their house. For instance, many passive designs require the residents to interact with the passive system by opening and closing windows, shutters, vents, etc., at different times in the daily heating cycle. Some owners find these to be easy and even satisfying chores, others find them inconvenient. Similarly, transferring heat into and out of the thermal storage requires a daily temperature cycle, often in the range of IO ^{0} to 200 F. Some people find this temperature cycling acceptable; others may level out the cycle by using auxiliary heating or by venting excess heat. In short, occupant behavior—the human factor—is a significant but largely unmeasured variable in the performance of many of these resource-efficient houses.

Column 5 of table 6 gives estimated values for the *gross heating loud* of the houses—the amount of heat required to maintain an average inside temperature of 60° F, assuming *no* internal "activity heat" input and *no* solar input, Many of the passive solar designs have projected loads of a magnitude similar to the "standard practice" house (typical conventional stock built after *1977).* On the other hand, heat-retentive houses have gross loads around or below the 2.5-Btu/ft^2/dd, a widely accepted standard for energy efficiency.

Column 6 gives estimated seasonal net loads after solar and activity heat inputs have been taken into account. Column 7 presents the cost of the auxiliary fuel-based heat required by each house, adjusted for size and location. These low

Table 6.—Cost and Heating Performance of Selected Resource-Efficient Houses

House	Location	Size (ft²)	Heating degree-days	Gross load[a] (Btu/ft²/dd)	Net load[b] (Btu/ft²/dd)	Total cost[c]	Net cost of solar[d] and conservation features	Adjusted seasonal cost of auxiliary heating[e] ($/1,000 ft²/1,000 dd)
Conventional								
1. "Standard practice"	New York	1,600	6,450	11.0	8.0	$61,000 (79)	$ 0	$94.19
Passive solar								
2. Green Mountain	Royalton, Vt.	1,264	8,269	7.0	3.2	40,000 (77)	1,350	39.03
3. Hunn	Los Alamos, N. Mex.	1,955	6,300	10.0	3.2	67,000 (77)	5,400	38.97
4. Cooley	Washington, Corm.	2,500	5,840	8.0	5.0	81,000 (78)	7,000	36.99
5. Shankland	White Rock, N. Mex.	2,000	6,155	11.0	2.7	65,000 (77)	4,000	32.17
6. Mobile/Modular	Los Alamos, N. Mex.	1,090	6,000	13.0	1.2	25,000 (77)	4,000	14.68
7. Star Tannery	Star Tannery, V.I.	1,250	4,224	9.0	1.1	34,000 (77)	NA	13.64
8. Balcomb	Santa Fe, N. Mex.	2,300	5,797	7.0		80,000 (76)	12,000	9.90
9. Kelbaugh	Princeton, N.J.	1,850	4,980	7.0	0.7	55,000 (77)	8,000-10,000	9.12
Heat retentive								
10. Leger	Pepperell, Mass.	1,100	6,800		2.6	54,000 (79)	400	30.48
11. Average of 13 residences	Saskatoon, Canada	1,100-3,500	11,000	3.0	1.7	—	—	—
12. Arkansas framing	Arkansas	1,200	4,300	4.5	1.2	30,000 (76)	0	13.95
13. Conserver	P. E. I., Canada	1,536	8,300	4.0	1.0	26,000 (78)	0	13.18
Combination								
14. MASEC 27008	Eau Clair, Wis.	2,000	8,000	6.0	2.5	80,000 (80)	2,200	21.00
15. MASEC 27004	Cedar Rapids, la.	1,200	6,500	3.0	1.0	56,000 (80)	1,200	12.31
16. ZumFelde	Wauseon, Ohio	3,760	6,000	2.7	0.8	84,000 (79)	5,000	10.11
17. Saskatchewan	Regina, Canada	2,016	10,800	2.0	0.2	NA (77)	{4,000 cons. / 15,000 active	2.76 / 0.00
18. Northfield	Northfield, Minn.	1,800	8,250	2.3	0.1	55,000 (77)	{1,800 cons. / 6,000 active}	1.62

aExcluding solar and activity heat inputs.
bIncluding solar and activity heat inputs.
cTotal construction costs, excluding donated labor.
dTotal cost of special solar or conservation features, less savings due to size reduction or elimination of conventional heating system.
eSeasonal heating costs, adjusted for differences in size and climate; assumes fuel costs at $12/MMBtu, or about $1/gal for oil burned in a 70-percent efficient furnace, or about $0.04/kWh for electricity used in a resistance system.

SOURCES:
1. Department of Housing and Urban Development, "Passive Design Ideas for the Energy-Conscious Architect," National Solar Heating and Cooling Information Center. The standard-practice home is a two-story frame structure with R-13 insulation in the walls, R-19 in ceilings, double-glazed windows (21 percent of floor area), and an unheated, uninsulated basement.
2, 3 and 5-9. Sandia Laboratories, "Passive Solar Buildings," SAND report No. *79-0624,* July 1979.
4 and 13. Solsearch Architects.
10. Jim Harding, "Surviving the Massachusetts Winter Without a Furnace," Soft *Energy Notes,* February 1960.
11. R. S. Dumont, H. W. Orr, C. P. Hedlin, and J. T. Makohon, "Measured Energy Consumption of a Group of Low-Energy Houses," prepublication copy, National Research Council of Canada, Division of Building Research, May 1960.
12. Owens/Corning Fiberglass, "Energy Saving Homes: The Arkansas Story," 1977.
14 and 15. Mid-American Solar Energy Complex, "Solar 80 Home Designs," 1960.
16. Dale and Paul ZumFelde, "A Passive Solar Energy House That Works," 1960. An independently designed double-envelope house similar to Tom Smith's thermal-envelope design.
17. Ft. W. Besant, R. S. Dumont, and G. Schoenau, "Saskatchewan House: 100 Percent Solar in a Severe Climate," *Solar Age,* vol. 4, No. 5, May 1979. A small (192 ft²) active solar collector is used to supply auxiliary heat.
18. David A. Robinson, "The Art of the Possible," *Solar Age, vol.* 4, No. 10, October 1979.

costs are indeed impressive and tend to confirm the occupants' claims that very little auxiliary heat is needed. If all U.S. housing required these levels of auxiliary energy, say 2 to 4 Btu/ft²/dd, U.S. residential heating energy consumption could be reduced by more than 80 percent, to only about 4 Quads/yr.

costs

Where estimates are available, column 8 of table 6 lists the incremental costs of solar and/or superinsulation features. Whenever possible, these are *net* cost figures: any savings due to reduced size or elimination of conventional heating systems have been deducted from the added cost of the solar system or extra insulation. The incremental costs are generally small and, in the case of superinsulated homes, can be almost incidental. These figures are somewhat speculative, but to the degree that they prove accurate and typical, incremental costs do not appear to be a barrier to achieving substantially improved thermal performance in new residential housing.

One of the most important implications of table 6 is that excellent thermal performance can be achieved by a wide variety of residential designs. It will not be necessary to demand drab uniformity in the name of efficiency, nor to vastly change consumer tastes concerning styles of housing, nor to plat every subdivision with an eye to protecting solar access. It would also appear that energy-efficient houses can be constructed throughout the entire price range.

Potential Problems

The following are some of the problems which have been encountered with resource-efficient structures.

Air Quality .–Indoor air quality is a matter of increasing general concern.[16] Very tight houses like the heat-retentive homes listed in table 6 have measured infiltration rates as low as 0.05 air changes per hour under conditions in which conventional houses would have about 1 air change per hour. Low air-exchange rates allow buildups of nitric oxides and carbon monoxides from a gas stove, radon from masonry, formaldehyde from furniture and plywood products, and carcinogens from cigarette smoke or other sources. Humidity can also build up to the point where condensation becomes a problem. To cope with air quality problems without losing heat, air-to-air heat exchangers are being installed (e.g., in the Leger house, Saskatchewan house, and Northfield house) which can recuperate up to 80 percent of the heat in outgoing air. A small residential heat exchanger can be built for $150 or bought (from a Japanese company) for under $250.[17]

[16] J. L. Repace and A. H. Lowrey, "Indoor Air Pollution, Tobacco Smoke and Public Health," *Science*, vol. 208, May 2, 1980, p. 464.

[17] C. Conley, "Clearing the Air: Air to Air Heat Exchangers in Energy Efficient Houses," *Soft Energy Notes*, February 1980, p. 25.

Temperature Control.–Passive structures, particularly direct-gain designs, often exhibit rather large daily temperature swings, often as high as 20° F. Because the living space is the solar collector and often the thermal storage as well, control is sometimes difficult and may demand considerable attention from the occupants. Indirect-gain structures (Trombe walls, greenhouses, etc.) have fewer problems with temperature control. Superinsulated homes have a relatively low mass and therefore are sensitive to sudden increments of energy. A south window area of only 100 ft^2 on the Leger house is large enough to cause overheating on sunny days. A gathering of people will rapidly raise room temperatures, and small operable window areas may not provide adequate natural ventilation.

Internal Light Levels.—South-facing windows on passive solar houses may make the interior painfully bright on sunny days, particularly in winter with snow on the ground. Fading of colored furniture and cloth is sometimes a problem. Direct-gain designs are more often subject to this problem than other passive designs. Conversely, reducing total window area to reduce heat losses in superinsulated homes, or reducing glazed areas on walls other than south in many solar homes, may make north rooms dark and unattractive. Good architectural design is needed to deal with this problem.

Livability.–Livability is a matter of taste and lifestyles, so hard and fast statements are not appropriate. However, the open floorplan characteristic of many passive designs, which permits natural air circulation and light penetration, also permits sound and odor diffusion. As mentioned above, system operation and temperature cycling are acceptable to some people but not to others.

Maintenance. —Few maintenance problems have been reported, but most of these homes are less than 5 years old, and some future problem areas seem possible. If transparent glazing is used, the large glazed areas will require cleaning. The greenhouse in the Zumfelde home, for example, is glazed with insulated glass panels covering an area 13 ft high by 40 ft long, and additional windows separate the greenhouse from the living space. Maintaining a clear view in such a house might require a considerable effort. In the longer term, ultraviolet radiation will eventually darken and weaken plastic glazing. Accidental breakage and vandalism are also potential problems. Very strong glazing materials such as polycarbonates are available but are also quite expensive.

Safety. -In addition to the indoor air quality problems already mentioned, fire safety may be a potential problem in thermal envelope designs. Some fire codes require fireproof dampers that will close off the north wall or ceiling cavities in case of fire. Large expanses of glass, particularly when placed high above the living space, can also become a hazard to the occupants. Tempered glass should be used in these situations.

Critical Factors

Public Perception and Participation

The two approaches to improved residential energy efficiency that have been discussed in this chapter—solar greenhouse retrofits and the construction of new passive solar or heat-retentive houses–are both highly decentralized. Most new home construction is done by small businesses operating only in their local area, and the average builder produces fewer than 20 units per year. Solar greenhouse construction has been accomplished largely by do-it-yourself or by "barn raising" workshops involving neighbors and friends. Both instances reveal the virtues as well as the limitations of decentralization, one of the major criteria of appropriate technology.

Home builders, whether they work under contract with the new owner or work on speculation, must serve the perceived needs, tastes, and budgets of the prospective buyers. "Spec" housing in particular must be as low-risk as possible, and the current high interest rates make rapid turnover critical. As a result, spec housing (which represents well over half of all U.S. housing starts) is not the place to experiment with new designs and features whose marketability is not yet proven. The vast majority of resource-efficient houses are custom-built for their owners.

It is to be expected that innovative energy-efficient architecture will penetrate the custom market first: risks to the builder are reduced, and the owner tends to be well-educated, aware of the available technologies, and relatively affluent. Penetration of the speculative housing market, depends on three interrelated factors:

- public awareness and acceptance of new resource-efficient designs and construction practices, insofar as they affect a house's appearance, thermal behavior, operation, first costs, financing, and marketability;
- builder awareness and acceptance and the rate at which information about and experience with new designs and practices can be disseminated (see below); and
- the degree of standardization that can be achieve-d in the designs and materials, which will reduce or eliminate the need for special architectural and engineering services.

Public acceptance occurs in two stages: first interest and awareness, then confidence and demand. The first stage has come relatively easily in the case of solar energy. As one prominent solar builder has noted, "Anybody who has participated in the early solar demonstration programs knows the wonder of opening the door . . . and seeing thousands of visitors heading down the walk. " However, he adds, the question is "when will these lookers become buyers?"[18] Marketability is also a concern for the owner/builders of existing resource-efficient houses, as demonstrated in the case study of the Cooley house.

The construction of solar greenhouse retrofits, on the other hand, has been largely outside the commercial market and mainly by owners or volunteer workshops. Awareness and interest have been generated by word of mouth, newspaper and

[18] Wayne D. Nichols, "Marketing the Passive Solar Home," Proceedings *of* the *2d* National *Passive Solar* Conference, Philadelphia, Pa., Mar. 16-18, 1978, p. 704.

magazine articles, and a few nationally distributed books.[19] The influence of demonstration projects on public perception and demand is marked. In New Mexico, says Bill Yanda, "For every workshop, 10 more greenhouses were built in the community." In Yellow Springs, Ohio, a community of about 5,000 people, a greenhouse was constructed by a workshop in the summer of 1978; as of spring 1980 there were seven other attached greenhouses in the community, all owner or workshop constructed. Because there is little formal marketing of the greenhouse idea, the critical factor in public awareness is a sufficient number and distribution of these local demonstration projects, so that a large number of people can become aware of the idea through direct observation and through the experience of their neighbors. Workshop participation also builds confidence and encourages people to move from "lookers" to "builders."

Finally, many people who are aware of the technology are not interested in the do-it-yourself approach. This would appear to create an opportunity for commercial construction, but the home improvement industry does not as yet appear to be aware of this opportunity—or to be technically prepared to undertake solar greenhouse retrofits. In addition, while economic payback may not be the most important criterion in the eyes of some do-it-yourself builders, commercial participation will require better economic and performance analysis than is currently available.

Essential Resources

The resources required to apply these energy-conserving technologies vary widely from house to house, according to the type and size of the structure. These resources include a building site, standard building materials, a few special solar materials, and labor.

Most solar installations work best on a generally southfacing site with relatively unobstructed direct sunlight. This does not limit their applicability to low-density suburban and rural areas, however; many opportunities exist for attached solar greenhouses and other retrofits on high-density urban housing. In addition, solar designs perform best in areas with high sunlight availability, which makes them more appropriate to a location with sunny winters like New Mexico (average solar availability 70 percent in January) than to an area with cloudy winters like Prince Edward Island or Ohio (25 to 35 percent availability).[20] In the latter locations, the greenhouse or glazed area would have to be larger (and more expensive) to give the same benefits. On the other hand, the heat-retentive designs in table 5 could be cost-effective under these conditions.

Most of the building materials for the houses described in the case studies were standard supplies, available at the local lumber yard or construction supply store. One of the goals of the Bethel House designers was to conserve materials in an area where all supplies are expensive. They did this by using plywood instead of solid wood and by making use of scrap wood where possible. Solar greenhouse builders in New Mexico also kept materials cost low by using salvaged glass and lumber when they were available, and Tom Smith made a point of using the cheapest materials possible in building his thermal-envelope house. Similarly, Solsearch Architects built their low-cost Conserver Home with as few special design features as possible. Some of the more elaborate passive solar and double-envelope designs do require specialized materials that may not be readily or cheaply available, such as glazing materials and ventilating fans.

Most of the labor required for construction was unskilled or semiskilled, and building contractors or subcontractors are generally available for skilled items such as plumbing and electrical wiring. The barn-raising approach of the New Mexico workshops was an effective way of developing the necessary local skill base, as well as a way to finish most of an attached greenhouse in a single weekend. This approach is less appropriate to the larger projects, however, but in some cases the owners provided a significant amount of labor—the Cooleys, for instance, lived in a tent on the construction site for 6 months, and were still working

[19] James McCullagh, ed., *The Solar Greenhouse Book* (Emmaus, Pa.: Rodale Press, 1978); and Rick Fisher and Bill Yanda, *The Food and Heat Producing Solar Greenhouse* (Sante Fe, N. Mex.: John Muir Publications, 1976, rev. ed. 1980).

[20] Paul S. Hoover and Phil Schneider, "Solar Availability in Ohio," AT, the Ohio Appropriate *Technology Bulletin*, vol. 1, No. 2, May 1980, p. 7., table 2.

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on their house almost 2 years after it was first begun. In addition, an increasing number of small contractors (like the local builder in Bethel) are mastering the construction techniques required by these solar and heat-retaining designs, which primarily require careful attention to details rather than unusual technical skills.

Technical Information and Expertise

General information on passive solar energy and solar greenhouses is available from Federal agencies like the National Solar Heating and Cooling Information Center, from State solar offices and regional centers, and from private organizations and publications such as Rodale Press, The International Solar Energy Society, *Alternative Sources of Energy,* Mother *Earth News,* and the Center for Renewable Resources. Most public libraries can also provide solar literature. If anything, the problem is selecting relevant sources of information from a very large and diverse pool.

However, *specific information* directly applicable to a particular locale, site, and design problem is not always easy to obtain. Much of the available information is national in scope or orientation, and too general to be of help to a builder or owner making vital design or construction decisions for a particular job. The lack of specific local microclimate information is a good example: it is desirable in most (but not all) areas of Ohio to orient glazing 15 to 20 degrees east of south, rather than due south, because winter mornings are clear more often than afternoons and because the prevailing winds are from the southwest. This sort of site-specific information is not readily available in many areas, although regional organizations like the Tennessee Valley Authority and the Mid-American Solar Energy Complex are developing designs that take advantage of local climatic conditions. KCC's Bethel House development is a good example of a design that is appropriate to local conditions; it and the other heat-retentive houses are less dependent on microclimate conditions than the solar designs.

Local demonstration projects have proven to be an effective means of disseminating technical information, since they give builders as well as buyers a chance to see that resource-efficient designs can work under local conditions. As in the Bethel case, some aspects of the demonstration design will be adopted by others in the same locality even though the entire design may not be. Arkansas framing, for example, is becoming common in the Midwest, due in part to the demonstration and publicity program of Owens/Corning. Similarly, more than 50 heat-retentive houses were privately constructed during 1978-79 in the Saskatoon area using principles developed and demonstrated at the Saskatchewan House.

As already noted, dissemination of solar greenhouse know-now and skills has been accomplished by a workshop process. In both design and construction workshops, the orientation is do-it-yourself and the information conveyed is very practical. However, as a means of transmitting technical information and expertise, the workshop approach is limited by a number of factors:

- The number of participants must be kept small (about 15 maximum for a construction workshop) to ensure safety and to give everyone a chance to participate.
- Management skills needed to organize, publicize, and supervise a workshop are considerable. If this effort were not voluntary, it might be cheaper to construct the greenhouse professionally.
- The programs do not always include follow-up, so the people participating in the workshop do not have continuing access to the expertise of those brought in to run the workshop.
- Only a limited number of people are interested in and prepared for undertaking solar greenhouse construction as a do-it-yourself or community project. Transfer of knowledge and skills to the private home-improvement sector may be necessary if these designs are to be adopted on a widespread basis.

In a few cases access to information or a technology is limited by proprietary interests, as with Norman Saunders' "solar staircase" roof. However, the ideas behind these systems are simple enough, and are discussed widely enough in the literature, that most architects and many builders should find no difficulty in producing similar designs of their own.

Financing

Skepticism regarding the workability, efficiency, and acceptability of passive solar homes often leads to problems in acquiring financing from local lenders, for owners and speculative builders alike. The Cooleys had difficulty obtaining a construction loan, and the Bethel House was possible only because KCC was willing to "loan" the funds needed for construction until the house could be sold. Obtaining a loan sometimes means that the lender just be educated or that the builder must accept design compromises, such as a conventional backup heating system that may increase building costs substantially and unnecessarily.

Single-family homes are financed primarily through local banks or savings and loan associations. There are some 23,000 lending institutions, so the task of educating lenders is considerable. The lenders tend to be risk-averse, and the appraisers who estimate sale values for them also tend to be conservative regarding the marketability of most innovations. These factors can pose a substantial barrier to the financing and diffusion of resource-efficient housing, and one housing developer notes that his first solar development "would never have happened if we had not been able to do the design, the financing, the land development, and the construction ourselves."[21]

Economic assessment of passive solar and heat-retentive houses is also difficult because their actual heating performance depends on uncertain and indeterminant factors such as weather, internal heat gains, and occupant behavior. Long-term *average* performance may be predictable, but potential owners and lenders are also concerned about day-to-day liveability. Similarly, the lifecycle analysis may be impressive, but lifecycle costing involves many uncertainties and is generally more important to society as a whole than to individual purchasers, lenders, or buyers.[22] The builder loses interest in the house when it is sold, the average purchaser moves within 5 years, and owners and lenders alike are more concerned about preserving equity and meeting monthly payments.

[21]Nichols, Op. cit., p. 706.

[22]M. A. Thayer, D. Brunton, and S. A. Nell, "Solar Economic Analysis: An Alternative Approach," Proceedings *of the 4th National Passive Solar* Conference, Kansas City, Me., Oct. 3-5, 1979, p. 241.

For the middle- and upper-income populations who are the major purchasers of new single family housing, energy costs of new conventional homes are a small part (10 to 15 percent) of the cost of home ownership. Thus, while low energy costs for passive and superinsulated homes have received attention and publicity, economic incentives may not be the only factor in decisions of current builders and purchasers. Noneconomic factors, such as achieving greater energy independence and security, concern about the environment, and the desire to innovate, also seem to play an important role.[23]

It is equally difficult to assess the economics of attached solar greenhouses. At least three potential benefits of this retrofit must be considered: added living space, food or flower production, and net heat energy production. Food production depends critically on the skills and attention of the gardener (see ch. 4), but limited analysis of the New Mexico greenhouses found construction costs in the range of $4 to $ 17/ft^2 and simple paybacks (in terms of heat and food production) of 4 to 8 years. In terms of heat production alone, the performance of the Hinesburg greenhouse, when extrapolated to 12 U.S. cities, shows a wide variation in fuel savings (see tables 3 and 4). This illustrates the difficulty of making generalizations about feasibility and points up the need for site-specific economic assessment, the lack of site-specific microclimate data (see above) may also be a barrier to commercial interest in solar greenhouse retrofits.

Institutional Factors

Other potential barriers to the diffusion and adoption of these resource-efficient housing technologies may arise from the patent system, the building industry, utility companies, and building and fire codes. Some of the designs, like the "solar staircase," are patented, although the owner of that patent allowed the Cooleys to use the design for a $15 fee if they would monitor its performance. David Bergmark of Solsearch Architects has indicated that low-energy house designers do not

[23]R. W. Gilmer, The *Social Control of* Energy: A *Case for the Promise of* Decentralized *Solar* Technology (Oakridge, Term.: Institute for EnergyAnalysis, March 1979).

always cooperate with one another in the exchange and improvement of concepts and designs.

Several of the designers have approached the builders of low-cost and tract housing about their designs, although with less success than in the Bethel case study. They attribute this lack of interest to the unfamiliarity of the technologies and the builders' aversion to risk.

A final barrier may arise from building and fire codes. In some of the case studies the local codes required electrical wiring installations that would reduce the depth of the insulation behind the outlet. Two owners wanted to install a Clivus Multrum comporting toilet, but code requirements forced them to build conventional septic tanks and drain fields. In other cases local codes forced the builders to enlarge the windows on the east, west, and north walls, or limited their use of glass panels on the roof. The double-envelope design raised concern because the free circulation of air around the structure might allow a fire to spread more rapidly. The designers believe they can remove this potential hazard by installing heat-activated dampers that will block air circulation in the event of fire.

Federal Policy

Background

Unlike some of the technologies studied in other chapters of this assessment, small-scale technologies for residential energy conservation enjoy widespread attention from the Federal Government. Congressional interest in solar and conservation programs can be found in a number of Acts, dating from 1973 to the present.

The Solar Energy Research, Development, and Demonstration Act of 1974 (Public Law 93-473) is the principal legislation authorizing broad-based solar energy research programs. The Solar Heating and Cooling Demonstration Act of 1974 (Public Law 93-409) calls for the commercial demonstration of solar heating and cooling systems; the Rural Development Act of 1972 (Public Law 92-419) authorizes a program of low-cost loans for energy-efficient retrofits and new housing; and the National Energy Act of 1978 (Public Law 95-618) provides purchaser tax credits for the home installation of solar devices as well as a loan program for solar devices through the Federal National Mortgage Association. Related legislation includes the Energy Policy and Conservation Act of 1975 (Public Law 94-163), which calls for the establishment of building energy efficiency standards and creates the Residential Conservation Service and Federal Energy Management Program. Other laws provide incentives to small businesses and farmers, encourage international programs, and mandate the use of solar equipment in military construction.[24]

In JuIy 1977, on the basis of these and other Acts, President Carter issued Executive Order No. 12003, setting forth energy performance standards for federally owned buildings. The order also calls for the development of a method for estimating and comparing the lifecycle capital and operating costs of Federal buildings, including residential.

Current Federal Programs for Residential Energy Conservation

The policies and programs mandated by existing legislation have been implemented by several Federal agencies in a large number of programs affecting resource-efficient architecture. The following discussion illustrates the scope and variety of these activities.

The Department of Energy (DOE), as the designated lead agency in these efforts, is involved not only in research, development, and demonstration programs, but also manages several different programs of technical assistance and information dissemination, as well as funding grants programs and providing much of the "pass through" funding for the programs of other Federal agencies. DOE is also responsible, under the Energy Conservation

2+ *Residential Energy* Conservation, op. cit., pp. 64-65.

and Production Act of 1976 (Public Law 94-385), for establishing and promulgating Building Energy Performance Standards (BEPS). The BEPS program has become the subject of some controversy, however, and the standards—which were to have been announced in August 1980 and included in State and local building codes by August 1981–have been delayed. Some of the objections to the BEPS program will be raised in the discussion of issues and options, below.

The residential energy-efficiency programs of the Department of Housing and Urban Development (HUD), like those of the Community Services Administration (see the section on Federal policy in ch. 4), emphasize self-help projects at the neighborhood level. One of HUD's major programs is its household counseling service, which provides conservation and other information through a network of 600 local community groups. Some of HUD's building energy-efficiency programs have been transferred to DOE, but one official at HUD's Office of Energy Conservation has suggested that technologies like those discussed in this chapter would fare better if DOE concentrated on R&D and HUD on financing and application. She points out that there is still some feeling at the Federal level that small-scale conservation technologies cannot have a large impact on the Nation's energy problems, and that the technologies might be adopted more rapidly if a greater portion of Federal funds went straight to the neighborhoods or if local groups were allowed a larger role in project planning.[25] In addition, around 400 VISTA volunteers are working on 90 energy-related projects nationwide, and an official says that VISTA hopes to raise the number to 1,000 volunteers in 1980.[26]

With pass-through funding from DOE, the U.S. Department of Agriculture (USDA) supports several research programs designed to promote the adoption and application of small-scale technologies. USDA, through the Farmers Home Administration (FmHA), also makes available low-cost loans for energy-efficient retrofits and new construction. USDA officials claim that their departments' energy standards for new rural housing are the strictest in the Federal Government, and in 1979 the FmHA loan programs provided for almost 175,000 new rural housing units. FmHA is also developing a "home energy indexing system" designed to "rate the energy efficiency of heating and cooling systems and construction features of specific house plans."[27] (Further discussion of the farm and rural energy programs of USDA will be found at the end of ch. 5.)

The Department of Defense (DOD), under its Energy Conservation Investment Program, has embarked on an ambitious program to retrofit existing military buildings (including residential) with solar energy systems and to include these systems in the designs of new buildings. The Military Construction Act of 1980 (Public Law 96-125) requires that DOD analyze all new family housing to determine whether solar designs would be cost effective, and, if so, to install or incorporate the systems. DOD is responsible for 400,000 housing units worldwide.

The Federal Home Loan Bank Board, the regulatory agency for the Nation's 4,400 savings and loan associations, is actively encouraging those associations to include energy-efficiency requirements in their home loan programs. There is no legislative mandate for these efforts, which the board has undertaken out of its concern for the national energy situation. In the past year it has conducted four workshops for local associations, providing technical and economic information on solar retrofits and solar systems for new housing and publicizing the different energy-efficiency standards that have already been adopted by *some* associations.

Issues and Options

The existing Federal programs for residential energy conservation, though extensive, have been variously criticized as misdirected, uncoordinated, or ineffective. The issues raised by these criticisms, as they relate to the technologies discussed in the case studies, fall into four related areas:

- program priorities and coordination;
- R&D;

[25] Gloria Cousar, Director, Office of Energy Conservation, HUD, personal communication, Aug. 15, 1980.
[26] Jack Colburn, VISTA, personal communication, August 1980.

[27] Donald L. Van Dyne, Policy Analyst, USDA, personal communication, and his presentation to the Northeast Agricultural Marketing Committee, Sturbridge, Mass., June 19, 1980.

- demonstration and information dissemination; and
- financing.

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A number of studies, including those presented in table 6, suggest that energy-efficient architecture can reduce residential heating loads by an order of magnitude and that energy-saving retrofits and new housing are cost effective against present energy prices. Other studies also suggest that improving the energy efficiency of buildings could represent the fastest and the cheapest means to reduce national energy consumption and U.S. dependence on imported fuels. An earlier OTA report concluded that "the potential for conservation before the end of the century dwarfs that of solar."[28]

Nevertheless, the impact of Federal activity on the development and application of passive solar and heat-retentive technologies in residential housing has been relatively limited to date. In large part, this lack of impact reflects a lack of emphasis on residential conservation in the existing energy programs of the Federal Government. Another OTA study suggests that:

> Because of the wide variety of programs influencing both housing and conservation, many mechanisms exist to affect energy consumption in homes . . . . [But] energy conservation has not been a major priority for most Federal programs, and there has not been strong coordination of the various departmental efforts. A stronger commitment to energy conservation, combined with improved technical work and more sophisticated cost analysis, could mean a much stronger response to conservation goals from both the public and private sector.[29]

As the lead agency, DOE, and especially its Conservation and Solar Energy (C&SE) Programs, have been the subject of particular criticism. OTA's critique of these programs included the following findings:

- C&SE lacks a clear vision of where it is going and how it will get there.
- DOE does not appear to have set priorities among the various programs in C&SE to ensure that the total resources are being apportioned to achieve the maximum benefit.
- C&SE needs to develop the capability to determine what it can accomplish for the country, to make sound policy and program decisions to reach these objectives, and to keep the programs moving steadily toward the goals in the face of pressures to alter course in ways not necessarily in the national interest.[30]

The study also found that:

- C&SE could improve its coordination with other Federal agencies, such as HUD, and other government levels (State, local, and foreign).
- Closer cooperation between solar and conservation programs is needed to formulate a least-cost buildings strategy for combining passive features, active systems, and conservation measures in the most economical way for different types of buildings and climates. Several important areas are underemphasized, including building retrofits.
- The Office of State and Local Programs needs increased technical capability and discretionary monies to properly encourage flexible and responsible efforts to meet local and State needs as well as national goals.[31]

Option 1-A: Review Federal Policy and Program Priorities.–Congress may wish to exercise its oversight powers to order a thorough review of Federal programs for residential energy conservation and/or to direct DOE to modify its priorities and programs to give greater emphasis to conservation measures, particularly those appropriate to low-cost retrofits and new low-income housing.

Congress has agreed to DOE's request for a 1-year delay in the promulgation of the BEPS conservation standards (see above), originally scheduled for August 1980. These standards are likely to

[28] *Conservation and Solar Energy Programs of the Department of Energy:* A Critique (Washington, D.C.: Office of Technology Assessment, U.S. Congress, June 1980), p. 14.
[29] *Residential Energy* Conservation, op. cit., p. 13.

[30] *Conservation and Solar Energy Programs of the Department of Energy:* A Critique, op. cit., pp. 3 and 13.
[31] Ibid., pp. 4, 5, and 32.

become the model for State and local building codes, and once established they will hasten the widespread application of the resource-efficient technologies discussed in this chapter.

Congress might also choose to investigate means of improving the programs of technical and financial assistance to State agencies and local organizations. The case studies suggest that locally based efforts are very successful in encouraging the adoption of these technologies.

Option 1-B: Redirect Federal R&D Efforts.–The case studies in this chapter and the studies cited in table 5 suggest that a variety of conservation measures can be taken at a reasonable cost, but much remains to be learned about the best combinations of features for different climates. OTA's *Critique* concluded that "DOE has paid insufficient attention to basic research directed at energy conservation and solar energy."[32] Similarly, OTA's *Residential Energy Conservation* found that:

> The short-term focus of current DOE conservation R&D ignores some longer term options that also have high returns . . . Research on attitudes, energy use patterns, institutional and legal barriers to conservation, and similar important areas have not received adequate emphasis. Research and policy decisions on energy technology do not adequately consider the conservation applications of new technologies, the potential of conservation to reduce demand and provide time for shifting to new energy systems is not fully appreciated. The policy appears to reflect an attitude by DOE and the Office of Management and Budget that conservation should be viewed as a stop gap that merits little Federal research funding, in sharp contrast to new production approaches.[33]

Congress may wish to direct DOE to reorganize its programs and redirect its residential energy R&D to reflect the findings of projects like those referred to above. In particular, there is a need to gather "social science" data on the attitudes and preference of home buyers and the effects of occupant behavior on the thermal performance of energy-efficient houses. This information would also be useful in determining the impact of resource-efficient design on the marketability and resale value of the houses to which these technologies have been applied.

Further R&D might also focus on the interaction of these technologies and the optimal combination of solar and heat-retentive features. Another area for further investigation is the cost of the conservation measures, particularly their lifecycle costs. An important technical area that has thus far been underemphasized is the potential benefit of energy-conserving retrofits for existing housing. Finally, because the application of these technologies is highly site specific, there is also a need for detailed microclimate information for different areas of the country.

ISSUE 2: Demonstration and information Dissemination.

Some demonstration projects have shown themselves to be very effective in increasing public awareness and interest in resource-efficient housing. The Cooley house has visitors almost every day, and when it was included on a local solar housing tour it had 450 visitors in a single day. Similar results were common in the other cases, and in the case of greenhouse retrofits a single demonstration house can lead to the adoption of this technology by a large number of families in the same community or region. The Federal Home Loan Bank Board's information program for lending institutions has also had a degree of success in disseminating information and changing attitudes about resource-efficient housing, as have some DOE efforts. DOE has three different information programs—the Energy Extension Service, the National Solar Heating and Cooling Information Center, and the Regional Solar Energy Centers—each located under a different deputy secretary and pursuing a separate mission. Some critics, however, have expressed concern that these programs are poorly thought out, poorly coordinated within DOE, and poorly coordinated with the efforts of other Federal information programs and the needs of State and local agencies.

Option 2: Establish a Central Clearinghouse.–Congress may wish to investigate the benefits of establishing a single office to gather and disseminate information on energy-efficient tech-

[32]Ibid., p. 26.
[33]*Residential Energy Conservation*, op. cit., p.13.

nologies for residential housing. Such a clearinghouse might also be given responsibility for developing a compendium of Federal programs for the use of State and local governments and for compiling handbooks of technical and microclimate data for local building contractors and owner-builders (see above). This information should include data on the design and cost of retrofits like the attached solar greenhouse. These goals might be achieved by expanding the National Solar Heating and Cooling Information Service, but a network of regional clearinghouses might also be effective.

ISSUE 3: .
Financing.

The case studies in this chapter represent only a tiny sample of the thousands of resource-efficient retrofits, additions, and new houses that have been built in the last 5 or 10 years. Like most of the case studies, the majority of these applications have been made privately by middle- and upper-income families, without Federal funds and often without a tax incentive.

To increase the rate of adoption, however, and to ensure the application of these technologies to Government-subsidized and private low-income housing, will require further efforts to reduce the risks involved for owners, builders, and lenders alike, whether private or public. The Federal Home Loan Bank Board's efforts in this area have been particularly effective, but a board official has said that the local savings and loan associations would prefer not to have formal regulation issued in this area, so that they may keep as much flexibility as possible in their programs. The newly created Solar Bank will provide subsidized loans, another useful new effort is an information and training program for real estate appraisers, whose familiarity with the technologies often influences the resale value and marketability of resource-efficient houses.

Option 3-A: Gather and Disseminate Cost Data.—The availability of reliable economic information, including detailed lifecycle costing, would do much to eliminate remaining uncertainties about these technologies. Congress might direct DOE to include the gathering and disseminating of such data among the priorities of its research and information programs (see above).

Option 3-B: Increased or Earmarked Funding.—Congress may wish to demonstrate its commitment to residential energy conservation by increasing the funding level of the programs and proposals discussed above, or by earmarking funds for these purposes in authorizations for other programs. Current funding has been called "woefully inadequate" to the potential savings that could be achieved through energy-saving retrofits and new housing. In view of these potential benefits, such funding represents a highly profitable social investment, and the investment might best be protected (and its benefits best achieved) through self-help and self-sufficiency programs like those of HUD and CSA. Through such programs, the funds cease to be a continuing subsidy and become instead a way to permanently reduce the energy needs of local households. Direct funding of neighborhood groups for workshops and other local self-help projects may prove to be far more cost effective than subsidies in achieving the Nation's residential energy goals.

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]

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.

[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.

[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/ft²/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 community 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

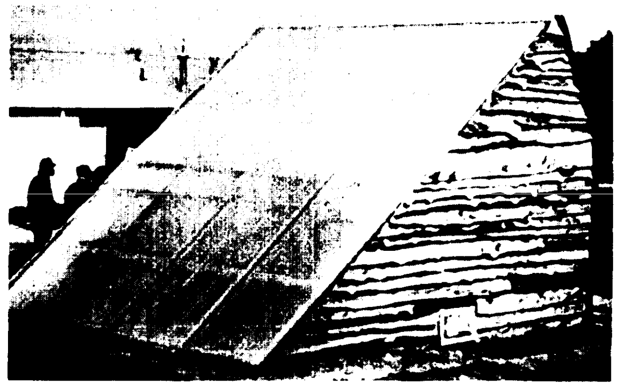


Photo credit: Office of Technology Assessment

Representative model of small freestanding greenhouse

deliver up to 33 percent more light to the plants during the winter.[3]

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

Photo credit: *Office of Technology Assessment*

Single row of water-filled 55-gal drums

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

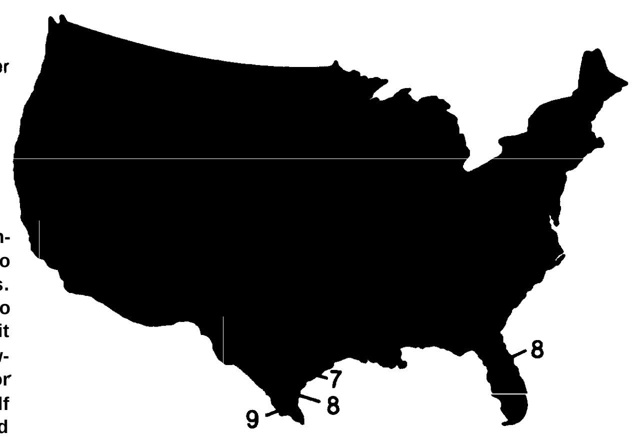
Zone 3 walls and roof, R-12
below ground, R-10 to 2 feet deep
heat storage, 3 gallons per square foot of floor

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.

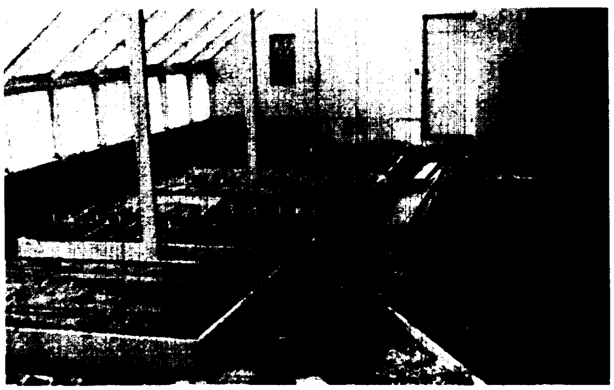


Photo credit: Office of Technology Assessment

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/ft^2/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 Con*ference 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

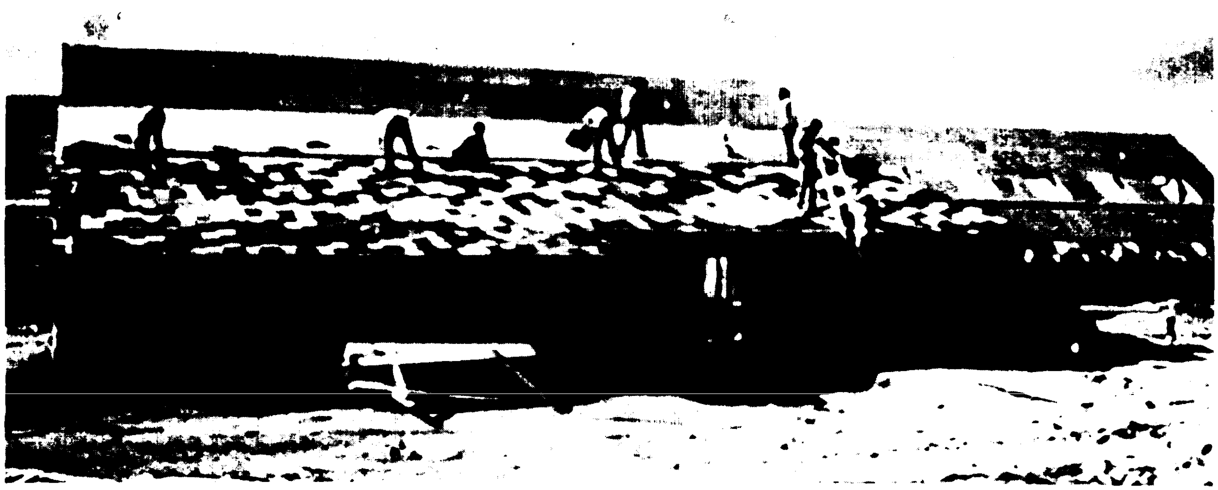


Photo credit: Office of Technology Assessment

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

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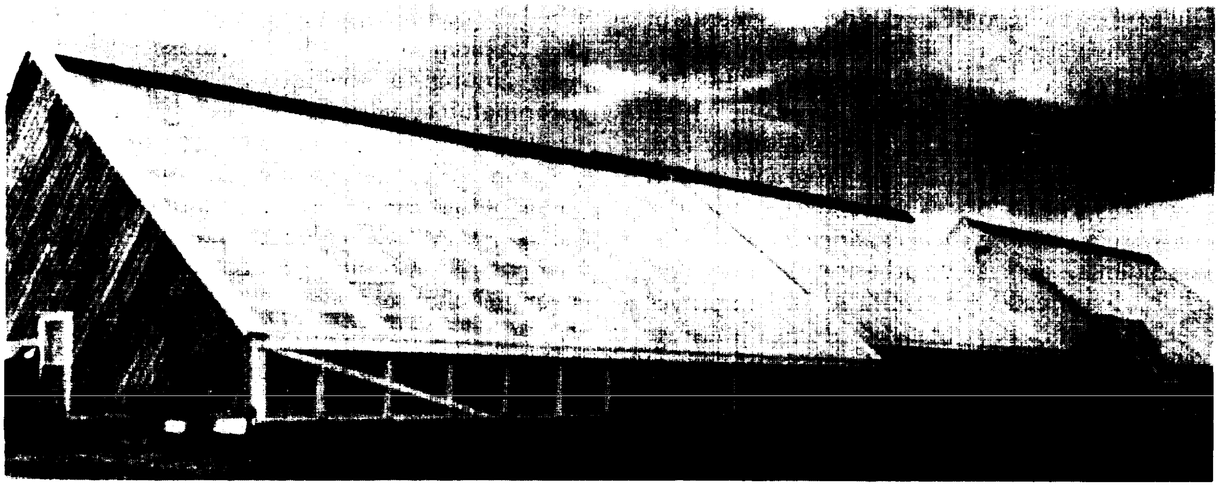


Photo credit: Office of Technology Assessment

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

Photo credit: Office of Technology Assessment

Community gardening plots help reduce family food costs

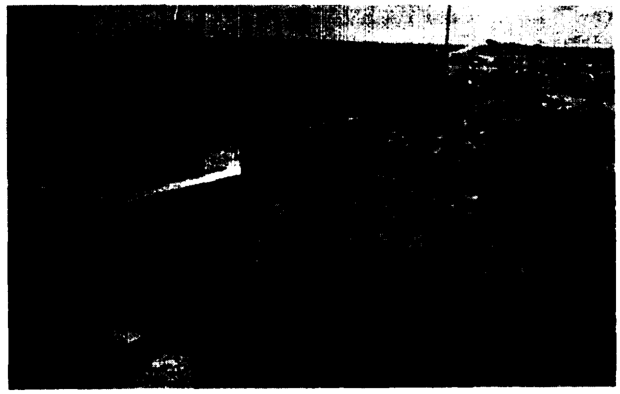
summer, with 50 percent of them going to low-income gardeners. Also located on the site are two solar food dryers, comporting bins, an adobe oven used for soil sterilization, and two small geodesic domes.

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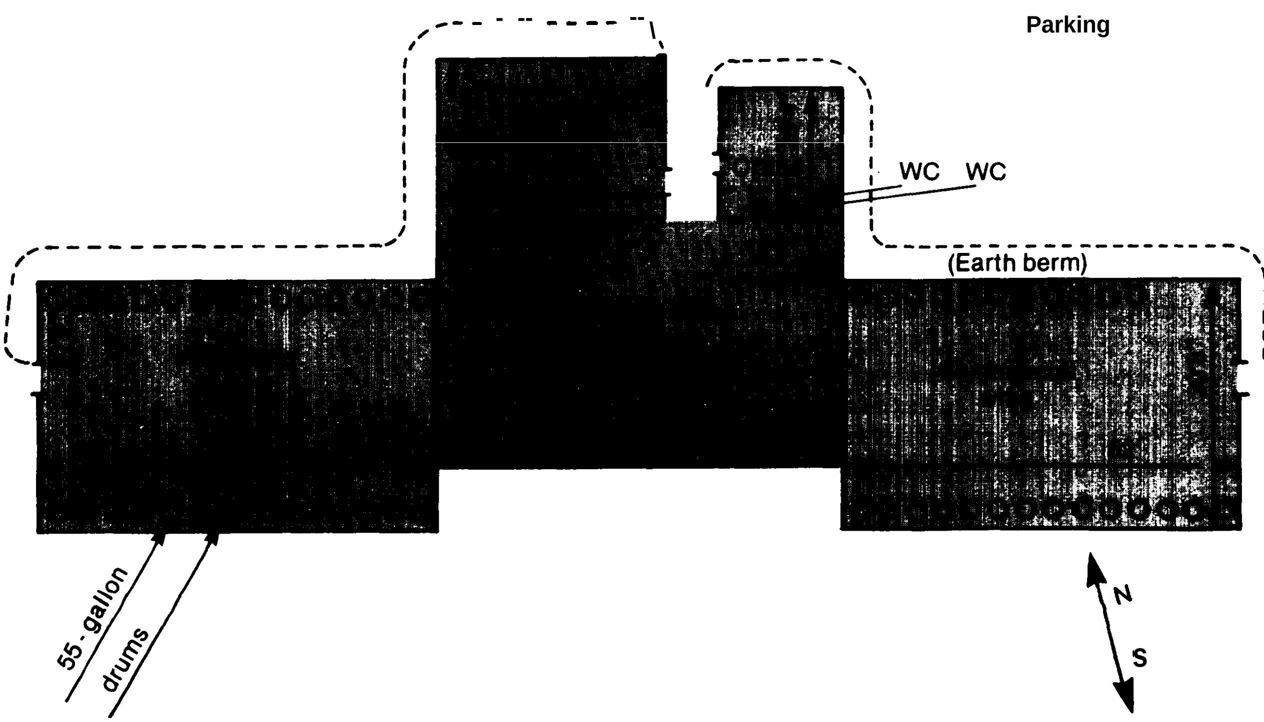
in a single row along the south kneewall and two or three high in a single row along the north wall. Each drum stores about 450,000 Btu/yr; the total heat storage capacity of the greenhouse is estimated to be almost 1 million Btu/yr. Backup heat is provided by two wood-burning stoves that were

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 graywater 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:

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

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.

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

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.

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-

[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.

‘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]

[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.

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-

[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.

[25] Paul Sleusner, U.S. Department of Agriculture, personal communication.

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

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.

Chapter 5

Small Farm Systems

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CHAPTER 5
Small Farm Systems

Introduction

The last chapter dealt with solar greenhouse technology as an alternative for family and community food production. This chapter and the next will deal with small-scale alternatives to large-scale, energy-intensive agricultural technologies—this chapter with systems by which the small farmer can reduce his energy costs and increase the self-sufficiency of his food-producing operations, and chapter 6 with the local farmers' market as a way for the small farmer to increase his profits by selling directly to the consumer.

Few trends since World War II have been more thoroughly documented—or more generally lamented—than the decline of the small family farm. A number of economic factors have contributed to this trend. The rapidly increasing cost of farmland (amortization and interest) has been the most important of these factors, because it makes farming more capital intensive and thereby encourages large-scale ownership. Rising energy costs and general inflation over the last decade have also made small-scale farming increasingly precarious. The three major costs (other than land) associated with farming are feed for livestock, fertilizer for the soil, and energy to run farm machinery and heat buildings. Rising petroleum prices affect the first factor indirectly and the last two directly; the combination has had a drastic impact on the economic viability of the small farm. Some larger farmers, with more assets to borrow against, have been in a better position to ride out the current cost-price squeeze; corporate growers in some cases have been able to balance increased costs with increased profits from other sectors of the food industry, such as processing, packaging, and distribution.

Small farmers have not had these options, and many of them, especially on the fringes of expanding urban centers, have felt compelled to sell their land to developers. According to the Soil Conservation Service of the U.S. Department of Agriculture (USDA), about 24 million acres of rural land were converted to housing developments, reservoirs, or highways between 1967 and 1975—an area about the size of the State of Indiana.[1] About half of this land was either active cropland or high-quality rural land that could have been turned into productive cropland with a relatively small investment. Recent figures suggest that rural land continues to be converted to these same uses at a rate of about 1 million acres per year.[2] No figures are available on how much of this acreage has come from small-scale farms, but the small farmer, who generally has been most vulnerable, has had the greatest economic incentive to give up his land.

Two ways to improve the viability of the small family farm would be to develop local markets where the small farmer can get a higher return on his produce (see ch. 6) and to develop local, low-cost sources of energy, fertilizer, and livestock feed. This chapter discusses two such attempts to reduce energy costs and increase the self-sufficiency of the small farm. The first is the New Life Farm, a research and educational center in the Ozark Mountains near Drury, Me., which is developing alternative energy sources and energy-conserving farming techniques. The second is the Small Farm Energy Project in Cedar County, Nebr., a 3-year research and demonstration program that is intended to show the impact of proven alternative energy technologies and conservation techniques upon the energy consumption and production costs of small-scale, low-income farmers.

[1] Jefferey Zinn, "Farmland Protection Legislation," Library of Congress issue brief No. IB7801, May 29, 1980, p. 1.

[2] Julian L. Simon, "Resources, Population, Environment: An Oversupply of Bad News," *Science*, vol. 208, No. 4451, June 27, 1980, p. 1435.

Alternative Energy Technologies (I)– Energy From Biomass

A recent OTA report on the energy potential of biomass concluded that:

> Energy from the conversion of wood and other plant matter represents an important underexploited resource in the United States. As renewable, abundant, and domestic resources, these and other sources of biomass can help the United States reduce its dependence on imported oil. The amount of energy supplied by biomass, now relatively small, could expand rapidly in the next two decades–a period when the Nation's energy problems will be particularly acute.[3]

Biomass currently produces about 1.5 Quads[4] per year, or about 2 percent of the U.S. 1979 energy consumption of 79.7 Quads/yr, primarily from the direct combustion of wood in the forest products industry and, to a lesser degree, in home heating.

By the year *2000,* between 6 and 17 Quads/yr could be produced from biomass sources, depending on a number of factors including how much cropland is used for food productions This represents between 8 and 22 percent of current domestic consumption, by comparison, imported oil and natural gas supplied about 23 percent of U.S. energy consumption in 1979. Assuming that U.S. consumption rises to 100 Quads/yr by 2000, energy from biomass could make a significant contribution to the administration's goal of 20 percent solar and renewable sources for that year.

Figure 15 shows the six major sources of biomass energy and their relative contributions to the high and low estimates of potential bioenergy supplies. (Energy from municipal solid waste, another potentially significant source, is discussed in ch. 7.) The three major processes for converting these sources into usable forms of energy are: 1) direct combustion and gasification; 2) distillation into alcohol; and 3) anaerobic digestion to produce biogas.

Direct combustion of wood is the most widespread application of bioenergy today, with between 1.2 and 1.3 Quads/yr used for process energy in the forest products industry and another 0.2 to 0.4 Quad/yr used in home heating and fireplaces. These uses are likely to expand considerably in response to rising energy prices, even without new Government incentives. *Gasification* of wood and herbage (i.e., grass and crop residues) could be more practical than direct combustion for supplying process heat, particularly in industrial applications. The widespread adoption of this technology could depend on the development of reliable, mass-produced gasifiers that could be attached to gas- or oil-fired boilers. Both gasification and direct combustion could compete with other uses of forest products, however, and would compete with coal in many industrial applications.

Alcohol *fuels* can be produced from a wide variety of biomass feedstocks, and they are the only renewable source of liquid fuels for transportation that uses available technology.[6] *Ethanol* (grain alcohol) is already being produced from grains and sugar crops as an octane-boosting additive to gasoline. About 50 million gal of fuel ethanol were distilled in 1979, and installed capacity may be as high as 200 million gal by the end of 1980; but with domestic gasoline consumption at 110 billion gal/yr, ethanol is a small addition to current U.S. fuel needs.[7] Production could reach 10 billion gal/yr (enough to blend 100 billion gal of gasohol) by 2000, but production of more than 1 billion or 2 billion gal/yr could put ethanol in competition with other uses of grain and have serious inflationary impacts on the price of food and animal feed.[8] *Methanol* (wood alcohol) can be produced from grasses and crop residues as well as from wood; no large-scale production facilities currently

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[3] *Energy From Biological Processes* (Washington, D. C.: Office of Technology Assessment, U.S. Congress, July 1980), OTA-E-125, p. 3.

[4] A Quad equals 1 quadrillion (10^{15}) Btu. This is approximately equal to the energy of 10 million bbl of crude oil, 50 million tons of coal, or the typical annual output of eighteen 1,000-MW electrical powerplants.

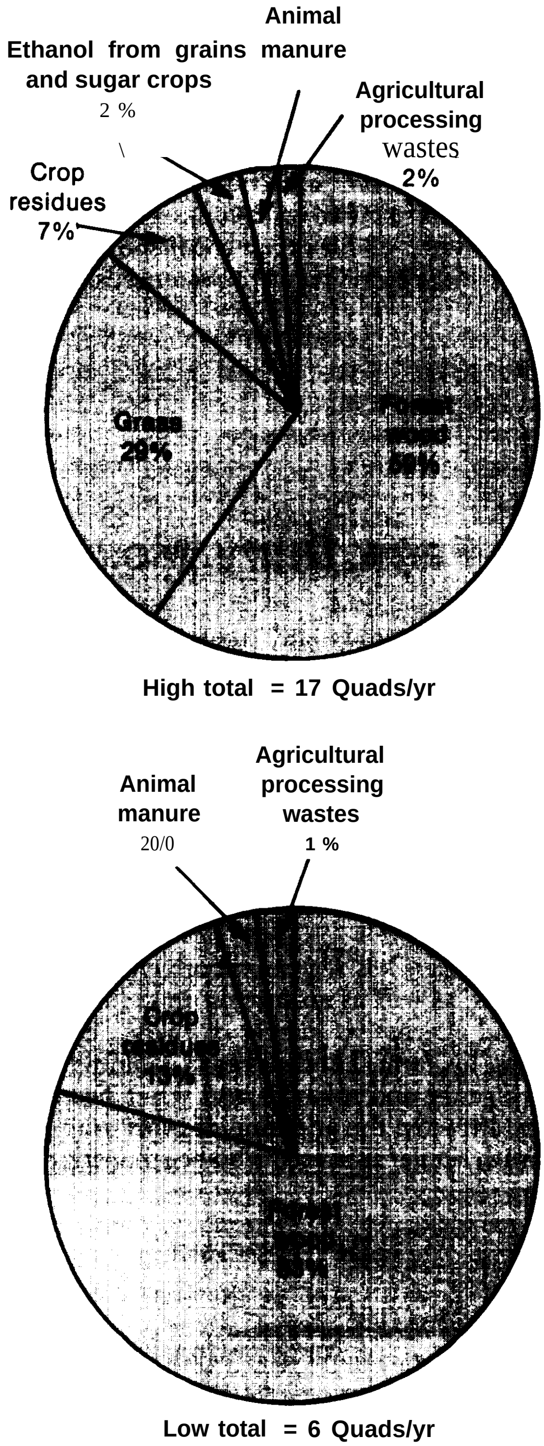
[5] *Energy From Biological Processes,* op. cit., PP. 23-24.

[6] Ibid., p. 6; see also OTA's technical memorandum, *Gasohol* (Washington, D.C.: Office of Technology Assessment, U.S. Congress, September 1979), OTA-TM-E-1.

[7] *Energy From* Biological Processes, p. 87.

[8] Ibid., p. 100.

Figure 15.—Potential Bioenergy Supplies (not including speculative sources or municipal wastes)

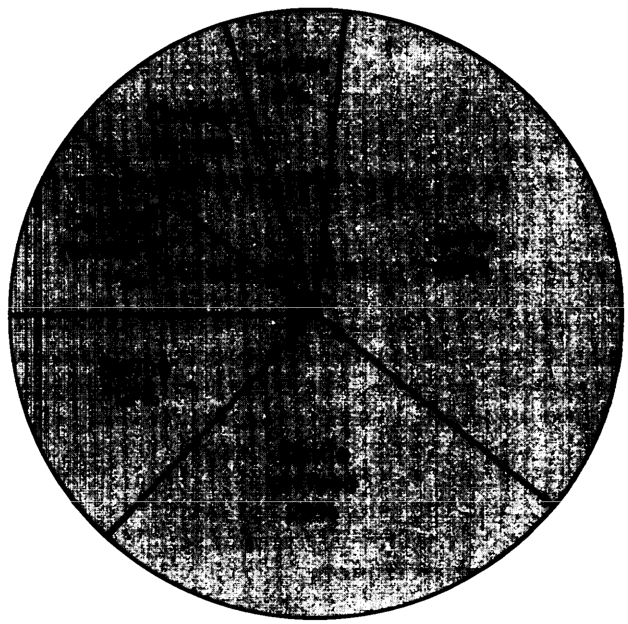


SOURCE: Office of Technology Assessment.

exist, however, and it is also estimated that methanol can be produced from coal at about half the cost of biomass conversion.[9]

Anaerobic *digestion* of biomass produces biogas, a burnable mixture of about 60 percent methane and 40 percent carbon dioxide. Potential feedstocks include municipal sewage and solid organic wastes, certain grasses and aquatic plants, and animal manure. OTA estimates the energy potential of manure alone at 0.2 to 0.3 Quad/yr (see figure 16).[10] Anaerobic digestion of manure is also

Figure 16.—Types of Animal Manure From Confined Animal Operation



Total energy potential = 0.2 -0.3 Quad/yr

SOURCE: Office of Technology Assessment from K. Smith, et al., "Animal Wastes," contractor report to OTA, March 1979.

an efficient waste treatment process whose byproducts can be used as a soil conditioner or dewatered for use as animal bedding, and may have potential as a high-protein feed supplement. In addition, the manure/biogas fuel cycle does not compete with the production of other commodities; instead, it makes use of an existing, underexploited resource without destroying its value for other uses.[11]

[9] Ibid., p. 103, table 9.
[10] Ibid., p. 123.
[11] Ibid., p. 12.

This biomass fuel cycle is best suited to small-scale exploitation because of the dispersed nature of the resource base:

> About 75 percent of the manure resource is on animal operations of 1,000 head of cattle or less (or the equivalent for other animals such as swine, turkeys, chickens, and dairy cows), and 50 percent is on operations one-tenth this size or smaller. Only 15 percent of the manure resource occurs on large feedlots of the equivalent of more than 10,000 head of cattle. Because manure cannot be economically transported for long distances, exploiting the manure resource will require digester designs suitable for relatively small animal operations. Important features of these digesters will be automatic operation and low installation cost.[12]

[12] Ibid., p. 127.

In short, anaerobic digestion of animal wastes is a technology whose resource base makes it particularly appropriate for small-scale onfarm applications. There is still a need to develop and demonstrate a variety of digester designs in order to improve their flexibility and reliability, reduce their capital costs, determine the biogas yield and effluent characteristics of different feedstocks, and explore alternative applications for both biogas and byproducts. The following case study examines the efforts of one group of Missouri farmers to develop digesters suitable to their needs.

A Case Study of the New Life Farm, Drury, Mo.[13]

The Community Setting

The Ozark region of southwestern Missouri is sparsely populated and affords a poor living for most of its residents. The hills have been heavily logged or cleared for fields and pastures, and much of the land is badly eroded, leaving few acres of good farmland. A large portion of the land is used for hog- and cattle-raising, but even these operations are only marginally profitable. Overgrazing has led to further erosion.

The traditional small farmers in the area are conservative and tend to distrust outsiders. They feel cut off from their fellow Missourians to the north, who tend to own larger and more productive dairy and hog farms, and often joke about seceding from Missouri and joining Arkansas. They are particularly distrustful of State and Federal officials and feel that they are being shortchanged by the various farm assistance programs in the area.

The New Life Farmers, by contrast, are by and large young and college-educated. Many are from urban backgrounds and came to the Ozarks as part of the "back to the land" movement in the late 1960's. Few of them joined communes, however; for the most part, they came alone or with their families to set up farms. They were interested in self-reliance and living in harmony with nature, but many had little experience with rural living or farming techniques.

[13] Much of the material in this case study is based on a working paper, "New Life Farm, Drury, Missouri," prepared by Michael Fischer and Michael Swack for the Harvard Workshop on Appropriate Technology for Community Development, Department of City and Regional Planning, Harvard University, May 15, 1979.

One of these young farmers was Ted Landers, who purchased a 240-acre farm near Drury in 1972. Landers has degrees in both engineering and business, as well as an interest in organic gardening and alternative sources of energy. Soon after buying his farm, Landers began building a methane digester and solar air and water heaters. His work attracted the attention of other young farmers with similar interests, who began working with him.

Development

After several years, as the young farmers became more experienced, many of them wanted to share what they had learned with others who had similar interests. Some of them also wanted a chance to use their skills in research and community organizing without having to take conventional, full-time jobs. They set about organizing

Photo credit: New Life Farm

New Life Farm, Drury, Mo.

New Life Farm (NLF) as a community institution with a number of goals:

- pursuing R&D techniques that could be used by local farmers to improve the productivity of their land while maintaining the natural balance of the ecosystem;
- acting as an educational center for training in these technologies and assistance in implementing them;
- providing periodic employment for laborers, researchers, and managers from the community; and
- serving as a focal point for community services like day-care and for activities such as theater groups and crafts collectives.

NLF was incorporated in the spring of 1978 as a tax-exempt, nonprofit educational and research organization. Its bylaws require members to contribute 6 days of work on the farm each quarter, and those who have done so for three of the last four quarters may run for the board of directors and vote on project decisions and changes in the bylaws. There were 40 members in November 1979, and members have served on the county Soil and Water Board and local University Extension Service advisory panel. One member teaches at the local university, and another has run for public office at the State level.

NLF has four major projects currently underway, two of which involve the development of methane or biogas digesters.[14] These devices consist of sealed tanks which are loaded with manure, grass, or other crop wastes; the organic material decomposes into a high-quality liquid fertilizer and a burnable gas that can be used in place of propane or natural gas for heating and cooking. The "Rural Gasification Project," funded bya$155,000 grant from the Community Services Administration (CSA), will design and build 20 such digesters, 4 in each of five regions across the country, for low-income farmers who will pay 10 percent of the cost. NLF is also involved in a joint research effort with University of Missouri faculty at Rolla to test and evaluate the performance of a large batch-loaded phytomass (or plant material) digester under a variety of circumstances. This project, funded by a 3-year, $230,000 grant from the Department of Energy (DOE), will try to determine what type of crops produce what types of gas and

14 Descriptions of these projects are based on various New Life Farm brochures and discussions with members.

fertilizer, as well as how the application of the fertilizer affects crop productivity over the long term.

Another project is the "Why Flush? Water Quality Conservation Project," which is funded primarily by the Rockefeller Foundation.[15] It is designed to educate the public on alternatives to current methods of handling sewage, with particular attention to onsite treatment systems such as comporting toilets. NLF's fourth project is "Solar Heating Made Easy," a joint effort with Southwest Missouri State University, which is funded by the U.S. Office of Education's Community Service and Continuing Education program. The project runs 2-day workshops throughout the State, during which a class of about 10 trainees is shown by NLF members how to install a simple, low-cost solar space or water heater in the home. (See chs. 3 and 4 for discussions of the workshop approach.)

The New Life Farm Systems of Technologies[16]

One of the unique features of the NLF approach is the way in which the technologies will be integrated into larger systems. Each technology becomes a component in a cyclic process whereby the byproducts of one stage (energy and/or materials) become the inputs for the next stage. Although some waste is inevitable, a well-designed cycle needs very few inputs of energy or materials from outside the system and produces very little waste that is not reclaimed. Conventional technologies, by contrast, can consume many external inputs and discard large volumes of wastes as solids, sewage, or air pollution. The NLF approach is intended to be less costly and gentler on the environment.

The NLF biogas project, which was selected for study in this report, illustrates how technologies can be integrated into a cyclical system. It combines alternative farming methods, fertilizer production, waste disposal, and energy production into a unified system designed not only for the needs of the small farmer but also for the ecology of the region.

The geology of the Ozarks, with a thin topsoil over a porous limestone base makes surface waste disposal difficult and possibly hazardous to health. Manure and sewage, which may still contain pathogens (disease-causing micro-organisms), and chemical fertilizers can pass quickly through the limestone without adequate elimination of pollutants, making groundwater pollution a potentially serious problem. The thin topsoil produces poor pasturage, and over the years the steady clearing and overgrazing of the hilly land has led to massive erosion. Soil quality has been further impaired because many farmers do not fertilize their fields due to the high cost of fertilizers. Finally, the region lacks indigenous fossil fuel resources, and the cost of importing energy (mostly propane and electricity) is very high, as a result, energy costs have become an increasingly significant percentage of the farmer's budget.

The biogas system addresses all of these problems simultaneously. The system begins with tree cropping. NLF grows a variety of honey locust trees, whose pods are high in protein and carbohydrates and can be used as animal feed. The trees produce four times the nutrients per acre that would be produced by oats, and their roots help to anchor the topsoil and prevent erosion. The grass growing beneath the locusts is no longer overgrazed and can be gathered in controlled harvests and fed into the digester, along with animal manure.

These organic materials are mixed with water in the digester to form a slurry that is about 10 percent wastes by weight. The slurry can be fed to the digester either continuously (adding a little fresh material each day) or in batches (reloading with a fresh slurry every 30 to 60 days), depending on the type of materials and the convenience to the farmer. The slurry is pumped into a sealed tank where it decomposes through the action of anaerobic microbes—bacteria and fungi that feed and reproduce rapidly in the absence of oxygen. One byproduct of this anaerobic decomposition is biogas, which is composed of about 60 percent methane

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[15] The project has received a $3,750 grant from the Rockefeller Foundation and $500 from the National Demonstration Water Project.

[16] Information on these technologies was supplied by Ted Landers of New Life Farm, but performance projections are based on limited data. For example, the quality and quantity of gas and sludge produced from different materials under different conditions is the subject of considerable debate. Landers claims that his estimates are conservative and is trying to confirm them through controlled experiments, but a great deal of research remains to be done.

(the main component of conventional natural gas) and 40 percent carbon dioxide, with traces of hydrogen, hydrogen sulfide, and nitrogen. The other byproduct is a sludge that is high in carbon and nitrogen compounds and makes an excellent substitute for conventional chemical fertilizers. Using this sludge, the topsoil can be enriched and built up over time with less danger of ground water pollution than is posed by either manure or chemical fertilizers.

Some controversy exists as to whether or not anaerobically digested nutrients exist in compounds that are more likely to remain in the topsoil than the compounds in chemical fertilizers. However, it does seem clear that anaerobic digestion (which takes place at temperatures of 950 F over a period of up to 60 days) succeeds in killing most of the pathogens present in manure. Thus, to the extent that sludge instead of raw manure is applied to the soil, some improvement in ground water quality should result.

One of the main goals of NLF research on biogas digesters is to gain a more precise understanding of the nutrient content of sludge, how it varies with the mix of materials being digested, and how these nutrients are made available to plants. The goal of NLF's development efforts is to build and demonstrate digesters that can be built easily by farmers, perhaps with some hired labor for specialized tasks, in a reasonably short time and at a low cost. These goals are combined in NLF's two biogas digester projects: the Rural Gasification Project (RGP), which is developing manure digesters; and the joint phytomass project, which is developing digesters for crop residues and other plant wastes.

NLF Methane Digester Design and Performance

NLF has built five small-scale, continuous-loading hog manure digesters for RGP and is designing a sixth. These digesters represent three prototype configurations, with slight variations in size and input mix, but are based on a common design (see figure 17). The digester is an insulated tank divided into upper and lower sections connected by a surge tube. A submersible sump pump in the loading pit moves slurry into the bottom or "active" section. The amount of slurry in the lower section, called the "active volume," is the usual measure of a digester's capacity; NLF's manure digesters ranged from 300 to 500 cubic feet (ft^3). The slurry is heated to optimal temperature by a hot water pipe or a coil gas heater like that in a hot water heater. As decomposition begins and biogas pressure increases in the active section, some of the slurry is forced into the upper or "surge" section. Biogas collects at the top of the active section and can be drawn off through a gas line to the household appliances or other uses (see below). Sludge is removed periodically through a discharge tube in the bottom of the active section and replaced with fresh slurry to maintain a fairly stable level of decomposition and biogas output.

Most biomass will produce 1 ft^3 of biogas per day for each cubic foot active volume of slurry, although some manure slurries will produce twice this yield. NLF feels that the latter estimate is true for hog manure, and the yield from their RGP-3 digester compares favorably with yields reported by other experimenters, shown in table 11. A 300-ft^3 digester like the RGP-3 would require input manure of approximately 180 1b/day, the daily wastes of about 120 hogs.[17] Table 12 itemizes the costs and potential energy savings of three RGP manure digesters. A digester of this size could easily supply all of the gas needed for cooking, water heating, and maintaining digester temperature on a small farm.

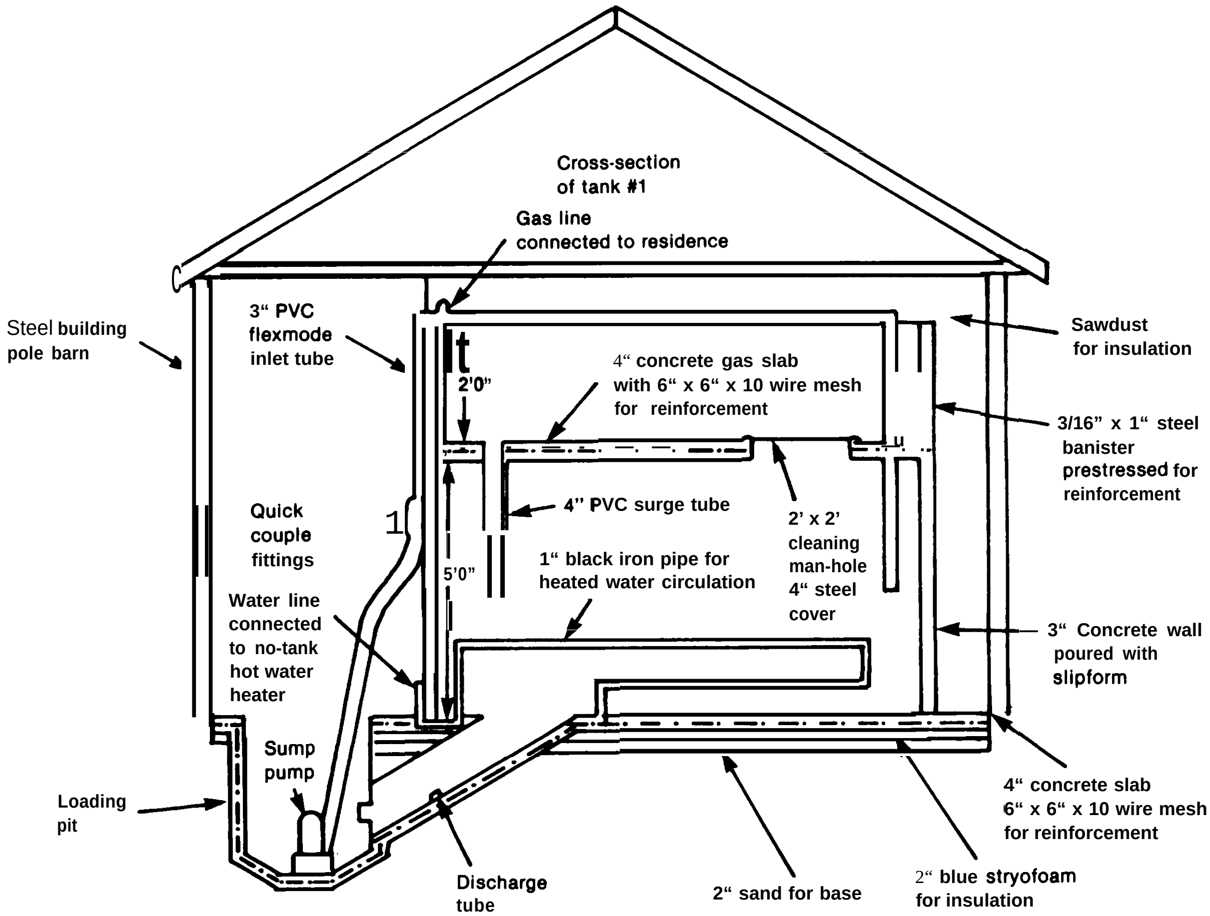
The NLF phytomass digester consists of four batch-loading reactors of 4,000-gal capacity each, which can be operated either in parallel or in series; this modular design gives the digester more flexibility in operation. The four reactors have a total active volume of 2,000 ft^3, which could yield 2,000 ft^3 of biogas per day. These units have not been operated extensively enough to provide reliable data, however, and the proposal submitted to DOE indicated that the facility would operate at a combined rate of only 1,210 ft^3/day.[18]

Initial test results with orchard grass cuttings show that a 5-percent slurry has an average daily biogas output of 200 ft^3 per reactor over the first 30

[17] Richard Merrill, "Methane Generation," in Energy Primer, ed. the Portola Institute (Palo Alto, Calif.: New Alchemy West, 1974), p. 143; the figure for steers seems rather low.

[18] James E. Gaddy, "Energy From Farm Crops," research proposal submitted to DOE, 1977; the author is a professor at Missouri State University, Rolla, and principal investigator in the NLF phytomass digester project.

Figure 17.—New Life Farm/RGP Biogas Plant #1



SOURCE: New Life Farm.

Table 11 .—Daily Yields From Several Biogas Digester Designs (ft^3 biogas per ft^3 active volume per day)

Builder/designer	Waste type[a]	Daily yield[b]
Chinese peasants	Unknown	0.67-0.83
Indian peasants	Unknown	1.25
Dr. William Jewell of Cornell University for DOE	Cow manure	2.50
Ken Smith of the Ecotope Group for DOE and State of Washington	Cow manure	1.67-6.67
Energy Harvest, Inc.	Cow manure	4.17
New Life Farm:		
RGP #3	Hog manure	0.60-2.40
Phytomass	Orchard grass	0.80 (estimate)

aAssumes 10-percent slurry by weight.
bAssumes biogas at 60 percent methane.

SOURCES: Ted Landers of New Life Farm and Lee Johnson, "Neighborhood Energy: Designing Democracy in the 1980' s," *Stepping Stones: Appropriate Technology and Beyond,* Lane de Moll and Gig Coe (eds.), (New York: Schocken, 1978), p. 183, table 5.

days. It is assumed that increasing the slurry to 10 percent phytomass would double the output to 400 ft^3/day per reactor. This yield of 0.8 ft^3/ft^3/day is about half the yield of manure digesters (see table 11). The four reactors, loaded in sequence at the optimal interval, should produce a reliable 1,000 ft^3/day of biogas. Figure 18 shows three measures of the phytomass digester's performance.

It is estimated that full-scale operation of the NLF phytomass facility would require inputs of 44 tons of dried plant wastes annually. This would amount to 17 acres of cornstalks or pasture grasses, or a little less than 33 acres of weeds or uncultivated grasses.[19] The same initial tests with orchard grass shows that the sludge from the digester

[19] Ibid.; and L. John Fry, "Practical Building of Methane Power Plants."

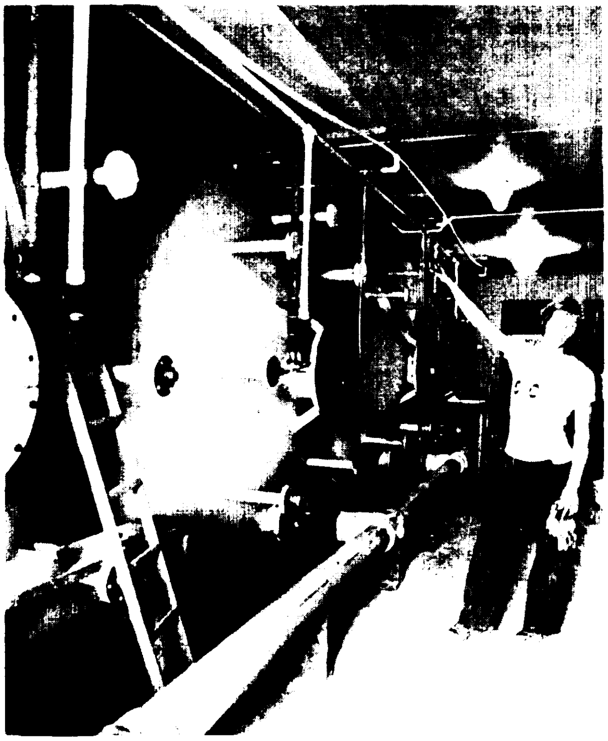


Photo credit: ***New Life Farm***

Methane digester tanks

would return significant amounts of nutrients to the soil. Table 13 presents the nutrient content of the sludge and the annual production of each nutrient by the NLF phytomass digester. Tables 14 and 15 present a cost/benefit analysis of the phy - tomass system, based on the present size and on double that capacity; note that the process shows some economies of scale.

Biogas Applications and Economics

The energy uses to which biogas might be applied vary considerably from season to season, while biogas production would be relatively constant year-round. Consequently, biogas must either be used to meet those energy loads which are more or less stable or somehow be stored for use in times of excess demand. Otherwise, the surplus energy of the gas would be wasted instead of used to offset the cost of the system. This is an important consideration in determining the most economical scale for a given farm: digesters large enough to supply winter space-heating needs (about 380 ft^3/day output) would produce a large amount of surplus gas in the summer, whereas the applications that are constant from day to day, such as hot water heating and cooking, demand relatively small amounts of gas (about 100 ft^3/ day).[20]

As it turns out, however, this innovative technology shows conventional economies of scale: large volumes of gas can be produced more cheaply than smaller volumes. Larger digesters would thus provide greater energy savings, and a better return on investment, if they could be applied to larger loads or their output somehow stored for later use.

[20]Consumption figures from Dawson, 1975.

Table 12.—Technical and Economic Data for Three RGP Digesters

Item	Digester #1	Digester #4	Digester #5
Active volume	**300 ft^3**	**400 ft^3**	**500 ft^3**
Tank construction	**Slip form concrete**	**Plastic**	**Plastic**
Materials cost	**$1,885**	**$2,000**	**$1,500**
Labor cost	**$1,885**	**$1,000**	$1,000
Levelized capital costs[a]	$480	$382	$318
Annual yield (50% utilization)	31.04 MMBtu	41.39 MMBtu	51.74 MMBtu
Levelized energy savings[a]	$604	$815	$1,015
Net savings	$124	$433	$697
Cost/MMBtu	$15.46	$9.23	$6.15
Cost/MMBtu (100% utilization)	$7.73	$4.61	$3.08
1980 cost of LPG/MMBtu	$6.49	$6.49	$6.49

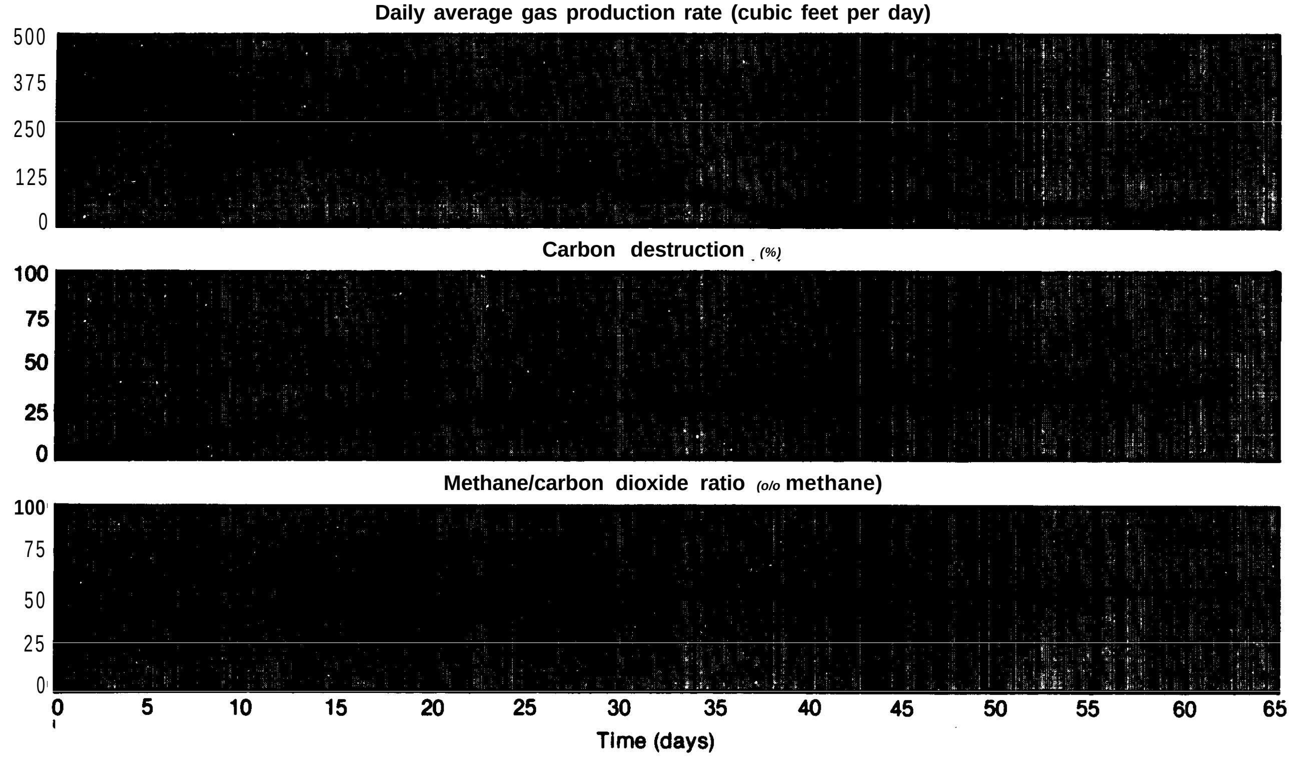
[a]Uses lifecycle costing methods presented in OTA's *Application Of solar Technology to Today's Energy Needs,* vol. II. Tax deductions, O&M expenditures, biomass costs, and replacement costs have been omitted. The following assumptions were applied:
Capital charges on a 10-year loan= 15%
Consumer discount rate =6% (current savings interest)
Life of system= 20 years
Initial cost of LPG = 60¢/gal
Inflation = 6%
Fuel escalation (above inflation) = 5%

SOURCE: New Life Farm.

Figure 18.—NLF Phytomass Digester Reactor Operating Performance

Reactor 4
Agricultural residue—orchard grass
Startup date Nov. 21,1979

Batch size–3,600 (gallons)
Percent Residue 5.5(%)
Culture/residue ratio 4:1



SOURCE: New Life Farm.

Table 13.—Nutrlent Content and Output of NLF Phytomass Digester

Nutrient	Percent of sludge	Annual yield (lb)[a]
Nitrogen.	3.3	825
Phosphorus.	1.2	300
Potassium	0.7	175
Sulfur	0.6	150
Sodium.	0.3	75
Magnesium	0.5	125
Calcium	13.2	3,300
Manganese	0.06	15
Zinc.	0.06	15
Iron	0.6	150

aTotal sludge = 25,000 lb/yr.

SOURCE: Office of Technology Assessment.

The conventional method for storing gas is to compress it and keep large volumes in a small space under high pressure. The NLF designers, however, generally oppose this approach: it would require a significant amount of gasoline or electricity to run the compressors, and the pressurized gas itself is highly explosive. Instead of storing the gas, they intend to use it to produce other forms of energy (such as electricity or alcohol) that can be stored more easily or for which there is a stable year-round demand.

Surplus gas from the 2,000-ft^3 NLF phytomass digester, for example, could be used as feed gas for

Table 14.—Capital Costs for Two Farm Digester Systems"

	NLF Phytomass (4 modules; 2,000 ft³)	Projected (8modules; 4,000 ft³)
Steel tanks, 4,000 gal minimum .	$2,660	$4,080
6-kW generators with engine, 120 VAC, 60 herz.	1,250	1,250
Gas storage tank with concrete pit.	700	900
Forage chopper with blower.	1,000	1,000
Building materials	1,460	2,080
Heater.	300	400
Sludge pump, 10 gal/min.	200	200
Piping, agitators, valves, miscellaneous	1,000	1,300
Labor[b]	500	700
Totals	$9,070	$11,910

aEstimates are presented for two digester sizes in order to demonstrate economies of scale. Modular reactors are batch-loaded in sequence in order to maintain relatively constant total yield. Note that these figures include costs for electric generators. Prices are in 1978 dollars.
bDoes not include cost of farmers' labor, only that of specialized help such as welders.

SOURCE: New Life Farm.

Table 15.—Energy Cost From Farm Digester

Size (ft³ active volume).	730	1,460
Yield (MMBtu/yr).	267	534
Capital cost.	$9,070	$11,910
Annual operating costs		
Biomass.	$150	$300
Maintenance, 2%	180	240
Capital charges, 8%	720	
Total.	$1,050	$1,490
Energy cost		
As methane (per MMBtu).	$4.10	$2.80
As electricity (per kWh at 20% efficiency).	$0.055	$0.038
Price of liquid propane (1978)		$4.60/MMBtu
Marginal cost of electricity (1979).		$0.060/kWh

SOURCES: New Life Farm and Rural Electrification Administration, USDA.

a 15-horsepower engine turning a 7.5-kW electrical generator. At 20-percent thermal efficiency, this system could produce 3,500 kWh/month, compared to average farmhouse loads of 900 kWh/month.[21] NLF might be able to sell its surplus electrical power to the rural electric cooperative or use it to supply another system in their farm operation. In addition, about 10,000 Btu/hr in waste heat is available in the exhaust gas and radiation from the engine, which could be used to heat the building that houses the digester.

A second potential use for excess biogas is to heat an alcohol still. Recent increases in the price of gasoline have helped make the production of alcohol fuels on the farm a more attractive option. Although operating an alcohol still consumes more than 50 percent of the energy in biogas that it produces in distilling alcohol, the alcohol can be stored much more easily. This arrangement would provide a constant, high-volume demand for biogas and allow the farmer to produce fuel for his machinery at a lower unit cost. Either system—biogas/electricity or biogas/alcohol–would increase the cost effectiveness of both technologies by reducing or removing the need for fuels or energy from off-farm sources.

The NLF biogas system responds to the local needs and condition of farmers in the Ozarks. In the case study that follows, a group of low-income farmers in Cedar County, Nebr., has addressed a somewhat different set of needs and conditions through the application of solar technologies.

[21]Consumption figure from Federal Power Commission.

Alternative Energy Technologies (II)–Onfarm Solar Applications

The energy needs of the small-scale farmer can give rise to a wide variety of innovative solutions. As in the case of the NLF system of technologies, they may involve the integration of alternative farming techniques with small-scale applications *of* alternative technologies. The techniques and technologies may be familiar; what is new is their integrated application to the particular needs of the small farmer, an application that responds to local needs and conditions by developing the means to make better use of local resources.

The NLF system is based on anaerobic digestion, a fuel cycle that produces energy from biomass. It evolved in response to the needs of hog farmers in the Ozarks, but many of its developers were from urban backgrounds and had engineering or management skills that might not be available in other communities. By contrast, the case study that follows examines a project that is designed to show how far a group of low-income farmers without special skills can progress toward energy self-sufficiency when provided with technical and cost-sharing support.[22] Its participants are established, full-time farmers who are developing their own applications of alternative technologies, most of them based on solar energy, to the resources and needs of small farming and livestock operations in northeastern Nebraska.

The principles of passive and active solar power have already been touched on in chapters 3 and 4, and the onfarm applications of these principles will be examined in some detail in the case history. For a more thorough examination of this subject, the reader should consult an earlier OTA report, *Application of Solar Technology to Today's Energy Needs.*[23]

[22] Rural Development, Inc., "Evaluation of the Small Farm Energy Project at the Center for Rural Affairs," contractor report to Community Services Administration, contract No. P-78-30, Dec. 1, 1979, p. 1.

[23] *Application of Solar Energy to Today's Energy Needs* (Washington, D. C.: Office of Technology Assessment, U.S. Congress, June 1978), vol. 1, OTA-E-66; and vol. II, OTA-E-77, April 1979.

A Case Study of the Small Farm Energy Project, Cedar County, Nebr.[24]

The Community Setting

Cedar County is a small rural county in northeastern Nebraska which has experienced a slow but steady decline in population during the past several decades—a pattern not unusual for poor rural counties in the Midwest.[25] In 1970 over 45 percent of the work force was engaged directly in agriculture and much of the remainder in the sales and service occupations that support it. Many of the residents are decedents of German, Czech, and Swedish settlers, and the county has a well-integrated community life common to an earlier period of U.S. history. This is illustrated by the extremely low crime rate in the county: 454 crimes reported per 100,000 population, compared to a rate of 3,619 per year for Nebraska as a whole.

In 1974 there were 1,258 farms in Cedar County, with an average size of 354 acres.[26] This indicates a pattern of small-scale agriculture that is unusual in Nebraska (average farm size 683 acres) and in most of the Midwest. The topography partially explains the persistence of small-scale farming. The area is characterized by rolling hills and numerous creeks and marshy valleys that impede the movement of large farm machinery across the fields. The hilly terrain and frequent dry spells pose a danger of wind and water erosion. Consequently, the local farmers often employ more traditional, labor-intensive methods of farming, including small fields, contour plowing, windbreaks, and terraced hillsides.[27]

Local farm operations are generally more diversified than in other areas of Nebraska, where farmers often rely entirely on grain for their cash crop. Cedar County farmers grow a number of crops, including alfalfa and soybeans as well as corn and oats. Local farmers use some chemical fertilizers, but they depend largely on crop rotation to main-

[24] Much of the following discussion is drawn from Rural Development, Inc., op. cit.

[25] Ibid., p. 19.

[26] U.S. Census Bureau, 1974 *Census of Agriculture*.

[27] Rural Development, Inc., op. cit., pp. 19-21.

tain soil fertility. The farms are mechanized, often with three or more tractors each, but they still require the work of the entire family.

Hog breeding and dairy operations are more common in Cedar County than in the rest of the State, and they are well-suited to intensive use of the available land. General livestock farms seem to be less vulnerable to energy price increases and supply disruptions than specialized operations of the same size. The major variable is electricity demand: dairy farms have a fairly substantial load for hot water and milkers year-round; and hog farms have a heavy load for space- and floor-heating during winter farrowing; but general livestock farms, which farrow less often in winter and milk fewer dairy cows, have a lower and more stable demand for electricity y.

Table 16 presents a social, economic, and agricultural profile of Cedar County and the State of Nebraska. Both median family income and per capita income are lower than the averages for Nebraska and the Nation as a whole. In 1970 the county ranked 2,684 out of the 3,067 U.S. counties in median family income. Farm production costs consume a greater percentage of gross farm income than in the rest of the State, and energy costs often represent 20 percent of the operating expenses for some of the smaller operations. Projections based on figures supplied by DOE indicate that energy costs on these small farms will double by 1984. Small farmers with low net incomes will be most vulnerable to energy shortages and price increases, which might in some cases make the smallest agricultural and livestock operations economically untenable.

Development

The Small Farm Energy Project (SFEP) is an attempt to address these local needs and conditions. The project is sponsored by the Center for Rural Affairs (CRA), a nonprofit corporation in Walthill, Nebr., as part of an advocacy program for small farmers and other low-income rural residents. CRA's interests include a wide range of agricultural methods and appropriate technologies, but because the cost of electricity was rising faster than other farm expenses, their particular focus in this project was on technologies that would conserve or produce energy.

CRA submitted its proposal to CSA, which approved it on October 1, 1976, as a "national research and demonstration project" and funded it for an initial 15-month period. A second CSA grant approved a year later provided the funding necessary to complete the 39 months of work outlined in the CRA proposal.

The objectives of the project are:

- to determine the energy price vulnerability of small farmers;
- to produce working models of technologies that save or produce energy;
- to calculate what impact these innovations

Table 16.—Socioeconomic and Agricultural Profile of Nebraska, Cedar County, and the Small Farm Energy Project

			Small Farm Energy Project	
Measure	Nebraska	Cedar County	All innovators	Major participants
Population change, 1960-70	+ 5.2%	– 8.8%	NA	NA
Per capita income, 1974	$4,508	$2,660	NA	NA
Mean years of education, 1970	12.2	12.1	12.0[a]	12.9a
Average family size, 1970	3.5	3.5	5.8[b]	6.2[b]
Average farm size (acres), 1974	683	354	357[c]	381[d]
Percentage of farms with more than 20 milk cows, 1974	4.0%	16.6%	62.5%[b]	66.7%[b]
Average gross farm income, 1974	$55,224	$40,047	$34,735[d]	$40,633[d]
Average net farm income, 1974	$13,057	$8,368	$2,919[d]	$5,066[d]
Profitability (net •/• gross), 1974	23.6%	20.90/o	8.40/o	12.5%

NA = not applicable.
[a]Average 1977 figures.
[b]1975 figures.
[c]1977 figures.
[d]1976 figures.

SOURCES: U.S. Census Bureau, 1970 Census of Population and 1974 Census *of Agriculture;* and Small Farm Energy Project.

have on farm energy usage, in terms of both Btu and dollars;

- to develop and implement an educational program; and
- to develop an energy and income recordkeeping system for small farmers.

The stated *research* objective of the project is to determine the impact of proven alternative energy technology and conservation techniques on the energy use, cost of production, and net incomes of low-income farmers. For this reason the project includes a control group of farmers keeping energy records. The stated *demonstration* objective of the project is to show how far a group of 24 low-income farm families can progress toward energy self-sufficiency when provided with technical assistance and cost-sharing over a 3-year period.

Fifty full-time, low-income farmers from Cedar County were selected as SFEP participants (see table 16 for a profile of this group). Twenty-five were in the innovating group, which received technical and cost-sharing assistance to help them construct alternative energy devices on their farms. The other 25 were in the control group, whose only involvement was to maintain detailed energy and income records for 3 years. In addition, a board of directors composed of local residents—two farmers, a lawyer, and a banker—was established, not only to help establish the project's credibility with the local farmers but also to serve as a channel for disseminating information about SFEP and gathering community opinion for management decisions. The project works out of a storefront office in Hartington, the county seat.

The SFEP Innovation Strategy

The project is designed to be a controlled experiment in innovation. The three major elements in its innovation strategy are:

Education.–First the farmers learned what technologies were available and how to make use of them. The project staff arranged a series of lectures and discussions by engineers, agricultural specialists, and farmers from other communities who had undertaken similar projects on their farms. They also held hands-on workshops with the innovating group, and individual staffers held one-on-one sessions with the "innovators" during farm visits. The Hartington project office set up a resource library and started mailing out an innovator newsletter.

Self-Selection and Installation.–Next each farmer chose a technology that he thought he could apply to his own farm. This self-selection by the innovators was the cornerstone of SFEP's approach to technology transfer. The project staff helped in preparing designs and cost estimates so the farmers could base their decisions on the probable construction time, payback period, and amount of cost sharing from project funds. The farmers built and installed most of their innovations, with technical support from the SFEP staff and sometimes with "barn raising" construction help from the staff and other farmers in the innovating group.

Data Gathering.—The innovating farmers have monitored the technical performance of most of their installations. The primary focus of SFEP recordkeeping, however, for both the innovators and the control group, was on energy: what kinds of energy were used, how much of each source, and how much they paid for it. Both groups of farmers submitted quarterly and annual records, which have been analyzed in the projects' annual progress reports, The results[28] are open to question because the sample is small and because the energy-awareness caused by recordkeeping also influenced the energy use of the control group. Nevertheless, the figures give a rough indication of the conservation effect of the innovating group's projects:

- innovators used an average of 37 million Btu less in 1978 than in 1977, while the control group used an average of 29 million Btu more;
- because of price increases, innovators still had an energy cost increase of 1.8 percent, but the increase was 9.8 percent for the control group; and
- for the first 2 years of the project, increases in energy expenditures averaged 12.4 percent for the innovating farmers and 22.7 percent for the control group.

**center for Rural Affairs, "Preliminary Report, January 1977 through December 1978, for the Impacts of Various Energy Innovations on Consumption and Net Incomes for 43 Small Farms," prepared for Community Services Administration, July 1979.

SFEP Innovator Energy Projects

Table 17 lists the types and numbers of energy projects undertaken by the farmers in the innovating group. Individual participants initiated as few as two projects or as many as nine, and most of them completed at least one project without technical or cost-sharing support. Almost 75 percent of the projects begun in the first 2 years were carried through and actually utilized, including most of the major ones.

Table 17.—Types of Projects Adopted by Innovating Farmers Under the Small Farm Energy Project, 1977-79

Conservation	
Insulation, storm windows, and doors	30[a]
Flue dampers	3
Energy-efficient waterers	2
Small conservation projects	21[b]
Subtotal	56
Alternative sources of energy	
Solar space heating	6
Other solar projects	14
Wood heat	9
Wind electrical generator	1
Subtotal	30
Agriculture	
Soil testing	14
Comporting and limited tillage	5
Subtotal	19
Total number of projects	105

aSome farmers insulated both their water heater and their walls, or both their farmhouse and their barn.
bExcludes 23 "projects" that consisted of adopting pressurized gas caps to prevent fuel loss by evaporation.
SOURCE: Rural Development, Inc., for Community Services Administration.

About half of the SFEP projects involved conservation measures, including improved insulation for the farmhouse, barn, and other buildings; installing energy-efficient watering and milking equipment; and doing tune-ups on farm machinery. A number of them involved changes or improvements in farming methods, such as soil testing, increased comporting, limited cultivation where possible, improving terraces to reduce fertilizer needs, and changing to a shorter season corn to reduce drying costs. Over a third of the projects, however, involved applications of renewable energy sources, including conversion to wood stoves for the farmhouse or workshop, a wind generator, and 20 applications of active or passive solar devices.

Most of the projects were fairly simple, home-built, low-cost devices constructed from locally available materials. Generally the farmer adapted the technology in a design suited to the needs of his particular farm operations. The following discussions of six of these installations include a brief description of the technology and an account of its design, operation, and benefits. In keeping with the spirit of the SFEP approach to technology transfer, the first two accounts are in the words of the farmers themselves unless indicated by brackets. The third and fourth are taken from reports submitted by a study team composed of Cedar County residents, and the last two accounts are based on SFEP's second-year report.[29]

Portable Solar Collector (figure 19).–This is an adaptation of an active solar hot-air system also referred to as the vertical-wall or "North collector," after the Colorado rancher who originally developed it. It can be built directly onto the south wall of the structure to be heated, or it can be constructed in the workshop and mounted later or, as in this design, moved from building to building. The collector plate is painted black and covered with a Filon fiberglass glazing, cool air from the structure is drawn first behind the collector (for preheating) and then through the air gap in front of the collector plate, where it picks up the solar heat and delivers it into the building. Like the south roof of a solar greenhouse (see ch. 4), the slope of the collector should be perpendicular to the Sun's rays in winter. Innovator Gary Young's account:

> A portable solar collector is moveable. I put it on an old grain trailer that I was going to junk. I made it portable so I could heat the house or dry grain. Construction on it is really a lot more simple than you would think. The most complicated part is figuring out the air gapping. The frame is made of lumber from an old hoghouse. When we heat the house it takes cold air off the floor. The one-inch air gap has air baffles in it to turbulate the air so that it will take all the heat possible off this black aluminum. Then I just nailed the Filon on. You don't want any outside air getting into the collec-

[29]See the working Paper, "Report From Community Study Team: Small Farm Energy Project."

Figure 19.—Portable Solar Collector

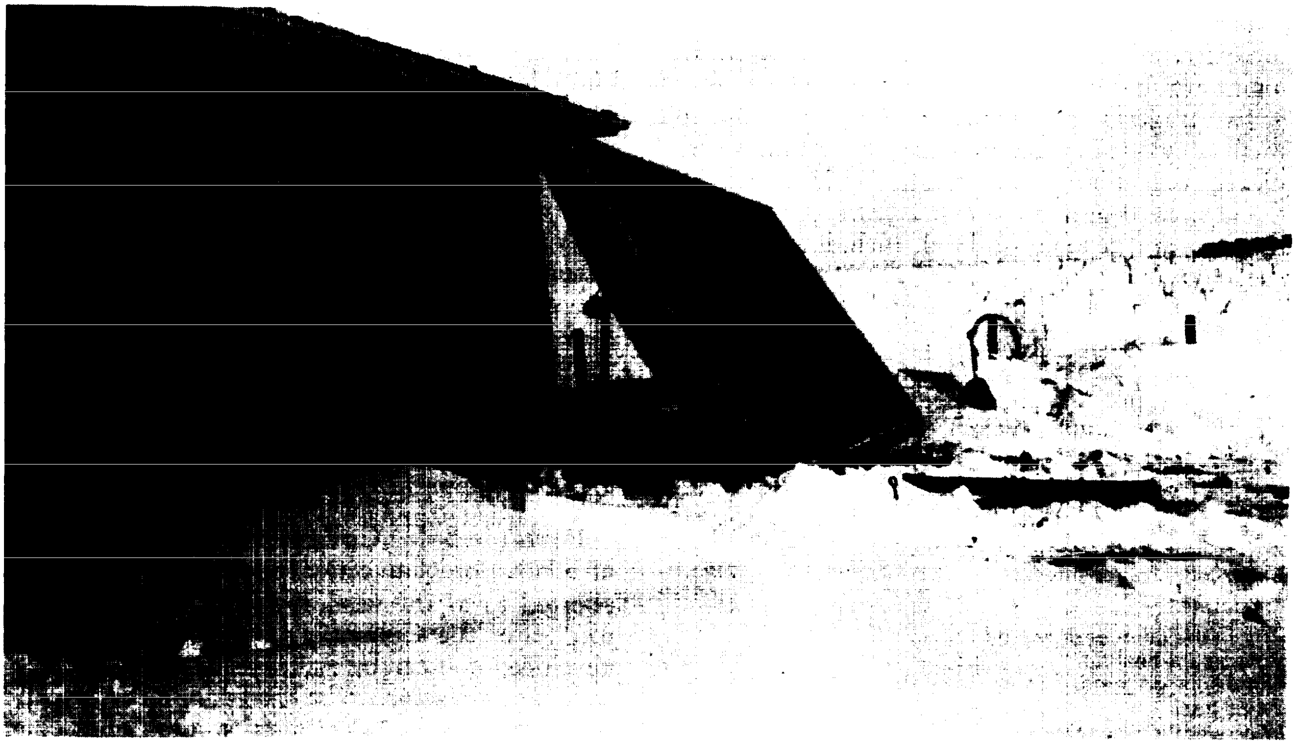


Photo credit: Office of Technology Assessment

tor in the wintertime, so you use a lot of caulk to seal everything. Sun shines through the Filon and heat gets absorbed by the aluminum; heat is transferred to the air in the one-inch air gap, and this air enters the house.

The SFEP people wanted me to build one a couple of years ago, but Delores [his wife] didn't want a collector sitting by the house or hanging on the house, because it would detract from the beauty of it. And then, when I [said] I wanted to make a portable collector, Delores said "yes" if it could be moved from the house in the summertime so she could raise her flowers. So we had to develop a way to attach it to the house and grain bin, so it could be moved from one place to the other.

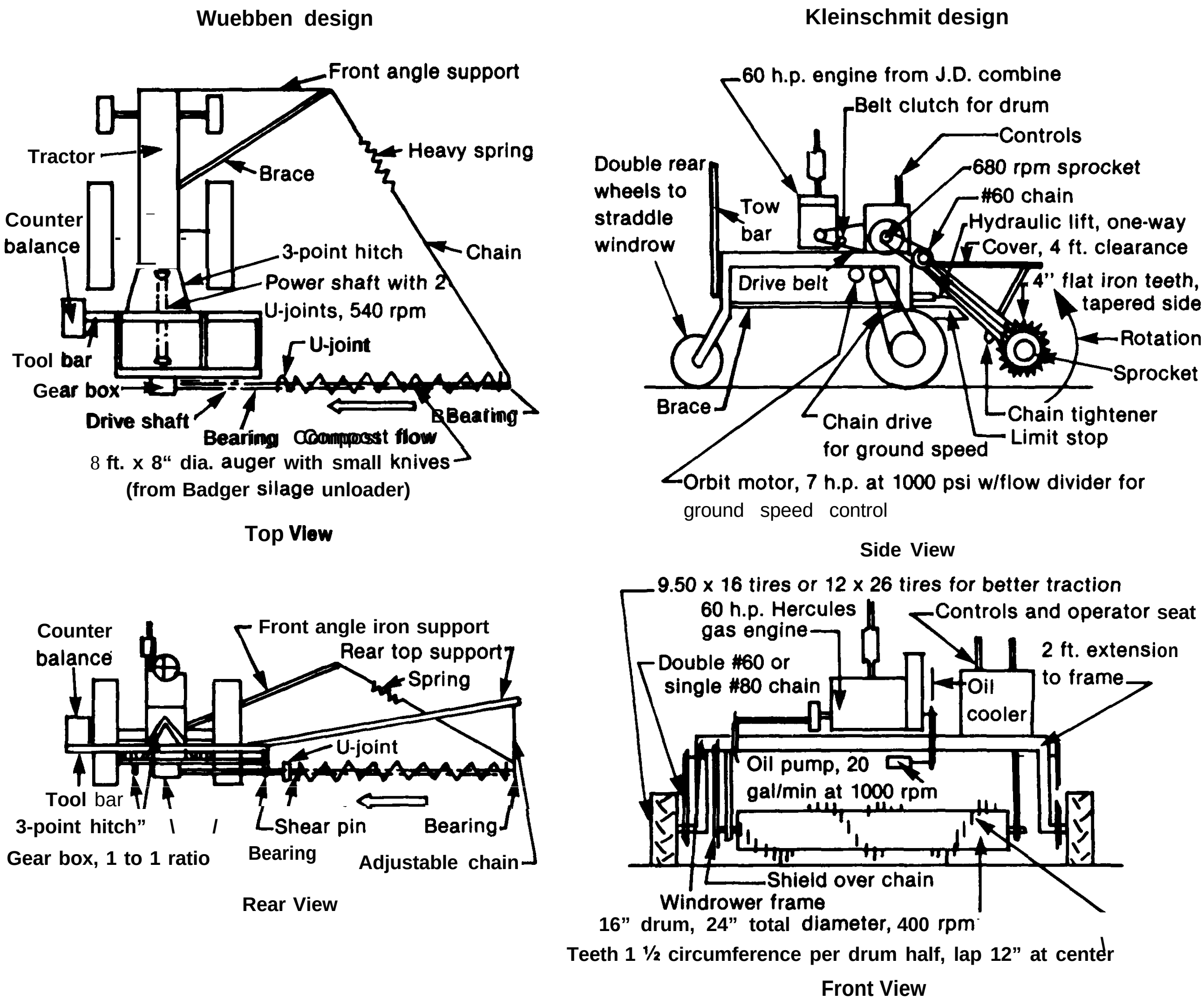
To hook up the collector, you use these innertubes with these adapter plates. One hooks onto the back side of the collector, and the other one hooks onto a plate just like this on the barn [or on] the house. I just bolt them together and seal them up. I think a portable one like this will have it over the permanent one, because farmers may have a bin at this place and another bin at another place a few miles down the road.

Another advantage of this design is that the tilt of the bed is adjustable so we can get maximum absorption of the sun. For the grain drying season, the sun was still quite a bit higher than it is in the wintertime, so we made it adjustable so that we can get more sun in the early fall. We get full absorption of the sun, and in the wintertime we can tilt it up some more and get maximum heat from the sun in the dead of winter.

The thing was pretty cheap, too. Not counting the time and my old lumber, I spent $1,300 to build it. That includes fan, motors, controls and everything. This one surely heats the house nicely. The furnace never runs except for an hour or two early in the morning. I'm sure our fuel bill will be far less than half what it was. Before, we filled the tank every 2 weeks—we have a 500-gallon tank—where we now fill it about every 6 to 8 weeks. On our house-our house has 1,200 square feet–we might recover the cost of this in 4 to 6 years. That's just on the house alone. It doesn't include grain drying.

Home-Built Compost Turners (figure 20).– Comporting is based on the aerobic decomposition of animal and vegetable wastes, a process that

Figure 20.—Home-Built Compost Turners



is described in chapter **7.** To aerate the wastes and keep them from overheating (which would destroy their nitrogen content), the compost pile must be turned periodically. Turning compost by hand, especially if large piles are involved, can be extremely time-consuming. An alternative is to lay it out in windrows (long piles similar to the rows into which grain or hay is raked for drying before it is stored or baled) and turn it with a machine designed for that purpose. Commercial compost turners are available in sizes ranging from the self-propelled, $52,000 Scarab used by the Bronx Frontier Development Corp. in their 365,000-ton/yr composting operation in the South Bronx (see ch. **7) to** the tractor-pulled, $5,000 Easy-Over composter that can turn 500 tons of compost in an hour.[30] Because 500 tons is about the *annual* volume of a 25-cow dairy operation,[31] it would clearly be an advantage to the small farmer if he could rent the machine out or share its capital costs with his neighbors. Two SFEP participants built their own compost turners at a much lower

[30] "Percy Knauth, "An Iowa Farmer Rediscovers Nature's Way," Quest, May 1980, p. **74,** Knauth's source, farmer Richard Thompson, estimates that it would take five men 20 hours to turn this much compost.

[31] Volume figures based on OTA, *Energy From Biological Processes*, op. cit., p. 130; and Richard Merrill, op. cit., p. 143.

cost with salvaged parts. Bill Kleinschmit developed a machine for turning windrows of compost. His account:

> There are a few basic reasons why comporting is a good idea. The nitrogen in the manure will stabilize, and it isn't going to be leached down by the rain. You save a lot of it, and it really nourishes the plants. Another benefit is that with compost you get rid of the threat of disease from having the manure around. A man from Iowa spoke at a seminar. He had a terrible colon infection in his hogs [and cattle] prior to starting comporting. Since he started comporting, he has had only minimal problems with infection. It helped get rid of the bugs, provided fertilizer for the ground, and produced better, healthier grain.
>
> My project with the Small Farm Energy people was building this compost turner. I started with a windrower that was no longer good for windrowing. It was completely shot. But the parts I wanted weren't. The engine and the drive mechanisms, chains, and the big pulley came from a big John Deere 55 combine that we used to have. I had to have something that was slow, so I took an oil pump, orbit motor, and a flow control valve and with this I could achieve as little as maybe 6 inches a minute or less, and then I could still go up to 10 feet a minute with no problem. And the drum was just a 16-inch drum and I had just taken some 4-inch scrap iron and made the angle for the teeth of the drum. That's pretty well what it's been made of—what one person might call a lot of junk.
>
> The windrow that my comporting machine is set up for is about 8 feet wide and 4 feet high. You can make the windrow whatever length you want it. I think the one I have now is well over 100 feet long.
>
> The thing was cheap to build. I paid $150 for the windrower, and the guy was happy to get rid of it because it had been sitting there for 5 or 6 years. I don't have over $1,000 in it right now. The engine may need an overhaul and I may stick a different engine on it that would take less fuel, but other than that, I don't feel there's too much that I would have to put into it.
>
> As far as the benefits, well, the first year I did this with just a manure spreader and a manure loader. I put about 10 loads of raw manure on one area, 10 loads of compost on another, and then the rest of the field had nothing on it. I had fairly good oats where I had put raw manure. Where I put the compost, I used half as much manure by volume, and I would say I had about half again more results. The other area I don't care to talk about—that didn't have anything.[32]

Solar Grain Dryer (figure 21).–Traditionally, corn was picked in the ear and stored in slatted cribs, where air flow removed the moisture. The advent of the combine (which picks and shells the corn in the field) led to the circular steel storage bin, in which the corn is dried with heat produced from propane or electricity. The energy used for this conventional method of drying corn often exceeds the total amount required for plowing, planting, cultivating, and harvesting the crop.[33] Four SFEP farmers chose to address this energy cost by installing solar grain dryers based on a simple design developed by Dr. William Patterson of South Dakota State University. In each case, a collector made of corrugated metal is attached to the southern two-thirds of the storage bin, with an air space between the collector and the wall of the bin. Solar heat transferred to the air as it passes behind the collector raises its temperature by 50 to 10° F and lowers its relative humidity. The warm, dry air then flows through the grain to remove its moisture. In the Wuebben dryer the air rises from the bottom of the collector, enters the storage bin through vents at the top, and is drawn down through the grain by an exhaust fan located at ground level. In the Fish dryer the air is drawn through vertical openings on the north side of the bin to a fan on the south side, which then forces the warm air up through the grain. Unlike Gary Young's portable collector, these permanent installations can only be used during the fall harvest, but they can still reduce the small farmer's energy needs. None of the four SFEP solar grain dryers is exactly alike, but all are home-built with materials that can be salvaged or obtained from the local lumber yard. The community study team's report:

> Solar drying is a form of low temperature drying. Along with saving propane and electricity, the method is believed by some farmers to result in a superior quality of dried grain. To construct a solar grain dryer a sheet of corrugated metal is painted black and wrapped around the south facing curve of the bin. The metal is open at one end and connects with an airtight shed at the other end. The

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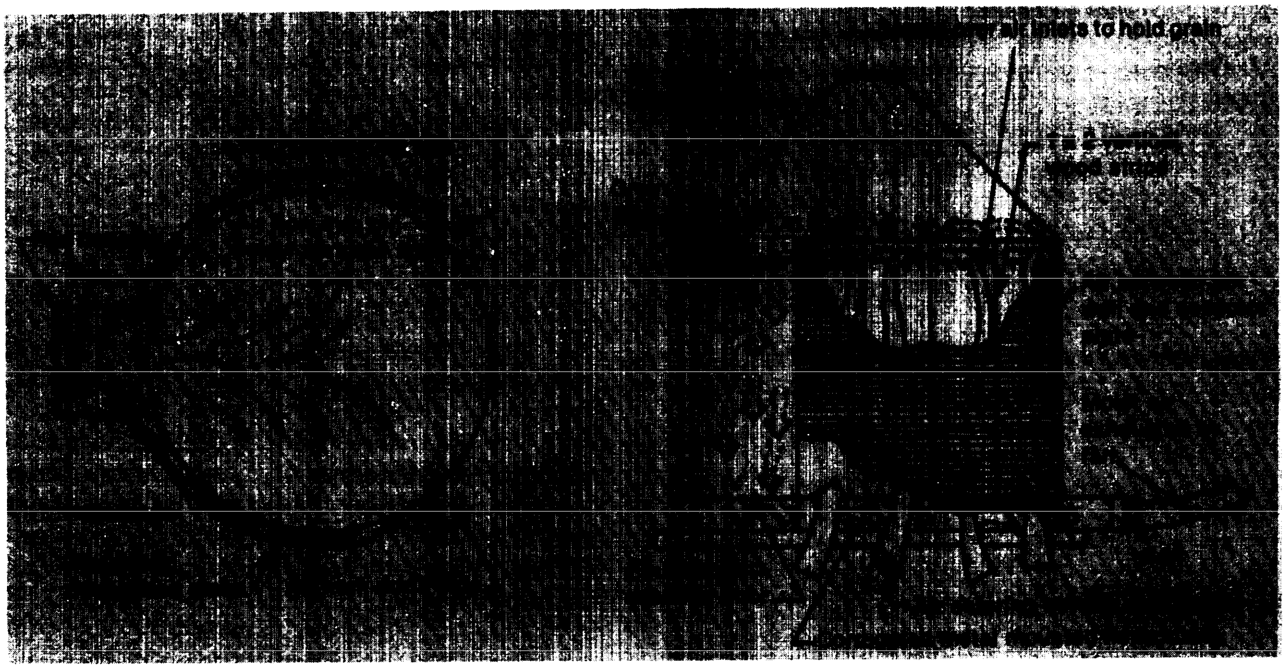
[32]Many small farmers in Cedar County apparently do not fertilize some of their fields, or do so only with raw manure.

[33]Rural Development, Inc., op. cit., p. 5.

Figure 21.—Top View of Fish Solar Grain Dryer and Wuebben Solar Dryer, West View



SOURCE: Small Farm Energy Project.

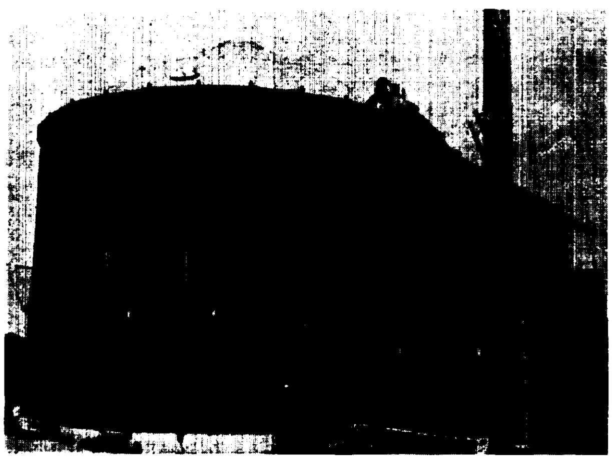


Photo credit: Office of Technology Assessment

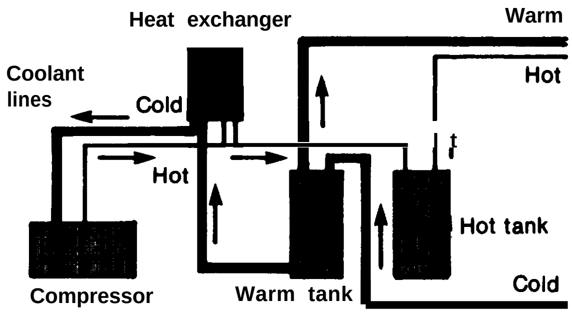
Solar grain dryer

shed contains a big fan that sucks outside air past the blackened metal, which heats it, and forces it into the bin. The Trubys have incorporated a fiberglass cover over the corrugated black metal collector plate in their bin. The bin holds 6,000 bushels and requires a 7-to 9-horsepower fan. The average solar grain dryer costs about $600, and it will achieve an annual savings of about $319.[34]

Solar Dairy Water Heater (figure 22).–Modern dairy farmers use automatic milking machines powered by electricity, which makes them highly dependent on this form of energy. However, they also use a significant amount of electricity to heat water for cleaning the machines and washing the cows for milking. Two of the SFEP innovators chose to apply an active solar energy system to their water heating needs: solar energy is transferred to water circulating through copper tubing attached to a 64-ft^2 collector plate on the south roof. The major problem with such a system in a cold climate is that it may freeze up. One solution is to use a mixture of water and antifreeze in the collector system and then use it to heat potable water. The SFEP design, in which the potable water itself circulates through the collector, is

[34]Six thousand bushels represents the corn harvest of 555 acres at average 1979 yields. The cost savings would be over a 10-year period, assuming 10-percent inflation and annual price increases of 2 percent for electricity and 5.7 percent for propane.

Figure 22.—Dairy Water Heat Exchanger



SOURCE: Small Farm Energy Project.

more efficient but more complicated, since it must be drained when there is a danger of freezing. The two SFEP installations incorporate a drain-down system designed by the Domestic Technology Institute at Lakewood, Colo., involving solenoid valves, a pump, differential thermostats, a freestat, and some rather complicated wiring. This complexity prevents the farmer from building the whole system himself and substantially increases the cost; it may be desirable to develop or select a simpler design such as the thermosiphon.[35] Edgar Wuebben, a dairy farmer who also built a compost turner (see above), has installed a drain-down, potable-water solar heater. The community study team's report:

> One of the energy-saving devices on the Wuebben farm is a solar water heater for the grade-A dairy barn. Water is pumped through the rooftop collector and then drains down into a hot water heater, where it can be warmed further with conventional power. In the winter, when there is danger that freezing might burst the pipes, solenoid valves open and drain the water out of the collector when a temperature drop tells [the switching mechanism] the sun has gone down.
>
> The Wuebbens use a 120-gallon storage tank. They could have used some type of antifreeze in the system, but the lower danger of contamination and the efficiency of the drain-down system seemed more appropriate.[36] The dairy operation required 50 to 80 gallons of water per day. Without the solar collector, heating the water required about 20 kWh per day; with the collector, the electricity used is reduced to 5 kWh per day. The Wuebbens expect to recover the cost of the system in about 6 years. However, [the SFEP] staff estimate the average cost of this type of heater at about $1,597 and the annual savings at about $175. This would mean a 9-year payback period instead of 6 years.[37]

Solar-Heated Farrowing Barn (figure 23).–Hogs are one of the major sources of income for farmers in Cedar County, and heated farrowing barns have become a popular means of increasing production by allowing sows to farrow year-round. These barns are usually heated with propane, kerosene, or electricity. With technical assistance from Professor Peterson of South Dakota State University (who also developed the basic solar grain dryer design, above), Rick Pinkleman converted an old dairy barn into a solar-heated farrowing barn.

Figure 23.—Solar-Heated Farrowing Barn

Photo credit: Office of Technology Assessment

The first step was to weatherize and insulate the barn. The south roof, which measured 17 by 50 ft and had a slope of 70° from the horizontal, proved to be an excellent location for the collector. He painted the corrugated metal roof black and covered it with clear corrugated fiberglass to trap the

[35] Rural Development, Inc., op. cit., p. 8.

[36] If antifreeze were pumped through the collector, heat would have to be transferred to the potable water in some way. Some designs call for the antifreeze to be piped through a heat-exchanger coil immersed in the hot water tank. Many local building codes forbid this practice, however, because any leaks that develop in the heat-exchanger coil will contaminate the potable water with antifreeze.

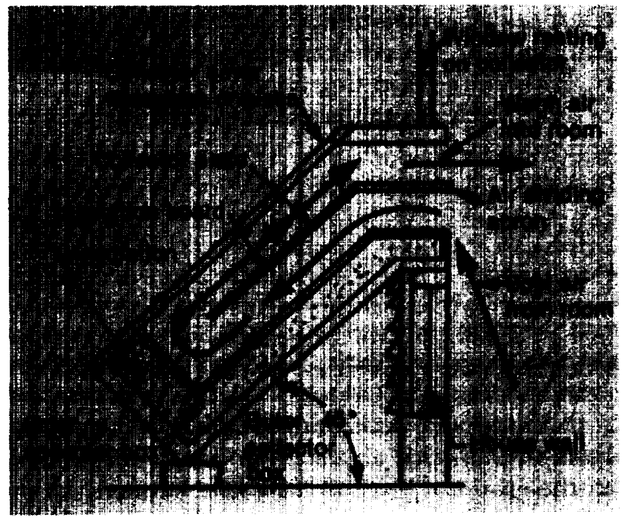
[37] Again, cost savings are over a 10-year period, assuming 10 percent inflation and annual price increases of 2 percent for electricity and 5.7 percent for propane.

solar heat. A fan pulls air from the attic through the collector and into a heat storage area containing 850 plastic, l-gal milk jugs filled with a mixture of water and methanol. A second fan pulls the preheated air through a ventilator duct into the barn itself. At night the heat stored in the water jugs is transferred to the air, thus helping to keep the barn warm. This system has too little heat storage to work without backup heat, but it should make a significant difference is space-heating costs for the farrowing barn.

Other SFEP Innovations.–Home space-heating costs can be reduced more effectively through conservation measures than through passive solar additions,[38] and most of the farmers in the innovating group added insulation to their farmhouse walls and ceilings, installed storm windows and doors, insulated their water heaters, and purchased pressurized gas caps to reduce the loss of fuel through evaporation. Nevertheless, one family built a solar greenhouse on an old porch (see chs. 3 and 4), another farmer built a small solar "window box" collector (figure 24), and several others installed fixed vertical-wall collectors similar to Gary Young's portable design (see figure 19). Another family's solar hot-air application was the solar food dryer (figure 25). In a slightly different kind of project, the Kaiser family bought a commercial wind generator and set it up on their farm. It produced electricity in winds over 8 miles per hour and had an average output of 200 kWh/month; this saved the family about 20 percent on its electric bill.

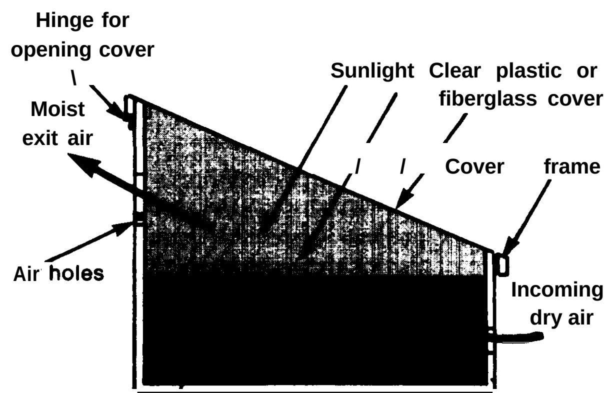
38 See *Residential Energy Conservation* (Washington, D. C.: Office of Technology Assessment, U.S. Congress, July 1979), OTA-E-92, vol. I.

Figure 24.—Solar Window Box Collector (cross-section view)



SOURCE: Small Farm Energy Project

Figure 25.—Solar Food Dryer (cross-section view)



Food tray of heavy netting or fiberglass screen supported by dowels

SOURCE: Small Farm Energy Project.

Critical Factors

Public Perception and Participation

The two small farm projects examined in this chapter illustrate the manner in which public participation can affect public perceptions of local development projects. The settings were not especially conducive to public interest or involvement: small farm communities tend to be conservative and to distrust outsiders. SFEP and NLF used different techniques for gaining public approval and participation.

SFEP made citizen involvement a feature of its project design from the very outset. The staff of CRA are all midwesterners, but they realized they still might be viewed as outsiders in Cedar County. Early in the planning phase, therefore, a board of directors was established to oversee the project and represent it in the community. The four directors were all native Nebraskans and influential, active community members whose participation helped to establish the project's credibility with local farmers. The CRA staff also surveyed county residents and institutions while the proposal was being developed to determine what activities would be most appropriate for the county's needs.

Planning and decisionmaking at the New Life Farm in Missouri, on the other hand, was limited to the group of original New Life Farmers, all of whom were outsiders. These people seem to have accurately identified the needs of small farmers in the region and are very open to public participation, but few natives of the community were involved in the organization's early stages or in its ongoing operations. NLF members have tried to establish personal relationships with local farmers, and several jobs at the farm have been filled by local residents, but the broader community still knows little about the project or its aims. NLF has recently stepped up their outreach efforts, in part to attract more private donations, but unlike the Cedar County project it has not come to be seen as a creation of the local community.

SFEP's greater success as a demonstration project results in large part from its stress on self-selection, which makes use of existing patterns of technology transfer. Traditionally, information and new farming techniques have been passed on from neighbor to neighbor and generation to generation. Recognizing this, SFEP's technical assistance focuses on one-to-one relationships and individual innovation, allowing local people to demonstrate technologies that can be useful in the kind of farm operations actually found in the area. This makes the farmers themselves active agents in technology transfer, and it also allows them to become active participants in the project without joining a formal organization. By contrast, NLF's organizational style seems to be more akin to an urban cooperative model than to traditional rural practice. This may actually work against public participation, because local farmers who want to learn about new farming techniques at NLF may feel that an active commitment to the organization would be required.

While it is difficult to determine from available data how well NLF has been accepted by the Ozark farmers, data on the SFEP outreach programs indicates widespread support in Cedar County. Over half of the local residents surveyed by the community study team knew about SFEP and its activities, and a number of nonparticipants had planned or begun building their own energy projects. So had 25 percent of the control group, which was subject to the same outside influences—i.e., SFEP's educational component as well as the general increase in energy consciousness throughout the Nation.

The lack of a true control group is one of several flaws in the project's quasi-scientific design; another is small size of the sample, but perhaps the most serious flaw is the lack of randomness in selecting the participants. Most of the SFEP innovators were self-motivated to participate, and they were apparently hand-picked by the staff and local advisory board. In addition, 9 of the 24 innovators undertook a disproportionate share of the projects, including the largest installations, and the data presented in table 16 suggest that these major participants were better educated and had more profitable farms.

Essential Resources

Most of the projects at NLF and SFEP can be built by the farmers themselves at low cost and with locally available materials. NLF's small manure digesters, which could supply the cooking and water heating needs of an average farm, can be built for between $2,500 and $3,500, although the designers think the price could be reduced in time (see table 12). Most of the SFEP projects have even lower costs, and many of them make use of salvaged materials. Most small farmers possess the carpentry and plumbing skills necessary for their construction, although they may need to hire local labor for some of the construction work on the larger installations. The most complicated materials, and the only ones not locally available, were the drain-down switches for the solar dairy hot water systems.

The costs of raw materials depends on the type of system and the type of crop used. Solar energy, of course, is free; but the amount of solar energy available will vary with location and season. Manure for comporting or for digesters is readily available and frequently underutilized by current farming methods. Plant wastes for the phytomass digester are also available at low cost: wild grasses and weeds can be collected for about $0.25 bale, or $264/yr; cornstalks can be gathered for $4.73 per 1,600-lb bale, or $150/yr.[39] Since the sludge from the digesters can still be used for compost or feed, this technology makes more efficient use of an available resource without destroying its value for other uses.

One traditional rural resource has not been exploited, however: the communal or shared labor of local farmers. The rural "barn raising" tradition may still exist in these communities, but it was not reported to have emerged among the innovating farmers in Cedar County,[40] not all of whom were close neighbors, or between NLF and the native farmers in the Ozarks.

Technical Information and Expertise

The literature on solar and biomass technologies is growing rapidly, but much of the early research was done under less than optimal conditions, and many promising areas have barely been touched. Part of the problem has been that very little money has been available for conducting formal scientific experiments, and even in areas where preliminary research has been done, there is considerable debate about whether these technologies are appropriate to real-life, onfarm applications. Both NLF and SFEP have tried to fill these information gaps.

NLF's experiments with biogas digesters are adding to the sometimes sketchy information generated by a handful of experimenters around the world over the last 20 years. There is a fairly good understanding of which parameters (feedstock, carbon-to-nitrogen ratio, temperature, etc.) affect gas yield, but as yet there is no precise understanding of what impact these factors have individually or in combination. Similarly, little research has been done on the nutrient value of biomass sludge, the availability of the nutrients to plants, or on the long-term impacts of applying sludge as a fertilizer and soil conditioner. NLF's research efforts address these questions, although the results are not yet widely available.

SFEP, despite its project design, is less a rigorous research program than a well-designed and highly successful education and demonstration program. Its workshop approach was particularly useful in disseminating information: agronomists and farmers came to speak to the Cedar County group, and consultants were hired to work with both participants and staff. The results clearly demonstrated the potential of farmer-built, self-selected technologies on these Nebraska farms, but there was very little new technological innovation in any of these applications.[41] Furthermore, because of the inevitable roughness of the onfarm data gathering and because of the number of uncontrolled variables and outside influences in the Cedar County "experiment ," it would be difficult to establish conclusively that the economic viability and energy vulnerability of these farms have been significantly affected, let alone that the results can be applied to small farms in other regions of the United States.[42]

If the NLF and SFEP installations are to be replicated on a widespread basis, more detailed information will be needed on the design, costs, and performance of these and other small-farm energy systems. A preliminary evaluation of the SFEP project suggested several methodological changes that might improve the usefulness of information generated by this program and similar efforts elsewhere:

- collect better baseline data on the farmers' attitudes toward change, in order to evaluate the project's impact in this area;
- include a larger number of farmers, in order to offset random effects and make valid conclusions;
- adopt a case study approach, in order to collect and analyze data on a technology-by-technology and farm-by-farm basis, rather than in the aggregate;

[39] Fischer and Swack, op. cit., p. 69.
[40] Rural Development, Inc., op. cit., pp. 53-54.
[41] Ibid., pp. 71-72.
[42] Ibid., pp. 40-41, 59,71.

- concentrate on the technologies that have the greatest potential energy-saving impacts;
- develop a model farm, with the active participation of the farmer, by installing a number of technologies to demonstrate the potential benefits of an integrated small-farm energy system; and
- utilize comprehensive cost-benefit analysis at all stages of the project .43

The NLF system of technologies is an example of the sort of model farm that might be developed, although the model should include solar as well as biomass applications. SFEP has indicated that it will undertake case studies of individual installations, but no studies are available as yet.

Financing

Both of these small projects have been financed primarily by grants. The NLF case study, like several others in other chapters, demonstrates that trying to survive exclusively by grants can cause an organization a number of problems.

NLF generally develops a prototype before it seeks finding for a project, which both reduces the risks involved and encourages grantors to take the project seriously; but dependence on Government and foundation grants has led to restrictions on its use of funds. The large DOE "Energy From Farm Crops" grant, for instance, is earmarked for specific research on the phytomass digester, and thus works against the type of integration that NLF would like to achieve. In addition, Government grants may not be forthcoming unless a project is in line with the current objectives and priorities of the granting agency. NLF has a friendly relationship with the local bank and can borrow against its savings account, but a conventional loan is highly unlikely at the present time. An alternative would be to pursue a broader mix of finding sources, like the "consortium funding" of the Bronx Frontier project (see ch. 7), but for this approach NLF might need the help of an experienced grants manager. Another alternative, since there seems to be commercial potential for the manufacture and sale of digesters, would be for NLF to investigate the possibility of selling its services as a design consultant.[44]

SFEP has avoided some of the restrictions imposed by the grants economy. Its project design stressed the installation of devices based on proven technologies and design concepts, which serves to reduce risks; but it also stressed self-selection by the innovating farmers, which led to a greater variety of applications. Cost-sharing, which has been used in a number of agriculture programs, appears to have been useful both because it is accepted by the farmers and because it reinforces the innovator's sense of ownership. However, while the cost share was found to be important in initiating innovations in the early stages of the project, it was not always needed to sustain the innovation process. Many of the SFEP farmers undertook projects without cost-sharing, and only 52 percent of the money allocated for this purpose was actually spent. The average cost share was 43 percent of the project cost; the staff and advisory board felt that a 100-percent share would be seen as a giveaway program and that more than a 50-percent share would be useful only for "high risk" or "first time" innovations.[45] The proposed model farm, however, may require a larger share because of the number of installations involved.

Institutional Factors

The full development and widespread dissemination of these small-farm technologies would require the active cooperation and backing of the land-grant colleges and the Agricultural Extension Service (AES). NLF has thus far enjoyed a cordial relationship with the local state university through joint research on the phytomass digester, and there seems to be a great deal of interest in the project from government officials at the Federal, State, and local levels. Similarly, SFEP has tried to establish friendly relations with the University of Nebraska Cooperative Extension Service, which has moved one of its energy specialists to nearby Concord. Institutional change has been slow, however, and a number of barriers remain.

AES operates with relative success throughout the United States, partly because its over 100 years of activity has given it legitimacy and credibility. However, its responsiveness to the problems of the small farmer varies greatly from one region to

[43] Ibid., pp. 17, 29, 39,64,66.
44 Fischer and Swack, op. cit., p. 79.

[45] Rural Development, Inc., op. cit., pp. 43-44.

another, according to a SFEP consultant. Extension programs are jointly funded by Federal, State, and county governments, but they are managed at the State level. This should allow them to respond to local agricultural needs, but some State-controlled programs tend to focus on the problems of large-scale farming groups, whom they perceive to be their primary clientele. According to information gathered by Rural Development, Inc., for CSA, nothing similar to SFEP had been undertaken by AES anywhere in the Nation.[46] This created an opportunity for SFEP, which employs a number of the educational and outreach techniques developed and used by AES, to supplement the activities of the existing extension programs. There is evidence, however, that the State AES agency opposed the establishment of SFEP.

To be eligible to receive its CSA grant, the SFEP proposal had to be approved by the Governor of Nebraska and the State Tax Commissioner (in his capacity as head of the State's Energy Office). During the review period, the Governor received a letter from the University of Nebraska opposing the project: the University, with the backing of Nebraskans for Progressive Agriculture (a group of large farmers with ties to the University), claimed that the SFEP staff was unqualified to undertake the project and that it would duplicate efforts already underway at the University through AES. SFEP was able to refute these arguments, but the incident apparently served to politicize the project. Three years later, in the spring of 1979, Rural Development, Inc., reports that:

> . . . during a conversation the evaluators had with the Director of the [University ofl Nebraska Cooperative Extension Service, it was clear that he was not open to cooperation with persons working on agriculturally-related problems who were not associated with land-grant or traditionally agricultural-mandated institutions . . . . The SFEP project had not significantly affected the University of Nebraska [Cooperative] Extension Service, although the project staff, advisory board and cooperators prefer that it would.[47]

NLF, too, has experienced opposition to its efforts to involve local high school students in its workshops.

The Missouri and Nebraska projects may, to some extent, find themselves working in competition with AES and local extension services. By addressing a new clientele (the farmers at the lower end of the income and acreage ranges in their areas) and by encouraging alternative agricultural techniques, they might unintentionally challenge the conventional methods advocated by the established institutions and threaten to usurp their local role. Joint grants and joint research, such as NLF has undertaken with the State University of Missouri at Rolla, may help to overcome these barriers, but institutional change is likely to remain a slow and incremental process.

Two regulatory issues have arisen from these projects: proprietary rights and patents, and digester safety. The SFEP participants view their small-farm technologies as examples of local innovation and adaptation which, as such, should be available for use by all farmers at the lowest possible cost. As a result, the staff has made no attempt to secure patents or copyrights, and some of the innovating farmers even suggested that a law should be passed so that some of the devices could not be patented. Biogas technology, on the other hand, raises a safety issue. The designers have sought to reduce the risks of oxygen contamination and explosion wherever possible, and the batch-loaded digesters are relatively safe because, once loaded, they remain sealed until digestion is completed. Nevertheless, NLF has installed a "gas sniffer" alarm in its digester building, and widespread adoption of biogas digesters may necessitate formal safety regulations, such as local building codes forbidding a digester from being attached to a livestock shelter.

[46] Rural Development, Inc., op.cit., p. 5.

[47] Ibid., pp. 55-56.

Federal Policy

Background

Unlike the cases studied in other chapters of this assessment, the two case studies in this chapter entail the development and adoption of a whole range of technologies, from new comporting techniques to solar and biomass energy systems. Consequently, they are related to and affected by a large number of Federal programs and policies. The development and diffusion of the small-scale farm technologies examined in these case studies, however, are most relevant to three broad, interrelated national issues:

- developing rural America;
- progressing toward greater energy self-sufficiency at all levels—national, regional, local, and individual; and
- retaining agricultural lands and preserving the structure of the farming sector.

The third issue, agricultural land retention, is discussed in chapter 6; the other two issues are discussed below.

Rural Development[48]

A 1970 congressional policy declaration stated that "the highest priority must be given to the revitalization and development of rural areas. " Defining the exact Federal role in these activities has been the focus of considerable debate ever since. Rural development has become a broad mission, involving initiatives by Federal, State, and local governments as well as the activities of the private sector. The coordination of these diverse efforts so that their results are mutually supportive has been a particular and continuing concern in the rural development initiatives of both Congress and the executive branch, several of which affect the development of alternative technologies for the small farmer.

The Rural Development Act of 1972.–This Act (Public Law 92-419) is the primary source of programs to promote economic and community development in rural areas, and most of the rural development activities of the legislative and executive branches have focused on the implementation of this legislation. The Act's stated purpose is "to provide for improving the economic and living conditions in rural America. " Of particular relevance is title V, "Rural Development and Small Farm Research and Education." Two of this title's goals are: 1) "to expand research on innovative approaches to small farm management and technology" and 2) "extend training and technical assistance to small farmers so that they may fully utilize the best available knowledge on sound economic approaches to small farm operations. " To this end the Act establishes the Small Farm Extension, Research, and Development Programs, which were to consist of:

> . . . extension and research programs with respect to new approaches for small farms in management, agricultural production techniques, farm machinery technology, new products, cooperative agricultural marketing, and distribution suitable to the economic development of family size farm operations. (sec. 502)

The Act designates USDA as the lead agency in Federal rural development efforts. USDA placed most of the operating programs under the Farmers Home Administration, while the responsibilities for lead-agency coordination were assigned to the Rural Development Service. A number of institutional changes have taken place since 1972, however, in part because of congressional criticism of the way in which the present and previous administrations have implemented the policymaking and coordinating mandate of the Act. These changes also reflect the findings of executive branch studies and reviews of rural development, the findings and changes which affect small farm technology are outlined below.

The earliest review was carried out in 1977 by a joint task force of officials from USDA and the Office of Management and Budget, under the direction of the Administrator of the Rural Development Service. The task force identified the following as one of the weaknesses in the current rural development efforts:

[48] Some of the material in this section is drawn from Sandra S. Osburn, "Rural Development: the Federal Role," Library of Congress, Congressional Research Service issue brief No. IB77113, June 23, 1980.

> Federal programs have concentrated heavily on public facilities investments which have improved the public infrastructure in many rural areas, but have not stimulated substantial private sector employment. Federal programs have also under-invested in human resource development and in technological innovation in rural areas.[49]

Their report also stressed the need to develop a national growth and development policy and to ensure that rural needs and interests would be included in any such policy.

A second review of Federal rural development policy took place as part of the White House Conference on Balanced National Growth and Economic Development, authorized under the Public Works and Economic Development Act of 1976, which took place from January 29 to February 2, 1978. On December 1, 1978, President Carter announced the findings of the conference's water and sewer task force; these proposals later led to an interagency Coordination and Service Delivery Agreement[50] that included a proposal to place more emphasis on alternative and innovative technologies for waste-management in rural areas.

The Secretary of Agriculture issued a memorandum on March 21, 1979, that set forth USDA's rural development policy and specified the following goals:

- improve rural income levels and increase rural employment opportunities;
- improve the access of rural residents to adequate housing and essential community facilities and services;
- provide a more equitable distribution of opportunities through targeting efforts on distressed areas, communities, and people;
- create and implement a process for involving the private sector and Federal, State, and local agencies in establishing policies and programs that affect rural areas; and
- strengthen the planning, management, and decisionmaking capacity of public and private institutions concerned with economic opportunity and quality of life in rural areas.

[49] Ibid., p. 6.
[50] Other agencies involved in the agreement are the Departments of Housing and Urban Development, and Labor; Environmental Protection Agency; Economic Development Administration; Council on Environmental Quality; and Community Services Administration.

96th Congress.—Continuing congressional concern about the implementation of rural development policy was demonstrated by several pieces of legislation enacted or considered by the 96th Congress:

- *Rural Development Policy Act of* 1980 (Public Law 96-355).–This Act directs the Secretary of Agriculture to prepare a comprehensive Rural Development Strategy, based in part on the goals and recommendations of local communities and on the need to strengthen the family farm system, and to update this strategy annually in a report to the appropriate House and Senate committees. The Act also creates the position of Under Secretary of Agriculture for Small Community and Rural Development, to be appointed by the President with the advice and consent of the Senate. Significantly, the Act also extends for 2 years the authorization for title V of the Rural Development Act of 1972 (see above) and specifically authorizes the Secretary of Agriculture to promote R&D efforts related to appropriate technologies for small- and medium-sized farms.
- Other *legislation.—To* ensure that rural interests are considered in the design and implementation of national programs in other areas, bills were introduced that would establish an Office of Rural Health within the Department of Health and Human Services (H.R. 2886 and H.R. 3882) and a Rural Area Transportation Office within the Department of Transportation (S. 839). All three of these bills, however, died in subcommittee.

Energy Self-Sufficiency

Since the 1973 OPEC oil embargo, policies to promote energy self-sufficiency at all levels have become an integral part of other domestic policies, including agricultural and rural development policies. Major initiatives have been put forth since 1977, and many of the more recent initiatives contained provisions encouraging energy conservation or production. The most important of these are presented below.

The Food and Agriculture Act of 1977 (Public Law 95-1 13) contains in its title XIV (the National Agricultural Research, Extension, and Teaching

Policy Act of 1977) findings that bear directly on small farms and appropriate technologies, and call for new Federal initiatives in several areas, among which are:

- more intensive agricultural research and extension programs oriented to the needs of small farmers;
- development and implementation of energy-efficient and environmentally sound methods of utilizing nonfood agricultural products and waste products; and
- investigation of the effect of organic waste materials on soil tilth and fertility.

To that end, the Act amends section 502 of the Rural Development Act of 1972 to emphasize programs that will develop new approaches to small farm products, marketing techniques, and finance, it also adds to section 502 a new subsection (d) specifying that small farm extension programs "shall [use], to the maximum extent practicable, paraprofessional personnel to work with small farmers on an intensive basis. "

Subtitle H of the Act encourages R&Don "uses of solar energy with respect to farm buildings, farm homes, and farm machinery," and promotes the establishment and operation of model solar energy demonstration farms in each State to determine "energy usage, income, costs, operating difficulties, and farmer interest with respect to these model farms. "

The Energy Security Act of 1979 (Public Law 96-294) also contains numerous provisions relating to small farms, but the majority of them are contained in its title II, the Agricultural, Forestry, and Rural Energy Act of 1979. These provisions include the following:

- that the Secretary of Agriculture implement an Agriculture, Forestry, and Rural Energy Production, Use, and Conservation Program to enable the United States to achieve net energy independence in agricultural and forestry production by 2000;
- that the Secretary implement an applied research program to develop economical and energy-efficient fuels from biomass; techniques for using energy so derived in the production, processing, and marketing of agricultural commodities and forest products; and energy conservation systems and techniques for farmers;
- that the Secretary establish not less than four and not more than eight Agricultural Biomass Energy Centers, in different geographic regions of the United States to undertake research, development, and demonstration projects on promising new farm energy technologies; to develop a data base and perform energy need analyses for rural residents and communities; to disseminate information on new energy systems and provide technical assistance to farmers; and to support energy-efficient model farms; and
- that the Secretary establish an extension program to disseminate the results of farm energy research, to encourage the adoption of energy conservation and production technologies, to conduct workshops for interested farmers, and to provide technical and cost-sharing assistance for the installation of farm energy systems.

In addition, there are several provisions in title VII (the Omnibus Solar Commercialization Act of 1979) which direct the Secretary to support the dissemination of information on renewable resource research and to establish a National Solar Energy Information Center as part of a coordinated information and outreach program.

Other legislation relating to small farm energy policy included the bill to amend the Consolidated Farm and Rural Development Act (Public Law 96-438), which authorizes the Farmers Home Administration to make or insure loans for the development, construction, or modification of solar and other renewable energy systems on family farms.

Issues and Options

Existing and proposed legislation provides a broad range of technical and financial assistance for the diffusion of small-scale agricultural technologies. No major institutional changes appear to be needed at this time. The specific issues that emerge from the cases examined in this chapter fall into two interrelated areas: 1) R&D, and 2) education and outreach.

ISSUE 1:
Research and Development.

These case studies include technologies at varying stages of development. For instance, knowledge of solar thermal phenomena is far more complete than knowledge of anaerobic decomposition.

As a result, solar thermal technologies like the vertical-wall collector and solar hot water system can already be demonstrated in onfarm applications. In fact, it is likely that further improvements in these systems might be discovered primarily through onfarm adaptation and everyday use.

However, some biomass systems like the biogas digester seem to be in two stages of development at once. Significant design improvements and cost reductions have been achieved through the experience gained in demonstrations, but much remains to be learned about both the basic biological processes involved in anaerobic digestion and about its operating parameters—the energy content of different feedstocks or feedstock mixes, their various biogas yields, and the nutrient value of the resulting sludge. Nutrient content and nutrient availability in digester sludge is the subject of particular debate.

In addition, little information has been generated thus far on the full potential of these solar and biomass installations as components in a larger, integrated system of farm technologies. The devices installed in the Small Farm Energy Project were not always those with the greatest energy-saving potential, and self-selection by the innovating farmers usually led to isolated, piece-by-piece installations. It would also be useful to gather more reliable data on the feasibility, costs, and benefits of an integrated farm energy system that combines a number of complementary energy technologies with a number of other conservation strategies, such as changing fuels in farm machinery, using low-tillage techniques, and incorporating some organic farming methods. Another focus for integrated R&D might be the investigation of alternative crop/livestock systems that make more efficient use of available resources and conditions as part of an integrated, sustainable, self-sufficient, and environmentally benign farming operation. New Life Farm, for example, modified the Ozark grass/hogs system by cropping a tree that had not previously been grown in the region, producing energy from hog manure, and returning sludge to the land to improve its fertility.

Option 1: Support increased R&D.–Congress may wish to accelerate the development and diffusion of alternative small-scale farm technologies by directing USDA and other Federal agencies to broaden and intensify their research efforts in the areas described above, as authorized by existing legislation. These efforts would generate more detailed and reliable information if individual projects were directed to give a high priority to information gathering; cost-benefit analysis would be especially desirable, and might be included in the technical assistance offered by the funding agency if local expertise is lacking.

ISSUE 2:
Education and Outreach.

The New Life Farm and the Small Farm Energy Project both had two functions: research and demonstration. NLF was perhaps more successful in its research component, but SFEP was particularly successful in its demonstration component. Self-selection by the innovating farmers simulates the manner in which such technologies might actually be disseminated on a local level, and the spread of conservation strategies among the nonparticipants in Cedar County illustrates how rapidly these technologies might be transferred in small farming communities.

Option 2: Support improved Demonstration and Extension Programs.—Legislation already passed by Congress (see above) calls for more intensive research and extension programs aimed at the energy needs of small farmers and authorizes the establishment of model farms in each State as well as a number of regional agricultural energy centers. Congress might wish to promote these initiatives by appropriating or earmarking additional funds to implement them. These model farms and regional centers might be located at AES or State extension research stations. An alternative would be to investigate ways to encourage regional "networking" among existing projects and community groups, particularly those with installations on working farms. It should be noted that NLF is incorporated as a research and educational organization, and that SFEP is funded by CSA as a "national research and demonstration project. " These and similar projects might serve as the nuclei for such regional networks. Finally, Congress might wish to promote the consideration and adoption of small-scale alternative agricultural technologies by directing Federal funding agencies to encourage project designs with a strong outreach component, and/or by directing the Secretary of Agriculture to disseminate the results of these projects to State agencies and county agents through AES.

Chapter 6

Farmers' Markets

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Introduction

The last chapter examined a number of technologies that can reduce the small-scale farmer's vulnerability to energy price increases and supply disruptions. These technologies can also improve the economics of small-scale agriculture by reducing production costs, particularly those related to nonrenewable sources of energy. Just as essential to the viability of the small farm, however, is access to dependable and profitable markets. With the advent of large-volume supermarket chains, which tend to rely on large-volume growers, the markets available to small-scale farmers has become increasingly limited. This chapter examines the farmers' market and other alternatives to this energy-intensive, mass-distribution marketing system.

The current U.S. marketing system for farm products, like current large-scale farming methods, has arisen since World War II in an era of cheap and readily available energy. Most of the domestic fruit and vegetables that Americans consume are grown in specialized growing areas like California where large highly mechanized farms have achieved a remarkably high productivity through the application of energy- and capital-intensive farming technologies. The produce is sold, transported, processed, and packaged, then transported again, resold, and retransported, until eventually it reaches the supermarket shelves. Four times as much energy is consumed in processing and distributing farm products as in the actual planting, cultivating, and harvesting of the crops.[1]

Just as most of the energy consumption and other costs of this mass-distribution system lie beyond the farmer's gates, so do most of the profits: of every dollar that consumers pay for fruit and vegetables, only 30 cents gets back to the original grower.[2] Furthermore, the increasing cost of fuel for this long-distance system has, over the last decade, led to increases in the prices of fresh fruit and vegetables that have far outstripped the increases in both other agricultural prices and the general cost of living.[3] In addition, this system has not only made the farmer dependent on distant markets, it has also made cities, metropolitan areas, and even entire States dependent on food that may be grown thousands of miles away.

For example, New England now imports between 85 and 90 percent of the food it consumes.[4] The New Hampshire Food Policy Study Committee recently concluded that their State "would find itself hard-pressed for adequate food for its citizens within 7 to 10 days of a serious oil embargo against the United States."[5] According to the U.S. Department of Agriculture (USDA), between May and October 1978 (the local growing season) New York City imported almost 8,000 truckloads of lettuce and other vegetables from California, produce that could have been grown locally. These transcontinental shipments consumed 6 million gal of diesel fuel and added 15 cents to the price of each head of lettuce; if the quantity of lettuce imported from California had been grown within 200 miles of New York City, the Nation would have conserved almost 130,000 bbl of oil, and the consumer would have saved 14 cents per head of lettuce.[6]

At the same time that prices to the consumer are rising, the relative return to the farmer is falling. Small-scale farmers, who are unable to take advantage of economies of scale, are particularly hard-hit by the current cost-price squeeze and are finding it increasingly difficult to break even. As a

[1] Colin Norman, *Soft Technologies, Hard Choices* (Washington, D. C.: Worldwatch Institute, June 1978), p. 25.
[2] A. Schumacher, et al., "Technologies for Direct Marketing," OTA working paper, pt. I, p. 14.
[3] Ibid.
[4] Neal R. Peirce and George M. Hatch, "Preservationists Seek Government Help as Farmland Gives Way to Developers," *National Journal*, vol. 12, No. 33, Aug. 16, 1980, p. 1,359.
[5] Neal R. Peirce, "Gardens in the City," Washington Post, Aug. 28, 1979, p. A13.
[6] Donald S. Leeper, "Lettuce: Food, Money, Energy," *New York Times*, May 14, 1980, p. A27.

result, the United States loses an average of 36,000 farms each year,[7] many of which are abandoned or (if they are near expanding urban centers) sold to developers. Almost 1 million acres are "paved over" each year, and often these are precisely the farmlands closest to the consumer. (See the discussion of farmland retention in the "Federal Policy" section at the end of this chapter.)

[7]Bernard Taper, "The Bittersweet Harvest," *Science 80*, vol. 1, No. 7, Nov. 1980, p. 79.

Alternatives for Direct Marketing of Local Farm Products

Many of the vegetables imported from California and other distant growing regions have been and can again be grown much closer to the major metropolitan areas in the Midwest and East. The primary barrier to small-scale local agriculture is limited access to markets: the mass-distribution system is geared to large-scale production, and distributors are unwilling or unable to deal with small lots from local producers. An alternative to the current distribution system is direct marketing of local produce to local consumers by the farmers themselves.

In a recent survey,[8] USDA has identified five major methods of direct farmer-to-consumer marketing:

- pick-your *own*, in which consumers go to the farm, harvest the crops they want, and transport the product to their own homes; this method usually means the lowest prices, but is least convenient to the consumer;
- *roadside stands and farm stores,* which are essentially retail outlets similar to the greengrocers of the past, involve some additional operating costs for the farmer but, since they are located on or near major highways, are more convenient to the consumer;
- *famhouse sales,* the most common method, is similar to the last method but uses the farmhouse or another available farm building instead of a specially built and maintained structure;
- *door-to-door,* which offers the best service to the consumer but involves the greatest inconvenience and transportation costs for the farmer; and
- *@die farmers' markets,* at which a number of farmers offer their products at a convenient centralized location; this method will be the focus of the balance of this chapter.

The USDA study found that only 15 percent of the farmers in the six States surveyed sell their products directly to consumers, and that only 6 percent of these farmers do so through farmers' markets. However, USDA also found that farmers' markets were "most advantageous to small farmers and those who do not have access to heavily traveled public highways or are located 10 miles or more from cities. "9 As a tool for local development, as well as an alternative marketing system, farmers' markets and other direct-marketing strategies offer the following advantages over the current mass-distribution system:

- they can provide consumers with fresh produce, of equal or higher quality and at equal or lower prices than the produce at the local supermarket, without requiring transportation to and from the farm;
- they can provide area farmers with a strong, reliable local market where they can get a higher return on their land and labor by eliminating the many processors and middlemen who normally stand between food producers and food consumers; and
- they can improve the economic health of local agriculture by allowing farmers to diversify their crops and keep their land in production, by encouraging them to adjust their production to local demands, and by giving

'Peter L. Henderson and Harold R. Linstrom, Farmer-to-Consumer *Direct Marketing in Six* States (Washington, D. C.: U.S. Department of Agriculture; Economics, Statistics, and Cooperative Service information bulletin No. 436, July 1980).

'Ibid., pp. 1 and 4.

them an incentive to adopt new and more efficient farming strategies and technologies that will both decrease their costs and increase their productivity.

This chapter draws on information gathered from six different farmers' markets around the country: Rutland, Vt., Morehouse Parish, La., Ravinia, Ill., Boston, Mass., Baltimore, Md., and Seattle, Wash. The diversity and success of these markets is evidence of the vitality and adaptability of the farmers' market as a technology for food distribution and local development. To make this survey as useful as possible, both for immediate analysis and for the benefit of communities that might wish to establish their own farmers' markets, the experiences and problems of these six markets are presented as case studies, with emphasis on the following points:

- How did the need for the market emerge?
- Who took the initiative in establishing the market, and what were the first steps taken?
- What organization and purposes were decided on? How is the market run, and by whom?
- What site was chosen, and how? What facilities are available?
- How were local farmers recruited?
- How were customers attracted and retained?

The diverse origins of the six farmers' markets show the range of local needs and interests such markets can address, the variety of groups and agencies whose initiative or cooperation can help get them started, and the number of avenues by which they can develop. Despite this diversity in motive and development, however, the results have been much the same in each case: a valuable service to the residents of the local community, and a stimulus to small-scale farming in the surrounding countryside. The six markets are therefore considered collectively in addressing the following questions about the performance and impact of the farmers' market:

- What have been the economic results and benefits?
- What changes have farmers made in land use or techniques?
- Have consumers' tastes and concerns changed farmers' production or methods?
- What additional changes in farming technique or technology could further improve small-farm productivity and profitability?
- What critical factors seem to have the most effect on the success or failure of a farmers' market?
- What recommendations for other communities or for Federal policy emerge from the experiences of these farmers' markets?

Farmers' Markets: Six Case Studies[10]

Rutland, Vt.

By the close of its sixth season in 1979, the Rutland County Farmers' Market had grown from a hesitant enterprise located in a church parking lot to one of the largest and most successful markets in northern New England, a community activity that promotes the welfare of the region's farmers and townspeople alike. Three factors seem to be most responsible for the market's success: 1) at the outset, producers and vendors organized themselves into a formal association with a defined set of purposes; 2) the association found and held onto an appropriate central location that would ensure the market's commercial success; and 3) the design and operation of the market responds to the social and economic needs of a diverse cross-section of both the urban and rural communities, thereby ensuring its integration into the social fabric of the region.

The original impetus for the market came from the Rutland Opportunity Council, a local Community Assistance Agency, which saw it as a useful extension of its food and nutrition program. (See ch. 4 for a discussion of other activities of the Community Food and Nutrition Program of the Community Services Administration.) The council recruited local farmers and community gardeners, who then incorporated themselves with

[10] Material in the following case studies is based on Schumacher, et al., op. cit., and particularly the annex, "Five Case Studies."

the State of Vermont as a nonprofit agricultural cooperative—the Rutland County Farmers' Market—with bylaws, a board of governors, and a set of clearly defined purposes:

- to provide a marketplace for local growers to sell their crops and for area craftspeople to sell their wares;
- to provide the consumer with quality local produce and handmade goods;
- to eliminate the need for a middleman, thereby providing a higher retail dollar for the farmer/draftsperson and a lower purchasing price for the consumer;
- to provide consumers with the assurance of quality they have come to expect in Vermont produce and crafts;
- to provide a festive marketplace that will add color and diversity to the city, benefiting local merchants and townspeople alike; and
- to Provide a vehicle in which the rural and urban qualities of Rutland County can blend in harmony.

Membership in the market is open to anyone from the community; those selling in the market are automatically members, and other supporters must pay a membership fee. The 10-member board of governors is elected by the general membership at an annual meeting, usually in April. All final decisions are taken by the board, but it takes its direction from standing committees for such things as entertainment, children's activities, and advertising.

Seasonal or daily fees are collected from the farmers and vendors and applied to operating costs. The fees range from $30 to $100 seasonally, or from $3 to $10 daily, depending on the size of the table or space used. In 1979, the operating costs for the market ran to about $6,000, including insurance, rent, and office expenses. The two biggest items were advertising costs and the salary of a paid coordinator. The Rutland experience shows, however, that a good coordinator is perhaps the best investment a farmers' market can make. Theirs began working for the market 2 years ago as a CETA worker, but is now paid out of market funds. His job includes allocating market spaces, collecting fees, coordinating various market activities, keeping records of gross sales in order to evaluate the market's growth and economic impact, and arranging for publicity. The market also provides a paid coordinator to arrange activities for children while their parents shop.

For its first 3 years, the market was located in a church parking lot outside the central business district, and business was so poor that on some days farmers went home having sold nothing at all. In 1977, after having sold a number of merchants on the idea of a Saturday market on the street in front of their stores, the market convinced the Board of Alderman to let them use downtown Center Street. Traffic was blocked off and vendors set up their tables in front of the stores, and market business improved dramatically. Because of continued resistance from the mayor and a few businessmen, they were forced to move the next year to their present location in Peoples Park, about 200 yards from the Center Street site, but the results were the same. The downtown locations were centrally located, highly visible, and provided more room for both vendors and customers. Local merchants now realize that they benefit from the market's overflow, and the outcome has been not only a more successful farmers' market, but a stronger and more mutually supportive relationship between the farmers and craftspeople, the local business community, and the consuming public.

For farmers in Vermont, where 95 percent of agricultural output consists of dairy products, the farmers' market provides a market where none existed before. Many were new to fruit and vegetable farming, having switched to them because of these new markets, or had previously relied on produce for only a marginal portion of their farm income. When they saw the high return they could get from selling produce at or near retail prices, the latter group began allotting more of their time, energy, and land to this part of their farming operation, which they now view as a major factor in their financial solvency. Some of these farmers now gross as much as $1,000 per week from their direct-marketed produce, having almost doubled their income from it in each succeeding year.

In addition to fruit and vegetables, the Rutland County Farmers' Market also offers local maple products, honey, flowers, and herbs, as well as baked goods, pickles, jellies, and jams. Local artisans—many of them retired senior citizens—sell handmade crafts such as needlework, jewelry, wooden toys, and pottery. To attract customers, the market distributes a small advertising booklet through local hotels and restaurants and uses weekly newspaper ads and hourly radio spots on market day. The market also sponsors live entertainment by dancers, theater groups, musicians, and mimes, who are allowed to pass a hat among the crowd of tourists and townspeople.

The result is an enterprise that responds to a cross-section of needs within the community and brings significant benefits to local farmers and consumers alike. The broad nature of the market's appeal may explain why it has succeeded where other community development projects—a food co-op, a women's health clinic, and a community cannery—have failed, its benefits as well as its appeal seem to cross political, occupational, age, and sex lines.

Morehouse Parish, La.

Morehouse Parish is a cotton-raising county in northeastern Louisiana. Of its 33,000 people, 18,000 live in the principal city of Bastrop, where a garment factory, two papermills, and a chemical plant are the primary employers.

The Bastrop Farmers' Market was set up by the Morehouse Parish Vegetable Producers Association as an outgrowth of a comprehensive small farms program initiated 20 years ago by the county extension agent. At that time, a study done by a consulting group, Doanne Agriculture, showed that 1,005 of the 1,426 farms in the parish contained fewer than 100 acres, and that cotton was the main source of income for these farms. Often the land was not even in one location, and over the years farmers had found it increasingly difficult to extract a decent income. Some were leaving for employment in local industries; others were forced to rely on welfare or social security. Overall, the economic outlook for the county was bleak unless the small farms could somehow be made more profitable.

One of the recommendations of the Doanne study was that small farmers should consider vegetable crops as an alternative to cotton, since vegetables offered a higher return per acre. However, a number of problems had to be solved. Not only did most local farmers lack experience in vegetable farming, but more importantly the local marketing system at the time consisted of only a few roadside stands and door-to-door peddling. Morehouse Parish farmers were also reluctant to change from their traditional cotton crop to commercial vegetables.

Recognizing these problems, the county extension agent began a reeducation program. He used community and neighborhood meetings to discuss vegetable production, set up demonstration plots in principal communities of the parish, and made numerous farm visits to discuss vegetable production with individual farmers. A number of the farmers began growing vegetables and entered into contract marketing agreements for cucumbers, tomatoes, and okra; but their return per acre was still low, and participation began to fall off.

Faced with this situation, the county agent and an extension service specialist conducted a marketing survey that showed that sufficient local demand for local produce existed. What was needed was to bring potential consumers and producers together in some kind of a permanent farmers' market. Accordingly, the agent met with the small farmers and together they formed the Morehouse Parish Vegetable Producers Association. To gain community support, they met with Chamber of Commerce members, police jurors, school board members, and other business and civic leaders. The response was enthusiastic. The local Chamber of Commerce bought a tent, which served as the first market in 1972. Sales that year totaled about $175,000. The next year the producers leased a vacant building and employed a manager with the help of a $1,600 grant from the State economic development district, and produce sales increased to $400,000.

The success of the first 2 years proved the need for a permanent market location. With the support of the Chamber of Commerce and a State Legislator, the Morehouse Parish Vegetable Producers Association received a grant from the Louisiana Department of Public Works to build a permanent market facility on a site in downtown Bastrop donated by the Parish Police Jury. Measuring 40 ft wide and 75 ft long, the building includes an office, a large board displaying the day's prices, a walk-in cooler for storing surplus produce over-night, and pea and bean shellers with which customers can process their purchases on the spot.

Today, the market continues to operate smoothly and with increasing benefits to area farmers, who exhibit an uncommon degree of cooperation. To prevent flare-ups over prices or unreasonable dumping, a pricing committee sets scale-weight and bulk prices for the produce, based on the prevailing wholesale and retail prices; during peak season the prices sometimes change daily. Moreover, a farmer will commonly drop his produce at the market and arrange for another farmer, who has more time to spend at the market that day, to sell his goods while he returns to his farm tasks. Finally, the members of the Morehouse Parish Vegetable Producers Association have realized significant savings by informally sharing farm equipment and by formally participating in cooperative purchases of seeds, herbicides, and pesticides. Savings from these bulk purchases range between 30 and 60 percent.

The association has over 100 formal members, from teenagers to senior citizens. Annual membership costs $5; there is a daily market fee of $2 for nonmembers and $1 for members, with exemptions granted to senior citizens. More than 400 families, however, use the farmers' market to sell their produce at one time or another during the year, and sales continue to expand. One 80-year-old part-time gardener made over $1,000 from a half-acre plot of tomatoes; another family earns a return of about $1,000 per acre from the peas, corn, and collards they truck into Bastrop.

Introducing such a small farm program has necessitated a long-term agenda for teaching adults a new set of skills. The county agent continues to provide technical assistance to help farmers in expanding their operations and responding to consumer tastes. As a way to further their education, farmers have gradually been given more and more responsibility for seeing that the market system functions smoothly. They have learned to plan and cooperate by serving on the market's pricing committee, and have developed leadership skills by having to rotate in the paid job of market manager. Despite these efforts, however, the full transition to a stable, self-reliant community with a healthy, small-scale agricultural base is still some years down the road—perhaps even into the next generation.

In recognition of the fact that the future of local small-scale agriculture rests with the young, the comprehensive small farms program includes a number of projects aimed at Morehouse Parish youth. Through the School Board, the county agent helped to establish a school vegetable farm, a greenhouse complex, a cannery, and a slaughterhouse as extensions of the parish's vocational training program. Moreover, all of these projects are linked with the other parts of the system, so that consumers who purchase vegetables from the farmers' market can have them shelled at the site and then use the modern processing equipment at the community cannery run by the students. Students also sell their vegetables at the market, and plow the revenue back into the school projects. The Morehouse Parish small farm program has thus been a catalyst in developing the community's resources, creating new jobs, and providing vocational training and consumer services.

Ravinia, Ill.

The "Market on the Green" in Ravinia, a northern suburb of Chicago, is one of the most successful farmers' markets in Illinois. Its two principal organizers were local businessmen with offices adjacent to the market, who started the venture in 1978 as a means of drawing more customers to the main business street on Wednesdays. Cooperating with 15 other neighborhood merchants, they made it clear to the farmers that their desire to promote the market derived from what they perceived as a commonality of business interests. As they wrote to the local farmers, "Our committee is formed of local merchants. We all know and understand that you are not coming to Ravinia to please us or sit under our shade trees, but to make *a profit.*" A hardworking farmer could hardly ignore their invitation to sell, which included a description of the market's location, facilities, and advertising program, and added that:

> Selling will be done under nearly ideal conditions . . . . Ravinia is in the center of 100,000 affluent families in Highland Park, Glencoe, Deerfield, and Northbrook . . . . We learned last year that the buyers expect two things: to quality mer-

chandise and a festive atmosphere. It is up to you to provide merchandise of the highest quality. It is our job to provide the festive atmosphere.

The organizers were keen to ensure the quality image of their market. They urged that farmers bring in only their best tasting, top-quality produce, for which they are rewarded with above-supermarket prices. At the farmers' market in neighboring Skokie, a less affluent community than Ravinia, there is a demand for larger volumes of more ordinary produce, so the farmers have an alternate market for seconds. There are also farmers' markets in Elgin, Northfield, and Evanston—all within 25 miles of Ravinia—but the Ravinia market does not directly compete with them, primarily because of its emphasis on and reputation for superior quality.

This demand for quality has had an interesting effect on local agriculture. Ravinia's consumers, who are concerned with freshness and wholesomeness, tend to question the farmers about their use of fertilizers and pesticides and are willing to pay a premium price for organically grown fruits and vegetables. As a result, some local farmers are adopting organic principles and methods to please their customers, and most of the farmers are changing their choice of seed varieties to meet the retail demand for quality and taste, rather than the wholesale demand for shelf-life and appearance. They now earn about 50 percent more than they would by wholesaling and enjoy a far more secure livelihood.

Some 2,500 persons shop at the Ravinia Market each Wednesday in season, some coming from as far as Chicago and Wilmette, 20 miles away. Sales average about $6 per customer; for the 17 participating farmers, this works out to nearly $1,000 gross sales per week, a sufficiently high return to bring two farmers from Wisconsin and one all the way from Michigan.

The self-interest of the local merchants and their ability to organize themselves played a major role in the success of the Ravinia Market, and they too have increased their business on Wednesdays, some by 20 percent. They realize, however, that without the farmers none of this would be possible, and they offer a number of tips to farmers who are thinking of selling their produce in a farmers' market:

- Make sure that the location of the market is in a traffic area and not in some God-forsaken spot outside of town.
- Be sure that you are not used to upgrade or update or revitalize a downtown district that is obviously on its way down and out.
- Be sure that the farmers' market is amply supported by promotion and advertising.
- Be very sure that you are not competing with wholesalers or fly-by-night middlemen or summer students who buy their produce on the wholesale market and come to the farmers' market for a quick profit.
- Emphasize quality and freshness, and sell your produce just as high as the nearest supermarket. Customers come for quality, not price.

Boston, Mass.

Like the Bastrop Market in Louisiana, the farmers' market in Boston–actually a network of six markets in different neighborhoods—came into being through the cooperation of producers' groups and government agencies. The original idea seems to have come from the Boston Urban Gardeners (BUG), a nonprofit group organized in 1976 to promote community gardening and other forms of urban food production. BUG, which coordinates the activities of existing gardening groups and programs, sought to better meet the needs of urban gardeners in Boston, one of which was for a market at which to sell their produce.

At about the same time, the Division of Agricultural Land Use (DALU) of the Massachusetts Department of Food and Agriculture (Mass Ag) had identified a number of rural groups who were mobilizing to revitalize Massachusetts agriculture and to preserve the State's existing (but rapidly vanishing) farms by making their operations more profitable. In 1976, a Farmers' Market Task Force was formed by representatives of Mass Ag, DALU, the State Department of Community Affairs, and the State Legislature, with the *function* of exploring the government regulations relevant to marketing the produce of local farmers, as well as strategies for lowering the cost and improving the quality of the food distributed to urban residents.

A third group was the Massachusetts Federation of Farmers' and Gardeners' Markets (MFFGM), a nonprofit organization dedicated to revitalizing local agriculture through direct marketing strategies. MFFGM, which issues a regular newsletter called The Mass Marketeer, was interested in the idea of a farmers' market in Boston because they felt that its potential high volume and high prices would attract farmers to the direct-marketing movement.

These diverse groups and agencies were brought together through the efforts of the Center on Technology and Society (CTS), a nonprofit organization that had worked out a method of solving problems by linking up different networks of human activity to achieve a particular goal. CTS's executive director describes "networking" in the following way:

> In this strategy, one or two individuals act as facilitators identifying individuals and groups with similar concerns and complementary resources and linking them together in collaborative efforts as well as in sharing information and moral support.

In late 1977 CTS began to develop a networking strategy to implement an alternative food distribution system for Boston's diverse neighborhoods, and in 1978 DALU hired the firm on a 12-week, part-time consulting contract to set up a farmers' market in Boston that same summer. By bringing together independent groups with interlocking needs and interests, CTS played midwife to a model system of big-city farmers' markets.

CTS and DALU held a strategy meeting with representatives of an antipoverty agency, two county extension services, a local community development corporation and—very significantly—two local growers. Although these diverse organizations and institutions all shared the overall goal of establishing a farmers' market in the Boston metropolitan area, they disagreed on exactly where it should be located. Since no centrally located, accessible compromise site could be found, it was decided, reluctantly at first, to establish three different markets during the first year.

Following are profiles of the three communities that served as sites for the Boston farmers' markets in the summer of 1978:

- Roxbury lies in the heart of the city, and has a population of 63,000, almost all of whom are black. Its population has dropped by 26 percent in the last 10 years, in part as a result of the physical deterioration of the area. Median family "income is $6,588, with 45 percent of the families under $5,000. It has the reputation of being a "high-crime area."
- The South End contains Boston's Chinatown and is the home of a number of ethnic groups, with about 36 percent of its 25,000 population being of foreign stock. Median family income is $6,532, compared to a median of $9,133 for all of Boston.
- *Dorchester* has a population of about 180,000, with a slightly higher than average median family income of $9,300. Fewer than 20 percent of families have an income under $5,000.

The actual market sites were as diverse as the communities that hosted them. Dorchester Gardenlands Preserve, Inc., the community development corporation that sponsored the Dorchester market, arranged to have a portion of their main street blocked off each Saturday morning. The farmers then parked along the street and sold directly from their trucks. This was the most elaborate operation, requiring one traffic patrolman to direct traffic. In the South End, the sponsor was a tenants' group, the Methunion Tenants Council, which owned a parking lot next to a local restaurant. This parking lot served as the South End Farmer's Market. The Roxbury Farmers' Market was located on a 4-acre abandoned lot owned by the Boston Redevelopment Authority, which leased it to the Roxbury organizers free of charge. However, the lot contained numerous potholes, frost heaves, and piles of rubble; its depressing appearance, and' the area's bad reputation, discouraged a number of farmers from participating.

To recruit growers to sell their produce at the markets, DALU's assistance proved invaluable. They put Boston organizers in touch with prospective growers through the *Greenbook,* an annual directory of Massachusetts growers that lists the farms and what they produce. With little money for mass mailings, CTS and a group of volunteers sent out a copy of a typewritten letter to more than 200 local farmers in May. They also spread information through local newspapers, agricultural bulletins, and selected newsletters, including MFFGM's Muss *Marketeer.*

The Dorchester Farmers' Market opened on Saturday, July 8. It was followed by Roxbury on July 14 and the South End on July 21. Table 18 gives a summary of the economic performance of the three markets during their first season.

Opening day in Dorchester saw only one farmer selling during the first hour, and consumers immediately bought him out. The farmer was interviewed by a local television station, and commented enthusiastically about how fast he was selling his produce. By the third week of operation, seven growers were selling their produce at the Dorchester Farmers' Market, most of whom said they came to Dorchester after seeing the television interview. In Roxbury, the market had to struggle from the very beginning and was eventually forced to close prematurely because of poor consumer and grower participation. Part of its problem was a Friday morning schedule, which turned out to be inconvenient for both shoppers and sellers.

The South End Market, on the other hand, was scheduled on Friday afternoons from 3 to 7 p.m., which accommodated the working population that had been excluded by the Roxbury market's early morning schedule. The schedule also appealed to growers, because it allowed them enough time to travel to Boston without getting tangled in the rush hours.

For their part, produce growers were attracted to the Boston farmers' markets because they provided a workable alternative to selling wholesale. One 63-year-old farmer from Tully, Mass., drove 140 miles round trip each week to sell at all three Boston markets. In an interview in the Boston *Herald-American,* he called them a "Godsend" and said they probably made the difference in his decision not to give up farming. In all, 26 growers participated in at least one of the 36 total market days held in Boston during the summer of 1978. During the following winter, informal questionnaires were sent out to more than 200 Massachusetts growers to find out how responsive farmers' markets were to their needs. Of the farmers who replied, almost all were impressed by the amount of produce they could sell in a short period of time and the overall volume of sales they had experienced. Many growers were reluctant to discuss exact figures, but average gross sales on any given market day appear to have ranged from $200 to $500, with occasional sales as high as $800. Sales were good enough, in fact, that a number of growers said they wanted more urban markets on other days of the week.

That winter, four new communities in the greater Boston area began planning to open their own markets in 1979, and new communities were advised to schedule their markets on each day of the week except Sunday. One of them was located in the affluent suburb of Brookline, in order to attract those growers who had been put off by locations in poor neighborhoods. CTS felt that once

Table 18.—Boston Farmers' Markets Summary, 1978

Market	Estimate of total sales	Seller's fee	Best selling items	Estimated customers/market
Dorchester **Saturdays (9a.m.-1p.m.)** **July 8-Oct. 7(14 weeks)**	$20,000	$2,$5,$10	Fruit, corn, salad greens	200-300
Roxbury **Fridays (9 a.m.-1 p.m.)** **July 14-Sept. 8 (9 weeks)**	$3,500	None	Corn, beans, tomatoes	100-200
South End **Fridays (3 p.m.-7 p.m.)** **July 21-Oct. 13(13 weeks)**	$10,400	None	Corn, beans, fruit	150-250

Total number of market days (all three markets): 36
Average sales per market: Dorchester ($1,500); Roxbury ($390); South End ($800)
Average sales per week at all three Boston markets: $942.00
Total estimated customers buying at the three Boston farmers' markets, 1978: 7,450

SOURCE: Office of Technology Assessment.

those growers ventured into Boston, their fears would be overcome and they would visit some of the other markets in the city. In 1979 all but one of the six markets had successful seasons, and many of the 40 or 50 participating growers said it was the best year they ever had. Five of the six markets were scheduled to return in 1980.

Baltimore, Md.

The idea for Baltimore's market came from a single consumer. In 1976, at one of the mayor's sounding-board meetings, a local citizen raised the question of what to do about skyrocketing food prices at the grocery store. This came at a time when food prices had been rising steeply for 3 years, far outstripping inflation in other sectors of the economy. "What we need," the citizen suggested, "is a good old-fashioned farmers' market, where people could buy direct from the farmer and eliminate the middlemen. " Intrigued by the idea, the mayor directed the city's Office of Promotion and Tourism to see what could be done about establishing a market.

Baltimore is fortunate in having a strong-mayor system and a history of active, effective mayors. In this case, the mayor's stamp of approval was the key to securing the cooperation and coordination of the various city agencies and their respective bureaucracies, a requirement for establishing any successful farmers' market.

The site chosen for the market, near the old fish market, turned out to be a natural. Parking space would be available for hundreds of cars, and a city college next to the site would provide water and restroom facilities for the farmers. To get farmers interested in the project, staffers from the Office of Promotion and Tourism got advice and names from Maryland's county extension agents and then went from farm to farm making personal contacts. Letters were then sent out to the farmers telling them about the facilities of the market and the details of its operation. In the first year no fee would be charged, and participants would not need to prove they were really producers rather than wholesalers in disguise.

To draw customers to the site, organizers sent out press releases to radio stations and newspapers, which run public service announcements and feature articles about the market, including tips to consumers on what to look for and how to prepare fresh produce when they get it home. They also arranged to provide both entertainment and ready-to-eat food each week, but after the first year's success the entertainment was canceled—customers came in such numbers that the space that had been used by the entertainers was needed to accommodate the heavy flow of people through the market area.

Unlike other cities, Baltimore has not done an evaluation of their market, and no official data has been collected on the gross sales or the volume of produce being moved. However, the rising number of farmers who drive their trucks to the market (which increased from 12 in 1977, to 70 in 1978, to approximately 100 in 1979) is some indication that they find the market profitable. Most of these farmers have holdings of between 50 and 300 acres, and many have long-established relations with wholesalers or a roadside stand of their own. For these farmers to take on the additional burden of planning trips to the Baltimore market on Sundays, the profit margin of this method of direct marketing must be considerably more attractive then their other options. Compared to running a roadside stand, the city market offers farmers the chance to move a larger volume of produce in a shorter time and with lower overhead costs. Rough estimates, based on the number of empty bulk containers at the market, place the average Sunday gross sales in the range of $700 to $1,000 per farmer, with several farmers grossing $2,000 to $3,000 per market day in peak season.

For the farmers, there is no question that the market works. On the consumer side, subjective evidence and a casual survey of prices indicates a similar positive benefit. A 1979 price comparison found that farmers' market prices were, on average, about 30 percent below those in nearby supermarkets. A large number of consumers spread the benefits over the entire year by buying in bulk and putting food up for the winter by canning and freezing. It was not uncommon to see produce carried away in large plastic trash bags.

The success of Baltimore's city-organized farmers' market shows that, given the right conditions, mayors and city agencies are capable of responding quickly and effectively to the needs expressed by their constituencies. Its example might encourage other groups and cities to develop this alternative and supplement to the present mass-distribution system of food marketing.

In contrast to Baltimore's informal system, the history of city-run markets housed in *permanent* facilities indicates that (over time) large-scale, institutionalized farmers' markets are subject to a number of economic and political pressures which can change their character and the function they serve in the community. An example can be found in the next case study, the Pike Place Market in Seattle, Wash.

Seattle, Wash.

The conditions that led to the establishment of the Baltimore Farmers' Market in 1976 are similar to those that led to the creation of Seattle's Pike Place Market 69 years earlier. Food prices had jumped 30 percent and the Seattle *Times* placed the blame on the city's food trusts, commission houses, and wholesalers. A city councilman, claiming that "the average man was the victim of organized greed," called for the creation of a public market where farmers could sell directly to consumers. The Seattle City Council eventually passed an ordinance establishing a market at Pike Place, which was a newly constructed roadway at that time. The market was to represent the "little guy"—the city resident, on one hand, and the local farmer, on the other, both of whom felt that they would benefit by eliminating the middlemen.

The Pike Place Market was an instant success, but over the years its profitability attracted developers, entrepreneurs, and wholesalers, who gradually encroached on the control and success of the small farmers. The market was plagued by corruption in the 1920's and by farm foreclosures during the Depression. A more serious reversal came during World War 11 with the internment of Japanese-Americans on the West Coast, many of whom were farmers; the number of farmers in the Seattle region plummeted by 65 percent. During the postwar period, housing developments and industrialization–much of it due to the growth of Boeing-began "pavin g over" agricultural land. Between 1945 and 1975, farmland in King County shrank from 165,000 to 55,000 acres.

The number of farmer-vendors participating in the market gradually declined, and by the 1950's its operation was no longer bringing any revenue to the city. Its buildings began to fall into disrepair; health, fire, and building code violations cropped up; and the blight spread to property surrounding the market.

The Pike Place Market was saved from extinction by an initiative passed by Seattle voters in 1971, which called for the creation of a 7-acre Market Historical District to preserve the market and its surroundings. Although the sale of produce by local growers was given the number-one priority by the historical commission, however, no farmers were represented on the commission itself or on the Pike Place Preservation and Development Authority (PDA), which carried out the actual rebuilding of the Market.

PDA's general approach has been to purchase buildings from the city and then obtain development financing through government loans and grants as well as through the sale of tax-exempt bonds. By the end of 1977, private investment in Market redevelopment had reached $13.5 million, and total public funding is projected to reach $40 million before redevelopment is completed. Close to $15 million in debt financing will have to be repaid out of rental income over the next 10 to 25 years, and this will mean greatly increased overheads for participating small farmers.

Low-income local residents have also been hurt by redevelopment: there had been 780 units of low-income housing in the area before redevelopment, but by 1978 the number had fallen to 128. Although there are plans to bring the number back up to between 325 and 405, low-income residents felt threatened by the wave of condominium development and the overall "gentrification" of the area, particularly as it affects the market itself.

One of the most visible changes in the market since redevelopment has been a sharp increase in the number of tourists (see figure 25). Producers and consumers alike complain about the tourists: local residents because of the crowds, which make shopping difficult, and local farmers because, as one of them put it, "All they want are T-shirts, jewelry, and *one peach.*" In addition, merchants who must appeal to these single-purchase customers are now choosing only the largest, best looking fruit from the wholesalers, gone are the lower cost, irregular size apples and pears that used to be available for bulk buyers, large families, and those on low or fixed incomes.

As a result, Pike Place Market today has more craftspeople than farmers, more tourists than local residents. It is no longer strictly a farmers' market at all—it has become a general retail market and tourist attraction. Nevertheless, surveys indicate that the market is still perceived primarily as a food market, and that it is the produce that attracts customers. And despite the declining participation of farmer-vendors, the market can still provide consumers with significant savings: a comparison with six local supermarkets showed that farmers' market produce was consistently more varied and less expensive. The produce vendors at the market still draw a large percentage of their customers from the immediate area, and the market's regular customers, who shop there on a weekly basis, are its real mainstay. Significantly, 85 percent of these consumers said that they would buy locally grown produce in preference to trucked-in varieties, if both were available.

Nevertheless, local agriculture in the Seattle area continues to decline. King County's 1,200 farms range from 1 to 100 acres, with an average of 20.3 acres for vegetable farms and 11.4 acres for berry farms. About 80 percent of this acreage is farmed by owners or part-owners, but although 60 percent of the county's commercial farmers earn their primary income from the sale of farm products, approximately 70 percent of them also work at second jobs away from their farms. The current trend among both vegetable and dairy farmers is toward steadily lower production and sales, and a survey conducted by the city in 1974 indicated that many were selling off their land, or were being forced to give up farming on leased lands because of high rents.

To help these farmers, King County has implemented agricultural zoning policies, current-use tax laws, deferred utility assessments, and marketing support for local farm products. None of these measures, however, has stemmed the tide of conversion from agricultural to residential and industrial uses. A ballot initiative to purchase development rights from the farmers for $35 million was defeated in 1978 by 180 votes.

Local farmers, interviewed about the future of small-scale agriculture in the region, were pessimistic. Their own children and grandchildren have no interest in farming, they said, and the young alternative-lifestyle farmers simply don't stick with farming long enough to gain experience. At the same time, however, these farmers also indicated that they were not interested in new farm technologies that would allow them to extend their production (and income) into the winter months–they already work too hard in the spring, summer, and fall, ran the usual response.

The Bulk Commodity Exchange.–The decline of local agriculture has led to concern that the redeveloped Pike Place Market might become a memorial rather than a market outlet for local farmers. One hopeful development has been the Bulk Commodities Exchange (BCE), a wholesale direct-marketing cooperative designed to link small farmers and local consumers by providing an accessible outlet for bulk sales of fresh produce. Incorporated in the summer of 1977 as a nonprofit producer/consumer cooperative, it includes local farmers as well as buying clubs, restaurants, and other institutions. Located in the Market, it was cosponsored by PDA, the King County Office of Agriculture, and the Hunger Action Center. BCE sells its members produce in the same quantities that farmers generally deliver to wholesale houses: a flat of strawberries, for instance, or 50 lb of onions, or 100 lb of potatoes. By the end of 1978, the gross sales had grown from $4,000 to $40,000, the number of participating farmers from 17 to 21, , and the number of consumers' groups from 40 to 70.

The BCE offers a marketing option that has attracted two additional groups of farmers: those who produce too much to sell at farmers' markets, but too little for wholesaler houses, and those who grow mainly for wholesale, but need alternate outlets for surplus cosmetically inferior produce. Small- and medium-scale farmers sell to BCE because it pays them very well, but the arrangement also has advantages for consumers. In September 1979, for instance, the local Safeway supermarket was paying farmers $4.50 case (five dozen ears) of local corn; BCE paid $5.50 per case, marking it up to $6.60 case to consumers; Safeway's advertised sale price for the same corn was $7.50.

The fact that BCE sells food in bulk is of critical importance, since at least 50 percent of its members purchase significant quantities of fruits and vegetables to put up for the winter. One member, an agricultural extension agent, sees BCE as an important link between small farmers and urban consumers; he would favor Federal support for a network of BCE-type outlets. "We need to encourage our local farming right now," he said. "Transportation and energy costs can be beaten by taking advantage of our local produce. " BCE financing now depends on Community Development Block Grants, but when the grants run out BCE will need to find stable, long-term funding.

Impact on Local Small-Scale Agriculture

In some cases, farmers' markets have created local markets for fruits and vegetables where no market had existed before; in others, they have provided an alternative to the direct-marketing systems that already existed, such as produce stands and door-to-door vending. In both cases, the markets provided higher prices to the farmers than had been available through wholesalers or contract marketing arrangements, in some cases by as much as 50 percent. Average gross sales of $500 or more were common, and in Baltimore and Ravinia some farmers were able to sell over $1,000 worth of fruits and vegetables each market day. Because of low overhead, high prices, and the large volumes that can be sold in a short period of time, this form of direct marketing offers the small-scale farmer a considerable financial opportunity.

In response to the opportunity provided by these markets, local farmers have begun to change their land-use patterns, planting schedules, and farming methods. Farmers who had already produced vegetables and fruits, but relied on them for only a small, marginal portion of their farm income, have begun to allocate more of their time, energy, and land to these crops. One family in Vermont now rents out half of their 200 acres to neighboring dairy farmers, plants 3.5 acres in produce, and uses the rest to extract syrup from maple trees, which previously provided two-thirds of their income. A farmer in Louisiana has made a similar reorganization in his farming operation, renting all but 25 of his 115 acres to a neighbor with a large cotton operation and concentrating all of his energies on growing fresh market vegetables on the remaining land; each of his children is given an acre to work for themselves, from which they receive about $1,000 per year.

Farmers' markets have also changed the planting schedules of participating farmers. They now plant two crops per year, spring and fall, instead of just one as they would under corn or cotton monoculture. They have also learned the importance of staggered planting, in order to assure themselves of a continuous flow of produce and to avoid flooding the market, which would erode their returns. Picking the crops by a certain date can also improve their return—in Morehouse Parish, for instance, the extension agent advises farmers to pick southern peas before September 1, because by that time most consumers have frozen and canned all they will need for that winter.

Local direct marketing has also made a difference in the varieties of crops the farmers plant. Large mechanized operations call for varieties of peas or tomatoes that are easily picked by machine, for instance; processors demand certain other varieties that are particularly suited to canning or processing into catsup or soups; and the mass-distribution system puts a premium on varieties that ship well, have long shelf-life, and look appealing to the supermarket shopper. For the farmers' market, on the other hand, the premium is on quality and taste; appearance and shelf-life are secondary. As a result, farmers in Morehouse Parish plant the pole variety of lima bean, which is in greater demand than bush varieties. Because the markets also demand a wider range of vegetables, farmers are able to diversify their plantings and thereby decrease their vulnerability to the failure of any one species or variety. In addition, careful selection of early or late varieties can allow the farmer to spread out his harvest, just as he does by staggered plantings–thus, one farmer in Rutland purchases seed for a special early pea variety from a firm in Prince Edward Island, Canada, in order to bring his peas to market in early June, a week or two ahead of other growers. Finally, the careful selection of seed varieties allows the farmer to grow what will sell best, and to adjust his production to local demand and taste.

All of these measures allow the farmers to increase the efficiency of their operations and make the best use of available labor, but the case studies also reveal that farmers are further improving the productivity of their operations by changing their farming methods and adopting technologies that are more appropriate to vegetable farming and direct marketing. This is most pronounced in Morehouse Parish, where farmers have begun an informal program of sharing farm equipment, thereby sharing capital costs as well, and have realized further savings through cooperative bulk purchases of seed, fertilizer, and pesticides. In response to consumers' concerns and premium prices at the Ravinia market, local farmers have begun shifting to organic farming methods, through which they can also realize savings by reducing or eliminating the use of fertilizers and pesticides, and replacing them with such methods as comporting and biological controls.

A number of additional technologies offer the farmer potential methods for extending his growing season, and thus his income, and perhaps even achieving a year-round operation. Black sheet plastic is widely used as a mulch, but it is also an excellent means of warming the soil and achieving early, high-value crops of tomatoes, cucumbers, sweet corn, and squash; in northern climates, it makes possible the cultivation of desirable crops such as cantaloupes and other melons. A second planting of tomatoes in July, staked and heavily mulched, can be protected with a 6-ft, plastic-covered teepee; this solar-heated and frost-proof technique can give an additional month of growth and yield late tomatoes that are very popular with consumers. A raised bed under a glass sash can also extend the growing season, and a larger greenhouse can produce fresh lettuce and salad greens from November through February (see ch. 4). In colder climates, well-insulated root cellars can also provide a simple, low-cost storage system based on historical techniques; in them, farmers can store squash, cabbage, carrots, onions, and parsnips for year-round sale to consumers.

These techniques are, for the most part, more familiar to organic gardeners and alternative-life-style farmers than to commercial farmers. And for the most part, these conventional farmers show little interest in technologies for extending their growing season or achieving year-round production. The usual reason given, particularly by farmers in the Seattle area, was that they already felt overworked after 8 months of planting, cultivating, harvesting, and selling produce. What may be needed, however, is a better understanding of available technologies for decreasing costs, increasing productivity, and extending the growing season. The steps taken by the county agent in Morehouse Parish–workshops, demonstration plots, and farm visits—proved to be an effective means of achieving this goal. These same techniques, however, could also be applied to the production of vegetables in solar greenhouses (see ch. 4) and in urban community gardens.

Critical Factors

Public Perception and Participation

If any one conclusion can be drawn from the six case studies in this chapter, it is that the single most important factor in the successful development of a farmers' market is the participation of the local farmers in the planning, design, and operation of the market. The deficiencies of Pike Place as a farmers' market shows that more attention must be given to the farmers' interests and problems, and that they must be consulted and given more responsibility. Of all the various actors in the redevelopment of Pike Place, the producers were the most vital but the least organized, and thus the least heard from.

In Morehouse Parish, by contrast, the market is operated by the farmers themselves, with the help of the local extension agent. Similarly, the successful market in Rutland, Vt., was organized by the local farmers, who also participate in its governance; spokesmen there attribute the market's success in large part to the fact that the farmers organized themselves into a formal cooperative with a clearly defined set of goals. In Boston, finally, the idea for a network of farmers' markets originally came from a local producers' group, and it was by putting this group in contact with a network of similar organizations that the State government and its consultants contributed to the project.

The Ravinia and Baltimore case studies show that local merchant groups and municipal governments can be effective in initiating a farmers' market, but in other cases these same groups have been barriers to implementing such projects, as will be seen below. The organizers of a farmers' market would do well to make early and close contacts with these groups, however, since their cooperation greatly facilitates the establishment and operation of the markets.

The farmers' markets have been well received and actively supported by the general public. They appeal to and serve the needs of a broader cross-section of the community than do some other local development projects, and the Boston and Rutland markets successfully enlisted community groups and individual citizens in the organization and governance of the markets. The evidence suggests that it is the identity of the market as a food market that is responsible for much of this appeal and support, and organizers should be certain that nonfood activities remain subordinated to this primary function, which should also be the focus of their promotional efforts.

Consumer participation is also important, and in most cases a carefully planned and vigorously pursued program of promotion and advertising can contribute significantly to the market's initial success and eventual self-sufficiency. Informational letters sent to local farmers, followed by farm visits to establish personal contacts, were useful in recruiting producers for the Ravinia and Baltimore markets; their continued participation, however, depended on attracting and retaining customers. Rutland's brochure on the market is one way of doing this, and most of the markets make use of paid advertisements in local newspapers or public service announcements on local radio stations, informing the general public of the market's existence telling them what to look for on a given market day, and in some cases quoting current prices. Media coverage of a market's opening can help to attract both producers and consumers, as happened in Boston. Feature articles in the food section, which Baltimore encouraged through press releases, can serve an additional function by educating the consumer on how to prepare an unfamiliar vegetable or how to make new dishes with fresh produce—a useful tool in a community nutrition program as well as a means for diversifying and strengthening the market for locally grown produce.

Essential Resources

The natural resource base on which a society relies—land, water, etc.—can be utilized to meet its production needs in different ways, along a continuum representing various degrees of centralization. Some regions might specialize in agriculture, while others are used primarily for industrial uses; but such an approach imposes extremely high costs for processing and transportation. Because of rapidly rising energy costs, recent development efforts have concentrated increasingly on creating and developing viable local economies. Implicit in this approach is the need for a system of mixed land use within any given region.

If local agriculture is to be part of this mix, its survival may depend on the existence of local produce outlets like the farmers' market or bulk commodity exchange. By decreasing costs and increasing both productivity and profitability, these local markets can help the small farmer to stay in business and keep his land in productive use. Small farmers outside Rutland, Boston, and Baltimore all testified to the high profitability of the markets and the difference they had made in the solvency of their operations. The farmers' market has had its largest impact, however, in Morehouse Parish, where marginal farmers saw no alternative to the cotton crop. Many of these farmers were

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saved by switching to more profitable vegetable crops and more efficient methods, and by establishing direct access to local consumers who want to buy what they produce.

Farmers will further improve their return if they adjust their production to the varieties or grades of produce that are in demand in a particular community. A market survey or careful recordkeeping can be a great help in making this adjustment. The variety of available produce and the reliability of the producer seem to be important factors in all of the case studies; but in some of the markets quality is the primary consideration, while in others price is more important, and in yet others the consumers are interested in the wholesomeness of organically grown vegetables. Very early and very late produce (May peas and October tomatoes, for instance) are also in great demand and therefore more profitable for the farmer who is willing to adjust his schedule or adopt new methods.

The physical design of the marketplace itself should give primary consideration to the functional use of space. Selling produce off the tailgates of trucks parked on a blocked-off street is the simplest and perhaps the most efficient arrangement. A more permanent facility needs lighting and drainage capacity, as well as a practical layout that facilitates the movement of shoppers and tourists; it also needs outside access in the form of parking and loading areas. Some consideration should also be given to the type of neighborhood in which the market is to be located and the schedule of its operation. Roxbury's reputation as a "high-crime area" discouraged a number of farmers from going there, but the site itself was uninviting and the schedule—Friday morning and early afternoon—was inconvenient for both the farmers and the working people of the community. The Boston network has scheduled its six markets on six different days of the week, so that farmers have a different market available every day except Sunday. Location, layout, and scheduling are all areas where organizers need input from local farmers and consumers.

The Pike Place Market shows some of the pitfalls to be avoided in the redevelopment of existing urban markets. Preservation rather than demolition was the rule in its redevelopment, but the planners appear to have concentrated on exterior appearance rather than on the real functions of the market. Within the Market, the design of sales and storage space seems to have proceeded without sufficient input from the local producers themselves. Moreover, according to some consumer interviews, not enough attention was given to the needs of local shoppers, who complained of crowding, lack of parking, loss of housing and services, and an actual decline in the availability of low-priced produce.

Technical Information and Expertise

Local farmers and gardeners are the main source of expertise, but in several case studies they were unfamiliar with direct-marketing techniques and with the tastes of local consumers, as well as with the methods of fruit and vegetable farming. The local agricultural extension service could provide invaluable assistance in these areas, as it did in Morehouse Parish, and the networking strategies used by CTS in Boston are also an effective way to spread information and experience.

A market survey can determine not only whether sufficient demand exists, but also what crops or varieties will be in particular demand by local consumers. The same information can also be gathered through careful recordkeeping by the participating farmers or, as in the case of the Rutland market, by a paid coordinator. In Ravinia, one of the local merchants who organized the market also serves as an unpaid market master; in Baltimore and Seattle this role is played by municipal employees. In all of these cases the arrangement removes the burden of actually running the market from the farmers, but the Morehouse Parish study shows that the farmers themselves are capable of assuming the management chores. By rotating the post of market master and membership on the pricing committee, this arrangement also contributes to the development of management skills in the community.

The Morehouse Parish example also shows the importance of a comprehensive program of education, information, and training in the techniques of vegetable farming as well as the management of the farmers' market itself. The local county extension agent not only got the local farmers interested in vegetable farming and direct marketing, but has also initiated a training program in the local school system and is trying to interest the community in running a cannery. Some of the Seattle area farmers suggested the development of similar agricultural apprenticeship programs to train new farmers and reverse the decline in their numbers.

Such training programs might also include exposure to innovative farm technologies that will increase productivity and extend the local supply of produce to a more nearly year-round basis. The lack of interest in these methods on the part of the Pike Place farmers might be overcome by a better understanding of the methods themselves and their potential economic rewards. Networking, as practiced in Boston, might accomplish the same end by bringing farmers together with those who are already familiar with these techniques.

Financing

According to available information, total investment in the Pike Place Market project has already exceeded $50 million. While it may be too early to determine whether the full impact of the redevelopment will justify expenditures on this scale, it would be reasonable to ask whether this use of funds reflects the needs of local farmers or the desires of local residents, and what its effect will be on the future character of the surrounding community. The functions of Pike Place as a *farmers' market* might well have been promoted with a smaller infusion of funds, and the redevelopment financed without placing financial burdens on the farmers in the form of higher rents to subsidize the capital costs of the project.

Judging by the experience of the five other markets, the initial financing needed to set up a farmers' market appears to be quite minimal, depending on whether it is quartered in a permanent facility or whether the produce is simply sold off the back of the farmers' trucks. The real need, at least in the beginning, is for operational expenses to pay the salary of whatever staff is required to coordinate market activities, run the advertising program, and carry out other duties. In the smaller markets, the fees paid by the farmers may be insufficient to cover these costs, but considering the ancillary benefits the markets produce in city neighborhoods, the expenses could reasonably be borne by the municipality, as they are in Baltimore or by the local merchants, as they are in Ravinia. The State grants that paid for the initial operating expenses in Morehouse Parish and the consultant's fee in Boston are appropriate ways to finance startup costs, but the Bulk Commodity Exchange in Seattle shows signs of becoming dependent on the Community Development Block Grants that support its operation, and when these grants run out it will need to find stable, long-term funding if it too is to become a viable, self-sustaining enterprise.

Institutional Factors

The farmers' market represents only a minor economic threat to local wholesalers and mass-distribution retail outlets, and these interests have not been particularly vocal or active in their opposition to the farmers' markets studied in this chapter. In fact, the markets often provide an outlet for farmers whose output is are too small to be of interest to traditional marketing systems. Wholesalers may represent a threat to local producers, however, when they compete unfairly with locally grown products or when they, rather than the small farmers, have a controlling voice in the operation of the market.

Opposition has come, instead, from local merchants and from municipal officials. As was the case in Rutland, store owners often fear that the farmers' market will detract from their business, and for this reason oppose having them on the street in front of their shops. Prior consultation with the Chamber of Commerce and other groups can often do much to allay their fears, avoid their opposition, and even enlist their support. In most cases, the markets had positive impacts on local business, and this information may help to convert the uncertain. In Ravinia, in fact, it was the merchants themselves who organized the market as a way of increasing their business, and in both Rutland and Seattle the markets significantly stimulated the tourist trade. The Baltimore case study shows that the municipal government can itself take the initiative in establishing a market. It also shows that the support of the mayor can be invaluable in obtaining the necessary cooperation of various city agencies that might oppose or impede the development of the market—the most likely candidates being Health and Sanitation, Public Works, Zoning, Weights and Measures, Tourism, and Police.

Federal Policy

Background

Like a number of the technologies examined in other chapters of this report, the farmers' market and other means of direct marketing have potential benefits that cut across several national issues; their success or failure can therefore be affected by a number of Federal policies. Energy conservation, for instance, is an important byproduct of the establishment of these markets. Farmers' markets, in turn, are affected by rural development and small farm policies, which are discussed in chapters 4 and 5, respectively. However, Federal policies most directly relevant to the development of farmers' markets are those which concern agricultural land retention and the encouragement of direct marketing. A third related topic, that of the role of the Agricultural Extension Service, will also be discussed at the end of this section.

Agricultural Land Retention[11]

By improving the economic viability of small farms near urban areas, the widespread adoption of alternative technologies for the production and marketing of farm products may help to slow the conversion of the Nation's cropland to nonagricultural uses, a trend that has become a topic of increasing debate at all levels of government. Between 1967 and 1975, according to USDA's Soil Conservation Service, about 24 million acres of rural land—an area about the size of Indiana—was converted to housing subdivisions, highways, reservoirs, parks, and other nonagricultural uses; by 1972, American farmers were planting 50 million fewer acres than they had in 1950.[12]

Recent years have seen a continued net loss of cropland:

> Each year 1.25 million acres are converted to efficient cropland by draining swamps and irrigating deserts, while 0.9 million acres are converted to urban and transportation use. The rest of the 2.2 million acres of rural land which goes out of use yearly is abandoned because it has "low soil fertility and a terrain unsuited to efficient use of modern machinery." A million acres yearly goes into additional wilderness recreation areas and wildlife refuges, and another 300,000 acres goes for reservoirs and flood control.[13]

In other words, for every acre of farmland created (at great cost) from swamps or deserts, an acre of previously useful land is "paved over" or "drowned" and lost to agriculture forever. Often this is precisely the farmland closest to the consumer.

This issue was concealed during the 1950's and 1960's by repeated crop surpluses; by Government payments to farmers to keep land out of production; and by low prices for petroleum-based fuels and fertilizers. In the early 1970's, increasing world demand for U.S. agricultural products and a temporary suspension of Federal set-aside programs led farmers to bring much of the available land back into production. At the same time, rising oil prices have sharply increased the costs of conventional, energy-intensive agricultural techniques. Concurrently, yields have been adversely affected by an increased variability in the weather: 1979 produced a bumper crop, but the 1980 crop was significantly reduced in many regions by heat and drought.

Concern about farmland conversion continues to mount. Some people feel that continued conversion to nonagricultural uses, combined with the deterioration of some of the remaining cropland, may hinder the achievement of the Nation's long-term agricultural production goals. Others point out that although 1.25 million acres are converted to cropland each year, this is usually done by draining swamps or irrigating deserts, which requires a high initial investment and an increased demand on the Nation's energy and water supplies. These views are discounted by those who feel that advances in conventional agricultural tech-

[11] Some of the material in this section is drawn from Jefferey Zinn, "Farmland Protection Legislation," Library of Congress, Congressional Research Service issue brief No. IB78013, May 29, 1980; and W. Wendell Fletcher, "Agricultural Land Retention," Library of Congress, Congressional Research Service report No. 78-177 ENR, Aug. 31, 1978.

[12] Zinn, op. cit., pp. 1, 2.

[13] Julian L. Simon, "Resources, Population, Environment: An Oversupply of Bad News," Science, vol. 208, No. 4451, June 27, 1980, p. 1435.

nology will offset any production losses or cost increases that arise from cropland conversion and abandonment. Still others think that the situation should be studied further before changes are made in Federal policy to deal with the problem on a nationwide basis. Finally, some think that farmland retention is an essentially local or regional problem.

Many State and local governments are currently considering legislation to protect farmland from indiscriminate development, and others have already adopted such measures and implemented a wide range of programs to carry them out.[14] The Federal Government is also assessing the impact of its own policies on agricultural land retention. The National Agricultural Lands Study, which is being carried out jointly by USDA and the Council on Environmental Quality (CEQ), is scheduled to present its final report in January 1981. USDA, CEQ, and the Environmental Protection Agency have either adopted or are now formulating policy statements in support of the concept of cropland retention. Despite these efforts, however, there currently exists no Federal program to assist State and local governments in developing farmland protection legislation and programs.[15] Members of both the 95th and 96th Congresses proposed legislation to establish such a program.

95th Congress.—In the 95th Congress, the Agricultural Land Retention Act (H.R. 11122) called for a commission to undertake a comprehensive study of agricultural land, and to recommend to the President and Congress methods for instituting a national policy for protecting farmland. In addition, its title III proposed a demonstration program to provide Federal funds and technical assistance to States and localities for testing and demonstrating farmland protection methods during the life of the proposed commission. The National Agricultural Land Policy Act (S. 2757) was generally similar to H.R. 11122. Neither of these pieces of legislation was enacted by the 95th Congress.

The Farm Tax Equity and Family Farm Development Act (H.R. 107 16) was more directly relevant to appropriate technology and agricultural land retention. Its title IV would have authorized low-cost small farm ownership and operating loans, to be made and insured by the Secretary of Agriculture, that would enable small, family, and low-income farmers and ranchers to acquire small-scale alternative farm technologies. Furthermore, its title V ("Farm Marketing Programs") would have authorized funds to support the development of alternative systems for the distribution and marketing of agricultural products. H.R. 10716 was not enacted by the 95th Congress.

96th Congress.—Members of the 96th Congress proposed legislation that was essentially the same as that proposed during the 95th Congress. The Agricultural Land Protection Act (H.R. 2551) would have authorized funds for conducting studies on the issues surrounding the retention of agricultural lands as well as for demonstrating different methods of cropland protection, but it also contains provisions which might encourage the adoption of appropriate technologies by small farmers. It directs the Secretary of Agriculture to conduct a comprehensive study of methods for protecting and improving agricultural lands in and around urban areas, which would set a precedent for including urban food production in the formulation of land retention policies. This Bill also declares that it is the policy of Congress to foster intergovernmental cooperation in making decisions likely to affect the conversion of agricultural land to other uses. After considerable floor debate, the House rejected H.R. 2551 on February 7, 1980 by a vote of 177-210.

Direct Marketing

The central piece of Federal legislation affecting the development of farmers' markets and other forms of direct marketing is the Farmer-to-Consumer Direct Marketing Act of 1976 (Public Law 94-463). The purpose of this Act is to promote "the marketing of agricultural commodities . . . directly to individual consumers, or organizations representing consumers, in a manner calculated to lower the cost and increase the quality of food to such consumers while providing increased financial returns to the farmer" (sec. 3). The Act authorizes USDA to promote direct marketing in three ways:

. continuous surveys in each State to deter-

[14] See Fletcher, op. cit., and *Untaxing Open Space* (Washington, D. C.: Council on Environmental Quality, April 1978).
[15] Fletcher, op. cit., p. 43.

mine the extent of direct marketing and its impact on financial returns to farmers and food quality and cost to consumers;
- financial and technical assistance to State departments of agriculture and extension services for programs to encourage direct marketing; and
- annual progress reports to the appropriate House and Senate committees.

USDA's Economics, Statistics, and Cooperative Service (ESCS), which was to conduct the surveys, has pointed out that the funding–$500,000 in a supplemental appropriation in September 1978—was insufficient for continuous nationwide surveys. ESCS had previously proposed an alternative approach consisting of statewide surveys of between 6 and 10 States annually, periodic surveys of cooperative marketing associations, and supplemental case studies of representative direct-marketing methods to be prepared through research agreements with State experimental stations. The first survey of 6 States was released in July 1980,[16] and ESCS has executed research agreements with 10 State experimental stations for case histories.

Two other USDA agencies have undertaken a joint effort to inform producers and consumers of the potential benefits of direct marketing. The Agricultural Marketing Service, which works with State departments of agriculture on technical assistance programs, and the Science and Education Administration, which works with State extension services on educational assistance, have invited each State to submit proposals for projects to promote direct-marketing methods. Through the end of fiscal year 1978, this program had disbursed $1,948,000 for 22 projects in 23 States.

In conjunction with Cornell University, USDA is also developing a computer planning model to assist farmers in making their marketing decisions. When fed information on a farmer's available labor, land, crops, and other variables, this model will produce a recommendation for the allocation of resources among different marketing methods—the marketing mix—that will maximize the farmer's return on his investment. Farmers are to have access to this computer model through their county extension offices, many of which have already been equipped with computer terminals.[17]

Finally, USDA has also undertaken direct-marketing programs under the authority of the Agricultural Marketing Act of 1946 (60 Stat. 1087), which provides matching funds for State marketing improvement projects, and the Smith-Lever Act of 1914 (38 Stat. 372), which established the Agricultural Extension Service. Of the 35 projects funded under the former Act in fiscal year 1978,4 were specifically related to direct marketing; under the latter, USDA reported in 1975 that "the cooperative extension service agencies in 18 States have established active, continuing direct marketing programs and have published over 100 related informational bulletins."[18] A recent evaluation of these extension service projects found that:

> In general, the direct marketing activities pursued by the cooperative extension service agencies appear similar to those authorized by section 5 of the Farmer-to-Consumer Direct Marketing Act of 1976-for example, 12 of the projects funded under the act involve planning farmers' markets and 11 involve roadside markets. The major difference appears to be that extension service activities are more limited in scope, due to funding constraints.[19]

Issues and Options

ISSUE 1:

Research and Information Gathering.

The Farmer-to-Consumer Direct Marketing Act authorized $3 million for a 3-year program to encourage direct marketing. ESCS subsequently received a supplemental appropriation of $0.5 million in fiscal year 1978 to conduct its surveys (see above), and equal amounts were budgeted in fiscal years 1979 and 1980. In a recent evaluation of the Act, the General Accounting Office (GAO) found that USDA's programs have been effective in

[16] Henderson and Linstrom, op. cit.

[17] Interview with Peter L. Henderson and Harold R. Linstrom, project directors, Impacts of Farmer-to-Consumer Direct Marketing on the Structure and Performance of the Food Delivery System, U.S. Department of Agriculture, Economics, Statistics, and Cooperative Service, Aug. 29, 1980.

[18] *Direct Farmer-to-Consumer Marketing Program Should Be Continued and Improved* (Washington, D. C.: General Accounting Office, July 9, 1980), report No. CED-80-65, app. IV, p. 36.

[19] Ibid.

aiding the expansion of direct marketing and in gathering a considerable amount of information on the extent and impact of different marketing methods. The report also found, however, that a number of the current projects cannot be completed before the end of the program, and that the full impact of some of these projects will not be measurable for a number of years. GAO concluded that extension of the Act "would help the States continue such projects until (1) the original objectives are reached, (2) the projects become self-sufficient, and/or (3) other sources of fundings can be obtained."[20]

Option 1: Reenact the Farmer-to-Consumer Direct Marketing Act of 1976.—Authorization for current USDA direct marketing programs ended on September 31, 1980. GAO recommends that the Congress continue its support for the Direct Marketing Program for an additional 2- or 3-year period by authorizing such funds as it thinks necessary for existing projects, new projects, and improved program coordination and evaluation. GAO also recommends that a single office within USDA be designated to coordinate direct marketing programs and to serve as an information clearinghouse. Reenactment would allow USDA to initiate new pilot programs, consolidate existing programs, and gather additional data on the impact of direct marketing on local food production, regional food security, energy conservation, income stability for farmers, and agricultural land retention (see below). USDA concurs with most of these recommendations.[21]

ISSUE 2:

Outreach and Information Dissemination.

The effectiveness of the innovative programs begun by the county extension agent in Morehouse Parish suggests that similar extension programs may be beneficial in other communities if they are equally well designed and imaginatively implemented. The Cooperative Extension Service's direct marketing programs have been hampered by inadequate funding, however, and have not as yet reached all regions of the United States.

Option 2: Expand* the Role of the Agricultural Extension Service in Promoting Direct Marketing.—Should Congress decide to extend the Farmer-to-Consumer Direct Marketing Act of 1976, it may wish to earmark certain funds for use by local extension agents for information and planning projects similar to those in Morehouse Parish and elsewhere. Congress may also wish to direct that the Agricultural Extension Service be given a larger role in disseminating the results of the pilot projects and marketing surveys initiated under the Act or in making the joint USDA-Cornell University computer model available to the largest possible number of farmers. Congress might also direct that the local extension agents and regional extension specialists throughout the Nation be encouraged to supply more information and suggestions for the design of direct marketing projects, and/or that they coordinate their activities with the related local programs of other Federal agencies, such as the food and nutrition program of the local CSA community action agency (see ch. 4 and the case study of Rutland, Vt.).

ISSUE 3:

Agricultural Land Retention.

The development of local direct marketing systems may contribute significantly to the survival of the Nation's decreasing number of small-scale and family farms. The data being gathered by the ESCS should eventually shed light on the impact of direct marketing on retention of local agricultural lands. This issue has national as well as local importance, however, and the results of these surveys, in combination with the results of the joint USDA-CEQ National Agricultural Lands Study, will be of vital interest in the formulation of future Federal policy and programs.

Option 3: Investigate the Impact of Direct Marketing on Agricultural Land Retention.—Should Congress decide to extend the programs initiated under the Farmer-to-Consumer Direct Marketing Act of 1976, it would allow ESCS to complete direct marketing surveys in every State, instead of the 18 to 26 currently proposed, and to

[20]Ibid., p. 15.
[21]Ibid., pp. 15-17.

complete the supplementary case studies being carried out by selected State experimental stations. Congress may want to review the results of the completed reviews and the results of the forthcoming "National Agricultural Lands Study," and to consider the implications of both studies in the formulation of future legislation, so that Federal policy and programs will be designed in such a way as to achieve maximum benefits in these interrelated areas.

Chapter 7

Resource Recovery From Municipal Solid Waste

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CHAPTER 7

Resource Recovery From Municipal Solid Waste

Introduction

Public and private organizations throughout the United States are investigating and investing in technologies that will recover resources from municipal solid waste (MSW).[1] Two increasingly serious problems—those of waste disposal and resource supply—are compelling them to do so:

> The United States annually generates more than 135 million tons of MSW. Its disposal is a rapidly growing problem for many areas of the country, where such traditional methods as open dumping, landfill, uncontrolled incineration, and ocean burial are too expensive or environmentally unacceptable. At the same time, MSW contains over two-thirds of the national consumption of paper and glass, over one-fifth of the aluminum, and nearly one-eighth of the iron and steel. If burned, the combustible portion of this waste would be equivalent to about 1.9 percent of the Nation's annual energy use.
>
> Resource recovery . . . recycling, and reuse can contribute to the wise and efficient use of materials, to conserving energy, to preserving the environment, and to improving the balance of trade by reducing our dependence on imported natural resources. By using materials more than once, virgin resources can be conserved for ourselves and for future generations.[2]

Major environmental legislation enacted during the 1970's ruled out several previously acceptable methods of solid waste disposal, and this put pressure on State and local governments to find innovative ways of disposing of MSW. At the same time, supply disruptions and price increases, such as the 1973 oil embargo and the recent OPEC price hikes, have caused uncertainty about the future availability and cost of energy and other raw materials. This uncertainty has in turn led to greater efforts to conserve these resources and, where possible, to recycle them for further use. Consequently, to the extent that alternative technologies for solid waste disposal can also recover energy and materials from MSW, they can reduce the cost of community services and promote local development, as well as serving the interests of health, environmental protection, economic well-being, and national security.

[1] As defined by the Resource Conservation and Recovery Act of 1976 (Public Law 94-580), sec. 1004, these "resources" include both energy and materials.

[2] *Materials and Energy From Municipal Waste* (two vols., Washington, D. C.: Office of Technology Assessment, U.S. Congress, July 1979), vol. 1, OTA-M-93, p. 3.

Alternative Resource Recovery Technologies

An earlier OTA assessment has identified two major methods for recovering energy and materials for recycling from MSW: source separation and centralized resource recovery. Source *separation* consists of programs to separate recyclable materials at the waste source and then collect them through such -methods as curbside collection, community recycling centers, industry-sponsored recycling programs, and commercial and industrial methods of source separation. These programs are the only available method by which wastepaper can be recovered for recycling into new paper products, and they also recover significant amounts of glass and ferrous and nonferrous metals. Industry-sponsored programs, for instance,

[3] Ibid., especially app. C; for a more extensive survey of research in this area, see U.S. Bureau of Mines, Bureau of Mines Research on Resource *Recovery, Reclamation, Utilization, Disposal, and Stabilization*, Bureau of Mines Information Circular 8750, (Washington, D. C.: Department of the Interior, 1977).

collected 25 percent of all the aluminum beverage cans produced in 1977. In addition, separated yard wastes and other organic matter can be composted to produce soil-enhancing materials.

Centralized resource recovery, in which mixed wastes are processed at a central facility, also can recover energy from MSW either by producing steam or by converting the organic components of the waste into some form of fuel. The upper limit on energy recovery from MS W would equal about 1.9 percent of current annual energy consumption in the United States, and the recovery of all of the recyclable materials would save an additional 0.4 percent—the energy it would require to produce these materials from virgin sources—for a total energy savings of 2.3 percent of current consumption. Technical and economic factors will keep energy recovery to a fraction of this potential for the foreseeable future; nevertheless, centralized resource recovery can play a small but significant role in conserving energy.

A number of alternative technologies for recovering materials and for burning the combustible portion of MSW or converting it into fuel are at various stages of development. *Commercially operational technologies* include the comporting of organic wastes and the magnetic recovery of ferrous metals, as well as two types of energy recovery systems: the mass incineration of raw MSW in waterwall furnaces or small-scale modular incinerators; and several processes that recover solid refuse-derived fuel (RDF) from separated and treated wastes.

Developmental technologies, which have been demonstrated in pilot operations but not in full-scale plants, include several processes for recovering aluminum and glass from the waste flow, as well as two methods of energy recovery: pyrolysis systems, in which the wastes are distilled at high temperatures to produce medium- and low-Btu gases and liquid RDFs; and landfill methane recovery, in which the gases produced by biological processes are removed through wells and treated to produce pipeline-quality methane. There is sufficient pilot experience with these systems to estimate full-scale performance, but technical and economic uncertainty is greater than with commercially operational systems.

Experimental technologies, which are still being tested in laboratories and pilot plants, include processes for the recovery of nonferrous metals and wastepaper from MSW, as well as two further energy recovery processes: anaerobic digestion, in which a mixture of methane and carbon dioxide is generated through bacterial action in a process similar to the activated sludge system of wastewater treatment (see ch. 8); and a waste-fired gas turbine. In addition, considerable research has been done on several hydrolysis processes, in which ethyl alcohol (ethanol) is produced from the organic portion of MSW through either acid treatment or enzyme action. There is as yet insufficient information to predict the technical or economic feasibility of any of these technologies.

This chapter consists of case studies of two projects that are applications of commercially operational technologies: the Recycle Energy System in Akron, Ohio, an example of centralized resource recovery through the waterwall combustion of raw MSW for steam generation as well as materials recovery; and the Bronx Frontier Development Corp. project in New York City, an example of source separation and the recovery of organic materials through comporting. Although these projects differ in scale and complexity as well as process and product, both are approaches to local development based on the assumption that solid waste is not a useless end-product to be disposed of, but rather is a resource that can be recovered and used in ways beneficial to the community.

In the case of Akron, the approach involves using solid waste as a fuel to generate energy needed for space heating and manufacturing in that city’s business district. In the case of the Bronx, it involves transforming organic refuse from a produce market into compost, which is then used to reclaim otherwise infertile land for parks and urban farming. Both present alternatives to the conventional techniques and institutional arrangements for dealing with MSW.

Centralized Resource Recovery-A Case Study of the Recycle Energy System, Akron, Ohio[4]

The Community Setting

Akron, population 269,000, is located in northeastern Ohio. The city's economy centers on trucking and manufacturing industries, primarily those involved in rubber production. Manufacturing sector employment declined by 20 percent between 1960 and 1970, while service sector employment increased by almost 40 percent. Employment patterns in the rubber industry, the major employer, reflect these local trends: older plants have been phased out and hourly jobs eliminated, while Goodyear and B. F. Goodrich have invested millions of dollars in administrative and research facilities. Nevertheless, the manufacturing sector still employed 38 percent of the city's work force in 1970, compared to a national average of 26 percent.

Like many other northern industrial cities, Akron has experienced a decline in the economic activity of its central business district over the last 20 years. While most of the retail stores have moved to the suburbs, however, there has been some development of educational, office, and government facilities. The University of Akron has grown considerably and has made capital investments of $65 million in the city since 1965. The old Quaker Oats mill has been converted into a successful shopping mall, hotel, and office building, and Ohio Edison has built a new headquarters in the Cascade Plaza complex. City and county agencies also employ a significant number of people in the central business district.

Most of these offices, as well as the surrounding churches, hospitals, shops, and other businesses, use steam for space heating and hot water. The steam is supplied by the local utility company, Ohio Edison, but since 1948 the company has wanted to abandon its outmoded steam operations and concentrate on providing electrical energy. The cost of providing steam energy from antiquated central plants had become more expensive than onsite production, and Ohio Edison's downtown plant was in violation of Federal environmental standards. Two of the major energy users in Akron's central business district, B. F. Goodrich and the University of Akron, operated their own powerplants and did not purchase power from the utility. However, both institutions encountered problems with their plants; Goodrich, in particular, was also in violation of Federal emissions standards, and compliance would have required major capital expenditures. In addition, both institutions were faced with rising demand at a time when the cost of fossil fuels was rising rapidly.

At the same time that problems were developing in the energy supply for the central business district, Akron and surrounding Summit County also began encountering problems with the disposal of their solid waste. As early as 1969, the adverse environmental effects of landfill disposal were becoming increasingly apparent: raw garbage was an unstable fill, generated noxious odors, and spoiled the landscape. In addition, the Hardy Road landfill, the city's major facility, was projected to be filled within 15 years. New sites were difficult to locate because of the high population density and stricter environmental standards; in 1976, the Environmental Protection Agency (EPA) indicated that it would not approve further landfill sites in the Akron area. If the sites were located farther from the city, however, the cost of transporting garbage to them would increase significantly.

It was in this context that, in 1968, planners in Akron began searching for an alternative solid

[4] Material in this case study is based on the working paper, "Solid Waste Fired Steam Plant," prepared by Randall Constantine and Jonathan Feld for the Harvard Workshop on Appropriate Technology for Community Development, Department of City and Regional Planning, Harvard University, May 15, 1979; background information on Akron was made available by the city's Department of Planning and Urban Development,

waste management system. Any new system would have to meet five major objectives:

1. processing the widest range of solid waste without special handling or sorting;
2. reducing the volume of waste to a minimum residue for subsequent landfill;
3. reducing air pollution;
4. making any new disposal system compatible with an urban setting; and
5. keeping solid waste disposal costs at their current levels.

After considering pyrolysis, site compacting, railroad hauling, incineration, and continued landfill, the city turned its attention to the Recycle Energy System (RES), which would incinerate solid waste to generate steam energy.

Development

When Akron began searching for a solution to its waste disposal problem in 1969, B. F. Goodrich donated $15,000 for a feasibility study of an energy recovery system. The study concluded that, although the system was technologically feasible, it would not be economical for the city to generate steam from garbage unless there was an increase in total demand for steam, particularly in the summer months when most users employed electric air conditioning. For this reason, and because of the large capital investment involved, the city did little to pursue the project at that time.

The 1973 oil embargo rekindled interest in energy recovery systems, and the project regained momentum. The greatest support for the project came from the City Council, particularly its President; the Mayor, on the other hand, was reluctant to commit the city to the large capital investment required for the development of a new technology. Unable to solicit Federal support, the city's Planning Department borrowed $1 million from Akron's revenue-sharing funds to finance a preliminary engineering study.

This time the study, conducted by the engineering firm of Glaus, Pyle, Schemer, Burns, and DeHaven, was more favorable, and the city retained an investment banking firm, Prescott, Ball, and Turbin, to float bonds to finance the project. The design work proceeded smoothly, but the underwriters had difficulty raising the necessary capital, in part because of problems encountered by similar plants elsewhere and in part because of the firm's lack of familiarity with this type of project.

In mid-1976 another banking firm, Dillon, Read & Co., agreed to help float the bonds for the project, and with their assistance additional steam users were found and contracts between them and the city were negotiated and signed. By December 1978 financing was completed and construction began. Once the details of the project took form, the Mayor and other members of the city government became more active in their support.

Photo credit: Teledyne National

The Akron Recycle Energy System became operational in 1979

By November 1979 the plant was operating at 60 percent of capacity and was due to reach 100 percent by the end of the year. The city owns the site and the plant, but Teledyne Industries is responsible for actually running the plant, and a user committee performs in an advisory and informational role.

The Recycle Energy System Technology

The RES process is an example of a technology for centralized resource recovery—that is, it can recover energy and recyclable materials from collected, mixed MSW. It combines a waterwall combustion systems with an air classifier for density

[5]Waterwall combustion systems have been used commercially in Europe since World War II; other communities in North America using these systems include Saugus, Mass., and Hamilton, Ontario,

separation and a magnetic separator to recover ferrous materials. According to previous studies, these technologies are estimated to achieve a waste reduction efficiency of 70 to 80 percent by weight and 85 to 95 percent by volume; a ferrous materials recovery efficiency of 90 to 97 percent; and an energy recovery efficiency of 59 percent. [6]

Figure 26 is an operational flow chart of the Akron RES plant. The sequence of events at the facility is as follows.[7]

Solid waste is delivered to the RES by garbage trucks, tipped into a pit, and carried up to the shredders by means of inclined conveyor belts. Closed circuit cameras monitor the pits and conveyor belts to watch for unsuitable kinds of waste—although the RES is designed to accept a wide variety of refuse, it cannot process liquids, large objects, or tanks of compressed gas. Unsuitable refuse is removed from the conveyors by an overhead crane.

Two pulverizer shredders force the waste through a shredding grate, and the shredded material is fed through a stream of rising air—an air classifier—that separates refuse according to density. Heavy material is then passed through an electromagnetic device that separates ferrous metals (for recycling) from nonferrous metals (for landfill). Low-density material, which will be burned, is conveyed to a storage bin and then, when fuel is needed, fed into the boiler.

Fuel and air are fed into the boiler through jets in the boiler walls in order to ensure uniform combustion. About half of the fuel burns while falling through the boiler; the rest burns as it rests on the bottom grate. Flue gases pass through electrostatic precipitators, which remove particulate matter, and are then evacuated through the smokestacks. Both the bottom ash from the boiler and the fly ash from the electrostatic precipitators are loaded into trucks for removal. Should shredded waste be unavailable to fire in the boiler, because of either mechanical failure or inadequate waste supply, the plant can fire up three auxiliary oil burners fed by a 200,000-gal reserve tank.

Solid waste has an average heating value of 4,500 to 5,500 Btu/lb, compared to 10,000 Btu/lb for coal. The major problem in using raw waste as a fuel is the fluctuation in its consistency and, therefore, its heating value; it tends to create surges of energy when incinerated. The RES in Akron will minimize this effect by shredding the waste, putting it through a density separator, and then storing it to ensure a mixture with a more uniform heating value. The air jets and pneumatic feed system in the boiler are also designed to provide the burner with a uniform feed. With this system, the shredded waste ultimately has a relatively uniform value of 6,500 Btu/lb.

Critics of the technology employed in the RES have raised a number of doubts about its success. The waste may "bridge" or jam in the pits or in the storage bin; the dead weight of the waste may damage the rams or the conveyor belts; soot and bottom ash may collect in the boiler, causing frequent shutdowns for cleaning; and increased corrosion of the inside boiler walls caused by burning 100 percent garbage may decrease boiler life. The system's proponents feel that, despite these possible technical problems, the project's risks are acceptable.

The RES borrows selectively from technologies already in use by other industries, interjecting innovations and new designs where necessary, to produce a system that can deal effectively with the problems of burning solid waste. The boiler was designed especially for the RES: higher thermal efficiency allows the system to work at lower temperatures; suspension burning and the constant mixing of air and fuel inhibits corrosion caused by oxidation of the boiler walls; and steam jets have been installed to clean soot from inside the boiler before corrosion can recur. Where other problems may arise, backup and alternate systems have been built into the plant, and contingency funds have been set aside to finance necessary modifications.

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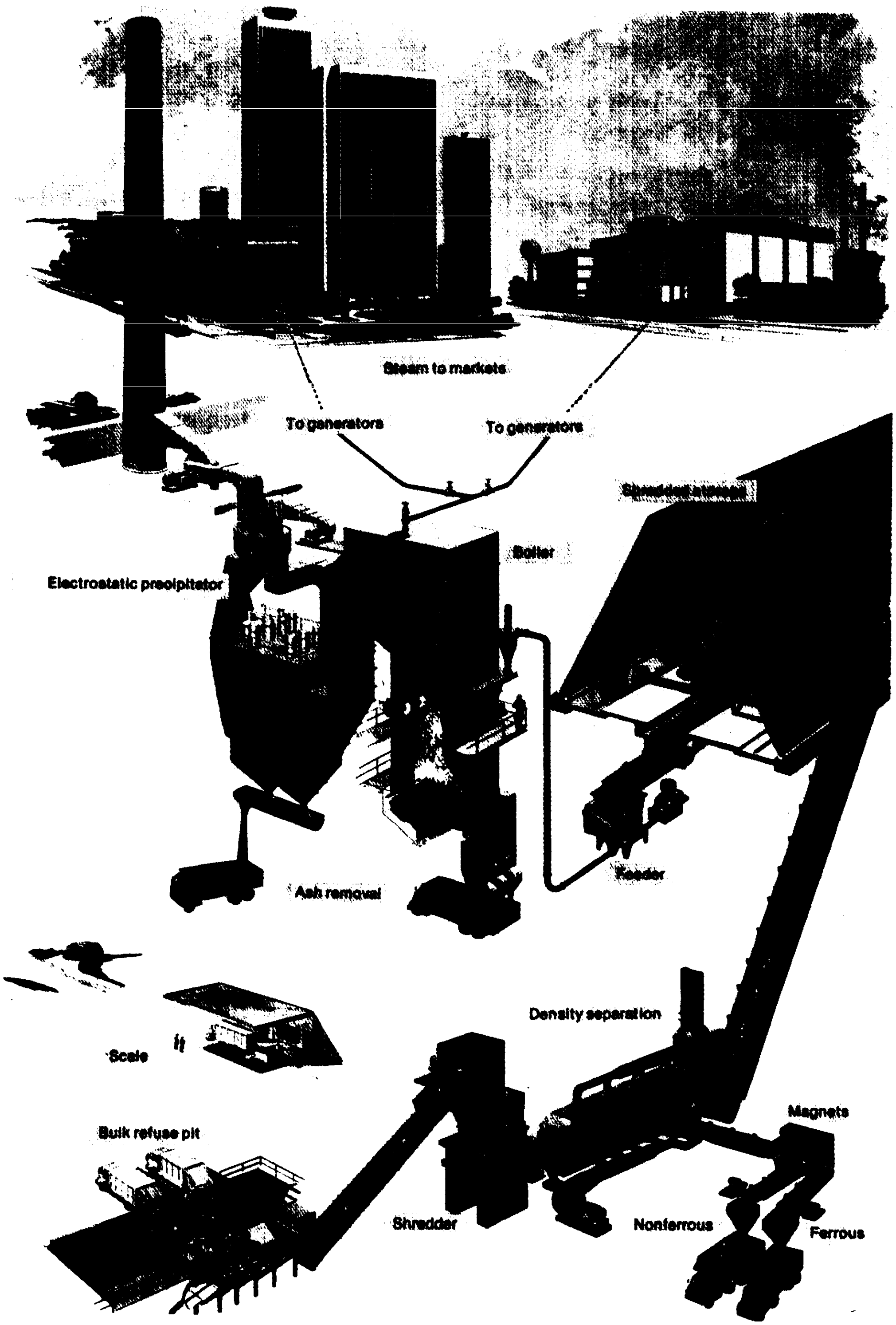
[6] *Materials and Energy From Municipal Waste*, op. cit., pp. 99-100, tables 32, 33, and 34. "There is currently no standard accepted way to evaluate the energy recovery efficiency of resource recovery systems . . . . System energy efficiencies can be calculated in terms of the energy content of the fuel produced, and in terms of output energy available as steam. " The 59-percent efficiency of the RES is in terms of the latter.

[7] Glaus, Pyle, Schemer, Burns, and DeHaven, "Feasibility Study of Solid Waste Reduction Energy Recovery," September 1977, and "Recycle Energy for Central Heating and Process Steam, " June 1977. Information on the operational characteristics of the plant is as projected by the designers; since the plant has been fully operational for such a short time, it is difficult to evaluate how accurate these claims are. Other resource recovery plants have not operated with the reliability their designers expected.

Figure 26.—Operational Flow Chart, Recycle Energy System



SOURCE: Teledyne National.

The Akron RES Facility

Akron's RES plant has been fully operational for less than a year, and the data have been insufficient to assess the system's impact on the environment. However, it typifies the current state of knowledge with regard to both pollution abatement and occupational safety and health. Air for the boilers will be pulled in from the plant, creating a negative air pressure that should prevent dust and 1itter from spreading to the surrounding area. The plant grounds will be pleasantly landscaped and well maintained, both as further protection against litter and to be esthetically pleasing. Little water will be discharged from the plant, and the combustion of shredded waste should produce fewer toxic gases than the combustion of coal. EPA is now monitoring pollution from resource recovery facilities as they come on line and is developing a data base which, if it proves necessary, should facilitate the development of further control technologies.

About 76 percent of RES revenue comes from the sale of steam, which is sold at prices competitive with Ohio Edison's rates. Steam users were required to sign 25-year contracts with the city in order to assure investors of the economic viability of the project; users who would not sign long-term contracts are required to pay a 20-percent surcharge.

Another important source of revenue is the tipping fee of $3.50/ton charged to haulers who dump their waste at the RES, which accounts for 16 percent of its revenues. The fee is lower than that charged at other dump sites in the area, and because the RES is centrally located haulers' transportation costs are also less than to more remote sites. However, in order to further assure itself of a steady and sufficient flow of wastes, the city has taken a controversial approach: it passed an ordinance requiring all haulers to deliver to the RES. Private haulers currently have a suit pending against the city challenging the legality of this ordinance.[8]

Another 8 percent of RES revenue comes from the sale of recovered ferrous materials. The city currently plans to landfill nonferrous byproducts of the RES, but potential uses also exist for these materials, and their sale could provide additional revenue. F1y ash and soot, for instance, can be used as construction fill or as a cement additive. An earlier OTA study projected potential markets for recovered aluminum, paper, and glass as well as iron and steel, that should exceed anticipated levels of recovery through 1995.[9] Akron has not depended on this source of revenue to make its RES project profitable, but it has provided incentives to Teledyne Industries, the plant operators, by giving them a portion of any revenues they can generate from the sale of reclaimed materials.

Total capital costs for development and construction are estimated at $56 million. Net operating revenues (total revenues less operating expenses) are projected to be $5.4 million in 1980, $5.7 million in 1981, and about $6 million per year from 1982 through 2004 (see table 19). Net profits after debt service, interest, and equipment replacement are expected to be over $1 million per year for the entire 25-year period.[10] While the RES is designed to generate income, however, the use of this income is restricted to the RES itself and cannot be mixed with general municipal funds. Any profits must be used to retire bonds early or to replace capital equipment.

Construction of the RES has assured downtown businesses of a reliable source of reasonably priced steam energy. As a result, some of them have begun long-needed renovation, and economic activity in the downtown area has been infused with a sense of optimism and confidence. The RES has also produced environmental benefits: the combustion of MSW produces fewer toxic gases than the coal-fired Ohio Edison plant; by reducing the volume of its wastes by 80 percent, the city has also reduced the pressure on its landfill and extended its useful lifetime; and RES residues provide inert fill that produces no odors, attracts no rats, and therefore does not need to be covered daily with dirt.

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[8] *Glenwillow Landfill*, Inc., *et al.* v. *City of Akron, et al.* Case C78-65A of the Northern District, Eastern Division of the Federal District Court of Ohio.

[9] *Materials and Energy From Municipal Waste*, op. cit. p. 63. However, the prices users would be willing to pay and the quality they might demand could present barriers to the profitable sale of large amounts of recovered materials if resource recovery were widely adopted.

[10] Ohio Water Development Authority, *Official Statement on the Recycle Energy Revenue* Bonds, 1976.

Table 19.—Profit and Loss Statement (projected), Recycle Energy System Project, Akron, Ohio

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Total revenues from sales of steam	$6,220	$6,618	$7,012	$7,131	$7,265	$7,421	$7,606	$7,805	$8,000	$8,181	$8,378	$8,581	$8,793
Disposal fees at $3.50/ton	1,278	1,278	1,278	1,278	1,278	1,278	1,278	1,278	1,278	1,278	1,278	1,278	1,278
Sales of recovered ferrous metal[a]	681	700	719	739	759	780	801	823	846	869	893	917	942
Total operating expenses	2,741	2,863	2,978	3,134	3,301	3,476	3,659	3,854	4,059	4,273	4,499	4,735	4,987
Net operating revenues	5,438	5,733	6,031	6,0 1	6,001	6,003	6,026	6,052	6,065	6,055	6,050	6,041	6,026
Total other income	885	591	317	360	398	414	415	415	415	415	415	414	414
Total funds available for debt service and cooperative agreement reserve funds	6,323	6,324	6,348	6,374	6,399	6,417	6,441	6,467	6,480	6,470	6,465	6,455	6,440
Debt service requirement	4,200	4,216	4,232	4,249	4,266	4,278	4,294	4,311	4,320	4,313	4,310	4,303	4,293
Funds available after debt service for payment to the following cooperative agreement reserve funds	2,123	2,108	2,116	2,125	2,133	2,139	2,147	2,156	2,160	2,157	2,155	2,152	2,147
Equipment replacement fund[b]	48	410	773	777	420	644	683	724	767	810	860	910	964
Interest on city and county notes[c]	450	225	—	—	—	—	—	—					
Working capital reserve fund[d]	641	127	28	19	(10)	39	25	26	27	27	29	30	32
Payment into surplus fund[e]	984	1,346	1,315	1,329	1,723	1,456	1,439	1,406	,366	1,320	1,266	1,212	1,151

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Total revenues from sales of steam	$9,028	$9,270	$9,509	$9,785	10,073	10,368	10,688	11,023	11,376	11,748	12,142	12,582
Disposal fees at $3.50/ton	1,278	1,278	1,278	1,278	1,278	1,278	1,278	1,278	1,278	1,278	2,178	1,278
Sales of recovered ferrous metal[a]	968	995	1,002	1,050	1,079	1,109	1,139	1,170	1,202	1,235	1,269	1,304
Total operating expenses	5,253	5,533	5,821	6,139	6,465	6,811	7,174	7,559	7,966	8,394	8,844	9,328
Net operating revenues	6,021	6,010	5,988	5,974	5,965	5,944	5,931	5,912	5,890	5,867	5,845	5,836
Total other income	413	412	411	410	409	407	407	405	404	402	401	401
Total funds available for debt service and cooperative agreement reserve funds	6,434	6,422	6,399	6,384	6,374	6,351	6,338	6,317	6,294	6,269	6,246	6,237
Debt service requirement	4,289	4,281	4,266	4,256	4,249	4,234	4,225	4,211	4,196	4,179	4,164	4,158
Funds available after debt service for payment to the following cooperative agreement reserve funds	2,145	2,141	2,133	2,128	2,125	2,117	2,113	2,106	2,098	2,090	2,082	2,079
Equipment replacement fund[b]	1,025	1,084	1,147	1,218	1,292	1,366	1,452	1,537	1,628	1,726	1,831	1,946
Interest on city and county notes[c]				—	—	—	—	—	—	—	—	—
Working capital reserve fund[d]	35	36	38	41	44	45	49	51	54	58	61	66
Payment into surplus fund[e]	1,085	,021	948	869	789	706	612	518	416	306	190	67

[a]Revenues are based on ferrous metal content of 6.7%, recovery rate of 90%, net price of $35/gross ton, and an escalation rate of 2.75% (50% of the average increase in the iron and steel wholesale price index 1968-73).

[b]The equipment replacement fund is comprised of: a) an annual payment of $40,000 during the first 5 years of operation and $380,000 per year thereafter adjusted to render increases in the wholesale price index for industrial commodities; and b) payment during the first 3 years of operation totaling 50% of the debt service fund.

[c]Interest payable at 4.5% on $10 million city and county notes for 18 months following commencement of operation of the project.

[d]Payment to the working capital reserve fund is made in accordance with the following: a) during the first year of operation, payments equal to 1 month's average fuel oil expense, 1 month's average operating and maintenance expense, and 1 month's loan payments and additional payments (these amounts are escalated at 6% per year over the term of the bonds); and b) at the end of the second year of operation of the project, payment to establish an unencumbered balance at $100,000.

[e]Amounts accumulated in the surplus fund in excess of $5 million shall be used to redeem bonds.

SOURCE: Official Statement of the Ohio Water Development Authority, Recycle Energy Revenue Bonds (1976).

Source Separation and Resource Recovery-A Case Study of the Bronx Frontier Development Corp. Comporting Project, New York City[11]

The Community Setting

The South Bronx is a large collection of poor neighborhoods whose unofficial boundaries have expanded tremendously in the last few years. Its acres of rubble-strewn lots and vacant buildings have made it a symbol of urban decay, and recent data illustrate the area's serious problems. During the first half of the 1970's, it experienced a severe population decline and a high rate of building abandonment, with some neighborhoods losing more than 50 percent of their population.[12] Family income levels in the area are extremely low, with more than 25 percent listed below the poverty line in 1975. Unemployment rates are high, especially among the young, and less than 25 percent of the area students entering the city's academic high schools end up graduating.

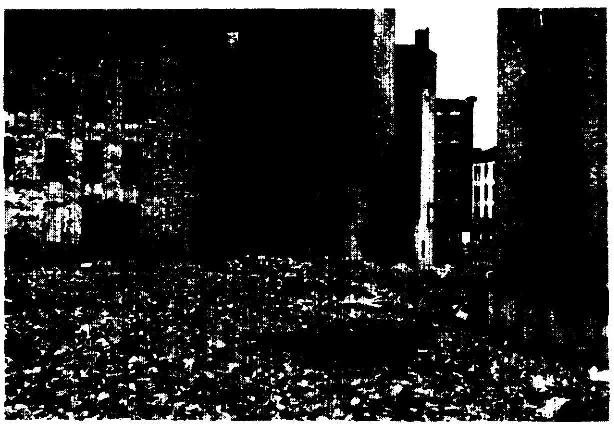


Photo credit: Bronx Frontier Development Corp.

Abandoned buildings and rubble-strewn lots became a symbol of urban decay during the 1970's

As one city planner pointed out, however, these aggregate facts mask different trends within specific neighborhoods.[13] Although urban blight appears to be spreading to certain areas that had formerly remained stable, other neighborhoods–those that had been the most visibly devastated and had the highest crime and arson rates and the most school crowding—are now showing some improvement. There is a feeling in some of these areas that opportunities for progress really do exist.

There are obstacles, however, to realizing these opportunities. One of these is a long tradition of noncooperation among various elements within the South Bronx community and within its competing political organizations. Not only is there distrust among groups, but also among individual residents. As one community worker observed, "People in this neighborhood are scared; they won't even talk to people in the next-door apartment. It took us three months to form a tenants' association in one building. Nobody would talk to anybody else. "

Most residents see housing and jobs as the most important local concerns; they attach less importance to human services and open-space issues. However, some community organizations believe there is a great need to develop programs that help residents help themselves. One such way to organize people and give them a sense of self-worth, as well as skills and supplemental income, is urban gardening.

The Bronx Frontier Development Corp. (BFDC) is a nonprofit organization that was formed to aid in the redevelopment of the South Bronx. Through its principal activity, comporting, it hopes to contribute to efforts undertaken by several neighborhood groups to revitalize the community by reclaiming barren land with parks and urban gardens. Comporting is a process that reclaims organic solid waste by converting it into humus, an effective soil conditioner. Comporting

[11] Material in the following case study is based on the working paper, "Bronx Frontier Comporting Operation," prepared by Beth Siegel and Ann Verrilli for the Harvard Workshop on Appropriate Technology for Community Development, Department of City and Regional Planning, Harvard University, May 15, 1979.

[12] Data drawn from New York City's Housing and Vacancy Survey of 1975.

[13] Peter Cantillo, New York City Department of Planning, Bronx Borough Office,

Photo credit: Bronx Frontier Development Corp

Urban gardens help revitalize communities

also provides an opportunity to recycle the organic component of MSW productively, while simultaneously relieving the pressure on dwindling urban landfill sites.

Development[14]

The initial idea of "greening the South Bronx" was inspired by a 1974 editorial in the New York *Times* written by the vice-chairman of the City Planning Commission, Martin Gallent. The editorial proposed that the city undertake a program of at least temporarily greening some of the vast tracts of rubble with parks and gardens until longer range plans could be developed. He suggested that opportunities for job-creating and income-producing ventures such as tree farms, nurseries, and cash crops be explored.

The editorial attracted attention throughout the city, and one local activist, Irma Fleck, decided to see how such a project could be brought about. Talking with local residents, urban gardening groups, city planners, and local officials, Fleck quickly established that community interest existed. She also found a major obstacle: the lack of good topsoil. The soil under the rubble was infertile, depleted of nutrients, and contaminated with lead and other toxic substances. Importing topsoil would be prohibitively expensive for community groups or even the city.

Photo credit. Bronx Frontier Development Corp.

A big grin of pride

Comporting seemed to be the best way to produce the necessary topsoil at lower costs. Humus,

14 Information on the history of Bronx Frontier Development Corp. is drawn from interviews with staff; from its publication, "BFDC's Long Term Goals, History and Background;" and from "Taming the South Bronx Frontiers," *Quest*, December 1978/January 1979.

produced by the natural decomposition of organic wastes, would provide nutrients and improve mineral and water retention; combined with clay and sand (which could be obtained by crushing rubble), it would produce good topsoil. The nearby produce terminal, Hunt's Point Market, could provide plenty of compostable vegetable wastes. The project also offered a way to provide employment and training for local residents, as well as a sense of purpose through community involvement, something Fleck considered essential to the long-term redevelopment of the South Bronx.

Discussions with New York City urban gardening groups and with the Institute for Local Self-Reliance indicated that a comporting program might work. The Institute, a Washington-based technical assistance group, studied its economic feasibility and reported in July 1976 that, with a capital investment of $250,000 for equipment and first-year operating costs, a comporting operation could be developed. Furthermore, if half of this compost were sold commercially, the operation could become self-supporting in another year. Armed with this information, Fleck and Jack Flanagan, a police community affairs officer in the South Bronx, were able to obtain seed money from the Community Services Administration (CSA) and additional funding from several private foundations.

The comporting operation was envisioned as a two-phase process. Phase I would involve setting up the comporting facility and distributing the compost free of charge to community gardens and parks. Phase 11 would consist of generating revenue by marketing the compost in bulk to the private sector (e.g., nurseries and farmers) and perhaps to city parks departments.

BFDC found that it had to file a long report with the New York State Department of Environmental Conservation, which had ruled that the comporting operation was a Solid Waste Management Facility and would have to comply with all the relevant regulations.[15] During 1977, BFDC signed contracts with the private waste haulers serving Hunt's Point Market for the delivery of vegetable refuse and with the suburban city of New Rochelle for leaves, and then leased a 3.7-acre city-owned site. Equipment was purchased, staff was hired, the site was prepared, and in June 1978, the first batch of compost was produced.

The BFDC Comporting Technology

The two major comporting processes are anaerobic *comporting,* in which microbes (bacteria and fungi) that do not require oxygen break down wastes in a sealed container; and aerobic comporting, in which microbial action takes place in the presence of oxygen. Anaerobic comporting requires less frequent attention, but it is a much slower process and gives off highly objectionable odors. Aerobic comporting, on the other hand, is relatively odorless, faster, and, because it gives off more heat, more effective in killing disease-carrying organisms. Most comporting systems, including BFDC, are aerobic.[16]

Aerobic decomposition involves a succession of microbe populations, each species reaching a peak population under different nutrient and temperature conditions. The temperature range within which the microbes can survive and function most efficiently is limited, so temperature control is a major concern. They also require a supply of nutrients (oxygen, hydrogen, carbon, nitrogen, phosphorus, and potassium being the most important) to thrive and reproduce; when these elements are plentiful and properly balanced, decomposition is more rapid. The most important measure of nutrient balance is the carbon-to-nitrogen (C/N) ratio, which should remain between 20:1 and 30:1. An excessively high C/N ratio slows decomposition and inhibits plant growth when the humus is applied to the soil; and excessively low C/N ratio can be toxic to the microbes and later to plant roots. Since waste materials vary in their C/N ratios, the proper balance is often achieved by combining two kinds of wastes in the system—for example, MSW and sludge from wastewater treatment. Moisture and

[15]See "Technical Report on the Bronx Frontier Development Corporation Comporting Project," submitted by BFDC to the New York State Department of Environmental Conservation, 1976.

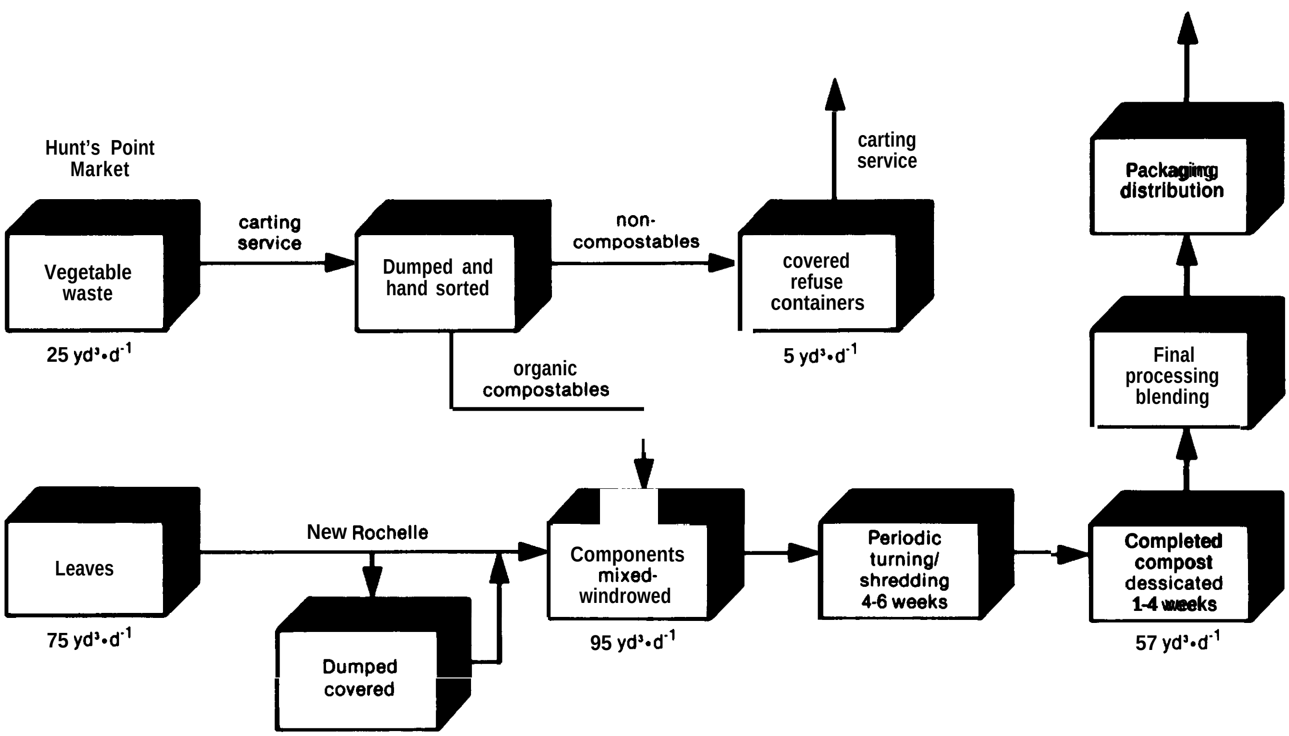
[16]Other communities Using composting processes include: Durham, N. H.; Burlington, Vt.; Tom River, N.J.; Bangor, Me.; Upper Occoquan, Va.; Windsor, Ontario; Camden, N.J.; Philadelphia, Pa.; Washington, D. C.; and Los Angeles, Calif. (Source: Jerome Goldstein, editor of *In* Business and *Compost* Science, The JG Press, Emmaus, Pa.)

oxygen content are also important, and can be controlled by a number of methods.

When BFDC first began operation, it used a version of the aerobic process known as "open windrow" comporting, which consists of six basic stages (see figure 27):

1. Compacted wastes, such as leaves and vegetable matter, arrive daily by truck. The leaves are stacked at the edge of the site, and the organic wastes are piled in a receiving area.
2. Laborers hand-sort the waste to separate out noncompostable materials, which are set aside for later pickup by the carting service.
3. The waste is laid out in windrows (long rectangular piles about 10 ft wide and 4 ft high) with a base of 3 ft of leaves topped by 1 ft of organic wastes, equaling three volumes of leaves to one volume of vegetable waste. Since the organic wastes can be very wet, the leaves serve as a bulking agent and help absorb some of the moisture.
4. The wastes are shredded and mixed by running a compost-turning machine through the windrow several times. Volume is reduced by about 60 percent during this step, and shredding also reduces the size of the particles so that a greater surface is exposed to microbial action, thereby accelerating decomposition.
5. Comporting begins. Over the next few weeks, decomposition is rapid as bacteria begin breaking down the material and heat is generated. During this period, workers monitor the windrows daily to check temperature, moisture level, oxygen content, and C/N ratio. The compost-turner is run through the windrow approximately three to five times per week to aerate the pile and redistribute heat and moisture. After about 2 weeks, the microbial activity begins to slow down and less frequent turning is required. The next 4 to 6 weeks allow the compost to mature and dry out. When temperature, C/N ratio, and

Figure 27.—BFDC Open-Windrow Composting Process



SOURCE: Bronx Frontier Development Corp.

other measures indicate that the humus is stable, it is ready for shipment.

6. After it is mechanically screened to remove pieces of plastic and glass, the compost is delivered to community gardens, where it is mixed with sand and clay and applied to the soil.

The principal drawback to the open-windrow technique, however, was that it could produce only a relatively small volume of compost on BFDC's 3.7-acre site. In order to transform the operation from the level of demonstration to that of a self-sustaining business enterprise, BFDC has turned to a second version of the aerobic process: "aerated pile" comporting. In this technique the compost piles are not turned; instead, electric blowers force air through them by means of perforated pipes placed through the piles. BFDC has installed a 40-kW wind turbine to run the blowers.

Since receiving a grant in 1979 from the National Center for Appropriate Technology (NCAT) to make this change, BFDC has expanded its capabilities in several ways. Its compost piles are now more than twice as large as those permitted by the open-windrow technique, comporting can be carried out in the winter. The increased temperatures generated inside the compost piles also allow for the safe inclusion of manure and/or sewage sludge. This combination of inputs, called "codisposal" because it combines wastes from two major waste streams (MSW and sewage), is a technology that one expert views as "the wave of the future. "[17]

[17] Dr James F. Parr, laboratory chief, Biological Waste Management and Organic Resources Laboratory, Agriculture and Environmental Quality Research Institute, U.S. Department of Agriculture, personal communication, July 25, 1980.

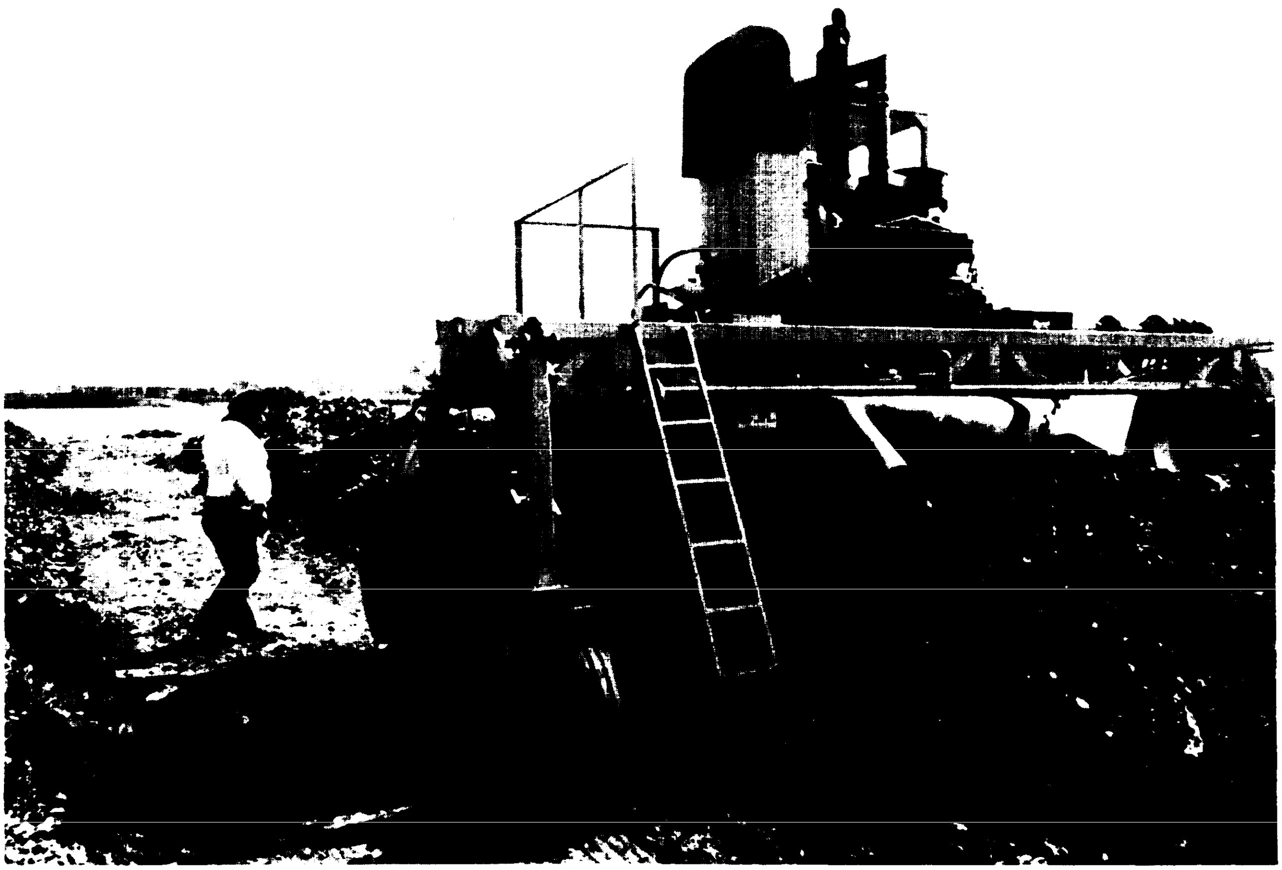


Photo credit: Bronx Frontier Development Corp.

A compost turner aerating vegetable waste at BFDC

The BFDC Composting Facility

BFDC estimates that at full capacity their operation could be run by one skilled person, but because of their commitment to creating jobs they will have eight people on the staff. Except for the technical supervisor, the staff consists of local residents. Most of the skills involved are relatively simple and easily acquired: hand-sorting, operating the compost-turner and a front-end loader used to arrange the windrows, maintaining and repairing the equipment, and performing tests to monitor conditions in the piles.

The process appears safe, although a few precautions are required. BFDC provides gloves, earplugs, and safety goggles to the staff; it carries insurance against accidents; and it complies with a variety of Federal, State, and city health regulations. To ensure product safety, BFDC (with the assistance of EPA and the Cornell University Extension Service) tests the compost for heavy metals such as lead, cadmium, and zinc. The major source of these contaminants is automobile pollution, which enters the waste stream through the leaves of roadside trees. Tests are also performed at the garden sites on a regular basis. To date, all of these tests have indicated that the BFDC compost is safe.

Economics.–It is difficult to calculate what the total costs of the project are or how to separate them into development costs, capital costs, and operating expenses. In part this is because so much of the equipment, labor, and services have been donated or subsidized. [18] There are also indirect overhead and administrative costs that cannot be allocated specifically to the comporting operation. Finally, since the project is still in the first phase of its development, it is also difficult to forecast what operating expenses will be when it is fully operational. Nevertheless, based on past expenditures and fiscal estimates prepared by BFDC,[19] it is possible to approximate some of the costs for the project's open-windrow process. These costs are presented in table 20, as are the projected costs of the aerated-pile process. These projections suggest the economies of scale that might be achieved by full implementation of the aerated-pile process. Note that unit costs decline from over $30/yd^3$ for a process rate of 50 tons per day (tpd) to only $10/yd^3$ for a process rate of 200 tpd.

Revenue comes from tipping fees charged to waste haulers and from the sale of compost, either in bulk or in bags. BFDC intends to undertake a market study to evaluate the potential market for its compost, but while preliminary research points to a strong demand for the product, potential revenue from sale of the compost is limited because of prior commitments the group has made for its use. BFDC has promised 2,640 yd^3/yr over the next 2 years as its matching contribution for a $1. 1-mil-

[18] It seems characteristic of man, of the projects OTA studied (particularly those where nonprofit organizations are involved) that traditional cost-accounting procedures are inadequate. This is especially true for cost items that are donated or subsidized. As a result, when unit costs are calculated (based on total costs excluding donations and subsidies) and compared to those for commercially available products, project proponents can often deceive themselves (and the community) into believing they are producing a less expensive product. The fact is, from a societal point of view, that these subsidized items have a real value and (if unit costs with the subsidy were the same whether commercially produced or produced by the nonprofit organization) this value is the price society pays to purchase the "unquantifiable" benefits of the project.

[19] "The Bronx Frontier Comporting Operation: Current Status, Spring 1979," prepared by BFDC for the New York State Department of Environmental Conservation, New York State Environmental Facilities Corp., and New York City Department of Sanitation, Apr. 20, 1979.

Table 20.—Projected Costs of Two Aerobic Comporting Processes

	Open-windrow process		Aerated-pile process		
	50 tpd	100 tpd	50 tpd	100 tpd	200 tpd
Capital investment[a]	$360,040	$360,040	$518,800	$530,400	$543,400
Operating expenses/year	170,079	170,079	122,500	146,200	186,800
Total annual expenses[b]	228,156	228,156	206,960	232,960	272,480
Unit cost of compost/yd^3[c]	33.81	16.90	30.67	17.26	10.09

aIncludes site preparation.
bIncludes Operating expenses, amortization of capital investment, and depreciation of capital equipment.
CBased on process output of 6,750 yd^3/yr at 50 tpd, etc.

SOURCE: Bronx Frontier Development Corp.

lion grant from the Department of Interior, the New York State Department of Parks and Recreation, and the New York City Department of Parks. The grant was given to South Bronx Open Space Task Force, a coalition of two other community groups trying to build miniparks on 15 vacant lots in the borough. In addition, the Frontier has provided more than 2,000 yd^3 of free compost to urban gardening groups in the South Bronx.

The remainder of the compost will be available for sale. Table 21 illustrates the projected cost/revenue balance and shows the extent to which operating costs and total annualized costs can be met with various combinations of bulk and bag sales.

Table 21 .—Projected Cost/Revenue Balance, Bronx Frontier Development Corp.

	100 yd/day	200 yd/day	400 yd/day
Bulk sales .	Doesn't cover operations	Covers operations	Covers total annual costs
Bag sales. .	Covers operations	Covers total annual costs	Covers total annual costs

SOURCE: Bronx Frontier Development Corp.

The project also offers distinct benefits to the private haulers who dispose of vegetable wastes from the Hunt's Point Market. Because the local landfill site in the Bronx is overloaded, these haulers have had to transport wastes to a landfill in Queens. The Frontier dumping site in the Bronx not only saves them fuel, but also charges them substantially less than the city landfill. Dumping fees at the BFDC site are only $l/$yd^3$ for uncontaminated vegetable wastes and $1.50/$yd^3$ for waste in nondegradable packages, compared to $3.50/$yd^3$ at the city landfill. This disparity in rates suggests that the dumping rates charged by BFDC are lower than they need be. Raising them, it has been suggested, would generate additional revenue and thereby improve the project's ability to sustain itself without further Government subsidies or grants.

Although BFDC's compost project cannot by itself alleviate the monumental waste disposal problems of New York City, it could, if adopted by other neighborhoods and boroughs, help extend the life of local landfills. A Government waste management expert has said that communities throughout the Nation should be able to replicate BFDC's comporting operation and its plans for co-disposal of sewage sludge, thereby multiplying its environmental benefits.[20] In addition, if the project becomes a commercial success and offers local residents the opportunity to learn marketable skills by participating in a business enterprise, it could also play a role, albeit very small, in addressing the social and economic problems of the South Bronx.

'"Parr, op. cit.

Critical Factors

Public Perception and Participation

The degree of public participation in the decisionmaking process varied considerably in these two resource recovery projects, primarily because of the different institutional settings. The RES was a municipal project, planned and executed in conventional ways by the Akron city government. The BFDC project, on the other hand, was setup as a community development corporation; as such, it tried to involve the community through a board of directors roughly representative of the South Bronx. Day-to-day management decisions are made by project staff, but the board of directors has final approval on all BFDC programs. However, it is not clear how active a role the board of directors played in formulating policy for the BFDC, nor whether all sectors of the community felt adequately represented by the board.

BFDC, through its active role in coalitions like the Open Space Task Force, is becoming an important organizing force in the South Bronx, but its experience demonstrates the difficulty of bringing community interests together. It has had difficulties in reaching the grassroots level of community organization. In addition, like other urban gardening groups, BFDC has reportedly encountered opposition from traditional political leaders of New York City's minority community. These leaders tend to identify themselves with multimillion-dollar housing projects and job training programs; they feel that low-cost, self-help approaches to redevelopment could be used as an excuse by Federal, State, and local officials to withdraw support from projects that involve more money. BFDC's answer to these criticisms has been that self-help projects create the necessary political and psychological foundation for redevelopment that previous efforts often lacked. BFDC's success in overcoming this opposition will depend on its ability to form coalitions with other self-help groups and to create a broad base of support from community residents.

BFDC also provides an interesting example of how local residents temper what might have been, in view of the limited expertise and resources available within the community, unrealistic objectives on the part of the project staff. The staff generally took a broad view of the problems of the South Bronx, but they were often overly ambitious in their attempts to address a wide range of issues with limited resources. The staff has spent much of their time fundraising, publicizing, and developing new programs; as a result, they have sometimes neglected the progress of the comporting operation, the core of the project. Day-to-day operations were often left to the onsite crew, who had too little expertise to deal with some of the problems that arose. Although many of the delays in the comporting project were beyond local control, part of its inefficiency was caused simply by the lack of management at the site. In many instances, the board of directors played an important role by "keeping the staff's nose to a specific grindstone." The board recognized the dangers of trying to accomplish too much and urged the staff to concentrate on the existing comporting operation rather than initiating new programs.

By contrast, the RES project in Akron was strictly a municipal undertaking, using traditional modes of urban planning and decisionmaking. When the city's Planning Department began investigating waste disposal strategies in 1968, the criteria used to evaluate the alternatives were largely technical, economic, and environmental. There is no evidence that any attempts were made to involve the public in the evaluation process through such devices as neighborhood study groups or public hearings. This approach typifies the way in which many municipalities go about making decisions on large, capital-intensive projects: they have been considered to be technical and economic decisions, rather than matters for public opinion or review (see chs. 7 and 8). In the case of Akron, not even the project's financing required public approval, because the revenue bonds which helped finance the project were issued by a special authority. Neither will the county's and city's general obligation bonds require public approval, since they will not increase the total municipal debt service above the existing spending limits.

The Akron steam users, a group with obvious interests in the project, played a very small role in the initial design and development of the RES. During contract negotiations over steam prices, users expressed resentment at not having been consulted; it was they who proposed forming an Users Advisory Committee. At first the city resisted, but it later agreed to the idea in order to allay user fears and accelerate contract bargaining. The committee will help spread information about RES to other users and will provide a forum at which to discuss common problems and difficulties. Although it has no official authority, the committee is perceived by the users as an effective way to exert their influence collectively.

Essential Resources

One of the most important technical issues confronting any attempt at resource recovery is the volume and quality of the waste stream: what goes into the process greatly affects what comes out, whether the waste is composted or burned. Both projects offer low tipping fees and other incentives to haulers, but problems remain.

Although Hunt's Point Market in the Bronx is a good source of compostable organic waste, a great deal of nondegradable material such as plastic wrappings and containers was included in the matter dumped at the project site. To correct this, BFDC developed a formal system for sorting and separating the waste at Hunt's Point Market, but thus far the private carters have resisted any collection plan that would force them to pick up and dump organic wastes separately. In addition, the union opposes having drivers and helpers separate waste unless new contracts are negotiated with the carters. The Hunt's Point merchants, for their part, view any source separation plan as something that would benefit the carters; as an incentive, they want collection fees lowered. Because of the complexities involved, BFDC thinks the only general solution would be to have source separation mandated by a legislative act. In the meantime, it is attempting to establish a wider range of organic waste sources: BFDC accepts Christmas trees gathered by the City Parks Department and is also negotiating with local race tracks to obtain stable wastes.

The technical and economic viability of the RES in Akron is affected by the quantity as well as quality of its input waste. Its most critical need is for a large, constant supply of combustible refuse so that it can meet its steam contract obligations. Any shortfalls must be met by using auxiliary oil-fired boilers, at substantially increased cost, and frequent use of the auxiliary boilers could cause the project to be economically untenable. For this reason, the outcome of the lawsuit brought by private carters against Akron will materially affect this technology's ability to compete economically with alternatives. It should also give other cities an indication of whether the legislative method of controlling the waste stream will work.

Financing

BFDC has relied primarily on foundation grants for the purchase of capital equipment and on CSA subsidies for operating and administrative funds. BFDC's goal is to achieve self-sufficiency through the retail sale of compost, but like many new small enterprises BFDC has had short-term cash flow problems. This has made it difficult to cover operating costs while the project is being expanded to an economically viable scale of production. Project revenues from the open-windrow process were inadequate to cover operating costs, but full implementation of the more efficient aerated-pile process could cover total annual cost (see table 21). The profits could then be used to fund the new programs BFDC would like to undertake in the future.

Optimally, BFDC might have spent several years at the 50-tpd process rate, operating at a deficit, in order to gain needed technical and managerial experience, but this schedule would have required either medium-term debt or subsidies to cover operating deficits. This option remained closed so long as BFDC's only source of operating capital was short-term grants limited to a specific use. This type of financing created two problems: first, staff time was diverted from project management to the search for new grants, leaving little time to correct problems or to prepare market surveys for its compost; second, new grants were often given only for new projects, and still more funding was required to cover the additional costs these projects entailed.[21] In this connection, BFDC came up with the concept of "consortium funding:" to avoid becoming restricted by dependence on money from a particular foundation, it instead sought small contributions from a number of foundations.

Financing for the RES in Akron has been supplied through both revenue bonds and general obligation bonds, which seems to be the most creative use of municipal debt instruments utilized in any of the cases examined in this study. The city retained the underwriting firm of Dillon, Read & Co., Inc., which had extensive experience with municipal bonds in general and with revenue bonds in particular. The firm also had extensive experience in financing other resource recovery and solid waste disposal facilities, including those in Toledo, Ohio, Hempstead, N. Y., and Dade County, Fla.

Dillon, Read's first decision in structuring the financing was to provide more money for the project: in addition to raising funds for construction costs and overruns, they established contingency funds for cost overruns and any necessary modifications after the plant became operational. They also recommended the local hauling legislation

[21]One example of these problems is the windmill that BFDC erected in the fall of 1979 to provide electricity for the planned aeration technology before the latter was even in place. The staff saw the potential for using wind power at the site; the group's fundraisers saw the opportunity to obtain a grant specifically for using wind power; and their proposal was accepted. However, this project diverted staff time and resources from the principal operation—comporting. While wind power represents an excitin, addition to the project, at present it may be more important to develop a secure market for BFDC's compost.

and long-term steam contracts to ensure adequate sales revenues to cover the bonds. As a result, debt service coverage was reduced from 175 percent to 150 percent, which in turn provided an additional $16 million without increasing Akron's debt service payments.

The city and county participated in the permanent financing as well, each selling $5 million in general obligation notes. These notes were advertised and sold publicly without the assistance of an intermediary. Proceeds of the notes were used to build steam lines to B. F. Goodrich, the University of Akron, and City Hospital; a portion was also used as a construction contingency fund, to be spent if revenue bonds proceeds were insufficient. Any proceeds remaining after completion of construction were to be used to retire outstanding debts.

Institutional Factors

Institutional problems in the development and implementation of source separation and centralized resource recovery programs include the following:

- uncertainty about cooperation by householders, businesses, and others who generate waste;
- uncertainty about cooperation by local waste collectors and haulers;
- opposition from competing landfills;
- arbitrary or inflexible application of health and environmental standards; and
- problems arising from fragmented and overlapping State and local jurisdictions.

Source separation programs like BFDC are particularly prone to problems of noncooperation by waste generators and haulers. Centralized resource recovery projects like the Akron RES are more likely to be hampered by problems of overlapping jurisdictions. Both types may experience problems arising from the application of health and environmental standards, plus those of competition from existing disposal systems. The suit against the Akron hauling legislation was brought by a landfill operator as well as local haulers, and if the suit succeeds it may reduce the project's supply of combustible wastes.

BFDC, on the other hand, has had problems not only with the waste sources at Hunt's Point Market and the local haulers, but also with overlapping jurisdictions and insensitive application of environmental regulations. The New York State Department of Environmental Conservation (DEC) ruled that the comporting operation was a "solid waste disposal facility, " which meant that it was subject to all of the rules and requirements for conventional landfills, incinerators, and dumps. BFDC had to submit permit applications not only to DEC but to the State Environmental Facilities Corp. and the New York City Department of Sanitation, and the time spent developing the supporting documentation caused significant delays and increased costs. BFDC also found that it could not include stable wastes in its comporting operation because of an city regulation that prohibits transporting manure except a sealed truck.

Federal Policy

Background

Several Acts have established national policies and programs for technologies which reclaim materials and energy from MSW. Taken together, they demonstrate Congress' growing commitment to resource recovery, primarily as a supplemental source of materials and secondarily as an alternative source of energy. However, these Acts also demonstrate a continuing commitment to large-scale rather than to small-scale projects. Because systems appropriate for smaller communities may have problems not shared by large-scale systems, an analysis of current and upcoming legislation can help to identify those areas which may need to be addressed if these alternatives are promoted in the future.

The Solid Waste Disposal Act of 1965, a part of the Clean Air Act Amendments (Public Law 89-272, as amended), was the first major law prescribing the Federal role in resource recovery and reclamation from MSW. The Act recognized the contribution of solid waste disposal to air pollution abatement, and it encouraged the design and testing of solid waste management and resource recovery systems that would protect public health and the quality of the environment. To this end, it provided technical and financial assistance to State governments and interstate agencies in planning and developing programs for solid waste disposal and resource recovery. The Act also emphasized the need to improve management techniques and organizational arrangements for collecting, separating, recovering, and recycling solid wastes and for disposing of unrecoverable residues.

The stated purpose of the Resource Recovery Act of 1970 (Public Law 91-512), the second of the three major laws, was to amend the Solid Waste Disposal Act of 1965 "in order to provide financial assistance for the construction of solid waste disposal facilities. " The Act not only stressed new methods of solid waste disposal, but also emphasized the importance of recycling and reuse of waste materials. In addition to monies allotted to conduct studies in several related areas, the Act made grants available for demonstration-scale resource recovery systems "of all types, and under representative geographical and environmental conditions." Further, its title II, the Materials Policy Act of 1970, established the National Commission on Materials Policy and required annual reports to the Congress on studies of various waste generation, materials recovery, and waste disposal options, practices, and policies. Under this Act the Administrator of EPA could fund resource recovery demonstration projects; award grants for State, interstate, and local planning; and recommend guidelines for solid waste recovery, collection, separation, and disposal systems.

The overall intent of these two laws, as expressed in the legislative findings of the 1970 Act, was to enhance the quality of the environment and conserve materials through the development of a national materials policy. Both emphasized that the primary responsibility for MSW collection and disposal rests at the local level.

The Resource Conservation and Recovery Act of 1976

Between 1970 and 1976, when the Resource Conservation and Recovery Act (RCRA) (Public Law 94-580) was passed, the issues of alternative energy sources, of materials recovery, and of technological size and complexity had become more important to Congress. RCRA reaffirmed that "the collection and disposal of solid waste should continue to be primarily a function of State, regional, and local agencies, " but it also found that "the problems of waste disposal have become national in scope . . . and necessitate Federal action." While protecting public health and enhancing the quality of the environment remained a major function of the Act, it also sought to encourage the recovery of energy and materials from MSW.

RCRA's stated purpose was to "provide technical and financial assistance for the development of management plans and facilities for the recovery of energy and other resources from discarded materials. " It established an Office of Solid Waste in EPA, through which all of the designated responsibilities except those pertaining to R&D were to be carried out (sec. 2007). Thus far, EPA has provided financial assistance to approximately 66 communities for feasibility analysis, development of a procurement strategy, and the solicitation and selection of contractors to design and construct facilities.

The Act also encouraged States and municipalities to take a more active role in the development of resource recovery projects. It called for the creation of "Resource Conservation and Recovery Panels," which were to "provide State and local governments upon request and without charge teams of technical, financial, marketing, and institutional specialists to render assistance on resource recovery and conservation" (sec. 2003). EPA, through its Technical Assistance Panels Program, provided staff and consultant expertise in these areas to over 160 communities during 1978 and 1979. EPA also provides States with funds to develop comprehensive plans for dealing with all areas of MSW management, and it has established planning requirements that require the removal of State laws that impede contracting for these projects. As a further aid, EPA has drafted a guide explaining how States can provide technical assistance, financial assistance, information dissemination, and other services to local communities.

Furthermore, in a notable expansion upon earlier legislation, RCRA required the Department of Commerce to promote the dissemination and commercialization of resource recovery technologies by providing: "l) accurate specifications for recovered materials; 2) stimulation of development of markets for recovered materials; 3) promotion of proven technologies; and 4) a forum for the exchange of technical and economic data relating to resource recovery facilities" (sec. 5001).

The Department of Energy (DOE), like EPA, also provides funds for feasibility studies by communities that are considering resource recovery projects. DOE also conducts and funds research into the basic science and technology underlying various processes for resource recovery.

Finally, beyond the provisions which promote recovery of energy and materials from solid wastes generally, RCRA contained several specific provisions which bear upon the technologies' appropriateness for local development. The first provided for information exchange among the several levels of government, and between government and private firms, regarding "technical and economic levels of performance that can be attained by various available resource recovery systems" (sec. 1008); this information on the range of available alternatives should aid local governments in choosing systems appropriate to their needs. Second, the Act required the EPA Administrator to "undertake a comprehensive study and analysis of systems of small-scale and low-technology waste management. " (sec. 8002) Although the subsequent report has not received wide distribution, EPA's Office of Solid Waste has launched a Small-Scale and Low Technology Program designed explicitly to respond to the waste disposal needs of small communities. This program is likely to encourage the diffusion of small-scale technologies that are appropriate for local development.

There is, however, one provision in the Act which may mitigate against small-scale technologies: section 8006 authorizes Federal grants for the demonstration of resource recovery systems; but subsection 8006(c)(B)(2) requires that the share paid by a Federal grant for the construction of a project which serves only one municipality cannot exceed 50 percent, while if a project serves more than one municipality the grant can pay for 75 percent of construction costs. This provision may allow several municipalities to build larger facilities and to realize economies of scale, but it may also cause individual communities to lose control over the design, financing, and operation of their own resource recovery systems.

Other Laws Having an Impact on Resource Recovery

The Energy Security Act of 1980 (Public Law 96-29+).–Title II of this Act contains several provisions dealing with "municipal waste biomass energy." It reconfirms the Federal Government's commitment to research, development, and demonstration of energy-from-waste technologies, but it also strengthens the existing mechanisms for promoting the adoption of these technologies. The Act broadens DOE's power to encourage the construction of municipal recovery projects by increasing the Federal share of construction loans to 80 percent and by allowing risk guarantees of up to 90 percent of principal and interest (sec. 233). The Act also allows DOE to make price support loans for existing projects and price guarantees for new projects (sec. 234). Finally, the Act established within DOE an Office of Energy from Municipal Waste to administer these programs.

The Energy Tax Act of 1978 (Public Law 95-618).–This Act contains provisions that should influence resource recycling and recovery. The first provides an additional 10-percent investment tax credit (for a total of 20 percent) for the purchase of equipment used to recycle ferrous and nonferrous metals, textiles, paper, rubber, and other materials for energy conservation (sec. 301(c)(i)). The additional credit is available for a wide range of equipment placed in service after October 1, 1978. The second provision sets recycling targets for major energy-consuming industries, including the metals, paper, textile, and rubber industries. Specific targets will be set for the. increased use of recycled commodities over the next 10 years.

Amendments to internal Revenue Code of 1954--Exempt Organizations (Public Law 94-568).–Section 4 of this Act requires that "the Secretary of the Treasury, in cooperation with the Administrator of EPA, make a complete study and investigation of all provisions of the Internal Revenue Code of 1954 which discourage the recycling of solid waste material, and that he should report his findings to Congress, along with specific legislative proposals and detailed estimates of their costs." In compliance with this requirement, the Department of the Treasury published *Federal Tax Policies: Recycling of Solid Waste Materials* (February 1, 1979).

The Federal Ocean Dumping Act of 1974 (Public Law 92-532, as amended by Public Law 93-254).—While the general intent of the Act is the international protection of the oceans, one of its major effects has been virtually to eliminate the disposal of domestic solid wastes in the ocean. To the extent that it precludes the use of a former option for solid waste disposal, this Act increases the amount of solid wastes that communities must deal with.

Issues and Options

The case studies presented in this chapter help to illuminate a number of issues which apply not only to incineration and comporting technologies but to alternative resource recovery technologies in general. In so doing, they point out some of the problems faced by the producers and consumers of these technologies, as well as suggesting a range of options available to the Federal Government for addressing those problems.

ISSUE 1:

Federal Financing.

The BFDC case study provides evidence that, even when Government funds are available, there may still be problems with the *type* of financing provided by the Federal sources, the use of this financing by the project staff, and the *approach* to financing appropriate technology projects. Government grants and subsidies are most desirable for those stages of a project that provide a social good but involve risks or potential returns on investment that are unacceptable to the private sector. In the case of the Bronx comporting project, the funds provided by CSA for feasibility studies, market surveys, organizational startup, and the purchase of capital equipment all served legitimate and appropriate purposes. However, BFDC also needs funds for long-range planning and administration. When money is made available for use only on a specific new program, it may encourage projects like BFDC to spread themselves too thin simply in order to obtain additional funding. Capital equipment and startup funds obtained in this manner may mistakenly be considered "free" by the staff, but these new programs carry with them present management duties and future capital obligations that can become a tremendous drain on limited manpower and resources.

Much of the problem may lie in the attitude of Federal programs and officials toward projects of this type. Local development projects like the comporting operation might be thought of exclusively as a human service—as "welfare'"-rather than as a potential new business enterprise. In such a situation the grantor may not fully take into account the financial aspects of the project or hold the grantee accountable for his financial decisions. By allowing the project to become over extended, or by encouraging new programs rather than the consolidation of existing ones, Federal support can become counterproductive from the point of view of local development. These projects are not intended primarily to be commercial operations, nor is it easy to separate social and economic objectives in a depressed area like the South Bronx. Nevertheless, those projects that prove to be successful economic enterprises are far more likely to provide a basis for community organization and local development—and therefore serve the purposes of the grant programs themselves—than those that are restricted exclusively to providing human services.

Congress may wish to address this issue by reviewing the procedures and standards by which existing Federal programs evaluate the financial performance of local development projects.

ISSUE 2:

Large-Scale Centralized Recovery Systems v. Modular Systems and Source Separation Programs.

Large-scale centralized energy recovery facilities, both mass incineration systems like Akron's RES and systems that produce RDF for sale to electric utilities, have experienced significant economic and technical problems.[22] The economic problems arise from the capital-intensive nature of these projects, recent high rates of inflation for all capital projects, additional capital requirements for plant modifications, unexpectedly high operating and maintenance costs, and the reluctance of both energy purchasers and financing sources to absorb the financial risks of the projects. Furthermore, the very size of projects like the RES can result in a built-in inflexibility making them dependent on a large and secure waste stream (see below).

The technical problems arise from uncertainties about the reliability of the technologies, unforeseen design problems that have caused excessive downtime and required extensive process and safety modifications, difficulties with boiler performance and corrosion, poor RDF quality, and reduced system energy efficiencies. In addition, there is uncertainty about the impact of future changes in emission-control regulations and monitoring techniques, and a widespread perception that (in view of these financial and cost/reliability problems) these technologies may become obsolete during their 25-year lifetimes as a result of future breakthroughs in resource recovery.

These problems and concerns are typical of new capital-intensive energy technologies, and they constitute a serious barrier to the implementation of mass incineration and RDF projects. The allocation of risk becomes harder to negotiate, and system vendors in particular have reacted to their negative experience with new installations by either withdrawing from the market or becoming far more cautious about the risk they will absorb. This trend, if continued, could make it even more difficult to implement similar projects in the future.

Option 2-A: Federal Intervention to Reduce or Absorb Risks.–Congress might wish to investigate methods of risk reduction, either by making centralized resource recovery projects eligible for tax-free bonding or by providing incentives or loan guarantees for manufacturers and/or municipalities.

Option 2-B: Investigate Other Alternative Technologies.–Congress may wish, in view of the continuing economic ad technical problems with capital-intensive, large-scale centralized systems, to investigate methods for encouraging the adoption of other proven technologies for resource recovery. Small-scale modular incinerators, for instance, have been used successfully to produce steam, hot water, and hot air in institutional and industrial applications. Individual furnace units are small but higher capacity can be achieved by adding several identical modules. This design should allow greater flexibility, and its two-stage combustion process may also reduce particulate emission problems.[23]

Another possibility would be to investigate methods of encouraging the establishment or expansion of source-separation programs. Familiar approaches include curbside collection, community dropoff centers, and commercial recycling operations. Such programs are labor intensive and produce relatively uncontaminated materials for recycling. They require greater cooperation by waste generators and may put a greater burden on collection, so such programs will require careful attention to design and implementation strategies.[24] Dissemination of information on program design, combined with some form of incentive to communities or local recycling entrepreneurs, might be effective in promoting such programs.

ISSUE 3:

Control Over the Waste Stream.

Because centralized energy recovery systems are subject to economies of scale, their viability depends on assured long-term access to a large supply

[22] The following discussion is drawn from a report prepared by Sandy Hale of Gordian Associates, Inc., for the Electrical Power Research Institute, 1979, pp. 39-47.

[23] *Materials and Energy* From Municipal Waste, op. cit., pp. 254-255.

[24] Ibid., p. 69.

of MSW.[25] Long-term waste flow control is difficult to achieve, however: other disposal options may have lower costs now or in the future; cooperation between several municipalities may be required, and flow control may be resisted by private haulers and competing landfills. The two basic methods to guarantee such a supply are: 1) offering lower tipping fees than competing disposal alternatives, which may endanger the economic viability of the project; and 2) legislating public control of the waste stream, which is now being challenged in the courts. The Akron waste control ordinance, which is now before the Federal District Court of Ohio, is therefore of national importance. The legal issues raised by the case, as summarized by a recent study, are as follows:

- *Interstate* Commerce.—The recycling of materials from MSW is considered to be a form of interstate commerce as is some hauling and disposal of MSW by private haulers. Such activities are thus regulated by a large body of Federal statutes which cannot be preempted by local or State legislation.
- Anti-Trust Violation.–The enactment of waste control legislation creates a monopoly which violates Federal law.

The U.S. Supreme Court has ruled that municipalities do not have the same exemption from Federal anti-trust provisions that States are allowed by terms of the Clayton Act. This sets legal precedent to the effect that cities cannot create monopolies, which indicates that any future waste control legislation may have to be enacted on a statewide basis. This, of course, is contingent upon a ruling in the Akron case that waste control legislation in general is not offensive on interstate commerce grounds .26

Option 3-A: Amend Federal Law to Allow Municipal Waste Control.–Congress may wish to investigate ways in which antitrust and interstate commerce statutes might be amended to exempt MSW and/or municipal waste control from their provisions.

Option 3-B: Encourage State Waste Control Legislation.–If municipal waste control legislation is found to be in violation of antitrust statutes but not in violation of interstate commerce, Congress may wish to encourage the adoption of State waste control laws. In some cases, for instance, municipalities and counties are constrained under their State charters from entering into the long-term contracts (20 to 30 years) that would be necessary to ensure adequate MSW supply for facilities like the RES; this problem is further complicated when MSW from several jurisdictions must be combined for a single facility. Two approaches have been taken: the State of Florida has enacted legislation requiring that MSW set out by community residents must be delivered to the resource recovery facility by private haulers; the State of Wisconsin has gone a step further, declaring that the municipality is the actual owner of the waste stream. Congress might investigate the advantages and disadvantages of these and other State approaches, and formulate a model waste control law to be recommended to the States.

[25] The following discussion is drawn from Hale, op. cit., Pp. 47-49.

[26] Ibid., p. 49.

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Chapter 8

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CHAPTER 8

Community Wastewater Treatment

Introduction

> A decade ago, the small neighborhood sewage treatment plant was generally regarded as a root cause of the American water pollution problem—poorly designed, cheaply constructed, improperly maintained, run by the mayor's brother-in-law and a couple of high school dropouts. So there was a strong trend away from small systems into large centralized facilities 1

Today, however, with a number of new community-based wastewater treatment systems available, centralized conventional treatment methods are only one choice among many. The purpose of this chapter is to introduce the reader to the alternatives that exist for community wastewater treatment and also to provide a more detailed insight into one community's efforts to develop one of these innovative technologies.

The Nation's stake in developing cheaper and more effective treatment methods is potentially enormous: more Federal dollars are being spent for this purpose than for any other nondefense public works program except the Interstate Highway System.[2] Many communities have yet to install treatment facilities that meet the Environmental Protection Agency's (EPA's) effluent standards, and EPA estimates that it will cost as much as $25 billion to complete the construction or upgrading of the needed treatment plants.[3] The General Accounting Office (GAO) has found that the funds required for this investment are not now available and may never be; GAO recommends strongly that lower cost approaches must be pursued.[4]

The range of wastewater treatment systems available to communities must be judged according to the unique needs of each community. For example, the conventional, centralized facilities rely on large trunk sewers to convey wastewater from outlying communities. Suburban expansion often follows these sewer "mains, " a situation which might be either favorable or undesirable depending on the community's growth plans. A community must consider a number of other factors in choosing the most appropriate wastewater treatment system: environmental elements, such as climate, geology, soil, and type of wastewater; socioeconomic factors, like treatment cost and effects on population growth; and the technical characteristics of the treatment system itself. Three levels or stages of wastewater treatment are generally recognized:

- *Primary treatment* removes large particles from raw wastewater through screening and sedimentation. Approximately 60 percent of the suspended solids, and about 35 percent of the 5-day biochemical oxygen demand (BOD5),[5] are removed during primary treatment.
- *Secondary treatment* reduces the concentration of suspended solids and BOD5 still further. EPA defines secondary treatment as "a treatment level meeting effluent limitations for BOD5 and suspended solids of 30 mg/l [each] on a monthly average basis or 85 percent removal of these parameters, whichever is more stringent. "[6]

[1] Clem L. Rastatler, et al., *Municipal Wastewater Treatment: A Citizen's Guide to Facility Planning* (Washington, D. C.: Environmental Protection Agency, January 1979).

[2] Claudia Copeland, "Municipal Pollution Control: The EPA Construction Grants Program, " issue brief No. IB80049 (Washington, D. C.: Library of Congress, Congressional Research Service, Oct. 27, 1980).

[3] *Large Construction Projects to Correct Combined Sewer Overflows Are Too Costly* (CED-80-40) (Washington, D. C.: General Accounting Office, Dec. 28, 1979), vol. 1, p. iii.

[4] Ibid.

[5] BOD5 is a conventional measure of wastewater quality, based on the amount of oxygen required by bacteria to decompose suspended organic waste over a 5-day period. Discharging wastewaters with high BOD5 into surface waters (rivers, lakes) can reduce their oxygen concentration to levels that are harmfully low for aquatic organisms.

[6] Environmental protection Agency, "Intent to Issue Revised Guidance Concerning Review of Advanced Treatment Projects for Construction Grants Program, Request for Comments, " Federal Register, vol. 45, No. 121, June 20, 1980, pp. 41,891.

- *Tertiary or advanced treatment* provides the highest quality of wastewater effluent. It removes nutrients, such as nitrogen and phosphorus, and further reduces BOD5 and suspended solids. EPA defines advanced wastewater treatment as a treatment level "providing for maximum monthly average BOD5 and suspended solids of less than 10 mg/l [each] and/or total nitrogen removal of greater than 50 percent."[7]

In addition to the standard processes described for primary, secondary, and tertiary treatment, chlorine (or in some instances ozone) is sometimes added to treated wastewater to destroy pathogens before discharge.

The Federal Water Pollution Control Act of 1972 mandated that all publicly owned treatment works achieve secondary treatment standards. However, there are still a large number of communities which must build or replace secondary treatment systems.[8] Many communities, especially in arid areas, are also attempting to recover wastewater as a resource, rather than treating it as a burden to be disposed of. Still other communities are concerned with high-quality treatment of wastewaters, in order to avoid such problems as lake eutrophication and ground water contamination. In light of these varying needs, the following discussion identifies a wide range of secondary and advanced treatment alternatives for community wastewater treatment.

[7]Ibid.

[8]Council on Environmental Quality, *Environmental Quality*: The Tenth Annual Report *of* the Council on *Environmental* Quality (Washington, D. C.: Executive Office of the President, 1979).

Conventional Wastewater Treatment Systems

The major conventional technologies for secondary treatment use biological processes to treat wastewater. The three most widely used conventional biological treatments are oxidation ponds, activated sludge and trickling filters.

The *oxidation pond* is used in about a third of the existing U.S. secondary treatment facilities. About 90 percent of these ponds service communities of less than 10,000 people.[9] In oxidation ponds, wastes are decomposed by bacteria. Ponds can be aerobic (containing oxygen in water), anaerobic (containing no oxygen), or facultative (aerobic at the top, but anaerobic at the bottom). The type of pond depends in part on the type of wastewater being treated; most ponds now in use are facultative. Oxidation ponds have lower construction costs, require less energy, and are easier to operate and maintain than the other conventional technologies. However, they remove suspended solids poorly, require large land areas, and do not work well in cold weather.[10]

The second conventional biological process, the *trickling filter,* has been in widespread use since 1936.[11] After primary treatment, wastewater is trickled through a bed of rocks or a synthetic medium such as plastic beads; micro-organisms living on the filter medium digest organic wastes. The treated wastewater is then collected by an underdrain and any solids are allowed to settle. This is a simple process that can accommodate a wide variety of wastewaters without difficulty. The system's simplicity is its main advantage: neither operation nor maintenance is difficult. However, if the system is upset, it requires a long time to recover. Other disadvantages of the system include: low tolerance for high concentrations of organic wastes, vulnerability to below-freezing temperatures, odor problems, and limited flexibility and control.

The most commonly used and versatile conventional biological secondary treatment process is the *activated sludge system.*[12] Like oxidation ponds, the activated sludge process relies on bacterial decomposition. However, unlike the pond system, the bacterial culture is aerated and agitated to en-

[9]*Environmental Pollution* Control *Alternatives:* Municipal *Wastewater* (Washington, D. C.: Environmental Protection Agency, November 1979) (hereafter "EPA 1979").

[10]Ibid.; and *Innovative* and *Alternative* Assessment *Manual* (Washington, D. C.: Environmental Protection Agency, 1980) (hereafter "EPA 1980").

[11]EPA 1980.

[12]Ibid.

sure that the wastewater and sludge are "activated''—oxygenated and mixed. After aeration, the activated sludge is allowed to settle and a portion is recycled to maintain the culture. *3 Activated sludge systems produce a high-quality effluent from varied wastewaters and do not require a great deal of land. Operation of the systems, however, requires more attention than either of the other conventional technologies, due to their tendency to be upset by variations in amount and composition of wastewater. They also cost more to build and consume more energy than either oxidation ponds or trickling filters. [14]

Two new technologies for conventional, centralized wastewater treatment also deserve mention. These processes are hybrids that combine elements of the activated sludge and trickling filter systems. The first, *rotating biological contractors* or "biodiscs," consist of a series of plastic discs which provide a large surface area for the growth of micro-organisms. These discs rotate through wastewater, exposing the micro-organisms to organic wastes. In this respect, the biodisc process is similar to the trickling filter concept, but the discs also aerate and agitate the wastewater as they rotate, like the activated sludge system.

The other hybrid system, the *activated biofilter*, is similar to the trickling filter in that wastewater is trickled over redwood slats covered with micro-organisms. Like the activated sludge system, however, the biofilter system also recycles part of the sludge to maintain a high-density bacterial culture.

Unlike the above secondary treatment systems, which are based primarily on biological processes, conventional advanced waste treatment systems are mostly physical-chemical processes. Advanced processes include the addition of chemicals to remove phosphorus; filtering processes to remove suspended and colloidal solids; filtering through carbon, which absorbs biologically resistant organics; and a variety of biological and physical-chemical processes to remove the different forms of nitrogen. [15]

[13]Ibid.; and *Wastewater Engineering*: Treatment, Disposal, Reuse, Metcalf and Eddy, Inc., 1979.
[14]EPA 1979.

[15]Ibid.

Alternative Wastewater Treatment Systems

Three types of alternative waste treatment systems are currently in limited use in the United States: the first type, land treatment, processes wastewater by applying it to the land; the second type, onsite treatment, includes systems appropriate for the individual home; and the last type, aquiculture, treats wastewater through the controlled cultivation of aquatic plants and animals. [16]

Land Treatment Systems

The most widely used and most reliable land treatment method is *irrigation*. Treated wastewater has been used to irrigate agricultural lands and pastures for over 100 years, but it is also being used to irrigate forest lands and recreational lands, such as golf courses. At present, about 400 to 500 communities in the United States are using some form of wastewater irrigation. [17]

Wastewater is applied to the land through irrigation ditches, by inundating the land with 2 or 3 inches of wastewater at a time, or by spray or sprinkler irrigation. [18] Pollutants in the wastewater are removed primarily through a combination of biological and chemical processes: some are taken up by growing plants; other are decomposed by soil micro-organisms or through chemical processes in the soil. Wastewater irrigation produces a high-quality effluent, which can either be collected for reuse or discharged to ground and surface waters. In some cases, crop production has been higher using wastewater irrigation than using

[16]Office of Technology Assessment, "Energy From Aquaculture" draft report, 1979.

[17]EPA 1980.
[18]*Alternative Waste* Management Techniques *for* Best *Practicable Waste* Treatment (Washington, D. C.: Environmental Protection Agency, Municipal Construction Division, October 1975).

conventional irrigation, and increased revenues from crops have helped to offset the costs of the systems. Irrigation systems, however, require more land than either conventional treatment systems or the second major type of land treatment, infiltration-percolation systems.

In contrast to wastewater irrigation, *infiltration-percolation* relies on rapid flow of wastewater through sandy soils. The soil filters the wastewater and soil organisms decompose organic wastes. Uptake of nutrients by vegetation, however, does not play the major role in this system that it does in irrigation treatment. The infiltration-percolation system is particularly useful in situations where it is useful to replenish ground waters—for example, to avoid saltwater intrusion—but the potential exists for ground water contamination, especially by nitrates. Infiltration-percolation systems require less land and (in most cases) less energy than irrigation systems. However, they have a limited capability for removing nutrients, such as nitrogen and phosphorus compounds; and consequently they require careful management to avoid ground water contamination, which tends to limit both their flexibility and lifespans.[19]

Onsite Treatment Systems

Onsite systems are wastewater treatment systems that serve individual households or clusters of homes. The most prevalent onsite system, the *septic tank soil absorption system*, serves about a third of the population of the United States. Like the land treatment system, septic tank absorption relies on complex physical, chemical, and biological processes in the soil to remove and decompose wastewater pollutants. While septic tank absorption systems are used widely, their effectiveness and safety in any given location will depend on soil permeability; the depth of the ground water table and bedrock; rainfall and seasonal flooding; and the distance to the nearest surface water or well.

In situations where septic tanks are infeasible, several other onsite systems are available. For example, the *septic tank mound system* disposes of wastewater in sand-filled, aboveground mounds. The engineered mound provides the same treatment functions as absorption beds.

In areas of low soil permeability and high net evaporation, another technique has evolved to dispose of *wastewater—evapotranspiration* (ET). An ET system works by evaporating wastewater from a bed of sand. Plants growing on the surface of the sand bed help increase the rate of water loss. ET systems are fairly widely used, especially in the arid Southwest, and approximately 4,000 to 5,000 are in operation in the United States today. Although ET systems require a great amount of land, they are an effective method of disposal and require a minimum of maintenance.

Two other types of onsite systems are often used at sites where a high-quality effluent is necessary for discharge to surface waters. *Aerobic treatment systems*, like activated sludge systems, maintain a highly concentrated bacterial culture that decomposes organics. These systems provide very advanced treatment, but they are also expensive and require a great deal of operational and maintenance attention.[20] A more practical and cost-effective method of producing a high-quality effluent for surface water discharge is the septic tank sand filter system. This system is similar to the soil absorption systems, except that the wastewater is filtered through subsurface beds of sand and then collected and drained by underdrains.

Aquiculture Treatment Systems

Although still in the development stage, two aquiculture systems have recently emerged as alternative methods of wastewater treatment. Both systems use vascular aquatic plants to increase the surface area on which bacterial decomposition can take place; the plants also absorb some of the nutrients, suspended solids, and heavy metals in the wastewater. The two systems differ in the types of plants they employ.

Natural wetlands have unintentionally served as waste treatment systems for centuries. Recently, however, *artificial wetlands* have been experimentally constructed to provide both primary and secondary treatment. Marsh plants, anchored in shallow oxidation ponds, provide increased sur-

[19] EPA 1979; EPA 1980; and Metcalf and Eddy, Inc., op. cit.

[20] EPA 1980.

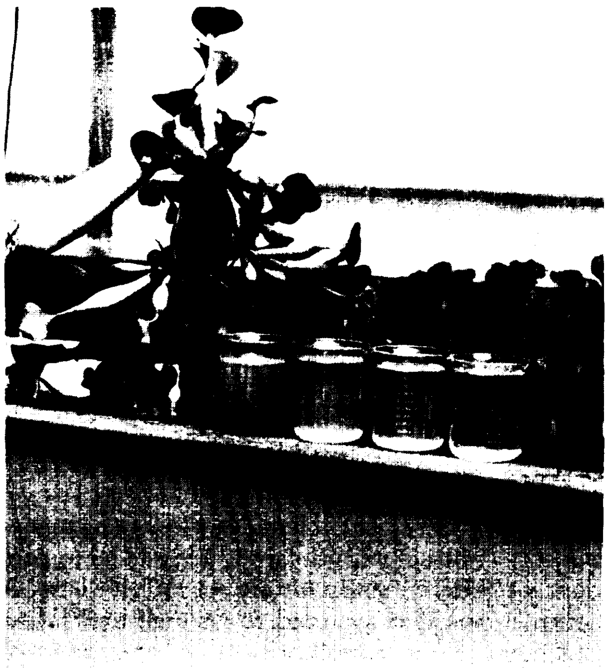


Photo credit: ***Solar AquaSystems***

Plants such as water hyacinths, shown here, absorb some of the nutrients, suspended solids, and heavy metals that are found in wastewater

face area for bacteria and also help remove nutrients from wastewaters.[21]

Aquatic systems combine the large, shallow lagoons of facultative oxidation pond systems with the controlled growth of floating plants, such as water hyacinths or duckweed. Most of the treatment occurs through bacterial action, but the aquatic plants also reduce nutrients, heavy metals, and suspended solids.[22]

The Solar AquaCell treatment system, which is discussed in the following case study, combines elements of the aquatic systems with components of other conventional wastewater treatment systems. The AquaCell technology will be described in greater detail in a later section, but the focus of the case study is on the community's attempt to develop and adopt a wastewater treatment technology that is appropriate to its unique local needs and goals.

[21] Ibid.; and OTA, op. cit.

[22] EPA 1980,

A Case Study of the Hercules AquaCell Project[23]

The Community Setting

The city of Hercules, founded in 1900 as a company town by the old Hercules Powder Co., is located in the northeastern San Francisco Bay area. Its rolling green hills and proximity to the ocean are attractive to newcomers, and since 1974 the town has experienced feverish growth, moving from a village of barely 121 people to a community of 7,000 in just 6 years.

Hercules is basically a middle-class community and has virtually no unemployment. Modal family income in March 1979 was between $23,000 and $29,000, and 90 percent of households had incomes between $18,000 and $60,000. About half the population is white, and of the balance 23 percent are Filipino, 11 percent black, 9 percent Chinese, 5 percent Hispanic, and 2 percent Japanese. The newer part of town, located inland, consists of small-lot, single-family housing tracts that are rapidly consuming the rolling landscape.

In 1977, the city government, led by a City Manager and Council, began looking for additional sewage treatment capacity to meet the needs of its growing population. They wanted a system that could be expanded incrementally as the city grew, and they looked at several options. One was to increase the capacity of the conventional plant where its wastewater was then being treated, in the nearby city of Pinole. Another option, which was being recommended at that time by EPA, was the construction of a consolidated regional sewage treatment facility for four localities—Pinole, Crockett, Rodeo, and Hercules—in line with regulations promulgated under the Federal Water

[23] Material in this case study is based on the working paper, "Solar AquaCell Wastewater Treatment, Hercules, California," prepared by Lee Bourgoin and Alice Levine for the Harvard Workshop on Appropriate Technology for Community Development, Department of City and Regional Planning, Harvard University, May 15, 1979, pp. 147-242.

Pollution Control Act of 1972. (Before the Clean Water Act Amendments of 1977, Federal water pollution policy promoted the establishment of regional districts to monitor water quality, implement treatment standards, and build regional sewage treatment plants.) A third option was for Hercules to build and operate its own municipal sewage treatment plant.

The first two options, however, would have put limits on the city's growth. The Pinole plant expansion could serve a maximum Hercules population of only 15,000, and a regional plan set forth by the Association of Bay Area Governments (ABAG) had likewise limited the city to a maximum population of 15,000. The city's own master plan, on the other hand, specified a 1990 population of 23,000, to be reached in steps by controlled growth. ABAG's ability to enforce its regional master plan came from its role as a State and Federal grant-approving entity: Hercules could build its own treatment facility, but unless it accepted ABAG's growth ceiling it could expect little outside financial support.

Fortunately for the city, outside financing was not necessary. A few years earlier, the Pacific Refinery, a subsidiary of a Houston-based corporation, had shifted the point of payment for its sales taxes from Houston to Hercules. This resulted in a tax windfall for the city amounting to $2 million per year, which meant that the city would be able to finance the construction of a sewage treatment plant out of its own revenues.

In addition to having a tax base that allowed it to exercise autonomy in building a treatment facility, the Hercules City Council was also interested in trying innovative, environmentally sound methods to deliver municipal services. They were interested in attracting further development, and they recognized the opportunity to make Hercules a showplace community with a reputation for farsightedness and leadership.

Development

During 1976, City Manager Ralph Snyder had read in the trade journals and in a San Diego newspaper about a treatment process designed by Solar AquaSystems, Inc. The process was innovative, and it produced water cleaner than was required by secondary treatment standards. He contacted the firm's president, Steve Serfling, for more information.

Sex-fling and his associates had developed the AquaCell Wastewater Treatment Process as a more marketable version of their earlier experiments with the cultivation of freshwater shrimp and fish in a closed system. After obtaining a patent for the AquaCell in 1976,[24] Serfling and his partner, Dominick Mendola, pooled about $15,000 to set Up a backyard prototype for research and evaluation. During the fall and winter of 1976-77, Solar AquaSystems built and tested a larger wastewater prototype to treat human sewage.

In early 1977, the Hercules city government signed a contract with Solar AquaSystems to conduct a feasibility study for an AquaCell plant. A contract was also awarded to Metcalf and Eddy, Engineers, for a feasibility study of the proposed expansion of the existing Pinole plant. Both studies were submitted in May 1977, and reviewed by the City Council and staff members, including Bill Chapman, the city engineer.

In comparing the two options (see table 22), the city took several cost factors into account, the most important of which was that the annual operating and maintenance costs for the AquaCell system would be much lower than at the Pinole plant. Assuming a population of 23,000 in 1990, these costs for the AquaCell system could be as much as $300,000 per year less than the conventional option:

AquaCell at 2.2 million gal/day (mgd) capacity (Solar AquaSystems' estimate, expressed in 1979 dollars)	$150,000 to $200,000 per year
Pinole expansion for 5,000 homes at $84/yr/connection and 2.2 mgd capacity at 1.5 cents/gal	$453,000 per year

Besides the financial considerations, there was also the question of which option would best handle the projected increase in the city's population. As mentioned above, the Pinole expansion would serve a maximum Hercules population of 15,000,

[24] Solar AquaSystems holds the patent on the system's greenhouse covers, ponds, bioweb substrates, floating plants, aeration system, and the "solar sprayers" that mist water into the air.

Table 22.—Projected Cost and Performance Comparisons of the Hercules AquaCell Facility Versus the Pinole Plant Expansion

	Hercules Municipal Sewage Treatment Plant using the Solar AquaCell System	Pinole Plant expansion of Conventional Activated Sludge System
1977 estimated capital costs per gallon of plant capacity	$2.57	$2.67
Effluent quality	Choice of secondary or tertiary.	Secondary only.
Expansion-contraction flexibility	Simple—change pond size. Can build incrementally as needed.	Difficult—requires new infrastructure. Must build for total future planned capacity.
Energy requirements	250 kWh/million gal treated.	625 kWh/million gal treated.
Disposal requirements	Sludge and hyacinths—225 ft^3/million gal if hyacinths are chopped, 165 ft^3/million gal if composted.	Sludge—360 ft^3/million gal.
Land area required	1.3 acre/1 mgd capacity.	1 acre/1 mgd capacity.
Labor required	1 person, part-time, 1 backup person. Biological/mechanical tasks.	None additional required. 6 people, full-time already employed. Mechanical tasks.
Other requirements	Aquatic plant harvester. Composter on site.	Truck access.
Operations	Flexible—keeps working if component fails. 24 hours to repair before overflow.	Inflexible—loses efficiency if component fails. 4 hours to repair before overflow.
Byproducts of potential value to Hercules	Aquatic plants: compost, animal feed, methane. Treated wastewater: industrial water, greenbelt irrigation, freshwater marsh enhancement, food production.	No current use of wastewater or sludge, although greenbelt irrigation and methane production are possible.

SOURCE: Solar AquaSystems; based on laboratory data and contractor estimates

and this additional capacity would have to be built (and paid for) all at once. Estimated cost to Hercules as of December 1977 was $4 million, against an estimated cost of $3.5 million for the AquaCell. The flexibility of scale in AquaCell construction thus became an important cost consideration: because of the modular design, economies of scale are slight, so the city could build to current capacity requirements and then expand the facility as demand increased, spreading capital costs over time as the city grew.

After considering all of these factors, the City Council selected the AquaCell system by unanimous vote. It could grow with the city, and as ‘one Council member pointed out, “we are buying the flexibility to grow to the [population] limit we want.” The appeal of local control over local development was echoed more forcefully by Councilman Joel Zieper:

> If you want to do something right, do it yourself. I couldn’t care less whether we get any money from the State, They would probably do it wrong anyway. We’ll do it right and then we’ll take all the credit.

City Manager Snyder added that the city wanted to make a “contribution to the state of the art, ” and summed up the benefits in the following way:

> There comes a time when it is necessary to consider other values than what may appear to be “safe.” The merits of energy conservation, water recycling, fish life production and agricultural byproducts use are, to me, very significant and achievable objectives not only in terms of the community but also for the nation and even parts of the world.

The Solar AquaCell Technology

In the Solar AquaCell Wastewater Treatment Process, waste-consuming plants and marine organisms occupy a lagoon enclosed under a greenhouse cover. The technology consists of three components:

1. An inflated polyethylene greenhouse cover is built over three treatment lagoons in order to stabilize water and air temperatures and to prevent excessive evaporation.
2. Anchored, buoyant plastic-mesh ribbons and tubes, called “bio-web substrates,” are placed in the lagoons (like marsh plants in an artificial wetland) to expand a hundredfold the surface area where the waste-digesting organisms live and graze. As a result, the organisms multiply more rapidly and hence take less time to digest the waste. As in the conventional activated sludge process, most of

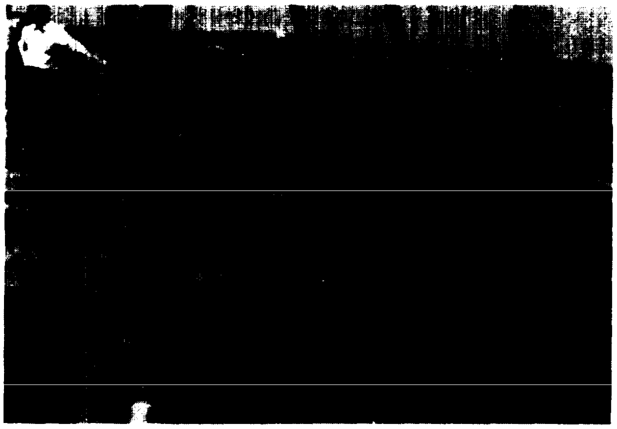


Photo credit: Hercules AquaCell

8-ft-deep lagoon, enclosed by greenhouse cover, where secondary treatment begins

the digestion of waste in the AquaCell occurs by bacterial action.

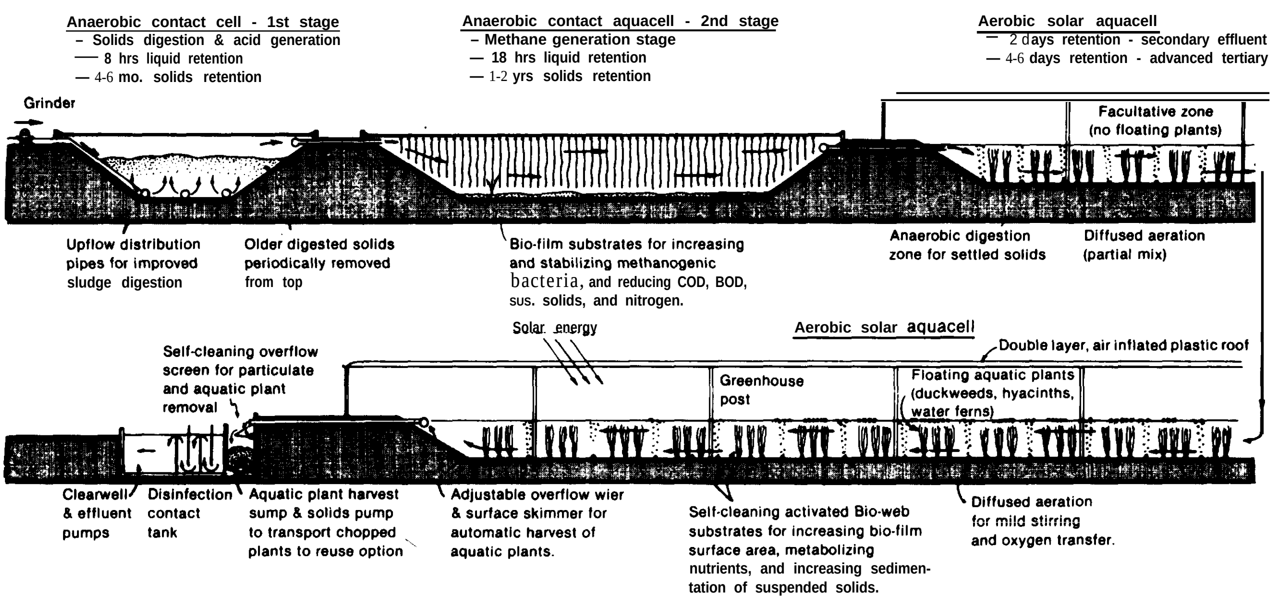
3. Aquatic plants, in this case water hyacinths and duckweed, are grown on the pond's surface. The plants subsist on nutrients from the wastewater, and also serve to screen the pond from sunlight, thereby preventing the growth of undesirable algae.

Figure 28 depicts the AquaCell process. Sewage passes through a grinder into a covered anaerobic pond, where grit and a large portion of the solid wastes settle out. The wastewater then enters a second anaerobic pond, also sealed beneath a floating black rubber cover, where abundant bacteria on the bio-web substrates begin to digest wastes, producing a small amount of methane in the process. Retention time for this stage is 18 hours.

After primary treatment, the treated wastewater flows into an 8-ft-deep facultative lagoon, where secondary treatment begins. This lagoon contains more bioweb substrates, which facilitate the growth of micro-organisms and encourage the settling of solids suspended in the wastewater. Bacteria and grazing micro-organisms continue to digest the wastes. Retention time for the facultative stage is an additional 18 hours.

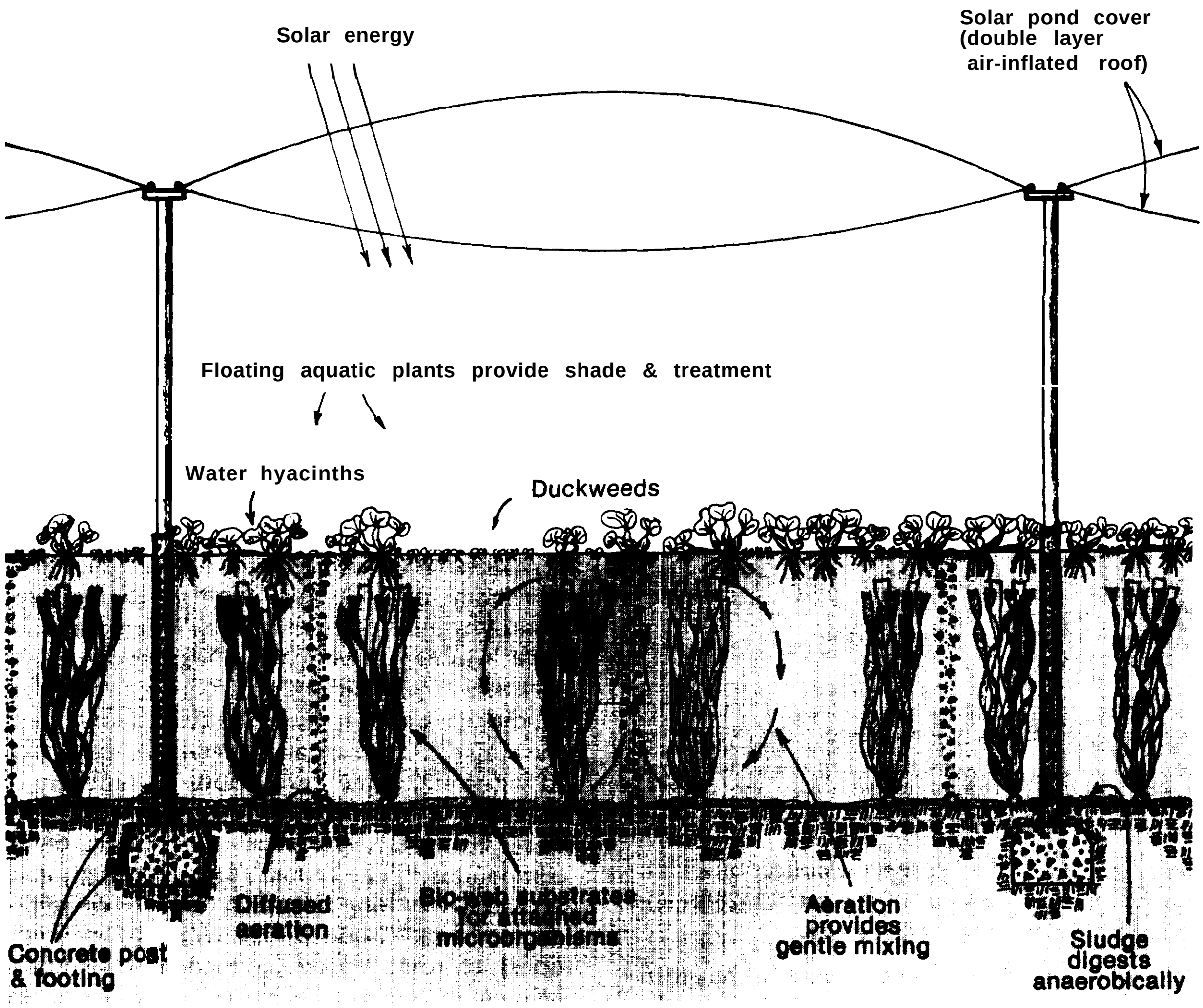
Secondary treatment continues in the main portion of the greenhouse lagoon (see figure 29), where other waste-eating animals have been added: protozoa, amphipods, grass shrimp, hydra, snails, worms, and additional micro-organisms. Water hyacinths and duckweed now cover the water's surface, taking up nutrients and heavy metals from the wastewater and keeping down algae growth by screening out the sun. Anaerobic

Figure 28.—Solar AquaCell System Process Flow Diagram



SOURCE: Solar AquaSystems.

Figure 29.—Section View, Solar AquaCell System



SOURCE: Solar AquaSystems.

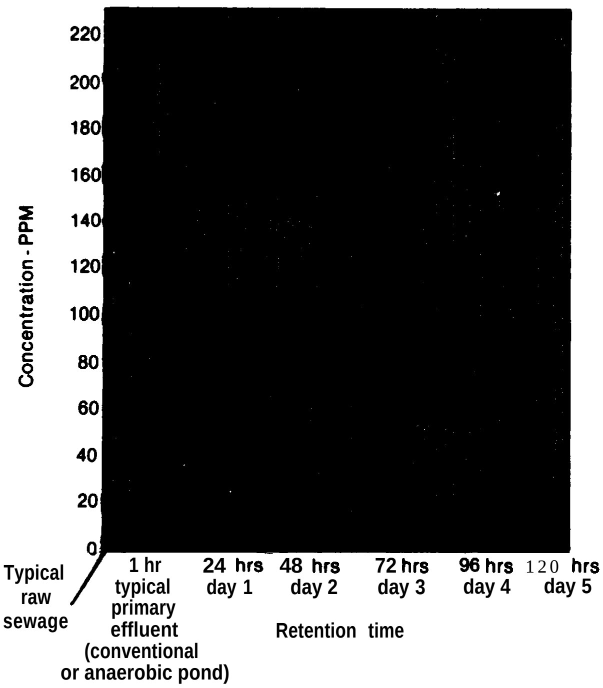
waste digestion occurs on the bottom of the lagoon, where sludge slowly builds up at a rate of between ¼ and 1/2 inch per year.

Trials of the AquaCell process in the 2,000- and 4,000-gpd prototype facilities showed that secondary treatment quality can be achieved with 2 days retention time for a l-acre pond handling 1 mgd of wastewater, a capacity that would serve a population of 10,000.[25] Advanced treatment quality was achieved after 4 or 5 days. However, as illustrated in figure 30, nitrates and phosphorus, which encourage algae growth, are only partially removed from the water within 5 days (50 percent of the nitrates; 10 to 20 percent of the phosphorus). If desired, the remaining phosphorus can be removed by adding lime to the water, and the remaining nitrogen by increasing the retention time.

Most of the pathogenic organisms (disease-causing bacteria and viruses) contained in the wastes die off during the long retention periods. Other pathogens get trapped in the sand filtration system, where they eventually die or are consumed by other organisms. Remaining pathogens are

[25] Data recorded and analyzed by the Environmental Studies Laboratory, University of San Diego.

Figure 30.—Treatment Performance in Relation to Retention Time for the Solar AquaCell Process~



aBased on data collected from the 2,000-gpd pilot-scaie Solar AquaCell Laboratory in Solana Beach, Calif., from October 1976 to March 1977; and current data being collected from the new 4,000-gpd pilot facility located at the Cardiff Wastewater Treatment Facility. Data from Cardiff facility is recorded and analyzed by the Environmental Studies Laboratory, University of San Diego.

killed with ozone in a contact disinfection chamber as the water flows out of the main lagoon and into a clear well to be pumped away.

A crucial component of the system is the greenhouse cover. It traps solar energy during the day and reduces heat loss at night, thereby helping to maintain the effectiveness of the AquaCell during colder winter months and reducing its energy consumption year-round. A water-mist spraying system helps reduce air temperatures during summer months. In dry climates, the greenhouse cover also reduces evaporation from ponds. This is especially valuable for systems whose object is to reclaim the wastewater for other uses. Also, since the greenhouse cover prevents evaporation, and because the aquatic plants and invertebrates consume minerals, the AquaCell system can decrease the concentration of dissolved solids, rather than increasing them as happens in conventional oxidation pond systems. Finally, the greenhouse cover

Photo credit: Hercules AquaCell

Ozone contact disinfection chamber under construction at the Hercules AquaCell Treatment Facility

will help to contain odors, although few are produced in normal operation.

Maintenance requirements include: monitoring environmental conditions, such as temperature, to assure the most efficient metabolic rate; sand filter back washing; removing sludge every 3 to 6 months; and harvesting the aquatic plants. Studies have shown that the aquatic plants used in the AquaCell process are generally hardy and able to withstand some fluctuations in nutrient content, and air and water temperatures, changes in water chemistry, and even the presence of toxic compounds.[26] The system's large holding capacity and relatively long retention time are designed to dilute "slugs" (sudden but transient concentrations) of toxic wastes in incoming wastewater, helping to protect the plants and bacteria from damage. In addition, the large holding capacity will give operators a longer period to correct malfunctions before the system begins to overflow-24 hours instead of the 4 hours of conventional systems.

According to Serfling, the final volume of solids requiring disposal will be less than half the volume produced by conventional activated sludge systems. The harvested plants may be composted alone or with the sludge to produce fertilizer and

[26]William S. Hillman and Dudley D. Culley, Jr., "The Uses of Duckweed," American Scientist, vol. 66, July-August 1978, pp. 442-456; B. C. Wolverton (cd.), *Compiled* Data on the Vascular Aquatic *Plant* Program: 1975-1977, prepared for NASA National Space Technology Laboratories.

soil-enhancing materials (see ch. 7 for a discussion of comporting). Because water hyacinths grown in sewage average 20 percent protein, and duckweed as much as 40 percent, they may also have value as animal feed so long as concentrations of toxic compounds are not excessive. The sale of these by-products, as well as reclaimed water, could further reduce operating costs.

The Hercules AquaCell Treatment Facility

The opening ceremonies for the Hercules AquaCell plant were held on Earth Day, April 22, 1980. However, about 6 months will be needed before the plant can be considered fully operational.

Figure 31 shows the AquaCell treatment facility designed to provide 2-mgd capacity, advanced wastewater treatment for the city of Hercules. The initial phase of construction was designed to han-

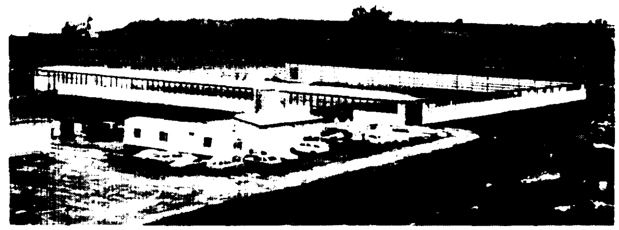
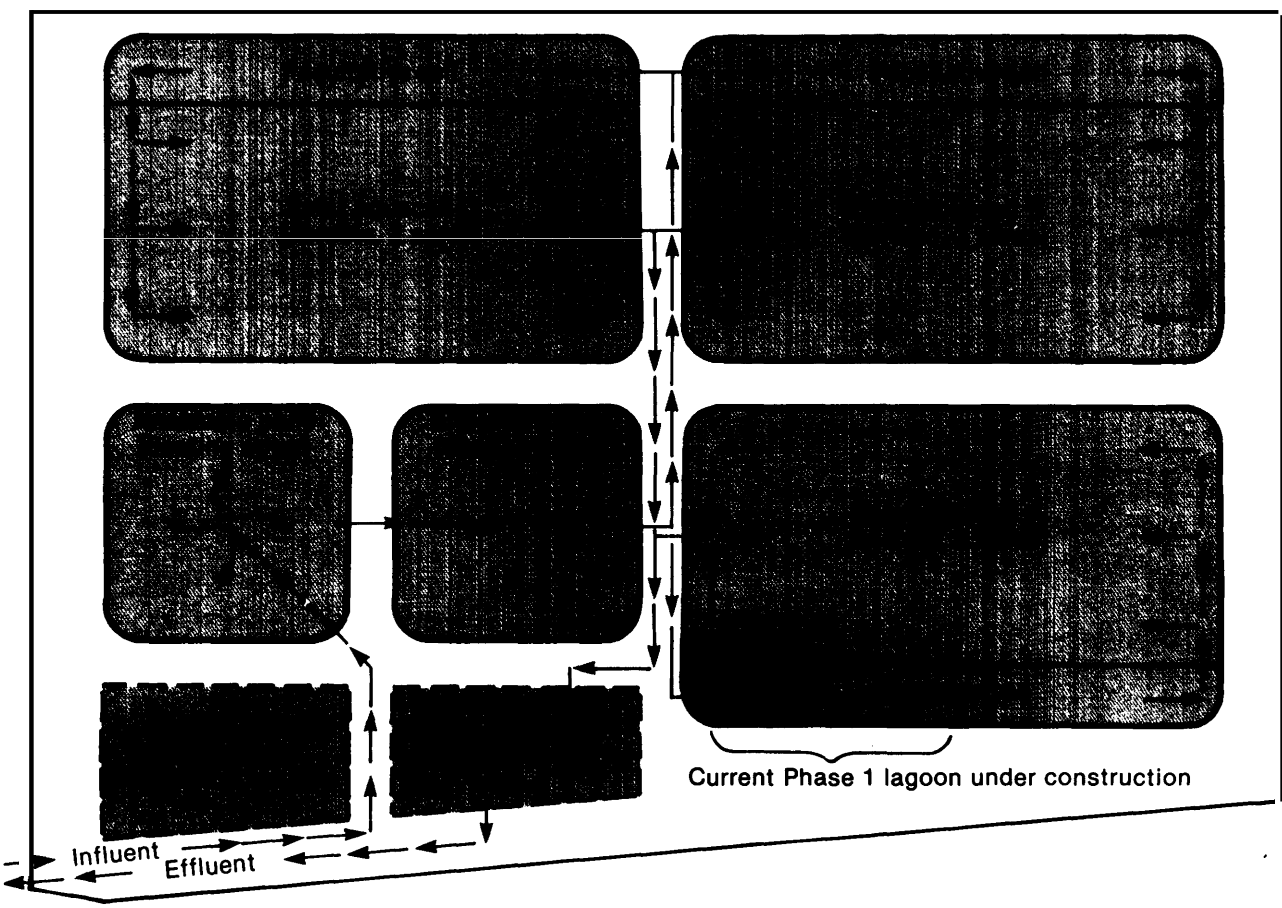


Photo credit: Hercules AquaCell

The Hercules AquaCell Treatment Facility

Figure 31.—Proposed 2. O-MGD Solar AquaCell Facility, City of Hercules



Plan view of the proposed 2.0-MGD Solar AquaCell Lagoon Treatment Facility for the City of Hercules, Calif. Each AquaCell will be 2.0 acres (6 acres total). The 0.35-MGD treatment phase currently under construction consists of a 1.5-acre AquaCell system with anaerobic, facultative, and aerobic stages, approximately one-half of AquaCell A.

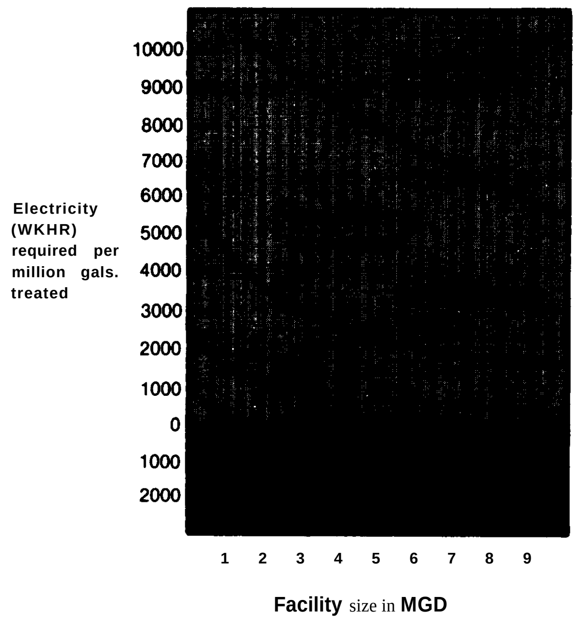
dle 350,000 gpd. A 1.15-acre earthen pond, about 220 by 230 ft has been built; this pond will be enlarged to 2 acres, and two additional 2-acre ponds will be built, when the plant expands. The initial phase does not include a separate anaerobic pond; instead, the single lagoon contains three cells—anaerobic, facultative, and aerobic—separated by walls of heavy rubber.

For the first few months of operation in Hercules, treated water will flow back to the conventional treatment plant at Pinole to be tested and treated again. If the AquaCell system works reliably, treated water will be pumped into San Francisco Bay through an outfall in neighboring Rodeo. In the future, however, Hercules is considering using the treated water for greenbelt irrigation. Nitrogen and phosphorous removal will not be required for this use, since these compounds will act as fertilizers. The city is also investigating the possibility of selling its reclaimed water to Pacific Refinery for industrial use.

Total capital costs of phase I construction for 350,000-gpd capacity were about $2 million, considerably higher than Solar AquaSystems' original estimate. The major reasons for this cost increase were the 50-percent increase in the size of the initial lagoon and the city's decision, anticipating future expansion, to build the initial AquaCell plant with adequate basic elements (tanks, pumps, and pipes) for capacities of up to *4.4* mgd. Another factor in the cost increase is that, because the Solar AquaCell is a new process unproven on a municipal scale, design and construction costs have escalated as engineers and contractors added relatively high contingency fees to cover risk; this added 10 percent to the cost of basic elements alone.

Total capital costs for expansion to full 2.2-mgd capacity are currently estimated at an additional $2 million to $3 million. Although the capital cost of the Solar AquaCell is comparable to Hercules' share of the Pinole expansion, it appears that operating and maintenance costs for the AquaCell will be relatively low. Experiments have shown that the AquaCell also uses less electricity than conventional systems (see figure 32), and (in the future), methane produced in the anaerobic stage may be used to generate electricity and further reduce costs.[27]

Figure 32.—Electrical Energy Requirements for Conventional v. Ecological Wastewater Treatment Systems



aDeveloped from E. B. Roberts and R. M. Hagan, *Energy* Requirements *of Alternatives in Water Supply Use and Conservation: A Preliminary Report,* California Water Resources Center University of California Davis, Contribution #155, December 1975; and from A. Cywin, Director of Effluent Guidelines Division EPA, "Energy Impacts of Water Pollution Control", *Energy, Agriculture and Waste Management,* William Jewell, cd., 1975.

bBased on biomass optimization for biofuels and electrical generation (no ozone electricity included).

SOURCE: Environmental Protection Agency. Draft Innovative and Alternative Technology Assessment Manual. EPA 430/9-7S-0001, 1978.

[27]Methane utilization is also a common practice in conventional wastewater treatment technologies. Anaerobic digestion yields a gas that is 65 percent methane and 35 percent carbon dioxide. One ft^3 of gas (enough to light a 60-watt bulb for 6 hours) is generated each day for every 100 gal of wastewater treated. The gas is typically used to provide one-third to one-half of the heating requirements of the treatment plant. (Wastewater Pollution Control Federation, *Wastewater* Treatment *Plant* Design IWashington, D. C., 1977], p. 531). See ch. 5 for further discussion of methane digesters.

Critical Factors

Treatment of wastewater by the Solar AquaCell is too new a technology to warrant a definitive evaluation as yet; there are as yet no reliable performance data. However, as an example of the problems of developing a new technology, the Hercules experience should be of interest to communities thinking of adopting innovative wastewater treatment systems of their own.

Public Perception and Participation

The issue of what to do with Hercules wastewater elicited little general debate among residents. Most of them knew that a new facility was under consideration, but few of them knew any details of the controversy. Apparently they were willing to leave the decision to the City Council, feeling that it would make the right choice and that their sewage would be adequately treated. The recent growth and constant state of change in Hercules seemed to have deterred community involvement: attendance at council meetings was usually low, and there were only a few informal neighborhood groups. Since the decision to go ahead with the AquaCell plant, the project has received a fairly high level of local publicity and support, although public involvement remains low. City officials are organizing neighborhood meetings and publishing a newsletter in an effort to increase citizen participation in this and other city decisions.

The response to the AquaCell technology was different in two other communities where the firm submitted proposals at about the same time. In early 1977, Solar AquaSystems submitted proposals to build AquaCell plants in San Diego, where the proposal is still pending, and on the Chemehuevi Indian Reservation at Lake Havasu, Calif., where it was rejected. In the latter case, the debate caused by the introduction of so unconventional a technology appears to have been responsible for its rejection. The Chemehuevi submitted a grant application using the system to the Department of Commerce's Economic Development Administration (EDA), but by the time the firm could explain the technology to EDA (who initially turned the proposal down in February 1978, but subsequently approved it), the controversy over the proposal and the prospect of further delays had created so much suspicion in the Chemehuevi community that they decided not to get involved in the technology at all.

In San Diego, on the other hand, Solar AquaSystem's proposal helped to engender local enthusiasm for using an innovative method of sewage treatment. The city subsequently submitted a grant application to EPA to fund some type of aquiculture-related wastewater treatment plant. EPA approved the application in January 1980, and San Diego is currently considering various systems, including the AquaCell.[28]

Whatever the problems in getting them adopted, however, once new ideas become realities they begin to have a ripple effect in the community. This has been the case in Hercules, where many people have taken a cue from the city's approval of an AquaCell to install low-flush toilets and restricted-flow shower heads in their own homes. According to some estimates, these actions will reduce local water consumption by as much as 40 percent. This also results in a more concentrated wastewater flow, which would be a problem in conventional systems.

Essential Resources

The performance of the AquaCell process is affected by climatic conditions and the amount of land available for its treatment ponds. Colder temperatures limit the efficiency of all biological wastewater treatment processes; communities with a less temperate climate than California's would find that retention times in either a conventional

[28]Other examples of aquiculture wastewater treatment projects exist in Lakeland and Disneyworld, Fla.; Mountain View, Calif.; and Vermontville, Mich. (Source: Jerome Goldstein, editor of *In Business* and *Compost Science*, The JG Press, Emmaus, Pa.).

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system or a Solar AquaCell would have to be increased in order to obtain the advanced treatment quality achieved in Hercules. Since the AquaCell has not yet been tested in colder climates, no precise adjustment tables are available, but this does pose a potential limit on the transferability of the technology.

Theoretically, scale is not a limiting factor, since the AquaCell system could be built small enough to handle sewage from 5 to 10 houses, or large enough to handle in excess of 100 mgd, the capacity required for a population of 1 million. Land availability, however, could be a limiting factor. The AquaCell requires about the same amount of land as an oxidation pond system, but more space than an activated sludge facility. In some densely developed urban areas, where land is expensive, this may weigh against the AquaCell; but its other benefits and cost advantages may still make it competitive. AquaCell's greatest competitive advantage may be in smaller communities, where land is less expensive and where there are diseconomies of scale in building conventional facilities.

Another factor limiting the transferability of the AquaCell to other communities is that water hyacinths are considered a weed problem in some regions, particularly in the Southeastern States where overgrowth clogs freshwater canals; the release of hyacinths from the AquaCell could aggravate this problem.[29] In California and many other areas, however, water hyacinths will not survive outside the greenhouse environment.

Technical Information and Expertise

Communities faced with the need to construct, expand, or upgrade their wastewater treatment facilities would profit from a broader knowledge of the technological alternatives available to them. For instance, there is a need for further study of which treatment systems are most appropriate for different kinds of communities—older cities, new towns, rural areas, and suburbs—as well as which are most appropriate to different climates and soil types. The Hercules facility, as the pioneer installation of one new technology, can be a valuable demonstration on a municipal scale and a source of information for other communities, and EPA has expressed interest in studying the Hercules AquaCell during its first 2 years of operation. In addition, conducting surveys to gather information about potential markets for reclaimed water and other system byproducts would be helpful in determining the feasibility of the technology and in planning local development programs.

Communities that decide to use a technology of this type would need the services of a design firm, engineers to adapt the design to a specific site, project development managers, construction workers, system operators, and maintenance personnel. Only the design phases, however, require special expertise. Under competent management, the actual construction should not be difficult, since it is based on typical greenhouse and lagoon designs. Operation and maintenance does differ somewhat from that of conventional plants, but the skills involved (such as harvesting aquatic plants) appear simple enough to develop through short training programs.

For both Hercules and Solar AquaSystems, the first year of the AquaCell plant's operation is crucial to its technological success and economic viability. Once the system is established, it is designed to need only minor adjustments to ensure that it is working at maximum efficiency. The city has given the firm a $54,000 contract to manage the facility during the startup year. As part of this contract, Solar AquaSystems has also agreed to train operators, prepare operation and maintenance manuals, and supervise testing of water chemistry and biological components.

Financing

The capital costs of the AquaCell are equivalent to those of expanding an existing conventional plant, according to current estimates. However, AquaCell costs may well be lower than those of a completely new conventional facility, especially in communities where smaller capacity requirements give conventional plants a higher per capita cost. AquaCell's lifecycle cost advantages are related primarily to the technology's flexibility. First, its modular design makes it simpler and cheaper to upgrade a facility for advanced treatment, and also allows enlargement of the facility to meet the

[29] Thomas Bull, Energy Program, Office of Technology Assessment.

demands of a growing community without requiring the community to spend large initial sums for oversized facilities.[30] Second, the system's biological components are relatively hardy, which allows them to adapt to changes in waste concentrations and reduces the possibility of system malfunction. Third, its operating and maintenance costs appear to be substantially lower than those of conventional systems, partly because the greenhouse cover reduces energy consumption and partly because the system produces less sludge.

Despite these economic advantages, however, the greatest single barrier to developing and implementing the technology has been the lack of a sufficient, steady source of financing. Conventional technologies and proven alternatives are more familiar to private and public sources of funding, and their costs are usually more clear-cut. In adopting new or unproven technologies, on the other hand, potential time delays and added costs should be calculated, or at least formally recognized, in order to arrive at a realistic determination of final costs. In the case of the Hercules project, part of the discrepancy between estimated and actual costs was due to time delays and the addition of contractors' fees and contingencies to cover risk.[31] The element of risk exists at nearly every stage, from the initial feasibility study, through the design and engineering phases, all the way to eventual construction, operation, and maintenance. As uncertainty increases at any stage, so do the potential costs of the project and the hesitation of the sources of financing.

The city of Hercules tried to obtain developmental funding from EPA's Office of Research and Development, but that office did not have the available resources to support a large '{experimental" project. (This situation has improved somewhat with the change of Federal policy reflected by the creation of EPA's Innovative and Alternative Technology Program, discussed later in this chapter.) EPA construction grant funds would have been available only if Hercules agreed to limit its growth and participate in either the Pinole expansion or the proposed regional treatment plant. This would have been a barrier to the transfer of this technology to communities that lack Hercules' tax base; Hercules was fortunate, and perhaps unique, in being able to find the multimillion-dollar AquaCell project out of its own revenues.

The Solar AquaCell case also illustrates many of the financial problems faced by innovators and entrepreneurs in appropriate technology. Lack of funds has prevented Solar AquaSystems, Inc., from hiring a sanitary engineer to help with design and to enhance the firm's credibility, and low salaries have been a strain on staff morale. The company's ability to plan has been restricted, and the size and diversity of its development hardware have been limited. Demonstration (and the capital it requires) is the key step to commercialization, but the firm's marketing operations have been hampered by the inability to visit prospective users or follow up on contacts. For example, the city of Santa Fe, N. Mex., has expressed an interest in the AquaCell system, but as yet the staff has lacked the time and money to make a presentation to that city. Similarly, the company was unable to send representatives to Hercules as often as it wished to facilitate construction there. Solar AquaSystems expects to break even on the Hercules project; only if other communities decide to use the system will they make a profit from their technology.

The failure of the firm to attract outside investment capital has not been for lack of trying. They found, however, that venture capital sources wanted substantial control over the firm before they would invest, usually amounting to 80 or 90 percent of the company. This was in part because of the high-risk nature of the investment, and in part because the venture capital market was extremely tight in 1976, when they were seeking funds. As one source explained:

> Venture capitalists require such a high ownership level because of the difficulty of selling their interest once the enterprise has become successful. Whereas it used to be possible to sell a company for 30 times its annual earning, 10 times earnings would be a more realistic figure today. Thus, to make a return on investment acceptable to the

[30]Council on Environmental Quality, Environmental *Quality—1975, the* Sixth *Annual Report of* the *Council* on Environmental Quality (Washington, D. C.: Executive Office of the President, 1975).

[31]For example, the contractor hired by the city to build the AquaCell greenhouse cover increased contract fees for structural engineering aspects in expectation of added costs due to possible unknowns regarding the unconventional technology.

venture capitalist, he or she must receive a larger share of the ownership in exchange for providing the same amount of capital.[32]

This issue, as it relates to the AquaCell case in particular and to innovative technology enterprises in general, is discussed at greater length in the section on financing in chapter 11.

Institutional Factors

The Hercules AquaCell project experienced relatively little opposition from local commercial interests. Some local builders opposed the proposal, fearing that the introduction of a new technology might cause delays in sewer hookups for new housing units. They urged the City Council to go the conventional route by paying for the Pinole plant expansion. Most such groups, however, saw the same advantages for the community that motivated the City Council.

A far more serious barrier to the implementation of this technology has been the resistance of Federal, State, and regional regulatory agencies. State and regional agencies for water quality control and public health have tended to prefer the conventional systems with which they were more familiar. The California State Water Resources Control Board, for instance, tends to judge wastewater projects by a set of criteria based on compact, mechanized conventional systems—activated sludge in particular. This board is made up of civil and sanitary engineers whose experience is rooted in these mechanical systems.

These engineers, as well as public health officials, have also been resistant to systems that reclaim wastewater for other uses and recycle wastes and other system byproducts. The majority of regulatory board members "believe in deep ocean dumping, " according to one former member;[33] and the State, regional, and county health officials have made it clear that the facility will not be given final certification until procedures for handling solid wastes are demonstrated to their satisfaction.[34] The comporting system at the Hercules facility was therefore vital, since for purposes of disposal the local health department defined the system's harvested water hyacinths as "contaminated, " undigested solid wastes.[35]

[32] John M. Smith, Jeremiah J. McCarthy, and Henry L. Longest, "Impact of Innovative and Alternative Technology in the United States in the 1980's," presented at the Seventh United States Japan Conference on Sewage Treatment Technology, Tokyo, May 1980.

[33] Roy Dodson, Special Consultant to the California Department of Health Services and former member of the California Safe Water Resources Control Board, personal communication, Mar. 23, 1978.

[34] Stephen Serfling, president of Solar AquaSystems, Inc., in a letter to the Hercules City Engineer, May 19, 1978.

[35] Ibid.

Federal Policy

Background

The Federal Government has provided grants for the planning, design, and construction of wastewater treatment facilities since the enactment of the Federal Water Pollution Control Act of 1956 (Public Law 84-660). In 1972, the Federal Water Pollution Control Act Amendments (Public Law 92-500) were passed, setting a uniform national minimum effluent standard of secondary treatment and authorizing an increase in the Federal share to 75 percent of eligible construction costs.

Although the Act encouraged alternative technologies for waste treatment, no incentives were provided. Most of the over $30 billion obligated to date has been used for the construction of conventional wastewater treatment facilities. With the passage of the Clean Water Act of 1977 (Public Law 95-217), Congress directed EPA to offer incentives for the use of alternative technologies for municipal wastewater and other waste treatment needs. In addition to the goals for clean water, Congress placed special emphasis on the use of technologies that:

- reclaim or reuse water;
- use recycling techniques, for example, recycling nutrients back to the land;
- eliminate discharges into surface waters;
- conserve or recover energy; and
- lower treatment costs.

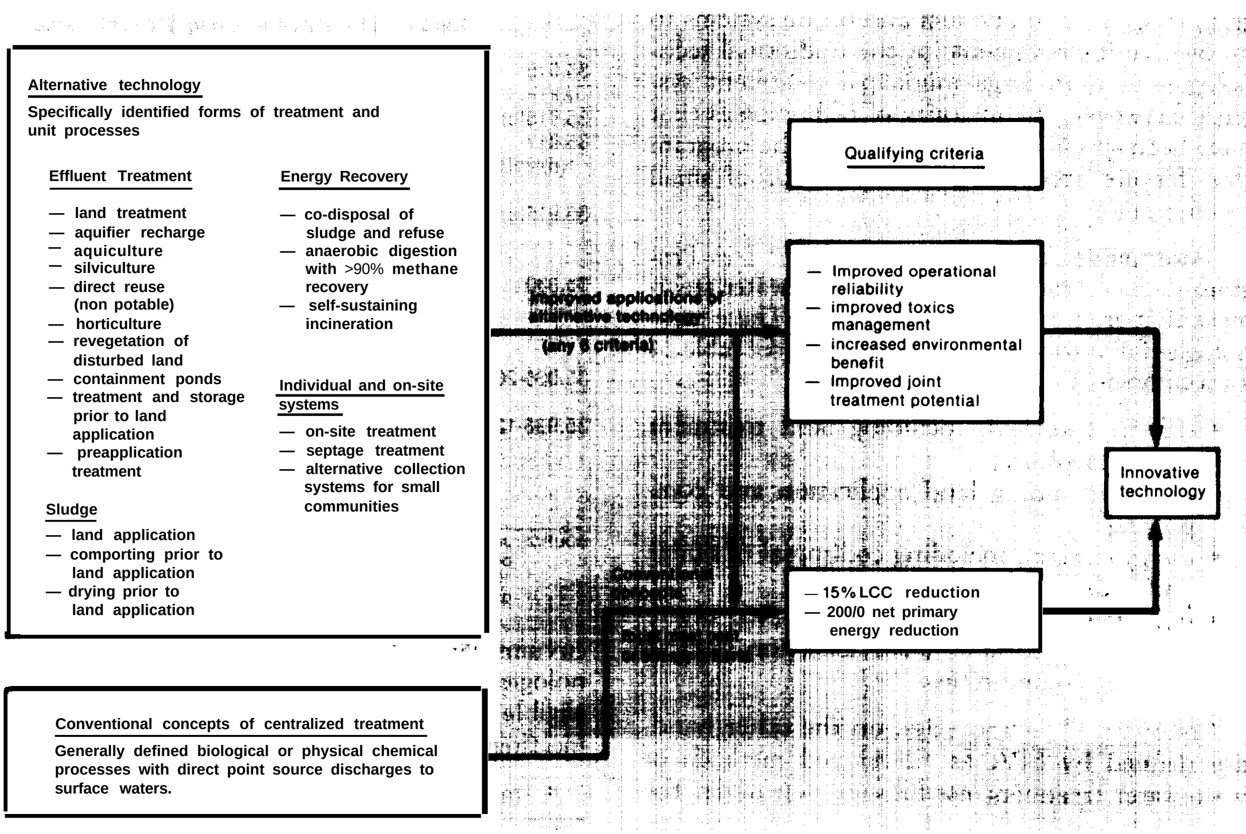
Congress also required all applicants for municipal waste treatment funds to fully study innovative and alternative wastewater treatment options which meet these goals.

Innovative and Alternative Technology Program

In October 1978, EPA established the innovative and Alternative Technology Program (1/A Program). This modification of the normal Federal Construction Grants Program enabled EPA to offer several incentives to communities:

- Increased Federal portion.—Federal grants for new treatment works using innovative or alternative technologies are increased to 85 percent of design and construction costs, as compared to 75 percent for traditional technologies. This means as much as a 40-percent savings to the community, a considerable incentive even when initial capital costs for the two options are the same.
- Set-aside *funds.*-- special fund is set aside from each State's allocation that can only be used to pay for the 10-percent grant increase for innovative and alternative technologies. This set-aside fund was 2 percent for fiscal years 1979 and 1980, and 3 percent for fiscal year 1981; at least 1/3 percent of each State's allocation must be set aside for innovative technologies. These set-asides in effect make more money available for innovative or alternative technologies and give a community wishing to use them an extra advantage in the State priority-setting process.
- Cost *preference.* —Innovative and alternative technologies can qualify for construction grants even if they cost up to 15 percent more

Figure 33.—Generalized Classification of Innovative and Alternative Technology



SOURCE. United States Environmental Protection Agency, *Draft Innovative and Alternative Techology Assessment Manual,* EPA 430/9-7 S-0001, 1978.

than conventional technologies. Thus, even though the alternative treatment facility may be more expensive, the increased Federal share still allows the community to pay less than it would for its larger share of the conventional facility.

- *Risk guarantee.* —Communities that choose innovative and alternative technologies are eligible for 100-percent construction grants for correcting or replacing the systems in the event they fail. This provision removes all financial risks to the community at least for the duration of the I/A Program.

See table 23 for a summary of innovative and alternative technology legislation and regulations.

The set-aside funds available under the I/A Program for fiscal years 1979 and 1980 totaled $84 million, which means that a maximum of $714 million in Federal construction grants were available for innovative and alternative technologies. Waste treatment methods that qualify for the program range from individual and onsite systems to innovative improvements in the traditional technologies used in large municipal treatment systems. However, the majority of technologies that have been specifically encouraged by the program thus far are appropriate for the needs of small communities.

"Alternative" technologies under the I/A Program include *proven* methods of wastewater treatment that are not yet in extensive use. These technologies fall into four major categories (see table 24 for a complete list):[36]

- *effluent treatment*, including land treatment and aquiculture;
- sludge, including land application and composting;
- energy recovery, including codisposal of sludge and refuse; and
- individual and *onsite systems*, including onsite treatment and alternative collection systems for small communities.

"Innovative" technologies, on the other hand, are defined by EPA as "developed methods of wastewater treatment *not* fully proven under the circumstances of their intended use."[37] These technologies (in which category the AquaCell falls) are eligible for funding if they show potential for meeting one or more of the following criteria:

. improved operational reliability;

Table 23.-Summary of Federal Legislation and Regulations Relating to Innovative and Alternative Technology

Legislation-Public Law 95-217, Dec. 27,1977	
Sec.	
201(d)	**Encourages the design and construction of revenue-producing facilities**
201(9)(5)	Requires all **applicants to study innovative and alternative technologies**
201(i)	**Encourages energy consevation in the design of all publicly owned treatment works**
201(e)	**Encourages the reduction of total energy requirements in the design of publicly owned treatment facilities**
201(j)	**Provides for 15% cost preference in the cost-effectiveness analysis for ail innovative and alternative technologies**
202(a)(2)	**Increases Federal grant from 75 to 85%**
202(a)(4)	**Limits grant eligibility to publicly owned treatment works (excludes sewers and sewer rehabilitation)**
304(d)(3)	**Requires EPA to develop guidelines for innovative and alternative technologies**
205(i)	**Authorizes innovative and alternative funding set-asides for fiscal years 1979, 1980, and 1981**
Regulation--40 CFR35, Sept. 27,1978	
Regulations	
35.908	**Describes innovative and alternative policy, funding, priority scheduling and replacement provisions of the Act**
35.9i5 (a)(l)	**Describes State priority system**
35.915(e)	**Provides for EPA review of State priority system**
35.917-l(d)(8)(9)	**Requires innovative and alternative technology and energy review**
35.915(b)	**Provides for establishment of State reserve set-asides to increase Federal share of cost from 75 to 8570**
35.930 (5)(b)	**Provides for 75 to 85% grant increase for new and replacement innovative and alternative projects**
35.935-20	**Provides for EPA postconstruction evaluation and inspection for 5 years**
35.936-13	**Provides exclusion to nonrestrictive specifications for certain innovative and alternative technologies and "buy American" provisions**

SOURCE: John M. Smith, Jeremiah J. McCarthy. and Henry L. Longest. "Impact of Innovative and Alternative Technology in the" United-States in' the 1980' s," presented at the Seventh United States/Japan Conference on Sewage Treatment Technology, Tokyo, Japan, May 1980.

[36]EPA 1980.

[37]*Innovative and Alternative Technology*, A *New* Approach *to an Old* Problem, brochure MCD-64, (Washington, D. C.: Environmental Protection Agency, March 1980).

Table 24.—Alternative Technologies for Wastewater Treatment

Effluent treatment systems
—land treatment
—aquifer recharge
—aquiculture
—silviculture
—direct reuse (nonpotable)
—horticulture
—revegetation of disturbed land
—containment ponds
—treatment and storage prior to land application
—preapplication treatment
Sludge systems
—land application
—comporting prior to land application
—drying prior to land application
Energy recovery systems
—codisposal of sludge and refuse
—anaerobic digestion with > 90% methane recovery
—self-sustaining incineration
Individual and onsite systems
—onsite treatment
—septage treatment
—alternative collection systems for small communities

SOURCE: Environmental Protection Agency.

- improved toxics management;
- increased environmental benefit;
- 15-percent reduction in lifecycle costs; or
- 20-percent reduction in energy use.

Modifications of convention, centralized treatment methods that are not yet fully proven are eligible for innovative technology funds only if they meet the last two criteria, reductions in lifecycle costs or energy consumption.

The Status of the I/A Program.–The I/A Program is a 3-year program, terminating at the end of fiscal year 1981 unless extended by Congress. At the end of the first half of the program, 212 innovative and alternative projects had been funded.[38] This amounted to only about 20 percent of the $84 million fiscal year 1979 set-aside funds available. Over 200 additional projects were undergoing review.[39]

Most of the innovative and alternative projects funded to date were already in the planning stage at the beginning of the program. Communities initiating projects after the program started in October 1978 are just beginning to apply for design funds. The alternative technologies have been primarily for small communities; most projects involve some form of land application of wastewater or sludge, but almost 40 onsite treatment systems have been approved, and more than 10 projects incorporate some form of energy recovery. Very few projects have been approved as innovative (or higher risk) technologies. Several systems incorporating land treatment have been classified innovative due to increased environmental benefit, but most of the innovative projects that have been approved has been energy- saving or cost-cutting modifications of conventional systems. Few systems as unconventional as the Hercules AquaCell has yet been funded.

Common to all alternative technology programs is the problem of disseminating information about the technologies and the program itself. To address this problem, the I/A Program has thus far:[40]

- established a clearinghouse and technical support group in the EPA lab in Cincinnati; a Small-Flows Technologies Clearinghouse has also been established;
- published an innovative and alternative technology assessment manual and distributed it to over 6,500 engineers;
- sponsored over 30 innovative and alternative technology seminars and workshops across the country; and
- prepared brochures and movies to give greater public exposure to the program.

The EPA Administrator has recently established an "active" I/A Program, providing extra manpower for technical assistance and promotion of the program. EPA is also considering a mechanism for expediting specific, prequalified innovative and alternative technologies. A quicker, simplified review procedure is being developed for communities wishing to use these technologies.

The midway point may be too early to evaluate the I/A Program's effectiveness, but it appears highly unlikely that the total funds appropriated for the program will be spent before it ends. The

[38] *Quality* Report–1/A Program Through March 31, 1980 (Washington, D. C.: Environmental Protection Agency, April 1980).

[39] Robert Bastian, Innovative and Alternative Technology Program, EPA, personal communication, 1980.

[40] Robert Bastian, Jeremiah McCarthy, Terry Yoise of EpA, personal communications, 1980.

primary reason for this is that 3 years—the length of the program—is a very short time in which to successfully introduce and implement these new systems, for the following reasons:

- Time is needed to hire staff and develop guidelines for the program, and to inform States and communities about the program.
- Conventional design procedures and standards, established in 1947 by the "Ten State Standards" of the Great Lakes-Upper Mississippi River Board of State Sanitary Engineers,[41] have been slow to change. Before alternative systems can effectively compete with traditional approaches, consultants and state engineers must acquire new design and review skills, just as professional schools and State review boards must be convinced to give innovative and alternative systems a fair hearing.
- Performance data for alternative systems are skimpy and often difficult to obtain. Land application systems are better researched than most of the other alternative technologies,[42] and only a few aquiculture systems are well documented. EPA sponsors both R&D and technology transfer programs at its Robert S. Kerr Envionmental Research Laboratory and Municipal Environmental Research Laboratory, but these programs take time, money, and manpower to become effective. Competition from other pressing, research efforts is severe.
- Because the I/A Program is funded for only 3 years some communities and consultants are hesitant to pursue the program.[43] From planning to construction of a wastewater treatment facility commonly takes 6 years under the Construction Grants procedures (of which the I/A Program is a part), and potential developers are concerned that the I/A Program incentives may be discontinued before their facilities are completed.

[41] Smith et al., op. cit.

[42] John R. Benneman, "Energy From Aquiculture Biomass Systems," report prepared for Office of Technology Assessment, U.S. Congress, 1979.

[43] John Hickerson, Director, El Paso Water Facilities, personal communication, 1980.

Issues and Options

Two major questions are raised by the foregoing discussions of the range of available wastewater treatment technologies, the Hercules AquaCell case study, and EPA's I/A Program:

- What should be the goals for Federal involvement with alternative wastewater treatment technologies?
- What types of programs (if any) should be established to accomplish these goals?

ISSUE 1:
The Goals of the Wastewater Treatment Program in Relation to Other Federal Programs and Goals.

Grants for the construction of wastewater treatment facilities represent the largest nonmilitary public works program since the Interstate Highway System.[44] One goal of the program (according to the amendments of 1972) is to achieve water quality that is clean enough for swimming and fishing. The Clean Water Act of 1977 (Public Law 95-217) amended the earlier law to provide additional money for municipalities which use technologies that: eliminate surface discharge, reclaim water or water pollutants, conserve energy, or otherwise achieve cleaner water at a lower cost. Some of these criteria are not traditionally associated with wastewater treatment.

A number of often conflicting national goals are related to wastewater treatment. Energy conservation and resource recovery, for example, are important goals, but they may divert funds from technologies which more directly improve water quality.

Some goals might be accomplished regardless of Federal incentives; others may require active involvement. For example, cost reductions for conventional technologies can occur through the workings of the marketplace. Elimination of surface discharge may not have the same economic incentives, yet it may be an equally important national goal. Traditional engineering firms, when given the option, are more likely to design lower

[44] Copeland, op. cit.

cost conventional technologies than to hire or develop expertise in entirely new approaches to wastewater treatment design.

Wastewater treatment can also have unintended effects on other programs. For instance, its impacts often act as de facto zoning regulations: conventional, centralized wastewater treatment facilities may encourage housing development along sewer mains, but may limit development to sewered areas alone. Community or onsite systems, on the other hand, allow more local control over population growth but make regional planning more difficult. For example, one of the reasons the City of Hercules chose to build the AquaCell facility was to avoid regionally imposed population growth restrictions.

Option 1: Determine the Extent of Federal Involvement.—Several degrees of Federal involvement in alternative wastewater technology are possible. These range from no involvement other than nonincentive funding under the pre-1977 Construction Grants Program, to providing community incentives such as the I/A Program. If Congress decides that the goals that can be achieved by alternative wastewater treatment deserve Federal involvement, the options for legislative action involve three major issues: information transfer, R&D, and community incentives programs.

ISSUE 2:
information Transfer—How Can Communities and the Engineering Profession Learn About Available Alternative Wastewater Treatment Technologies?

This issue is generic to all types of alternative technologies. For wastewater treatment, two types of information are necessary:

- *technical information* to local, State, and consulting engineers for design and review of alternative technolgoies,[4] and
- *nontechnical information* to educate community leaders and citizens about the advantages and disadvantages of the wide range of treatment alternatives.

Option 2: Clearinghouse and Technical Support.–Reauthorization of the EPA's I/A Clearinghouse, technical support group, and other information programs might be considered independently of the rest of the I/A Program. The information transfer accomplishments of the I/A Program (see above) have been quite impressive, given the short time the program has been in existence.

ISSUE 3:
R&D—How Can New Wastewater Treatment Technologies Be Developed?

R&D activities are taking place primarily in the private sector. Some direct Federal support for this research is coming from EPA, the National Aeronautics and Space Administration, and the National Science Foundation, but this support is not extensive.

Alternative wastewater treatment research is funded by EPA's Office of Research and Development under its Water Quality Public Sector Activities Program. Less than $15 million was available in fiscal year 1980 for the entire program. Federal funds devoted to innovative and alternative construction grants also indirectly promote research. However, consulting firms do not receive direct compensation for research activities, and must rely on the new markets encouraged by the program for marketing their products.

An important factor for the successful introduction of new technologies is the mix of laboratory research, pilot-scale projects, and full-scale demonstration. Full-scale demonstration projects are the most costly, but they are necessary for professional acceptance. Engineers are often hesitant to accept the results of small-scale research, precisely because laboratory-scale results do not always accurately predict full-scale performance.

Option 3-A: Direct Federal Research Funds.–Alternative wastewater treatment technologies may be given separate authorization in EPA's R&D budget.

Option 3-B: Demonstration Programs.—A full-scale demonstration program might be established. One option is to establish a design competition, similar to architectural design competitions: communities could be chosen to represent a range of population and geographical conditions, and projects could be chosen to represent a range of alternative technologies. Engineers and community groups would then have the opportunity to inspect a variety of operational facilities.

Option 3-C: Evaluation Programs.–Evaluation of existing alternative wastewater treatment facilities could be separately authorized. Programs to evaluate the entire treatment process, rather than just monitoring the final effluent can provide valuable information on new designs. Innovative and alternative technology construction grants can then fulfill more effectively the dual purpose of meeting community wastewater treatment needs and furthering research efforts.

ISSUE 4:
Community Incentives.

The financial incentives available to a community for using innovative and alternative technologies under the I/A Program were discussed earlier. Several problems were also discussed, including the length of the program and the relatively small number of innovative technologies approved to date.

Option 4-A: Length of **Authorization.—** Authorization for the incentives for innovative and alternative technologies ends in fiscal year 1981. Because of the short length of the program (3 years, as compared with 5 to 6 years from planning to construction), the program may not be able to achieve its full potential. Authorization could be continued for a specified number of years, or based on "sunset" provisions that would fund a predetermined number of alternative and innovative projects in specific areas of the country and of specific types.

Option 4-B: Risk Guarantees.–The Clean Water Act provides for 100-percent construction grants for correcting or replacing innovative and alternative systems that fail. However, the guarantee is authorized only for the duration of the program. Communities are uncertain of funds being available for replacement after the end of the program, and are hesitant to assume the financial risk of failure. The guarantee provision could be authorized for a specified number of years of facility operation.

Option 4-C: Different Financial Incentives for Innovative v. Alternative Technologies.—From the viewpoint of the communities, the financial incentives under the I/A Program are identical for alternative and innovative technologies. Furthermore, consulting firms receive few benefits for the additional work involved in designing innovative technologies and are therefore more likely to suggest proven alternative systems. Providing different incentives for innovative v. alternative technologies may encourage the consideration of unconventional wastewater treatment systems.

Option 4-D: Fast-Tracking Innovative and Alternative Technologies.–Innovative and alternative technologies are currently subject to the same administrative procedures as conventional construction grants. EPA is considering streamlining some of these procedures, and congressional action can further streamline the process by removing some of the requirements stipulated by the Clean Water Act. This can be done either by providing exemptions for innovative and alternative technologies or by removing the I/A Program from the Construction Grants Program.

Chapter 9

Community Energy Generation

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CHAPTER 9

Community Energy Generation

Introduction

Water power has been a major domestic energy source since the colonial era and was first used to generate electricity commercially in Appleton, Wis., in 1882. Today, hydropower is the most widely used renewable source of energy to generate electricity in the United States, with a total generating capacity of about 64,000 megawatts (MW), or between 13 and 15 percent of the Nation's total supply of electrical energy.[1] Hydropower is also a cheap source of electricity: existing hydropower facilities produce electricity for as little as 3.5 mills (0.35 cents) per kilowatt-hour (kWh) and newly installed hydropower will cost between 1.5 and 8 cents/kWh, compared with 4 to 5 cents/kWh for nuclear power, 6 to 8 cents/kWh for power from coal, and 10 cents/kWh or more for electricity generated by combustion turbines.[2] By contrast, electricity from wind-power generators costs an estimated 6 to 15 cents/kWh, and electricity from photovoltaic cells an estimated 55 to 90 cents/kWh; however, these two renewable sources are still in the development stage.[3]

Shortages and price increases for fossil fuels, as well as environmental considerations, have made hydroelectricity increasingly attractive over the last 10 years and have led to a new interest in developing the Nation's hydropower potential. A recent survey by the U.S. Army Corps of Engineers indicates that the Nation's total hydroelectric power potential is almost 513,000 MW, over eight times existing capacity. The Corps suggests that installed capacity at the 1,251 existing facilities might be supplemented—perhaps by early in the next century—by almost 95,000 MW at 5,424 existing dam sites (either by adding more capacity or by installing generators at dams that do not currently produce electricity) and an additional 354,000 MW generated at 4,532 sites that do not yet have dam developments.

The Corps cautions that these figures are theoretical and perhaps overly optimistic: they do not balance the potential for power generation against the competing uses for dams, such as recreation, flood control, irrigation, and drinking water; nor do they take fully into account the engineering, economic, and environmental factors that would constrain the full development of this potential. For instance, about 75 percent of this additional capacity (over 338,000 MW) would come from undeveloped large-scale sites (25 MW or more) that the Corps itself estimates would operate less than 30 percent of the time. Construction costs at these undeveloped sites would be high, particularly compared to the expected returns for this low peak-load utilization, and it is doubtful that public utilities would be willing to invest in these large-scale developments even if they could find the capital to do so.[5] Furthermore, an extensive study of the environmental impacts of alternative sources of electricity generation indicates that new large-scale hydroelectric facilities are probably the worst choice, in terms of ecological damage, due for example to the flooding and loss of productive agricultural lands they will cause.[6]

The outlook for developing the Nation's small-scale hydropower potential is somewhat brighter. The 842 existing small-scale sites (under 15 MW)

[1] Paul A. Weinberger, "The Potential for Small-Scale Hydropower Development in the U.S.," *Energy* (Booz-Allen & Hamilton, Inc.), spring-summer 1980, p. 7.

[2] Donald B. Chubb, president, Safe Harbor (Pennsylvania) Water Power Corp., quoted by William J. Lanouette, "Rising Oil and Gas Prices Are Making Hydropower Look Better Every Day," *Natl J.*, Apr. 26, 1980, p. 685; Ronald A. Corso, director, Division of Licensed Projects, U.S. Federal Energy Regulatory Commission, quoted ibid., p. 686.

[3] Private communication from Lou Devine, Department of Energy, and the Solar Electric Corp., Rockville, Md. These cost calculations assume a capital recovery factor of 0.15, with varying estimates of capital costs and capacity factors.

[4] U. S. Army Corps of Engineers, *Preliminary Inventory of Hydropower Resources*, 6 vols., July 1979; the report is based in part on an earlier survey conducted by the Corps in 1977.

[5] George Grimes, engineering development program manager, Division of Small-Hydro Projects, Department of Energy, quoted by Lanouette, op. cit., p. 687.

[6] *Energy in Transition: 1985-2010*, final report of the National Academy of Sciences/Nuclear Regulatory Commission Committee on Nuclear and Alternative Energy Systems (San Francisco: W. H. Freeman, 1980), p. 476.

represent two-thirds of all U.S. hydropower sites but only 5 percent of the Nation's generating capacity, or about 3,200 MW. Estimates of the potential capacity of all small-scale sites range from 13,000 to 58,000 MW, although recent studies tend to favor the lower figure. About half of this potential is at existing dams. This includes dams where there are no generating facilities, where existing facilities can be upgraded, or where generating facilities have been abandoned due to the proliferation of large-scale power grids since World War 11.[7]

A small but significant boom in small-scale hydropower development is currently taking place. As a rule, investor-owned utilities have not been interested in small-scale hydropower projects, both because their capacities are too small to meet generating needs and because the high financing rates paid by utilities makes small-scale projects economically unattractive. A number of private entrepreneurs and industrial developers have applied for licenses to construct small-scale facilities, either as a business prospect or as an alternative to rising fuel and utility prices. But by far the largest category of small-scale hydropower developers, both now and in the foreseeable future, consists of municipalities, cooperatives, and irrigation districts. These developers are favored by Federal licensing requirements and have access to low-cost or tax-free capital for small-scale projects.[8] Over 40 municipalities have license applications pending at present, including such communities as Madison, Maine, Springfield, Vt., Saugerties, N. Y., Paterson, N.J., Martinsville, Va., Columbus, Ohio, Vanceburg, Ky., Muscatine, Iowa, New Roads, La., and Gonzalez, Tex.[9]

Small-scale hydropower cannot, by itself, significantly reduce the Nation's energy problems. It can, however, contribute to the share of the Nation's energy mix that is supplied by hydropower. The capital-intensive nature of hydroelectric projects (both large and small) means that financing costs have a major impact on the price of the power they produce, sometimes as much as 90 percent of energy costs,[10] but the energy they Produce is relatively immune to both inflation and rising fuel prices. For communities located near existing but undeveloped damsites, small-scale hydropower may represent an economically viable alternative that can address a number of local problems, including rising municipal energy costs.

This chapter examines small-scale municipal electricity generation by focusing on two communities in New England—Wareham, Mass., and Woonsocket, R.I.–that are planning to build small hydroelectric powerplants at existing damsites. Wareham is developing a 250-kW electric generating capacity at the Tremont Dam to produce power for sale to the local utility. Woonsocket plans a 1. 1-MW facility at the Woonsocket Falls Dam, which would generate enough electricity to supply 90 percent of the needs of the regional sewage and water treatment plants. These two projects present some interesting contrasts and similarities in planning and financing, as well as in technologies.

Wareham and Woonsocket are characteristic of the New England region in many ways. They have a pervasive sense of history and visible reminders of industries that once flourished. The abandoned factories are tangible symbols of the high unemployment, low incomes, and physical obsolescence in each town. Both communities also face rising energy costs because of their dependence on fossil fuels. The development of locally based solutions to these problems is important to the people of Wareham and Woonsocket because, like other New Englanders, they pride themselves on their "Yankee ingenuity" and a tradition of self-reliance.

[7] Weinberger, op. cit., p. 7.
'Ibid., pp. 8-9.
[9] Lanouette, op. cit., p. 689"
[10] Weinberger, op. cit., p. 9.

Small-Scale Hydroelectric Technology

Technology

Hydroelectric plants (see figure 34) transform the potential energy of the water into electrical energy in three basic steps: 1) water from a reservoir or diversion structure is carried through the penstock to a turbine; 2) the falling water turns the turbine, which is connected to a generator; and 3) the high-speed rotation of the generator coil generates electricity, which is then transmitted from the plant.

The water above a dam possesses potential energy because its level is higher than that of the water downstream. The amount of energy in the falling water is directly related to how many feet or meters it falls, a quantity called "hydraulic head."[11] The amount of power (energy per unit time) that can be extracted from the water is proportional to the head and the flow rate of the water.

Small-scale dams–those with a rated capacity of less than 25 MW[12]–are often referred to as "low head" dams, although they could be located on small but precipitous mountain streams that had high head but a low flow rate. New England streams, however, are large (high flow rate) but with a gradual drop, or low head (usually less than 66 ft).

[11] Actually, head consists of components due to the velocity and the static pressure of the water as well as its height, and is given by the Bernoulli Equation:

$$H = \frac{v^2}{2g} + \frac{p}{g} + y$$

where:
H = hydraulic head
v = water velocity
g = gravitational acceleration (32.2 ft/sec²)
p = static pressure
y = height water falls

[12] Electric *power* is the amount of energy used or produced per unit of time and is measured in watts, kilowatts (kW or 1,000 watts), megawatts (MW or 1,000 kW). Electric energy is the amount of power used over time, and is measured in watt-hours, kilowatt-hours, and megawatt-hours (Wh, kWh, MWh). For example, if you ran a 100-W light bulb for 10 hours, you would have used 1,000 Wh or 1 kWh of energy.

Most large hydroelectric projects dam up a river and store water in a reservoir behind the dam. This allows the dam operator to buildup a supply of water when the river flow is at its peak and then release it when power is needed. Small-scale dams, on the other hand, are often operated "run of river." This means that all of the water flowing downstream at any given time will flow through the dam or over the spillway; virtually no pond or reservoir is created. Because a run-of-river dam does not store up a large amount of water, its power capacity varies with the changing flow rate of the river.

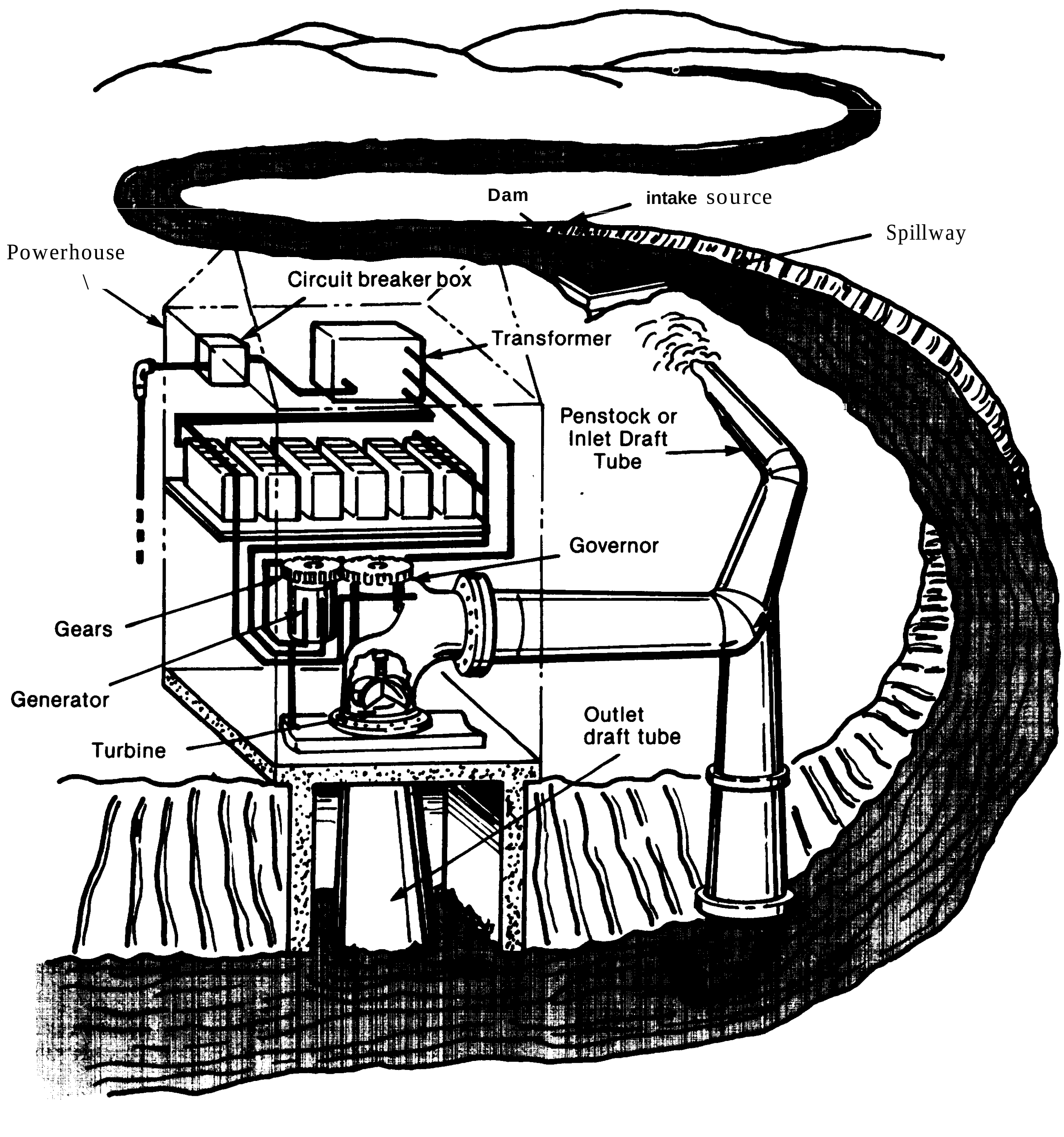
A user whose need for power fluctuates in the same manner is often difficult to find. In southern New England, for example, most electrical users have peak consumption during summer months, when they run their air conditioning, and low usage in the winter, when they heat their buildings with oil. Unfortunately, river flows tend to peak in the spring and are very low in the summer.[13] There are, however, several kinds of municipal loads that meet the constraints of run-of-river hydropower. One example is public schools, which have high usage from September to June when school is in session and virtually no usage in the summer. Another example is municipal street lighting, for which demand is high on long winter nights and low on shorter summer nights.

Economics

Water power played a major role in the early industrial development of New England, which is dotted with hundreds of old dams–nearly two-thirds of the existing but abandoned dams in the United States. The capital costs of installing a hydropower plant at one of these old river dams is

[13] The situation is more favorable in northern New England, where river flows are more uniform throughout the year and where there is less of an air conditioning load in the summer.

Figure 34.—Low Head Hydroelectric installation



SOURCE: Adapted from: Independent Power Developers' brochure "Hydroelectric Power". Adapted by: National Center for Appropriate Technology in Micro-Hydro Power (U.S. DOE).

high, however, since they involve feasibility studies, planning and design, and upgrading the civil works, as well as purchasing and installing the generating equipment. Low-head hydroturbines tend to have higher equipment costs per installed kilowatt of capacity than do high-head units.[14] Operating costs are lower, however, because the water is free and the dam requires little attention or maintenance.

By far the largest direct benefit of municipal low-head hydroelectric projects is the reduction of energy expenditures, but they also have important indirect benefits. Hydropower from existing small dams is an environmentally safe substitute for energy from more polluting sources, such as nuclear power, coal, and oil. Restoration of a small dam's civil works could also be a labor-intensive activity carried out by a public works job corps. The development of a local manufacturing industry for the retrofitting of low-head generating equipment could also stimulate the regional economy. Finally, the power produced by small-scale dams, if it can be sold at rates lower than those of local utilities, could be offered as an incentive for new industry to locate in the area, creating more new jobs and tax revenues.

[14] The expense has to do with the relationships between head, turbine diameter, and turbine speed. Given a constant flow rate, the turbine diameter required to extract a given amount of power from the water will increase quite rapidly as the head decreases.

A Case Study of the Tremont Dam Project, Wareham, Mass.

Community Setting

Wareham is a town of about' 16,000 people located in southeastern Massachusetts. Its economy is based on the shipbuilding, fishing, and tourist industries, and on the cranberry bogs which dot the landscape and provide seasonal employment at harvest time. The town, however, has been seriously affected by the industrial decline of the New Bedford-Fall River metropolitan area, of which it is part. The present unemployment rate is 15 percent or above—much higher than the rest of the State. To alleviate its problems, Wareham has initiated a program of economic development, including the creation of an industrial park to provide sites for new industry that will bolster its tax base.[15]

The Tremont Dam was orginally built by the Tremont Nail Works in 1845 as a source of power for its plant on the Weweantic River. It was operated from 1920 to 1938 by a shoe manufacturer, which sold electricity to the local utility company (a forerunner of the present New Bedford Gas & Edison Light (NBG&EL)) after its manufacturing operation moved south in the late 1920's. In 1938 much of the generating equipment was dismantled and moved with the shoe factory to South Carolina. In 1962, the Town of Wareham acquired the damsite, including water rights, pond, and 12 acres of land below the pond.

In the early 1970's, the Massachusetts Department of Public Works (DPW) issued several plans for the deteriorating Tremont Dam, which had become an eyesore. The last DPW plan, issued in 1974, called for demolishing the powerhouse and using the debris to permanently fill in the gates which controlled flow to the turbines. It was unclear whether any DPW money was forthcoming, however, and the Wareham Board of Selectmen asked the town's grants manager to investigate other possible sources of funding for restoration of the dam.

Interestingly, the early restoration plans were not focused on the dam's value as an energy project, but as an opportunity to provide temporary jobs for seasonally unemployed local construction workers. In 1975, Wareham secured a $400,000 Title X Public Works Job Opportunity matching grant form the U.S. Economic Development Administration to restore the dam, with the town putting up $100,000. The dam restoration occurred between February 1976 and July 1977, and a 1978 CETA Parks and Rivers grant paid for the

[15] Data and information on the history of the project come primarily from conversations with Bob Packard (grants manager) and John Healy (director of community development).

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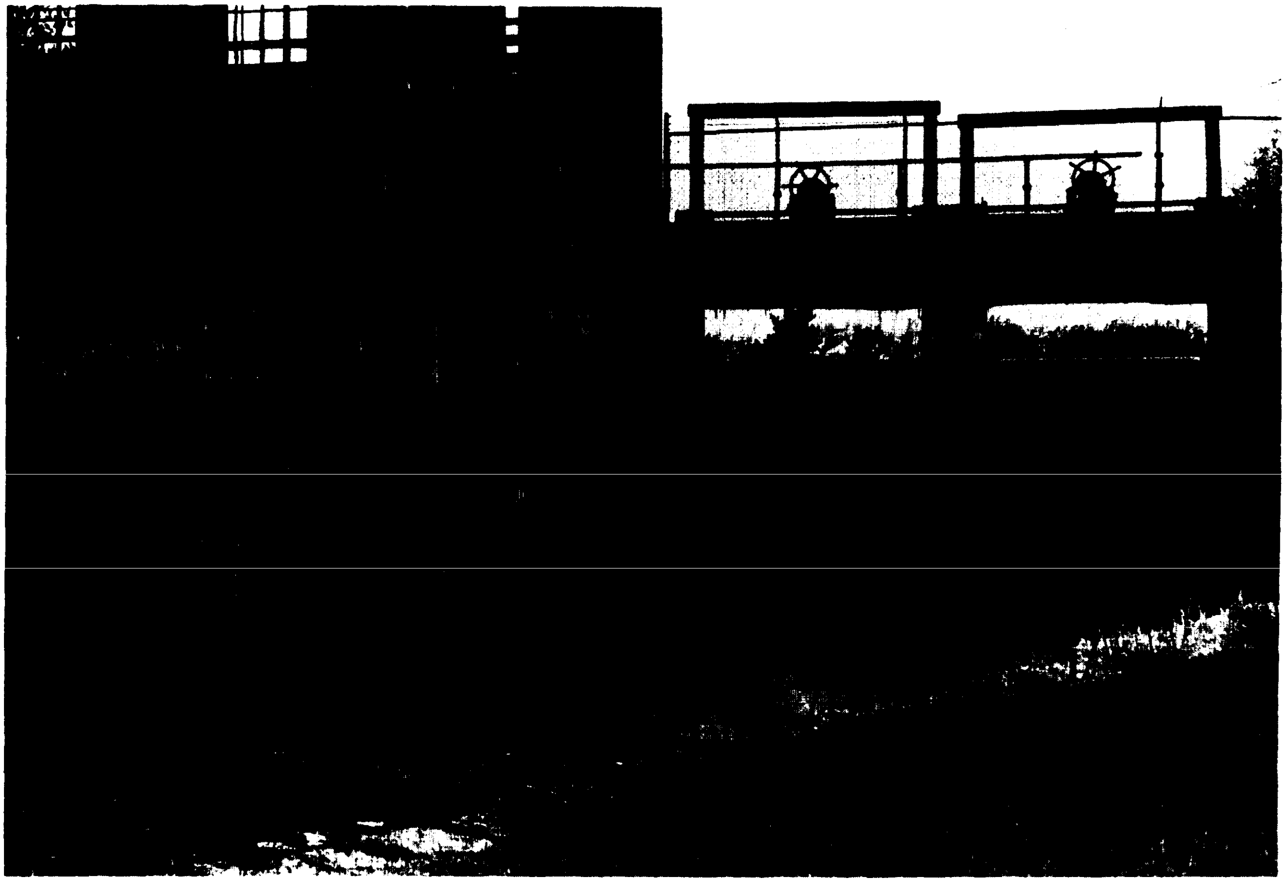

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clearing of the banks and riverbed below the dam and the building of a small recreation area.

Development

In 1978, the United Technologies Research Center of East Hartford, Corm., approached Wareham about applying for a study grant for the Tremont Dam under a Department of Energy (DOE) program to fund 54 feasibility studies of small-dam electricity production. A grant was awarded in mid-1978, and in February 1979 the study concluded that the site was feasible for power production. United Technologies also approached NBG&EL about the possibility of purchasing of power produced by the dam, and NBG&EL proved to be very interested in the project's potential public relations value: the company was moving its main office to Wareham, and involvement in the project would start its relationship with the town off on the right foot; in addition, the company had been criticized by local antinuclear groups, and participation in the hydropower project would demonstrate its commitment to environmentally benign power sources. [lb]

In August of 1979, Wareham received a $25,000 grant from the Massachusetts Office of Energy Resources for the purchase of turbines, but the town still needs an estimated $160,000 to complete the project. It rejected a grant from DOE that would have paid 15 percent of remaining costs and currently has an application before the Department of Labor for a 100-percent grant with which to purchase and install power generating equipment. (See *Critical Factors.*)

[16]NBG&EL is also participating in a solid-waste-burning powerplant (see ch. 7) and a windmill project, both within 10 miles of its new office in Wareham.

Equipment

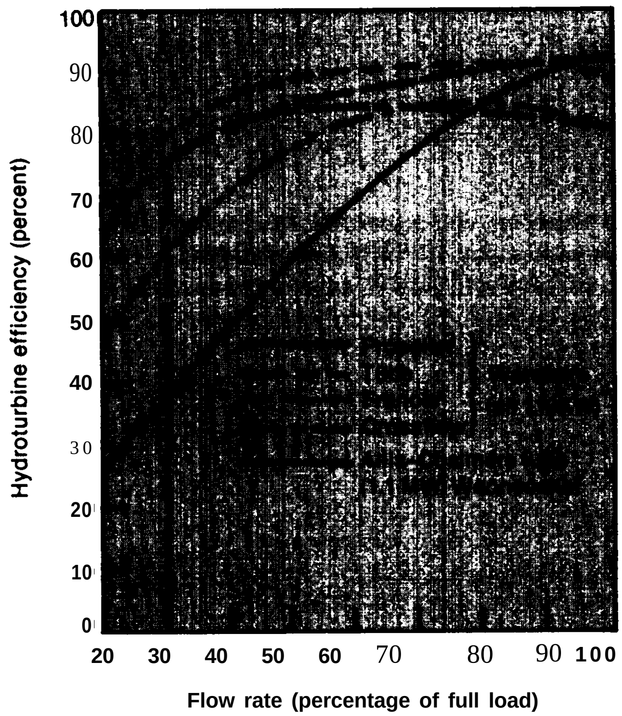
Very little additional work is needed to complete the whole project and begin producing electricity. The dam produces a hydraulic head of about 22 ft and could be developed economically to a capacity of 250 kW. The powerhouse is equipped with two elbow draft tubes which previously housed two Francis turbines. Although the draft tubes need to be replaced, the configuration will be retained and two vertical-axis turbines installed. Present plans are to install a modern 110-kW crossflow unit and a reconditioned 140-kW Francis turbine.[17]

The efficiency curves for the four turbine types that were considered for the Tremont Dam are presented in figure 35. The tube turbine has excellent partial-load efficiency and maximum efficiency, but for reasons that will be discussed later it would be infeasible at Tremont Dam. The propeller turbine has very poor partial-load efficiencies and it would, therefore, have been a poor choice for a dam that would experience seasonal drops in flow rate. The Francis turbine has modestly good partial-load efficiency and a maximum efficiency of over 80 percent. It will perform adequately in this site, but the major reason for choosing it was that the original units in the powerhouse were Francis turbines. It was felt that the project would have greater demonstration value if an older reconditioned unit could be run side-by-side with a newer unit.

The crossflow design was chosen for the modern unit because of its excellent partial-load efficiency, which is almost as good as the tube turbine's. This means that the efficiency of the equipment changes very little regardless of the flow rate, a highly desirable characteristic if the streamflow fluctuates greatly, as is the case in run-of-river hydropower projects. Some sacrifice in efficiency is experienced as the crossflow turbine approaches full load, but operation in conjunction with the Francis turbine will partially offset this deficiency.

[17] A complete discussion of the equipment proposed for the Tremont Dam can be found in E. S. Wright and J. J. Mankauskas, *Feasibility Study of the Tremont Dam Power Project*, United Technologies Research Center, February 1979.

Figure 35.—Hydroturbine Efficiency Curves[10]



SOURCE: Office of Technology Assessment.

Economics

Capital costs include $500,000 for restoring the dam and penstocks and $185,000 for purchasing and installing the turbines. The restoration costs are unusually high for a dam this size because the title X grant required a very high budget for labor; much of the work which could have been automated was not, in order to create jobs. Costs for feasibility studies, which should also be included, are in the neighborhood of $50,000. The total capital cost comes to $735,000, or $2,940 per installed kilowatt. An additional but probably insignificant cost is that of filing a licensing application. (Recent regulatory changes make available a simple and inexpensive—less than $500-procedure for obtaining an exemption from Federal licensing.)

First-year operating costs (excluding debt service) are projected to be $6,883. These costs include turbine and site maintenance ($0.004/kWh generated in the first year), depreciation, insurance (1.5 percent of turbine value), and any energy purchased to operate the automated gates. Debt service would also be an operating cost if Wareham had financed the project through a bond issue; dependence on grants, however, has created its own set of problems (see *Critical Factors,* below).

Revenue will accrue to the project from the sale of electricity to NBG&EL. Because the utility company refused to let Wareham lease its transmission lines, the town was prevented from using its hydropower directly for schools, street lighting, or other municipal purposes. Wareham will simply sell its power to the utility, which in turn will sell it back to the town at a higher price. While no rates have been agreed on, negotiations on first-year rates indicate a range of 2.6 to 3.0 cents/kWh. Strict comparison of these rates with present prices that NBG&EL charges the town would be inappropriate, since the NBG&EL charges also include a demand fee, fuel surcharges, and taxes, which may not be calculated on a per-kWh basis. Assuming that such a figure could be arrived at, it would probably be somewhat higher than the 2.6 to 3.0 cents/kWh rate offered by NBG&EL to the town, reflecting the utility's reluctance to give the town full credit for its power. Nevertheless, with an annual output of just over 1,000 MWh, this would yield revenues of $26,700 to $30,800, which would significantly reduce the town's electricity bill.[18]

Cash flow summaries prepared by United Technologies, assuming debt service at 7 percent for 30 years on the remaining $185,000 for turbine purchase and installation, indicate that first-year net revenue after debt service and all expenses would be $7,203. The cash flow assumes that operating costs will increase at a rate of 7 percent annually and fuel costs at 8 percent; however, both of these figures seem low, as does the spread between them, which suggests that revenues could be substantially higher. But using these assumptions, the project has an internal rate of return of 15 percent and a 10-year payback period. It must be pointed out again that this figure includes only about 25 percent of the real capital costs of the project; it excludes the $500,000 cost of dam restoration and another $50,000 for feasibility studies, both of which were financed with Federal grants (see above). If all costs are included, it would be difficult to say whether the project would be profitable at all; but by the same token, it would be difficult to put a dollar value on the benefits derived from increased employment or a new recreation area.

The project has already provided 70 full- and part-time jobs for dam restoration and the creation of the recreation area. It has no adverse environmental impacts, and the town hopes it will become an example of innovative technology that will attract local officials and visitors from all over the country.

[18] Wareham may receive substantially higher rates from NBG&EL when the State public utility commission implements the provisions of the Public Utility Regulatory Policies Act (see Federal Policy). For instance, under this Act the New Hampshire commission requires utilities to pay between 7.7 and 8.2 cents/kWh.

A Case Study of the Woonsocket Falls Dam Project, Woonsocket, R.I.

Community Setting

Woonsocket, R. I., is a city of 46,000 with pressing economic problems and low incomes. The city is dominated by the large brick and stone mills that were built along the edge of the Blackstone River in the 19th century to tap the available water power. These buildings are reminders of New England's industrial heritage, but although some of the mills are still in marginal use, the peak of activity has long since passed. Those who work in the mills consider $3.75 a high hourly wage, unemployment is severe, and one-third of the population has incomes below the poverty line.

The original dam at Woonsocket Falls stood until 1955, when it was destroyed by a flood. The present dam was begun in the same year by the

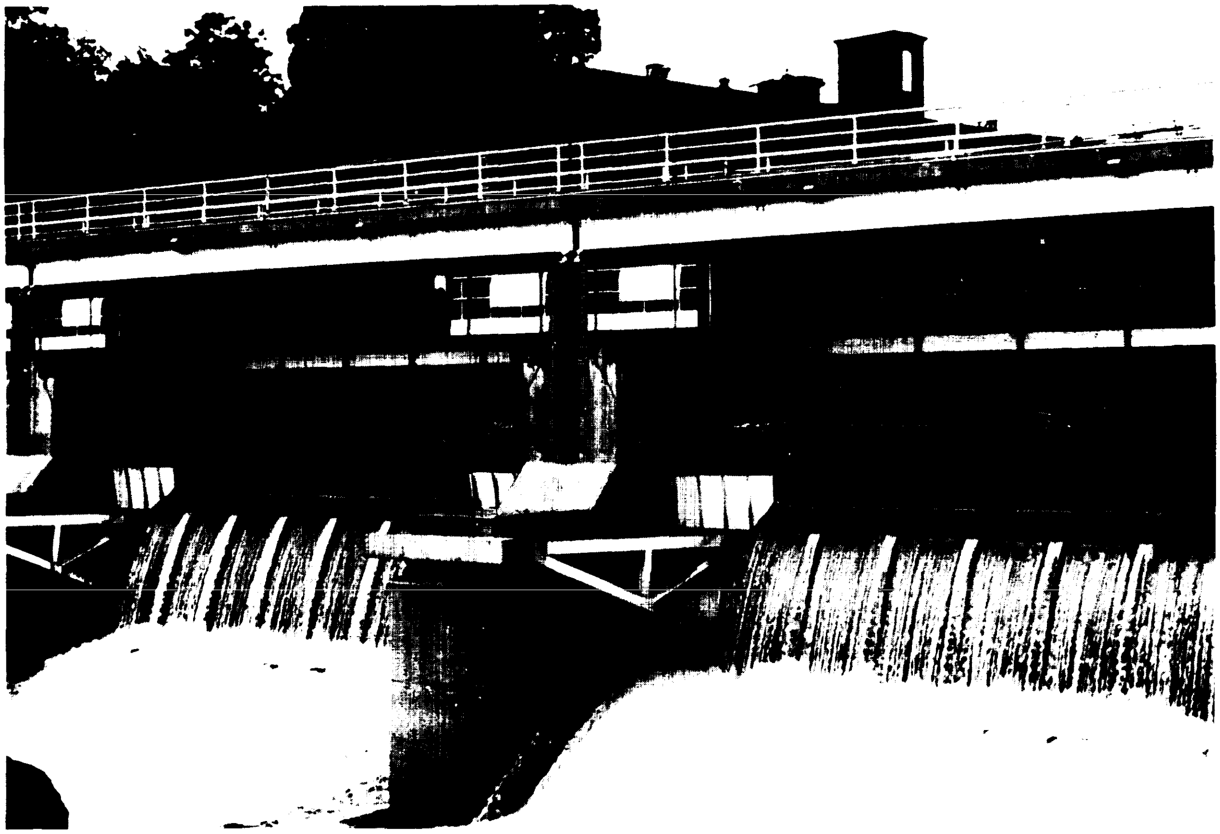


Photo credit: Office of Technology Assessment

Woonsocket Dam, Woonsocket, R.I.

U.S. Army Corps of Engineers as part of a local flood protection plan. The city now owns the dam and operates it according to Corps specifications.[19]

Proposals to build a municipal hydroelectric plant at the Falls date back to the 1960's. At the time, oil was cheap, there were no environmental regulations, and the citizens of Woonsocket did not take public power production seriously. The soaring price of energy since 1973 has changed their minds.

Development[20]

In 1978, the Governor's Energy Office urged the city to apply to DOE for a grant to study the feasibility of producing electricity at the dam, The $66,000 grant was awarded to a study group from the University of Rhode Island that also included State energy and environmental officials, city planning officials, and utility company representatives. The study was completed in January 1979, and after considerable debate the City Council approved the plan. In November 1979 the voters approved the bond issue for it by an overwhelming 95 percent majority. An update of the feasibility study has been completed, and the city has applied to DOE for a grant to cover 15 percent of the construction costs.

Equipment

The Woonsocket Falls Dam has a hydraulic head of only 18 ft, but because the dam is relatively new and well maintained it presents an excellent opportunity for hydropower development.

[19]Interviews with Joseph Anazer and Leo Millette of the U.S. Army Corps of Engineers.

[20]The history of current hydropower initiatives comes primarily from interviews with Joel Mathews and Marvel Valois of the city planning department.

The city has chosen a vacant lot 300 ft downstream of the dam as the powerhouse site, and it presently plans to develop the project to a capacity of 1.1 MW.

Two turbine configurations are under consideration, both manufactured by the Allis-Chalmers Co. The first is a standard 1.1-MW Kaplan tube turbine. Its efficiency curve (see figure 35) shows that to get any power at all from the unit, the turbine must operate above 30 percent of full load. However, above this lower limit the partial-load efficiency never drops below 75 percent, and maximum efficiency is above 90 percent; overall, this is a highly efficient unit.

The city is also considering a second configuration with two 550-kW turbine units. The advantage of having two units would be that, during periods when demand for power is low, one unit can be turned off and the other operated at full load for better efficiency. This is generally more economical than running both generators at partial load, because efficiency decreases under partial load conditions. For instance, a 25-percent total load would not run a 1. 1.1-MW unit, but would produce close to 90-percent efficiency in a single 550-kW unit.[21]

After considering several options, Woonsocket has decided to use the project to provide power for a regional sewage treatment plant and the city water works. The sewage treatment plant is less than 25 percent completed at present; when completed, it will have a peak demand of 4 MW and will obviously need power from another source as well.[22] However, at present it could absorb about 2,950,000 kWh from the hydroplane. The water works will consume about 2,760,000 kWh, or 79 percent of its energy needs. The city is currently negotiating an arrangement with Blackstone Valley Electric (BVE) to "wheel" power to these facilities over existing utility lines. (Wheeling is an arrangement whereby the city can transmit its power over the utility's lines through a rental agreement—an agreement that the power company in Wareham, Mass., refused to make.) The wheeling rate will be determined on the basis of the utility's equipment amortization: that is, a percentage of the capital costs of constructing the line.

Economics

Capital costs for restoring the dam, building the penstock and powerhouse, and purchasing and installing turbine equipment are projected at $2,682,950, or $2,439 per installed kW. The cost of the feasibility study, which was not included in any of the cash flow projections, was $66,000, or about $60 per kW. First-year operating costs are estimated at $40,885, including wheeling charges but excluding depreciation. Debt service is assumed to be $238,681 annually for a bond issue at 6-1/4 percent over 20 years.

Average annual energy production at the Woonsocket Falls Dam is estimated at about 6,570,000 kWh, of which about 87 percent will be consumed by the sewage treatment plant and water works. The surplus power would be sold back to BVE at day rates of 3.06 cents/kWh and night rates of 2.43 cents/kWh, for an annual city revenue of about $289,000.

Net revenue in the first year is projected at $9,556, reflecting all costs except the feasibility study. In following years, the city projects that costs will increase 9 percent annually, while revenues will increase with the price of energy at 13 percent annually.[23] No rate of return was given for the cash flow, but to give some idea of the profitability of the system, the projected net revenue for the twentieth year of the project is almost $2.5 million.

[21] Descriptions of the dam and proposed equipment can be found in John S. Krickorian, Jr., "Hydroelectric Power Potential, Woonsocket Falls Dam," University of Rhode Island Center for Energy Studies, January 1979; and John C. Halliwell, P. E., "Demonstration Project Proposal for Woonsocket Falls Dam," Halliwell Associates, Inc., Aug. 23, 1979. The Halliwell report also includes a cash-flow study.

[22] One reviewer suggested that this sewage plant, too, should be assessed for its appropriateness: "Why should sewage plants use so much electricity?" See ch. 8 for a discussion of alternatives for community wastewater treatment,

[23] Halliwell, op. cit., p. 14; rates of inflation are based on recent data from the Library of Congress, the Massachusetts Electric Co., and the Narragansett Electric Co. and are considered "moderately conservative."

Critical Factors

Public Perception and Participation

A survey showed that most local citizens were aware of the two hydropower projects and supported them, at least in principle. Most of those surveyed, however, had little detailed knowledge about the projects and were uncertain about their purposes. Many thought that the power should be used to deal with pressing local needs, and there was almost universal agreement that hydroelectricity and/or the revenue it provides should be used to reduce people's energy bills in some way. One common misconception was that the energy generated at the dams could be applied directly to space heating needs, despite the fact that heating requirements in that region are met largely by oil and some natural gas, not by electricity. In addition, many people overestimated the power-producing capacity of the projects; they spoke of generating enough electricity to meet the needs of all local residents or of all municipal services.

Local citizens in both Wareham and Woonsocket also expressed frustration with their local governments. They thought that they had not been provided with enough information to allow them to reach decisions intelligently, and often expressed irritation at the failure to hold town meetings where they could ask questions about the projects and discuss what they really meant for the communities. In addition, some residents said that a few influential people controlled the local decisionmaking process and that, as a result, these decisions did not always coincide with basic development needs. Despite these criticisms, however, the majority of those interviewed firmly agreed that hydropower is a valuable local resource, one that could provide significant benefits and deserves serious exploration.

Essential Resources

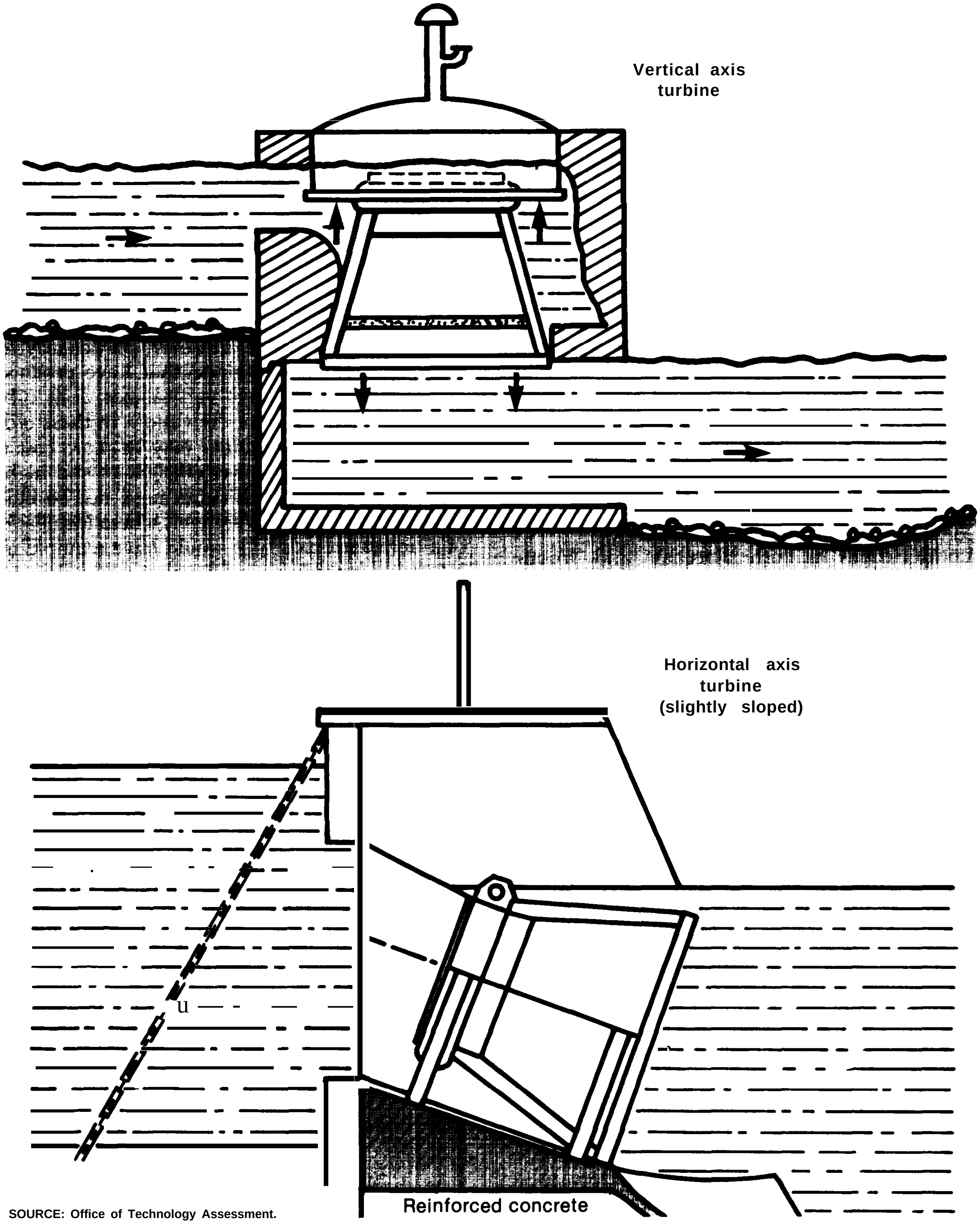
A potential constraint identified in these case studies concerns the availability of low-head turbine equipment. Hydroturbines can be broadly classified into two categories: those with vertically mounted shafts and those with horizontally mounted shafts (see figure 36). Vertical turbines were used frequently in New England in the early part of this century, and the two units most often utilized today are the Francis turbine and the propeller turbine. The horizontal or "tube" design, which was developed later, improves the efficiency of the system by permitting simpler draft tubes and smaller powerhouses. The resulting capital cost savings make the horizontal-axis turbine a logical choice when building a new powerplant or extensively modifying existing works.

Many existing dams, however, particularly the older ones in New England that have produced power in the past, have vertical-axis draft tubes that require little or no renovation. In these older dams, vertical-axis turbines may be more cost effective, despite their lower efficiencies and higher cost, because new draft tubes need not be built. This was the case in Wareham, where installation of a horizontal-axis tube would have required unjustifiably expensive modifications to the dam and works.

Unfortunately, there are few small-scale hydroelectric equipment manufacturers worldwide, and even fewer in the United States. When engineers in Woonsocket were looking at tube turbines, only one American manufacturer (Allis-Chalmers) produced a standard unit that met their specifications. (A second U.S. manufacturer—Tampella-Leffel-has recently entered the market.) The city also investigated the possibility of purchasing a reconditioned unit, but decided not to because of the limited experience of the firm. Several Japanese and West German firms produce a variety of tube turbines, but the city's construction grant from DOE indicated a preference for American-made equipment.

The situation in Wareham was somewhat different. The original equipment in the dam was two Francis turbines manufactured by an American firm. Fortunately, there are a large number of these units in abandoned small-scale hydroelectric

Figure 36.- Vertical and Horizontal Axis Turbines



SOURCE: Office of Technology Assessment.

plants all over the United States, and engineers located one that is compatible with the Tremont Dam site. Reconditioning these abandoned units could be a profitable business opportunity for some American firm.

The second turbine unit at Wareham will be a modern crossflow unit. Again, there are few American manufacturers of crossflow turbines, with the Bell Co. being the leader; worldwide, the largest manufacturer of crossflow equipment is the Ossberger Co. of West Germany. Wherever this turbine is purchased, however, it will have to be engineered to specification and will thus cost more. United Technologies favored customized turbines, arguing that flow and head conditions vary so widely from site to site that standard units usually result in less than optimal equipment.

Technical Information and Expertise

One of the most serious constraints on the development of a municipally owned small-scale hydropower project is the depth of engineering expertise required to implement the project. Because the small-scale hydropower industry went into decline earlier in this century, few engineering firms have experience in this field. Those that do have hydropower experience tend to be familiar only with large-scale systems and are either uninterested in the small returns from a small system or are unfamiliar with modern small-scale technologies.

One solution is to hire a consultant. Wareham has contracted with the research branch of United Technologies, a high-technology firm with little hydropower experience, feeling that the firm's lack of direct experience would make it less biased in the selection of equipment or manufacturer. (There are, however, several reputable consulting firms in New England that have both hydropower expertise and a reputation for providing reliable advice.) The original feasibility study for the Woonsocket Falls Dam was the effort of a team of faculty and students from the University of Rhode Island, working with a task force of State and local officials and representatives of the utility company. Dr. Krickorian, the study team leader, has developed a computer model which might be useful to other municipal officials in getting a rough estimate of the feasibility of the proposed hydropower project.

Another technical problem is evaluating the resource base; in the case of a hydropower project, this means compiling an accurate streamflow record. Because streamflow can vary substantially from day to day, month to month, and year to year, this record should consist of frequent readings over many years. The U.S. Geological Survey (USGS), which maintains gauging stations throughout the country, is often the best source of these records. For many damsites, however, historical streamflow data is unavailable, and the lack of this data at the outset can add substantial cost and uncertainty to the project. At the Tremont Dam, for instance, two estimates of streamflow were available, but neither was based on records obtained at the damsite: one estimate extrapolated data from a nearby river; the other used rainfall records and assumed runoff to estimate streamflow. When United Technologies took several months of streamflow measurements in 1978, neither estimate was found to correspond to the actual data. Instead, United Technologies examined all USGS records from gauging stations within 25 miles and a station whose hydrological conditions seem to approximate those at the Tremont Dam. Even after all of this effort, however, there is still uncertainty as to the accuracy of the data.

Financing

Energy generation projects require a variety of capital throughout their development. The first capital requirement involves funding a feasibility study and other preliminary planning. Feasibility studies for small-scale hydropower projects can be quite expensive because of the depth of engineering expertise they require: costs are typically between $30,000 and $75,000, and they seem to be unrelated to. the size of the project. This expenditure also entails a high level of risk, since there is no guarantee that the project will prove feasible or that the money will earn any return. Private enterprises routinely undertake this kind of risk, but municipalities do so only if the project is absolutely necessary, like new schools, or if it has the potential for considerable local benefits.

For this reason, some innovative projects will find it difficult to obtain municipal financing for feasibility studies, and another approach must be sought. DOE's hydropower study grant program, which funded 54 feasibility studies (including both Woonsocket and Wareham), is no longer available, but DOE has established a low-interest loan program in order to fund additional feasibility studies. The loans cover 90 percent of study costs and bear interest at 71/B percent over a 10-year term; however, no payments are due during the first 3 years of the loan, and if the project proves infeasible the loan will be forgiven. DOE and other agencies also perform "reconnaissance analysis," a quick and inexpensive evaluation of a damsite's potential, and the Corps of Engineers has issued a manual, Feasibility *Studies for Small-Scale Hydropower Additions*, which reportedly can be used even by those with little or no experience with hydropower.

By far the largest capital needs for a municipal energy project, however, come during the construction phase. At that point, since the project will presumably provide revenue after completion, debt financing becomes a reasonable option for the municipality. However, some communities (such as Wareham) still look for grant financing. This has several drawbacks. First, grants are often restricted in use and, as a result, several grants (from different agencies and for slightly different purposes) will have to be assembled in order to complete the project. This creates delays and financial insecurity, since projects can be left half-finished if one grant doesn't come through. Restricted-use grants, like the title X funds for the Tremont Dam, can also cause the project to be much more labor intensive than necessary and thereby drive the total cost of the project up.

Another characteristic of grant financing is that few grant programs will cover the total cost of the project. Wareham's title X grant provided 80 percent of the cost of restoring the dam, with the city putting up $100,000. For the purchase of turbines, Wareham received a $25,000 grant from the Massachusetts Office of Energy Resources and planned to apply to DOE for the remaining $160,000. The city found, however, that DOE would only cover 15 percent ($27,500) of these costs. DOE feels that debt capital is available for these projects and hopes the communities will use the 15-percent grants as seed money to attract private capital. (For rural communities, funds may be available through the Rural Electrification Administration.)

Woonsocket has approached construction financing differently and has been able to proceed much more rapidly. Total project costs are estimated at $2.68 million, but cash flow projections are very favorable and for this reason the city has received permission from both the State of Rhode Island and its own residents to raise the construction capital through the sale of general obligation bonds. (Unlike Wareham, Woonsocket also applied for the 15-percent construction grant from DOE.) Because the project shows a profit, after debt service, every year over the life of the loan, it looks like a good candidate for revenue bonding. But the profit margin in the project's early years may be too tight to count on, and the cash flow projections include assumptions about capital costs and energy price increases which might not prove accurate.[24] In view of these problems, general obligation bonds appear to be a safer approach.

Although Woonsocket city officials appear confident in their ability to sell their bonds, they must first obtain a firm commitment from BVEC on wheeling charges and buyback rates, and this agreement must specify conditions for future price increases. DOE has encouraged projects that do not show a profit after debt service in early years to offer their power to local utilities at a flat rate that does not increase over time. A utility may be willing to pay a price that is higher than present replacement costs if it is assured that the price will not rise in the future, this would give the municipality sufficient revenue in early years to cover

[24]An example of this problem faces Woonsocket at present. It was initially believed that power from a recently completed facility in Quebec would be available to BVE at rates lower than the cost of producing that power at oil-fired powerplants. Recent projections indicate that although the Quebec project could provide a more stable source of energy than foreign oil supplies, its cost will not differ greatly. However, instabilit, in world oil markets has affected projected revenues to the project so dramatically that the project may ultimately be restructured entirely. Increasing oil prices have increased the buyback rates the utility company is willing to pay for power purchased from the dam so greatly that the cit, now wishes to wheel smaller amounts of power to its two electricall, heated schools (both of which have more favorable demand profiles given the load profile for the dam) and sell more power to BVE. Updated cash flow summaries for this option were not available for inclusion in this assessment.

debt service on a revenue bond issue. Unfortunately, this approach denies the municipality the full value of its power, and local utility companies justly fear that if fuel prices continue to rise as rapidly as they have in the past, a flat-rate deal would be a politically untenable arrangement. In general, the municipality will derive the greatest value from the power it generates if it uses it to satisfy its own energy needs, rather than selling it to a utility. This problem may be resolved by the implementation of the Public Utilities Regulatory Policies Act in early 1981 (see Federal Policy).

Institutional Factors

Unless energy generated at a hydroelectric plant is to be used onsite, it must be transmitted to its point of use. Because transmission lines represent a large additional investment, most municipalities (like Wareham and Woonsocket) will probably either seek wheeling arrangements with local public utilities or sell their power to the utilities. The utility companies, however, are reluctant to wheel power, first because they lose revenue when customers drop electric service, and second because it is difficult to determine a fair wheeling rate, since there is no precedent for this service and it is not regulated by public utility commissions. In the future, with increasing numbers of small power producers, wheeling may become a more common and standardized process; but whether the majority of utility companies would be receptive to such a situation is questionable. The State of New Hampshire is considering legislation that would set wheeling rates and force utility companies to comply, and Congress has recently enacted legislation that deals with this issue (see below).

Federal Policy

Background

Water power became the primary source of energy for American industry in the early 19th century, and, because there were few restrictions, the development of this energy source was relatively simple for the growing manufacturing economy. It presented problems, however, for future use of water resources by other sectors, particularly agriculture. Public policy regarding hydropower evolved, therefore, from a desire to ensure that such development on navigable streams was in the public interest of a growing Nation with diverse and growing needs.

A fear of private monopoly and the loss of public control of a vital natural resource prompted congressional action to slow private development in the early 1900's. The policy of Government control through licensing was embodied in the Federal Power Act of 1920, which established the Federal Power Commission to issue licenses for the construction, operation, and maintenance of dams, reservoirs, powerhouses, and transmission lines. A series of laws enacted between 1920 and 1950 increased Federal involvement in the development and operation of hydropower facilities and the sale of hydropower. These laws included amendments to the Federal Power Act, the Boulder Canyon Act of 1928, the Tennessee Valley Authority Act of 1933, the Public Utility Act of 1935, the Bonneville Act of 1937, and the Flood Control Acts of 1936, 1938, and 1944. Today, a complex set of rules, regulations, and institutions govern the development of hydroelectric power.

The rise of the environmental movement and the demand for more efficient Government operations led to attempts during the 1960's and 1970's to integrate water resource activities into a comprehensive package of resource development and conservation. This effort was guided by the passage of such legislation as the Wilderness Act of 1964, the Water Resources Planning Act of 1965, the Wild and Scenic Rivers Act of 1968, and the National Environmental Policy Act of 1969.

Small-Scale Hydropower Programs

Until the 1970's, most people thought of hydropower as big dams and large-scale generating facilities. Shortages of fuel and other resources, rapid increases in oil and gas prices, the 1973 Arab oil embargo, and mounting pressure from environmentalists have led to increased interest in alternative forms of hydropower, including the restoration of existing small-scale dams and hydroelectric equipment.

By itself, small-scale hydropower cannot significantly relieve the Nation's energy problems. The Federal Energy Regulatory Commission (FERC) estimates that the undeveloped hydroelectric potential at existing dams with a capacity of less than 5 MW would total no more than 26,600 MW. Nevertheless, this represents a savings of 139 million bbl of oil,[25] or about 3 weeks' imports at current rates. Because energy generated at small-scale hydropower sites is immune to rising fuel costs, it will also be increasingly competitive with other sources of electricity. For communities located near existing but unused hydropower sites, therefore, small-scale hydropower may represent an economically viable alternative that can help in addressing a wide range of local problems, including rising municipal energy costs.

President Carter publicly recognized the potential for small-scale hydropower projects in 1977, and Congress took an active role in the promotion of these projects by appropriating an initial $10 million to establish a small-scale hydropower program in DOE. Since then, the DOE demonstration grants program has funded $50 million in studies and construction, and funding is also available through other programs in the Departments of Energy, Agriculture, Labor, and Commerce, as well as the Community Services Administration (CSA).

Major legislation that affects small-scale hydropower projects includes the following:

- *Federal Power Act of* **1920** (41 Stat. 1063), as *Amended in* 1935.—This law contains a provision (sec. 7A) which, according to some critics, may discourage private development of small-scale hydropower. Section 7A concerns competing applications: under its provisions, a public body such as a municipality will be granted preference over a private developer in securing the licenses for a hydropower site, regardless of the order in which the applications are submitted and regardless of the capital already invested in the site by the private developer. For example, a private developer who had developed and operated a site under Federal license for a period of years might still lose license at the time of renewal, if a public body chooses to apply for a license to operate the same site.
- *Public Utilities Regulatory Policies Act of 1978 (Public Law* 95-617).–This law streamlines the licensing process for small-scale hydropower projects; provides cost-sharing funds for feasibility studies, for license application costs, and for architectural, engineering and construction costs; declares them not to be utilities and therefore exempt from local utility commissions; and requires local utilities to allow them to use their power grids and to purchase power from them at rates to be set by State utility commissions by February 1981.
- *Energy Security Act of* **1980** (Public Law 96-294) V-This law further streamlines the licensing process for small-scale hydropower by exempting projects under 5 MW from FERC licensing. This exemption does not extend to review and processing by other Federal agencies, however, and some procedural problems remain. (See the discussion of this issue below.)

Major legislation introduced in the 96th Congress includes amendments to the Internal Revenue Code to provide tax credits for equipment used at small dams to produce hydroelectric power, to extend tax-free financing, and to make small-scale hydroelectric property eligible for residential energy credits. Other proposed bills cover items such as a trust fund for R&D in alternative energy resources, increases in funds for feasibility studies, provisions for surveying and other technical assistance, provisions for construction of small hydroelectric projects not specifically authorized by Congress, permission for Federal agencies to enter into agreements with States to avoid duplication of and delay in licensing procedures, and changes in the definition of small-scale hydropower.[26]

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[25] Mary M. Allen, "A Report on the Potential Use of Small Dams to Produce Power for Low-Income Communities," prepared for the Community Services Administration, contract report No. B8B-5584, Aug. 4, 1978, p. 1-15.

[26] Warren Viessman, Jr., and Christine DeMoncada, "Water Resources: Small-Scale Hydroelectric Power, " Library of Congress,

Issues and Options

ISSUE 1:

Coordination of, and Community Access to, Federal Assistance Programs.

Despite the number and variety of Federal programs for small-scale hydropower projects, there are complaints about the adequacy and coordination of Federal assistance. These problems have to do with the definitions and objectives of the programs themselves, the application procedures for licensing and financing, the regulatory structure for public utility rates and wheeling arrangements.

One difficulty arises from confusion over what exactly constitutes a "small scale" hydropower project. DOE, for instance, defines a small-scale project as a site with a head of less than 66 ft and a power potential of between 50 and 15,000 kW. The Corps of Engineers, on the other hand, defines small dams as structures less than 40 ft in height with a potential capacity of less than 5,000 kW.[27] As a result, a project may be eligible for funding under one program's small-scale criteria, but not another's. Because the funding from a single program rarely covers the total cost of any given project, multiple sources will usually be required, as was the case in both of the projects studied in this chapter. Consequently, these differing sets of criteria complicate the application process, increase the time and expense involved, and may in some cases bring the project to an impasse.

A related problem has to do with the differing objectives of the various Federal small-scale hydropower programs. Often these programs dictate the objectives of the grant and the uses to which the funds can be put, but these requirements differ from act to act, from agency to agency, and from program to program. These requirements can sometimes conflict with one another or with the objectives of the local community, and these conflicts can distort the results of a project or increase its costs. For instance, the grant for the Tremont Dam project in Wareham specified how much of the money should be used for jobs and how much for materials. As a result, the project was far more labor intensive than necessary, and it probably cost both Wareham and the Federal Government more than it should have.

A similar complaint concerns the burden placed on the limited resources of small communities by the complicated and time-consuming procedures for obtaining permits and licenses for hydropower projects. Statutes that affect the licensing process include the National Environmental Policy Act, Fish and Wildlife Coordination Act, Endangered Species Act, Historic Preservation Act, Water Pollution Control Act, Water Quality Improvement Act, Wilderness Act, Wild and Scenic Rivers Act, Coastal Zone Management Act, and Federal Land Policy and Management Act. FERC licenses all non-Federal development on Federal lands or navigable rivers that affect interstate commerce, but the Commission's jurisdiction has been defined so broadly by the courts that it covers virtually all hydropower projects.[28] FERC introduced new application and licensing procedures in 1978 to reduce paperwork and accelerate approval for projects under 1.5 MW,[29] and these procedures were further streamlined by the Energy Security Act of 1980, which authorized FERC to exempt hydropower projects under 5 MW from licensing.

This exemption will not necessarily ease the regulatory burden, however, because small-scale projects still remain subject to review by agencies other than FERC. According to one official, it does little good to require one of the agencies—i.e., FERC—to streamline its review and licensing procedures unless the remaining agencies are also required to do so.[30] For example, the Corps of Engineers has jurisdiction over all navigable rivers, including changes to the streambanks, streambeds, or streamflows. As with FERC, legal rulings give the Corps control over even the smallest streams; but many interpretations and rulings are left to the Corps' regional offices, and some differences re-

Congressional Research Service, issue brief No. IB 78035, May 12, 1980, pp. 4-7; Wendy H. Schacht, "Appropriate Technology: Alternative Domestic Technologies, " Library of Congress, Congressional Research Service, issue brief No. [B 77090, Jan. 13, 1980, pp. 8-10.

[27]Allen, op. cit., p. 112.

[28]1 bid., p. V-5.

[29]Viessman and DeMoncada, op. Cit., p. 4.

[30]Ronald A. Corso, Division of Hydropower Licensing, Federal Energy Regulatory Commission, personal communication, July 30, 1980.

portedly exist among these offices.[31] Special reports and consultations are also required by different bureaus within the Department of the Interior, the Advisory Council on Historic Preservation and State historic preservation offices, and the Department of Agriculture.

When conflicts arise in the above procedures, hearings are sometimes necessary, which entail more expense and time and may lead to long delays. Even without conflicts, however, the substantial amount of manpower and legwork involved in obtaining financing, licenses, and regulatory permits is a burden on small communities and a serious barrier to the implementation of their projects.

Option 1-A: Designate a Central Clearinghouse for Information on Low-Head Hydropower.—At present there is no central location to which communities can go for information on the various Federal programs, their objectives and their eligibility criteria. Communities seeking aid would be helped immensely by having a compendium of these programs, regulations, and requirements readily available. The National Center for Appropriate Technology, the Library of Congress, or the agricultural and energy extension services might be logical clearinghouses for such information. Technical data, which is also needed by interested communities, might also be distributed through the same outlet.

Option l-B: Establish Agreed-On Definition of Smal1-Scale Hydropower and Further Streamline Licensing Process.—In view of the confusion created by the different definitions of "small scale" hydropower employed by various Federal agencies, it would be useful if some organization, such as DOE or the Corps of Engineers, were to devise a standard definition of small-scale hydropower; this would simplify data collection and aid in the licensing process. While some effort already has been expended to streamline these procedures, it appears to be taking place on an agency-by-agency basis. It may be helpful for Congress to review the total licensing process with an eye toward bringing about a more coordinated and thorough streamlining of the process.

ISSUE 2:
Technical Assistance.

As discussed above, municipal hydropower projects require a considerable range and depth of technical expertise, particularly in the evaluation and planning stages. This expertise is often beyond the resources of a small community.

Option z: Make Technical Assistance More Accessible to Local Governments.–The Corps of Engineers has conducted a comprehensive survey of potential hydroelectric sites and has also issued a guidebook for simplified feasibility studies at small-scale sites. USGS could assist municipalities in evaluating their resource base by preparing estimates of average monthly streamflow at existing damsites. FERC has prepared manuals for local officials on how to plan, develop, and manage a small-scale hydropower project; similar efforts have also been undertaken by the Corps, DOE, and CSA. Widespread dissemination of these planning aids to State and local governments might encourage additional projects by making the first steps in a community hydropower development simpler and less risky. A seminar program for engineering professionals from both the public and private sectors would be useful in disseminating information, in focusing on new developments in the field, in encouraging conventional engineering and consulting firms to enter the field, and in establishing a network of contacts between communities and between sectors.

31 Ron Alward, Sherry Eisenbart, and John Volkman, "Micro-Hydro Power: Reviewing an Old Concept," prepared by National Center for Appropriate Technology for Department of Energy, report No. ET-78-S-07- 1752, Jan. 1, 1980, p. 47.

Chapter 10

Health Care Systems

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CHAPTER 10
Health Care Systems

Introduction

The cost of health care has increased sharply in the last decade, and many of the Nation's 7,000 existing hospitals are in serious financial trouble. As many as 1,400 hospitals–20 percent of the total number—showed deficits in 1977-78 and may be forced to close within the next 5 years; of these, perhaps 100 are in communities that have no other medical facilities, including about 30 large public hospitals in major metropolitan areas.[1] In response to these conditions, some hospitals have resorted to promotional campaigns to attract additional doctors and patients; critics point out, however, that such tactics may further inflate hospital costs by creating artificial demand and overuse of facilities.[2] Other hospitals are using market research as a means of avoiding the duplication of services and unnecessary competition for the declining numbers of patients. Some medical centers have begun to investigate the cost effectiveness of expensive procedures that may have only marginal benefits for patients or society at large.[3]

Similarly, the Department of Health and Human Services (DHHS) has begun to investigate the costs and benefits of a number of new medical procedures. Its Health Care Financing Administration (HCFA), which administers the medicare and medicaid programs, is required by law to pay for all "reasonable and necessary" medical services, but in the past this has been interpreted to mean all procedures that were medically safe and effective. Alarmed by the rising costs of these programs,[4] however, and by the possibility that they are diverting resources from large numbers of other patients who might be helped more by the same amounts of money, DHHS has directed HCFA to develop a new definition of "reasonable and necessary" services that considers a wider range of "medical, social, economic, and ethical consequences. "[5]

Another approach to the containment of health care costs is the health maintenance organization (HMO), which has occupied a prominent place in Federal health policy during the last decades As defined by the Health Maintenance Organizations Act of 1973 (Public Law 93-222), an HMO is both an insurer and a provider of health care: it provides a comprehensive package of ambulatory and hospital services to a defined, voluntarily enrolled population that pays a fixed annual per capita premium independent of the actual use of those services. Because the HMO exists in a primarily fee-for-service environment, it must compete for both enrollees and physicians; this means that the HMO must try to provide benefits and services comparable to those offered by its competitors. But because the HMO assumes at least part of the financial risk (or gain) of delivering services within a fixed or constrained budget, it has a direct financial incentive to provide those services more efficiently and to provide fewer unnecessary services; this will result in higher profits for the HMO, or lower premiums for its enrollees, or both.

Proponents of HMOS feel that they represent a "cost-effective" way to provide health care and a promising strategy for both controlling health care costs and encouraging a more rational allocation of resources to the Nation's health care needs. As such, claim their advocates, HMOS offer a "competitive market alternative" that is more desirable

I Spencer Rich, "U.S. Begins Program to Bail Out Hospitals Serving Poor Areas," Washington Post, June 25, 1980, p. A18; Cristine Russell, "Hospital Assistance Plan Starts With $15.4 Million Project in N. Y.C.," Washington *Star,* June 25, 1980, p. A9.

'Joann S. Lublin, "Hospitals Turning to Bold Marketing to Lure Patients and Stay in Business," *Wall* Street *Journal,* Sept. 11, 1979, p. 33.

³Victor Cohn, "Can the U.S. Afford the New Medical Miracles?" Washington Post, May 9, 1980, p. A lO.

⁴For example, Congress directed medicare to begin paying for dialysis treatments and kidney transplants in 1972. At that time, it was estimated that the cost would be $250 million per year; but by fiscal year 1981 the cost had risen to $1.5 billion, and it is expected to reach $2,7 billion per year by 1984.

⁵Victor Cohn, "U.S. indicates Some Medicine May *Be Too Costly,* Washington Post, June 13, 1980, p. A2.

⁶The following discussion is based on a recent OTA report, *The Implications of Cost-Effectiveness* Analysis *of* Medical Technology (Washington, D. C.: Office of Technology Assessment, U.S. Congress, August 1980), OTA-H-126, especially ch. 10, "Health Maintenance Organizations," pp. 123-140.

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than increased Federal regulation for achieving these goals.[7] Evidence does indeed show that HMO enrollees pay between 10 and 40 percent less in total health costs than comparable conventionally insured groups;[8] almost all of these cost savings are due to lower hospitalization rates, which are 25 to 35 percent below those of comparison groups.[9] A cost-benefit analysis of Federal assistance to new HMOS, conducted for the Office of Health Maintenance Organizations in 1979, found that Federal assistance costs are recovered (in the form of community health care savings) after 8 years of HMO operation; and the study projected even more substantial future savings.[10]

The Federal HMO program has been responsible for a great deal of the expansion in prepaid plans over the last decade, but the growing momentum of HMO development has also involved a "substantial private initiative."[11] This in turn reflects a growing concern with the quality as well as the costs of health care. As the delivery of health services became increasingly bureaucratized in the 1960's, it came under criticism from a number of client and consumer groups. Middle-class populations were displeased by the increasing depersonalization of medical care; minority and poverty groups complained of being discriminated against by practitioners and health care organizations; and health care in general was criticized as overspecialized, fragmented, and inaccessible, as well as too expensive. As a result, a broad social movement has developed with the aim of increasing consumer and community involvement in the delivery of health care.

[7]Kenneth E. Warner, "Health Maintenance Insurance: Toward an Optimal HMO," *Policy Sciences*, vol. 10, 1978-79, p. 121; *The Implications of Cost-Effectiveness Analysis of Medical Technology*, op. cit., p. 124.

[8]*The Implications of Cost-Effectiveness Analysis of Medical Technology*, op. cit., pp. 123.

[9]Ibid., pp. 124, 127.

[10]"Cost Benefit Analysis of Federal Assistance for HMO Development," prepared for Department of Health, Education, and Welfare, Washington, D.C., Apr. 5, 1979; cited in *The Implications of Cost-Effectiveness Analysis of Medical Technology*, op. cit., p. 124, note 2.

[11]Public Health Service, Office of Health Maintenance Organizations, National HMO Development Strategy Through 1988 (Washington, D.C.: Department of Health, Education, and Welfare, September 1979); cited in *The Implications of Cost-Effectiveness Analysis of Medical Technology*, op. cit., p. 125.

The first major mandate for public participation in health care was contained in the Economic Opportunity Act of 1964 (Public Law 88-452), which authorized the establishment of Neighborhood Health Centers in which community residents were to participate in formulating and implementing policy. The HMO Act also contains provisions calling for increased community participation the planning and operation of HMOs, and in recent years Congress has mandated programs to encourage public participation in emergency medical services, health planning agencies, and community mental health centers. Consumer participation has also been encouraged at the State and local levels and by the private sector.

In some of these programs, participation is open to actual consumers of medical services, or to those whose enrollment in prepaid plans entitles them to those services; in others, participation is open to community residents at large, whether or not they are clients of the health center. Participants may have purely advisory roles, or they may be given some formal decisionmaking powers. These efforts have had varying degrees of success in encouraging public participation in health care delivery; it is not clear, however, whether they have resulted in actual community control or whether such control has had any specific impact on the quality, effectiveness, or costs of local health care services. (For a further examination of this issue, see the discussion of public participation and institutional factors that follows the case study.)

The following case study focuses on one community's experience in developing a community-based HMO–the Hyde Park-Kenwood Community Health Center in Chicago, a not-for-profit, consumer-governed group health care center. The case study deals primarily with three central aspects of this local development project: 1) the impact of three payment systems (fee-for-service, prepaid health plan, and Government assistance) on health care costs and methods; 2) the degree to which the organizers have succeeded in involving community representatives in the management of the health care center; and 3) the implications of the Hyde Park-Kenwood experience for similar community projects elsewhere.

A Case Study of the Hyde Park- Kenwood Community Health Center

Community Setting

Hyde Park-Kenwood is a diverse community of 46,000 on Chicago's South Side. The area is primarily middle-class, although it also has a large number of low-income households and more than 20 percent of its inhabitants receive some form of Government aid. It is also a racially mixed area—58 percent white residents, 38 percent black, and the remainder oriental—but it exists in economic and social separation from the black ghettos that surround it on three sides.

The community is dependent on a few large local institutions, the most influential of which is the University of Chicago, which has spent millions of dollars over the past two decades on development projects in the area. The university also employs many local residents, provides a cultural base, and attracts people with technical expertise into the community.

Hyde Park-Kenwood has a long-standing tradition of political independence, social involvement, and organized citizen activism. Unlike neighboring communities, it has resisted urban renewal, and local citizens once chained themselves to trees to prevent the construction of an expressway. It also supports a number of successful consumer-run institutions, the most venerable of which is the 30-year-old Hyde Park Co-op, a large cooperative supermarket.

In spite of its relative affluence and influence, however, the Hyde Park-Kenwood area had suffered from a shortage of primary health care for at least two decades. Many of the neighborhood's doctors had retired or moved their practices, so that only a small number of physicians remained. Local residents obtained primary care from downtown physicians or from the emergency rooms and clinics of the nearby Michael Reese and University of Chicago Hospitals. Residents on State aid, in particular, were almost entirely dependent on hospital emergency rooms and clinics for primary care. Some local physicians were disillusioned with traditional health care delivery, and they were eager to participate in a project that offered an alternative.

Development

The original initiative for a community-based health care system came from a Hyde Park mother whose visits to her pediatrician had left her increasingly concerned about the unequal relations between doctors and patients. She and two other academics from the University of Chicago came together to work under the auspices of the Health Committee of the Hyde Park-Kenwood Community Conference, a community organization with a membership of 2,000 local residents.

The Conference had become involved in health care when the Mid-South Health planning Organization, an agency of the former Department of Health, Education, and Welfare (HEW), approached it in the early 1970's with the idea of developing a network of health care facilities throughout the South Side of Chicago. The Conference formed its Health Committee to keep abreast of the activities of the Mid-South Organization and to develop proposals for an alternative health care delivery facility for the Hyde Park-Kenwood community. Said one member of the Health Committee:

> We wanted an alternative to fragmented and inadequate health services, to individual physicians in private practice, to hospital emergency rooms for primary care. We envisioned a community-controlled health center, but we had no idea what form it might take.

In 1971, committee members met with several local physicians who were interested in setting up a group medical practice, and found that they shared similar views on the problems of health care delivery: outpatient medical services were insufficient, and the traditional, hierarchical doctor/patient relationship meant that the patient's real needs did not always receive proper consideration. The Health Committee also held additional discussions with other neighborhood physicians to elicit their suggestions and possible participation.

The Health Committee became convinced that the problems of health care delivery could be solved only by replacing the fee-for-service system with some kind of prepaid plan. Accordingly, it applied for and received a $40,000 grant from the Illinois Regional Medical Program, another health planning agency of HEW, to study the feasibility of setting up a prepaid group practice in Hyde Park. The full Conference then formed a Health Task Force and hired a fill-time health planner.

In 1972, the Health Task Force met with the Mid-South Planning Organization and considered joining a local center, funded by the Office of Equal Opportunity, that would serve several surrounding black communities in addition to the Hyde Park-Kenwood area. Given the disparate nature of the communities, however, this plan did not come to fruition. The Hyde Park-Kenwood organizers wanted to design a center more appropriate to the specific needs and desires of their particular community.

Consultations were then held with the Illinois Regional Medical Program of HEW, community groups from adjacent neighborhoods, the University of Chicago, insurance companies, the Health Maintenance Organization Program of HEW, and the Group Health Association of America. In the course of these consultations, the Task Force was advised that its goal of a self-contained prepaid plan for the Hyde Park-Kenwood area was not feasible: the community was too small, and it had too few employers to establish the needed enrollment base. In addition, some local doctors who were willing to join a health center refused to do so unless they could also continue to serve their private patients on a fee-for-service basis.

In view of these problems, it was decided that the Health Center would not establish its own prepayment system. When it opened in June 1975, therefore, the Center offered health services to fee-for-service patients and those covered by Government aid. Later, when the Center was financially stable, it also contracted with existing prepaid plans in Chicago.

The Health Committee organizers had concluded, in the course of their investigations, that prepayment was a desirable financial mode, but there seems to have been little interest in or support for that goal outside the Committee. The physicians, for instance, were interested in group practice or preventive medicine, only one of them advocated prepayment. The decision against prepayment also appears to have been consistent with prevailing community sentiments. Whether the community should support prepayment is not the issue here—the evidence suggests that it did not, and the Committee's decision to use a mix of payment modes was therefore consonant with local values as well as the advice of outside experts.

Medical Services

The Hyde Park-Kenwood Community Health Center opened in June 1975 on the second floor of an older rehabilitated building in the central part of the community, and it now provides primary health care to 9,500 people. It is run by a Community Board of Directors, elected by the people who use the Center. The Board is responsible for setting policy and for administering the Health Center through an appointed executive director. It contracts with a separate Medical Group to provide health care services.

The 34-person Health Center staff, most of whom are local residents, consists of 8 physicians, 1 nurse practitioner, 1 nurse, 2 lab technicians, 5 medical assistants, 1 nutritionist, 1 health educator, and 15 administrative and clerical employees.

Medical services include general family practice, internal medicine, pediatrics, obstetrics and gynecology, and dermatology. The Health Center also contracts with outside specialists to provide certain medical services not available through its own staff. Physicians on the staff are affiliated with a number of Chicago hospitals, to which each may send his patients when necessary. In addition, the Center has a working relationship with nearby Illinois Central Hospital for secondary care and certain outpatient services for prepaid subscribers.

The Health Center currently contracts with two prepaid plans to provide all primary care, pediatrics, and ob/gyn; most secondary or specialized services; and certain hospital outpatient services for their subscribers. In return, the two plans handle the marketing of the benefits package to employers, collect the premiums, and reimburse the Health Center monthly on a "cavitation" basis–a fixed amount for each enrollee, multiplied by the total number of enrollees. If services to enrollees cost the Center more than the cavitation received, the Center is at financial risk; if services cost less, the Center may use the surplus revenues as it wishes. This method of reimbursement (like that of all HMOs) is intended to give the Center an incentive for avoiding unnecessary services and practicing preventive care, thereby avoiding overutilization and incurring fewer health center visits by enrollees, while at the same time keeping them healthy.

Hospitalization costs for enrollees are paid directly by their plans, although the Health Center gets a rebate from the plans when the total number of hospital days used by enrollees falls below a preset figure based on average hospitalization rates for the State of Illinois.

Thus, in its prepaid aspect, the Health Center serves as the delivery outlet of an HMO system, and it currently serves more prepaid subscribers than any other delivery outlet on Chicago's South Side.[12] Because of the scarcity of similar outlets in other neighborhoods, prepaid users come from a wide geographic area to use the Center. Only 25 percent of the prepaid users of the Center live in the community, compared to 70 percent of those who pay on a fee-for-service basis and 30 percent of those who pay through medicare and medicaid.

From its inception, the Center has put strong emphasis on comprehensive health maintenance and preventive care. It offers a number of health education classes stressing "well care, " such as La Maze, care of newborns, nutrition, and cardiopulmonary resuscitation. Consumers are encouraged to participate in these health education programs, which reflect a philosophy made explicit in the Health Center's statement of operating principles:

> The Health Center will foster innovation in such areas as health education, fuller use of health personnel, greater role of the consumer in continuity of care, and increased physician-community partnership in decisionmaking.

Costs and Modes of Payment

The Health Center became operational with less than $100,000 in startup grants, $40,000 of which came from the Federal Government. Another $110,000 was raised by selling debentures, in amounts of $100 or more, to members of the community. By fiscal year 1979, the Center was in the black, with an operating budget of $643,365.

Consumers pay for their health care in one of three ways: fee-for-service, Government assistance, or prepayment. On a fee-for-service basis, they are billed directly each time they use the Center, according to preestablished fees for each service provided; these fees are usually equal to or less than those charged by other health centers and private physicians in the area. Government assistance is provided through medicare (title XIX) for those eligible under social security, medicaid (title XVIII) for the medically indigent, or both for the elderly who are also medically indigent.

Service to prepaid users under the Federal HMO program did not begin until 1976, by which time the Center was in a better financial position and was able to hire an obstetrician-gynecologist, thereby meeting one of the requirements of the HMO legislation. By paying a fixed premium, individuals and their dependents who voluntarily enroll in a health plan through their employers, unions, or associations are entitled to health care benefits at no extra charge.

Enrollment in HMOs expanded throughout the Nation in 1975, when the Federal Government required that all employers of 25 or more workers who offered health plans must offer a "dual choice" between traditional health insurance and the HMO option, in locations where HMO plans existed. Because the HMO program was new and untried, the Center's financial expectations from prepaid care were uncertain. Few of the organizers thought that prepaid care would be profitable for the Health Center, let alone more profitable than fee-for-service. However, early returns showed that income from prepaid users, after subtracting outside services and administrative costs, was $18,882, or 300 percent above projections; had the

[12] Some HMOs are self-contained, with prepayment plan and delivery functions in a single administrative structure. In other cases, the plan handles the marketing and the assumption of financial risk, but contracts with an independent medical group to deliver the health benefits package. The Hyde Park-Kenwood Community Health Center is an example of the latter.

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same patients used the Center on a fee-for-service basis, the net income would have been only $15,000.

In view of this, the Board decided to gradually increase the number of prepaid users. In 1977 the Center was certified as a delivery outlet by HEW and the Illinois Department of Health, enabling it to contract with other federally certified plans. The number of prepaid users increased by 1,900 from 1978 to 1979, or from 14 percent to 33 percent of all users. During the same time, the number of fee-for-service users rose by only 24 persons, and as a percentage of all users declined from 68 to 53 percent.

Recent financial statements show that the Center continues to be more profitable in its prepaid sector than in its fee-for-service sector. This is consistent with the experience of other HMOs which have demonstrated lower total health costs for prepaid users than for conventional health insurance plans.[13] One reason for this financial success appears to be the lower number of clinic visits and hospital days per prepaid enrollee: for 3 straight years the hospitalization rate for the Center's prepaid subscribers has been below the assumptions of their respective plans. As a result, the Center has received substantial rebates from the plans; for the year ending June 30, 1979, these rebates totaled $93,367.

A second reason, which is related to the first and may in fact explain it, is the financial structure of cavitation and prepayment, which gives the physicians an economic incentive to avoid excessive hospitalization by practicing preventive medicine and by encouraging self-care. Other possible explanations include the superior health status of prepaid enrollees, broader ambulatory care coverage, and the collective norms of group practice; opponents of prepayment also point to organizational arrangements that discourage prepaid enrollees from using services when they want to.

Nevertheless, while it would appear that the Health Center is prospering from its prepaid clientele, it is also dedicated to serving local residents better. As a result, it has recently decided to limit the number of its prepaid consumers in order to provide better service to members of its own community.

Organization

The Health Center was established as two different corporations: the Community Health Center, governed by a Community Board of Directors that appoints an executive director to handle the administration of the Center, and the Medical Group, headed by a medical director. This dual organization was adopted in order to conform with the Illinois medical practice law, which forbids the employment of physicians by "laymen."

The Board has 27 directors, 24 of whom are elected by the dues-paying membership of the Health Center; the 3 other positions are filled by representatives of community organizations designated by the Board. All Board members must be dues-paying members of the Center, and a majority of the Board must also be users of the Center. Thus far, all Board members have been community residents. All prepaid and fee-for-service users are eligible for membership in the Health Center, as are all residents of the Hyde Park-Kenwood community. Annual membership dues are $5 for an individual and $8 for a family. However, although the Center's principles include consumer participation in policymaking, only 150 of its users are dues-paying members; and only members are entitled to vote for (or serve on) the Board and participate in Health Center Committees. A staff member is now working full time to increase membership, which also entitles the user to receive the Center newsletter and to enroll in health education courses at reduced rates.

The Board hires and fires and sets salaries for the staff. It also sets fees for health care, establishes programs in health education, chooses needed specialties, and determines the scale of services and facilities. When the decisions of the Board pertain to medical personnel, it must obtain the agreement of the medical director.

In 1978, three issues required cooperation between the Board and the Medical Group: the evaluation of each physician, the creation of a physicians compensation policy, and the hiring of a

[13] George B. Strumpf, Frank H. Seubold, and Mildred B. Arrill, "Health Maintenance Organizations, 1971-1977: Issues and Answers," *J. of Community Health*, vol. 4, fall 1978, pp. 33-54.

new executive director. One of the physician evaluations was negative: the doctor was criticized for a lack of productivity and the type of health treatment he proposed. The two directors agreed that the physician would be offered a contract for 1 year rather than the usual 3, and that during that year he would seek another position. However, the medical director subsequently modified the evaluation process so that future evaluations would take place within the Medical Group itself, with the medical director reporting its conclusions to the Board for its final action.

In February 1978, a formal physicians' compensation policy was worked out jointly by the Board, the executive director, and the medical director. It established the range for salaries and additional benefits for physicians, as well as the criteria to be used by the executive and medical directors in evaluating each of the physicians. These two evaluations were to be used together in establishing any increase in salary, and the range of salaries was to be reviewed in the first quarter of each calendar year in the context of prevailing market values. This policy was a mutual undertaking of representatives from both corporations, apparently without disagreement.

When the executive director indicated her wish to resign, it was necessary for both groups to agree on the choice of a replacement. This process elicited heated disagreement: of the three final candidates, the Board preferred one and the Medical Group another. Both candidates were members of the community; the Board's choice was experienced and highly regarded in the health field; the Medical Group's choice had limited experience, but he was perceived by the physicians (some of whom were friends) to be charismatic and potentially excellent at grantsmanship and community outreach. In the end, the Medical Group chose not to veto the Board's choice, but the disagreement left a residue of resentment that emerged in the next confrontation between the two groups.

When the time for contract review came in 1979, the medical director presented salary requests that violated both the guidelines of the physicians' compensation policy and the agreement on evaluations of individual physicians. The medical director proposed that the Health Center should allocate salaries in a lump sum to the Medical Group, which would, through internal peer review, evaluate one another's merits and determine individual salary increases. The doctors were prepared not to come to work if their demands were not met.

The Board took an equally strong position, maintaining that all prior agreements must be honored and that it would not be fulfilling its responsibility to the consumers if it were to relinquish its power to evaluate and reward individual physicians. The two groups eventually compromised, agreeing *on* temporary salaries while negotiating teams reviewed the physicians' compensation policy. More will be said about this conflict in the discussion of institutional factors, below.

Critical Factors

Public Perception and Participation

The organizers of the Hyde Park-Kenwood Community Health Center had relatively little difficulty in gaining access to public forums and decisionmaking bodies. They were, in fact, greatly aided in their efforts by the existence, approval, and active support of both local community groups and Federal health planning agencies. The Hyde Park-Kenwood Community Conference had already formed its Health Committee to investigate alternative health care systems, and similar efforts were being undertaken by the Woodlawn and Kenwood-Oakland Community Organizations, citizens' groups in adjacent neighborhoods. The Health Committee had been formed in response to an initiative from HEW's Mid-South Health Planning Organization, and the efforts of the Health Center Task Force were also greatly assisted by the cooperation and encouragement of two other HEW agencies, the Illinois Regional Medical Program and the Office of Health Maintenance Organizations. To a lesser degree, their efforts were also supported by the tradition of activism in the community and the example of its well-established cooperative supermarket.

Although the project was initiated by local residents, however, and although all of the subsequent members of the Board of Directors and most of the Center's staff have likewise been residents of the community, underrepresentation of the local community has led to concern about whether the consumer's interest is being adequately represented. While the community generally accepts and supports the Center, only about 10 percent of the population of Hyde Park-Kenwood uses the Health Center, and less than half of its total users are local residents.

Only 150 of the Center's 9,500 users are dues-paying members. Prepaid users account for more than a third of the Center's patient visits and income, but 75 percent of these users live outside the Hyde Park-Kenwood community and they, too, have been consistently underrepresented in Health Center governance. Furthermore, medicare and medicaid patients—whether local residents or not—are ineligible for membership in the Center and are therefore completely excluded from governance. Use by fee-for-service patients (most of whom are local residents) has also been declining. Many local residents who would like to belong to the Center on a prepaid basis are ineligible for such coverage, precisely because the Health Committee decided not to establish its own prepayment plan.

It should be noted, however, that very few complaints about the Center have been registered with the HMO headquarters for Illinois. A survey of prepaid users indicated that they are satisfied with the Center, despite the fact that they are a "captive audience" due to the scarcity of other prepaid outlets in Chicago. Nevertheless, there is a growing feeling at the Center that the rising number of prepaid users is in conflict with the practice of community control, and the Board has recently decided to limit their numbers. It is not immediately clear, however, why service to nonresident prepaid enrollees necessarily conflicts with the goals of the Center. Its facilities are not overcrowded, nor are community residents who want service being turned away.

If the purpose of community control was to bring about specific local goals—such as community cohesion, creating a training ground for local leaders, building confidence among the disadvantaged, or responding to the unique health needs of the area[14]—then it might be argued that such goals are potentially threatened by the large number of prepaid users who are not local residents. The purpose of community control at this Center, however, was to provide accessible ambulatory care to those members of the community who wish it, and in so doing to reduce the customary social distance between doctor and patient, to encourage self-help and prevention, and to eliminate the profit motive as the exclusive basis for the physician's interaction with patients. None of these more limited goals seems impaired by the present arrangement.

It is also possible that consumers and community representatives could work together effectively in Center governance. One study of hospital boards has shown that mixed boards of consumers and community representatives have greater influence on hospital operations than do boards made up of only consumers or only community representatives.[15] Community representatives bring an external perspective: they know who lives in the area and what their needs are; they also serve as a channel for local opinion; and they help to give the Center legitimacy in the community. Consumer representatives, on the other hand, bring an internal perspective: they know particularly well how the Center actually works, and how it might work better. These different interests and abilities could mesh on the Board in such a way as to improve both the Center's health care delivery and its service to the community.

Membership patterns and their influence on public participation are a legitimate concern for the Center, its users, and the community at large. Similar election patterns may exist in other situations, such as local school boards or State legislatures, and the principle of community govern-

[14] Melvin Mogulof, "Advocates for Themselves: Citizen Participation in Federally Supported Community Organizations," Community *Mental Health J.*, vol. 10, 1974, pp. 66-76.

[15] Jonathan M. Metsch and James E. Veney, "A Model of the Adaptive Behavior of Hospital Administrators to the Mandate to Implement Consumer Participation," Medical Care, vol. 12, April 1974, pp. 338-350.

ance remains valid regardless of how many citizens chose to participate in the process. Nevertheless, when less than 2 percent of the Center's clients actually participate in governing the organization that serves them, it leaves what should be a democratic institution open to charges of elitism. To correct this situation, the Center has hired a full-time staff member to encourage both consumers and local residents to become members of the Center. A further step that might be taken is to open membership to those receiving Government assistance, who represent 20 percent of the community and 30 percent of the Center's consumers, by offering reduced membership fees for medicaid patients and free membership for senior citizens.

Essential Resources

The Health Center had little difficulty in acquiring the needed material resources, and it was particularly fortunate to be located in a community rich in the needed human resources. The Center is located in a rehabilitated building rather than in a newly constructed facility. Medical equipment was provided by the physicians in the Medical Group, many of whom had existing practices in the area. Assistance in planning and organizing the Center was provided by community volunteers who conducted a market survey, drafted legal documents, wrote grant proposals, prepared budget projections, and designed sales brochures. Health professionals, bankers, lawyers, architects, and physicians—all of them local residents—also contributed their professional skills. Two internists practicing in the community helped during the organizational stages and later joined the staff, bringing along their patients, most of whom were also members of the community. Similar resources would be available in few low-income communities.

Technical Information and Expertise

As noted above, the Hyde Park-Kenwood community is very rich in both citizen action and professional skills. Physicians and other health care professionals living in the area participated in the development and operation of the Health Center, technical information and management know-how were also readily available, in large part because of the presence of the University of Chicago. This was fortunate for Hyde Park-Kenwood, but it raises serious questions about the transferability of their experience and methods to other, less favored communities. Theirs was not a unique case, but neither was it typical of the low-income rural and inner-city communities where the need for primary care facilities is greatest.

Financing

Funds for the Center were first allocated by the Illinois Regional Medical Program, a now-defunct agency of HEW, in the form of a $40,000 planning grant. When those funds were nearly exhausted, volunteer fundraisers were able to raise a total of $110,000 by selling debentures (in denominations of $100 or more) to local residents and employees at the nearby University of Chicago. Additional funds were secured in 1977 from the Robert Wood Johnson Foundation.

One of the innovative features of this project was the manner in which the local community participated directly in its funding through the purchase of debentures. The Health Committee had the creativity and the courage to try this unique approach; and the community had the funds with which to respond, as well as enough confidence in the venture to do so. Perhaps the community's prior experience with cooperatives gave legitimacy to this funding approach, by the same token, it is possible that bank financing would also have been available because of the credit-worthiness and management capabilities of the organizers.

The applicability of this technique may be limited to middle-class areas, and this once again raises questions about the transferability of the Hyde Park-Kenwood experience. Where the technique is appropriate, however, it provides an opportunity for community residents to finance as well as develop their own institutions. One question not addressed in the study team's report is the terms under which these loans are to be repaid and how those terms might affect the finances and operations of the Health Center.

Institutional Factors

Opposition to community control of health care delivery has come primarily from inside rather than outside the Health Center. It was not opposed by health insurance companies, in fact, it was the initiative of Blue Cross of Chicago in devising HMO plans that could be serviced in a variety of health facilities that enabled the Health Center to develop an HMO outlet for South Side residents. Its development has decreased the number of patients seeking primary care in local hospitals, to which the Center still sends patients for secondary and specialized care.

However, some observers from outside the Center—private physicians and representatives of conventional health facilities—have criticized the concept of community control on the following grounds:

- The profit motive produces better health care by allowing the marketplace to work: consumers are the best judges of the health care they receive, and they can exercise influence by giving or withholding patronage of a physician or health facility.
- Community control puts politics before health, it is cumbersome, slow, and results in less efficient health care.
- The essential relationship in health care is between doctor and patient; any attempt to interject a community board or other intermediary into this relationship destroys mutual concern and respect.
- Community control diffuses medical responsibility; if physicians are to be ultimately responsible for the health care they deliver, they should also have full control over the policies for delivering that care.
- It is unfair to make doctors, who have invested so much time and money in their education and experience, submit to the authority of a community board.
- A community board may give the impression of community control, but it is often controlled by an elite few, worse yet, such a board can be coopted by the very people it is set up to control, leaving the consumer with less representation than before.

Other critics supported the concept of community control but differed over exactly what the concept should mean. Some pointed out that community control does not need to be formalized: it can be exercised through many established channels, including civic organizations, church groups, and newspapers. Others suggested that health care facilities can interact with the community in terms of both input and outreach, and that they serve the community best through health education programs or teen counseling in the schools. A few admitted that community involvement is important during the formative stages but insisted that, once the facility is operational, all decisions should be left to health professionals; a community board is desirable, but should serve only in an advisory capacity.

Within the Hyde Park-Kenwood Health Center itself, the executive director felt that the Board should be involved in financial planning, policymaking, soliciting community input, and initiating and evaluating programs, but should not concern itself with implementation of these plans, policies, and programs. A number of Board members, on the other hand, felt that they should be less complacent and passive, and more active in initiating programs and fighting for the interests of the community. The prevailing feeling among these Board members was that the physicians have not grasped the meaning of community governance, nor do they understand that in exchange for giving up certain privileges (including unlimited income and the ability to set their own hours) they gain certain rewards (including regular hours and freedom from insurance paperwork, financial recordkeeping, and personnel problems).

The manner in which medical professionals and consumers share power, however, is an ongoing problem, and in this regard the struggle at the Health Center is not unique. In studies of other health care centers, researchers have found that physicians usually seek to control the conditions of their work.[16] The efforts of the Hyde Park-Ken-

[16] Eliot Friedson, The Profession of Medicine (New York: Dodd, Mead, 1970); and Marcia Steinberg, "Multiple Leadership in Prepaid Group Practice: Interaction Among Administrators, Physicians, Consumers, and Community Members," presented at the annual conference of the Group Health Institute, New York, June 1978.

wood physicians to do so by setting salaries, controlling the evaluation of their colleagues, and deciding which physicians to hire is typical of physician behavior in traditional organizational settings. These settings—e.g., conventional hospitals—provide a system of professional authority in which physicians control both the content and the conditions of their work. The entry of consumers into decisionmaking roles thus destabilizes arrangements already in existence between physicians, administrators, and other groups.

It is still too soon to say what a new division of authority would look like, since the widespread involvement of community groups only dates from the first legislation authorizing Neighborhood Health Centers in 1964. However, it is possible to see the probable shape of the new patterns by looking at sites where consumers have policymaking or advisory authority, such as the Neighborhood Health Centers, some group practices, and some hospitals. As the consumer or community board carries out its role, disagreements tend to occur with administrators, physicians, and other parties with decisionmaking powers, such as Government agencies. Issues of concern include the hiring and firing of the medical staff and the executive director, decisions about what new services are to be offered, and budget allocations. As the parties try to resolve their differences, a new distribution of authority develops, and the distinction between physician and nonphysician reappears. In the end, physicians usually obtain effective control over salaries and medical staff, with some limited form of review by the community boards. The board exercises advisory or decisionmaking roles over matters pertaining to organizational policy, particularly the selection of services to be offered, but seldom penetrates areas of organizational decisionmaking that have traditionally been controlled by physicians.[17]

If experience is a guide, therefore, eventual resolution of the disagreements between the Board of Directors and the Medical Group at the Hyde Park-Kenwood Health Center will probably be one which grants the Medical Group the authority it seeks.

[17] Lawrence Koseki and John M. Hayakawa, "Consumer Participation and Community Organization Practice: Implications of National Health Insurance," Medical Care, vol. 17, March 1979, pp. 244-254; Milvoy S. Seacat, "Neighborhood Health Centers: A Decade of Experience," J. of Community Health, vol. 3, 1977, pp. 156-168; Steinberg, op. cit.; Marcia Steinberg, "The Relative Emphasis Upon Physician Practice and Organizational Affairs of a Consumer Council in a Prepaid Group Practice Health Plan," J. of Community Health, vol. 4, summer 1979, pp. 3 12-320; Ann Stokes, David Banta, and Samuel Putnam, "The Columbia Point Health Association: Evolution of a Community Health Board," Am. J. of Pub. Health, vol. 62, September 1972, pp. 1229-1234; and Daniel I. Zwick, "Some Accomplishments and Findings of Neighborhood Health Centers," Milbank Memorial Fund Quarterly, vol. 50, pt. 1, October 1972, pp. 387-420.

Federal Policy

Background

Over the last 10 to 20 years the primary focus of Federal health care policy has shifted from the availability of health care to its costs. About 26 percent of the Nation's health care costs were paid through medicare or medicaid assistance in 1977, when the total expenditures added up to $142 billion. By 1979, expenditures had risen to about $206 billion–a little more than 9 percent of the gross national product. At the present rate of increase, health care costs will double in less than 5 years, a rate of increase far in excess of general inflation. This pattern has held for 30 years: between 1950 and 1978, while overall inflation was 171 percent, physician costs rose 304 percent and hospital costs jumped 997 percent.[18]

The rapid increases in health care costs has led to a concurrent rise in Federal expenditures through the medical assistance programs of medicare and medicaid. In addition, the many low-income families who remain ineligible for such aid have become more vulnerable to catastrophic medical expenses: 7 million families have uninsured health care expenses in excess of 15 percent of their incomes; between 10 million and 20 mil-

[18] Sen. Edward M. Kennedy, "A National Health Insurance: A Plan to Control Medical Costs and Improve Care," Phi Kappa Phi -1., vol. 60, No. 2, spring 1980, p. 30.

lion Americans have no health insurance at all; and as many as 65 million have insurance that is inadequate to cover office visits or routine tests.[19] Families with incomes below $10,000 are twice as likely to be without health insurance as families with larger incomes, and one-third of those not covered by insurance are fully employed heads of households—10 percent of the U.S. work force.[20] Collectively, low-income people seem to be in poorer health than middle- and high-income groups, and continued ill health can lead to low productivity, high absenteeism, unemployability, and chronic dependence on public assistance programs.[21]

Cost is not the only barrier to adequate health care. Availability of physicians, facilities and specialized diagnostic and treatment equipment remains a problem in many communities.[22] The combination of these factors can, in some cases, bring about a situation in which medical services are in effect "rationed."[23] And while the primary focus of many Federal programs remains on the direct containment of costs, many people now feel that the current voluntary cost ceilings, while needed, are not the only way to address the rising costs and declining availability of health care. Among the alternatives that have been included in recent Federal legislation and assistance programs are preventive medicine, including improved nutrition; self-care and well-care, as opposed to crisis care; and community participation in the planning and operation of local health care delivery.

Legislation

Previous Federal involvement in health care delivery is typified by the Hospital Survey and Construction Act of 1946 (60 Stat. 1040, as amended), which initially authorized $75 million for grants-in-aid to the States for the construction of hospital facilities. Since its beginnings in the 1940's, this program has disbursed over $4 billion in Federal funds for more than 12,000 projects, involving 7,000 medical facilities in over 4,000 communities. The program is administered by the Bureau of Health Facilities of DHHS, which is also responsible for the programs of direct loans and loan guarantees authorized by the Public Health Service Act of 1944 (58 Stat. 682, as amended), as well as the hospital mortgage insurance program authorized by the National Housing Act (48 Stat. 1246, as amended), formerly administered by the Department of Housing and Urban Development. Increasingly, however, due to subsequent amendments and funding changes, the Bureau of Health Facilities has ceased to fund large amounts of new hospital construction. It has instead become responsible for monitoring the economic viability of existing hospitals and enforcing compliance with a section of the Public Health Service Act that requires health care facilities (in exchange for Federal financial assistance) to provide community services and certain categories of uncompensated care for their low-income patients.[24]

As was mentioned in the introduction to this chapter, the central piece of legislation dealing with public participation in health care was the Economic Opportunity Act of 1964 (Public Law 88-452). This Act authorized the establishment of Neighborhood Health Centers and required the participation of local residents in the formulation and implementation of policies in these centers. Another section of the Act established the Community Food and Nutrition Program of the Community Services Administration; this preventive-care program is discussed at length in the Federal policy section of ch. 4.

Other legislation mandating consumer and community participation in health care delivery are the Health Maintenance Organizations Act of 1973 (Public Law 93-222), which authorized the creation of community-based HMOs; the National Health Planning and Research Develop-

[19] Ibid.

[20] Sen. Robert Dole, "Catastrophic Health insurance: A Practical Alternative," *Phi Kappa* Phi -1., vol. 60, No. 2, spring 1980, p. 29.

[21] Charles E. Lewis, Rashi Fecir, and David Mechanic, A Right to *Health*: The Problem *of* Access *to Primary* Medical *Care* (*New* York: John Wiley, 1976), p. 165.

[22] For a more thorough discussion of these factors, see the previous OTA reports, The *Implications of* Cost-Effectiveness Analysis *of* Medical *Technology* (OTA-H-126, August 1980); Forecasts *of* Physician *Supply and Requirements* (OTA-H-1 13, April 1980); Assessing the *Efficacy and Safety of Medical* Technologies (OTA-H-75, September 1978); and Development *of* Medical Technology: Opportunity *for* Assessment (OTA-H-34, August 1976).

[23] Lewis, Fecir, and Mechanic, op. cit., p. 15.

[24] See Florence B. Fiori, director, Bureau of Health Facilities, "Bureau of Health Facilities' increasing Responsibilities in Assuring Medical Care for the Needy and Services Without Discrimination," *Pub. Health* Reports, vol. 95, No. 2, March-April 1980, pp. 164-173.

ment Act of 1974 (Public Law 93-641), which established local health system agencies and State health coordinating councils like those that contributed to the creation of the Hyde Park-Kenwood Health Center (see above); and title 111 of the Community Mental Health Center Amendments of 1975 (Public Law 94-63). Congressional concern with the costs and benefits of medical care, particularly new techniques and equipment, is also reflected in the passage of the Health Services Research, Health Statistics, and Health Care Technology Act of 1978 (Public Law 95-623). This Act provides for the establishment of a National Center for Health Care Technology, under the auspices of DHHS, charged with undertaking and supporting a variety of programs aimed at identifying potential issues and consequences of the development and application of new health care technologies.

Issues and Options

User and community participation in health care delivery seems to be widely accepted as a matter of Federal policy, but the implementation of this policy—through the establishment of local, consumer-run delivery systems like the Hyde Park-Kenwood Community Health Center–will be affected by two larger issues:

- the relationship of Federal and State health care efforts; and
- the effectiveness of preventive medicine and other innovative, low-cost health care techniques.

ISSUE 1:

Conflicts Between Federal and State Health Care Efforts.

Federal legislation has established a number of programs for achieving U.S. health care goals, but interviews in Hyde Park-Kenwood and other communities as well as in Washington, D. C., suggest that in some cases these Federal programs may not be adequately coordinated with related State programs. In addition, there seems to have been no specific attempt to coordinate the local efforts of Federal programs in health care with related programs such as nutrition or food production (see chs. 4 and 6). In other cases, however, State laws appear to be barriers to some specific programs and contradictory to Federal intentions generally.

State medical practice laws can, in some instances, be impediments to effective community participation in health center governance and health care delivery. In the Hyde Park-Kenwood case study, for instance, Illinois law prohibited the hiring of physicians by laymen. The resulting dual organization of the Center has led to internal conflicts that may jeopardize the goal of community participation that is embodied in the Economic Opportunity and HMO Acts. Virginia law also makes it illegal for nonphysicians to engage in "the prevention, diagnosis, and treatment of human physical or mental ailments, conditions, diseases, pain or infirmities by any means or methods."[25] This and similar State medical practice laws may restrict the use of well-care and other preventive medicine techniques administered by nurse practitioners or health care paraprofessionals.

Option 1: Review of State and Federal Health Care Laws and Programs.—Congress may wish to identify these potential conflicts by directing DHHS to expand its annual review of State and Federal health care legislation to include a more detailed examination of the following points:

- the goals of the various laws and programs, the priorities (explicit or implicit) among these goals, and the areas in which State law is in potential conflict with Federal policy; and
- the degree and adequacy of communication and coordination between Federal programs and State health care efforts.

ISSUE 2:

Community Health Centers and Innovative Health Care Techniques.

The innovativeness of the Hyde Park-Kenwood Community Health Center was medical as well as organizational. Their well-care programs include encouraging the patient to participate in his own treatment and encouraging community members to participate in health education classes on such

[25] Lori B. Andrews and **Lowell S.** Levin, **"Self-Care and the Law,"** *Social Policy*, vol. 9, No. 4, January-February 1979, p. 44.

subjects as nutrition, child care, and personal health maintenance.

Other health care centers have also begun to include self-care instruction in their regular services. The Midpeninsula Health Service in Palo Alto, Calif., offers a daily telephone call-in hour to eliminate unnecessary clinic visits and to minimize the use of lab tests, equipment, and drugs. At Helping Hand, a community clinic in St. Paul, Minn., patients are given a pamphlet describing their condition and its treatment or are referred to an appropriate health education class. Other clinics offer rebates to their patients for taking courses in self-monitoring skills, such as taking their own blood pressure or preparing throat and stool samples.

The principal goal of these and other well-care and self-care techniques is to help the members of the community to improve their general health. There is as yet no conclusive proof of the value of these techniques or their impact on future medical needs and costs. Secondary effects of preventive medicine, however, might include a reduction in the number of subsequent clinic visits; a resultant increase in the efficiency with which existing health care services are utilized; and–ultimately–a potential reduction in health care expenditures for the individual, the local community, and the Nation. As noted above, however, some State medical practice laws may effectively bar the adoption of these techniques by forbidding community members from participating in the delivery of clinic services or the teaching of health care in the school system.

Option 2: Investigate the Potential Benefits of Preventive Care Techniques and the Barriers to Their Adoption in Community Health Centers.–Congress may wish to investigate the potential benefits—both medical and economic—of self-care and other preventive techniques as part of a comprehensive, community-based health maintenance program. In parallel with such an investigation, the legislative and program review proposed above might also attempt to identify potential barriers to the adoption of these techniques by local health care centers. It has also been suggested that broadening the HMO prepayment package to include both life and morbidity/disability insurance, as well as medical insurance, would provide insurers with a financial incentive to learn the value and effects of health education and preventive care. [26]

[26] Warner, op. cit., p. 127.

Chapter 11

Overview

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Introduction

The treatment of the case studies in the preceding chapters derives less from an interest in any one specific technology than from an interest in the process by which the technologies were identified and adopted by particular communities, their impact on the communities, and the factors that might have an influence on their wider adoption and diffusion. The case studies focus on three substantive areas:

- energy conservation, particularly methods for increasing the energy efficiency of private housing;
- agriculture, particularly the survival of the small family farm; and
- the delivery of community services, including health care and social services as well as waste management.

It should be noted that the cases do not include examples in the industrial or manufacturing sector. Nonetheless, these three areas include some of the most important and intractable problems facing the Nation.

Each chapter also includes an analysis of relevant Federal policy and programs, but this should not be taken to mean that expanded Federal involvement is necessary or even desirable for the local development of these technologies. In several cases, notably energy-efficient housing and farmers' markets, local adoption seems to be going forward without direct Federal involvement; in other cases, existing Federal programs have been quite effective and appear to need no major alteration. Federal policy has been a focus for analysis, rather, because this report is designed for Congress, one of whose responsibilities is the evaluation and improvement of Federal programs that encourage and assist community development.

Because of this Federal interest, it has been necessary to consider not only the local impact of these projects but also the likely effects of widespread replication by communities throughout the Nation. The projects are of interest precisely because they tailor technology to local needs and resources, and most of them have been relatively successful in achieving local goals. In some cases, however, the local resources are sufficiently unique that it is uncertain whether the projects could be replicated elsewhere. Nevertheless, enough similarity exists across the cases to draw several general lessons about the factors that aid or impede the process of community adoption.

This overview chapter will present thumbnail profiles of the case studies and then comment on their significance, first from the local perspective and then from the national. This will be followed by a summary of the critical factors affecting the success of these projects, and steps that might be taken to promote similar projects elsewhere.

Profiles of the Case Studies

Resource= Efficient Residential Architecture (ch. 3)

These projects, developed in communities as diverse as an Eskimo village in Alaska and the middle-class exurbs of Connecticut, involve the application of a wide spectrum of technologies that make considerable energy savings possible for individual families. The technologies range from well-known solar designs to new, highly efficient heat-retentive houses that hold great promise for the future.

Local and National Significance.–The striking diversity of the applications—in cost and complexity, as well as performance—is both a strength and a problem. On the one hand, they represent solutions to the problem of energy conservation that can be adapted to every region of the United States. On the other hand, because such a large variety of approaches have been developed in so many locations, no "preferred" solutions have yet gained nationwide acceptance from financial institutions, homebuilders, and the general public. Low-cost retrofits, notably the attached solar heating greenhouse, are being built by individual homeowners, and local initiatives have been effective in encouraging these individual efforts, the community workshop appears to be a particularly effective mechanism for promoting more widespread adoption of this technology. The higher initial costs of the passive solar and double-envelope houses, however, are such that they are being built primarily by middle- and high-income families. From a national perspective, this may mean that lower cost options, like the Bethel and Conserver Homes, will be more appropriate for energy-saving tract houses and low-income housing.

Critical Factors.—In several of the case studies, large numbers of people have turned out to inspect the houses, but thus far there has been less acceptance from financial institutions than from the general public. One housing developer commented that his first solar development "would never have happened if we had not been able to do the design, the financing, the land development, and the construction ourselves. " From these case studies it would appear that one of the most significant barriers to the widespread transfer of these technologies from the custom housing market to the mass housing market is the lack of reliable data on the cost and performance of the various energy-efficient designs. The Bethel house, which was developed in part to influence the design of low-income housing in rural Alaska, has had some local success in this regard.

Federal Policy.–Federal programs could assist the diffusion of these technologies by making data gathering a required part of sponsored projects and by making detailed local microclimate data available to prospective developers and owner-builders. Increased Federal encouragement of "networking," community workshops, and other locally based dissemination mechanisms could also be useful; these approaches have proven to be successful in several of the projects described in this and other chapters.

Food= Producing Solar Greenhouse (ch. 4)

The Cheyenne Community Solar Greenhouse appears to be an effective mechanism for delivering social services, such as productive activities for the elderly and youth offenders. It also seems to have contributed to a local program to encourage residential energy conservation. It has not, however, been cost effective in its role as a food-producing greenhouse, and since it cannot be operated as a research facility, it has been unable to collect sufficient performance data to establish its economic feasibility.

Local and National Significance.–The project is notable for the extent of public participation in the construction, operation, and management of the greenhouse. It offers activities for the elderly and the handicapped, job training and work experience for the unskilled, alternative service for youth offenders, and educational activities for children. In addition, this highly visible demonstration may have contributed to the widespread adoption of smaller attached solar heating greenhouses in Wyoming, which now has more such retrofits relative to its population than any other State. However, the capital and operating costs of the greenhouse are rather high, and as presently used it may not be the most cost-effective mechanism for delivering social services. Neither is it an effective means of demonstrating the feasibility of large-scale solar greenhouse horticulture, Crop yields have been low by commercial standards, but the project has neither the staff nor the resources to carry out scientific research on plant varieties and production techniques for solar greenhouses.

Critical Factors.—The technical problems encountered in Cheyenne point out the need for expert advice on solar greenhouse design and construction. More reliable information on costs, energy savings, production methods, and crop yields will also be required if the technology is to be adopted by communities, cooperatives, or commercial growers on a widespread basis.

Federal Policy.—Existing Federal programs include construction grants for community food production projects and a few monitoring projects that should produce needed information on greenhouse performance. Additional Federal efforts to promote the technology might include programs to disseminate this new information, as well as selective tax credits to individuals or subsidies to community groups.

Small Farm Systems (ch. 5)

The New Life Farm (NLF) in Missouri and the Small Farm Energy Project (SFEP) in Nebraska are community-based attempts to improve the economic viability of small-scale farming in their regions. NLF is a local initiative by young farmers to develop a promising new renewable energy technology—manure and phytomass digesters that produce methane from farm wastes. SFEP has established a particularly successful program of technical assistance and cost sharing that has encouraged local farmers to apply proven technologies to the energy needs of their own farms.

Local and National Significance.–Of the two projects, SFEP seems to have had a broader impact on local farmers, largely because the farmers were allowed to select and build their own projects. But although self-selection has led to a variety of innovative solar applications, it has not always led to maximum energy savings, since the farmers often failed to pick the most promising combination of technologies or installations. NLF's concept of an integrated "system" of farming techniques shows more potential in this regard, but the technologies themselves are still in the development stage. Both projects, however, demonstrate that farmers and other local groups are capable of developing and installing low-cost, energy-saving technologies that are appropriate to the needs and resources of their particular farming operations. Widespread replication of these projects might make a significant contribution to the related national goals of conserving energy, making more efficient use of available resources, and aiding the survival of the small family farm,

Critical Factors.–The local success of SFEP results from its project design, which encourages public participation through self-selection and a comprehensive program of workshops, seminars, and individual technical assistance. Cost sharing also appears to be an effective form of financial assistance, but a number of local farmers (participants and nonparticipants alike) undertook projects on their own. NLF has also held workshops, but its primary efforts have been in developing the biogas digester; its inability to involve large numbers of local residents may pose a problem for the local dissemination of this technology in the future.

Federal Policy.–Widespread dissemination of the results of these and similar projects through the Agricultural Extension Service would promote the spread of these technologies, as would the encouragement of networking among local and regional groups with related interests and activities. Further research is needed on the effectiveness of integrated farm systems, the performance characteristics of biogas digesters, and the nutrient value of digester sludge. Federal funds for establishing model farms at State agricultural centers might contribute to this type of research, as well as providing local demonstrations that could increase interest in these systems among the Nation's small-scale farmers.

Farmers' Markets (ch. 6)

Farmers' markets and other direct marketing strategies represent the revitalization of a food distribution system that, having fallen into disuse after World War 11, has become attractive again due to rising energy costs. They can benefit farmers and consumers alike, and by encouraging local agriculture they can contribute to the conservation of energy and the security of local food supplies.

Local and National Significance.–The case studies include farmers' markets established through the initiatives of a variety of local groups—farmers, consumers, businessmen, and municipal governments. By creating a local market where none had existed before, these markets improve the economic viability of small-scale agriculture and encourage local farmers to diversify their crops and keep their land in production. All of the farmers' markets appear to have promoted local development, although the redevelopment of the Pike Place Market in Seattle seems to have had a negative impact on the availability of low-income housing and low-cost produce. Widespread development of farmers' markets throughout the United States could result in considerable energy savings and should contribute significantly to the survival of the small family farm and the retention of agricultural land near urban areas.

Critical Factors.–All of the markets depend vitally on the participation of the local producers and consumers. In Morehouse Parish, La., the market was established and managed by the farmers themselves, but a network of interest groups in Boston proved to be an equally effective way of organizing markets. Where the markets were part of a larger educational and technical assistance program, like the one initiated by the county extension agent in Morehouse Parish, the benefits to the local farmer have been further increased. The financing required for the markets is minimal and most of them are self-supporting. Large-scale urban redevelopment projects like the Pike Place Market may not be the most cost-effective means of encouraging local agriculture or making low-cost produce available to local consumers.

Federal Policy.–The success of the comprehensive program in Morehouse Parish suggests that similar efforts elsewhere by the Agricultural Extension Service could be useful in promoting the widespread development of farmers' markets. Reenactment of the Farmer-to-Consumer Direct Marketing Act of 1976, which expired in 1980, would also allow the U.S. Department of Agriculture to complete its State-by-State surveys of current farm marketing programs and to expand its existing programs of technical and financial assistance to farmers' markets and marketing cooperatives throughout the Nation.

Resource Recovery From Municipal Solid Waste (ch. 7)

These two case studies of alternative technologies for waste management and resource recovery illustrate not only the contribution they can make to the redevelopment of deteriorating urban areas, but also the crucial problems and constraints posed by the size and quality of the "waste stream."

Local and National Significance.–The Recycle Energy System (RES), which uses combustible wastes as fuel to produce steam for space heating and industrial uses, has made an important contribution to the revitalization of downtown Akron, Ohio. Replicated on a nationwide basis, this technology could produce almost 2 percent of annual U.S. energy consumption, in addition to recovering significant amounts of glass, aluminum, iron, and steel. The Bronx Frontier Development Corp. (BFDC) converts vegetable wastes from a large produce market into compost for parks and community gardens in the South Bronx, and this technology may also have potential for comporting sludge from sewage treatment plants. Both technologies could, if widely adopted, contribute to the national effort to recycle materials, conserve energy and other resources, and reduce the environmental problems caused by waste disposal.

Critical Factors.–The Akron RES was almost totally an undertaking of the municipal government and its consultants; greater public participation might have made a difference in the size and/or development of the project. BFDC, on the other hand, has experienced some opposition from the traditional political leaders of the community, and it is not clear that local residents have had an effective voice in the project. The "consortium financing" developed by BFDC freed it from some of the constraints imposed by the grants economy, but the project could improve its finances considerably by charging competitive tipping fees to haulers or by increasing its income from the commercial sale of compost. The principal constraint on the feasibility of both these projects is the quantity and quality of the waste stream. To assure itself of an adequate supply of combustible waste, and thereby reduce financial risks, Akron was forced to pass an ordinance (since challenged in court) requiring private haulers to dump at the RES facility. The BFDC operation, on the other hand, requires a relatively uncontaminated supply of organic wastes, and its organizers too feel that it may be necessary to require source separation by means of legislation. The institutional problem of overlapping jurisdictions further complicates the issue of control over the waste stream.

Federal Policy.—Existing Federal programs provide funds for research, development, and technical and financial assistance for waste management and resource recovery. Federal policy has not yet addressed the overarching issue of control over the waste stream. If the Supreme Court decides against the city of Akron in their pending case, Congress may wish to investigate the desirability of permitting municipal control over the waste stream, including passage of enabling legislation if necessary.

Community Wastewater Treatment (ch. 8)

The General Accounting Office has recently concluded that, due to the scope and enormous costs of upgrading the Nation's sewage treatment system, it is imperative that lower cost approaches be found for providing this municipal service. The Solar AquaCell system is one of a number of alternatives that have the potential for reducing the operating costs of secondary treatment, as well as for reducing both the capital and the operating costs for more advanced wastewater treatment.

Local and National Significance.–From the local perspective, an important benefit of this wastewater treatment facility is that local control of the technology has also given the town control over its future growth by freeing it from the constraints of regional sewage planning. From the national perspective, such local treatment plants may serve to remove one of the few effective means of regional planning. At the same time, however, this and other new treatment technologies offer a badly needed, lower cost approach to expanding and upgrading of the Nation's sewage treatment facilities.

Critical Factors.–The Hercules AquaCell facility was a municipal undertaking, and like some of the other projects examined in this report it has involved relatively little participation by local residents. General acceptance of this technology by the engineering profession will require reliable data from a full-scale facility like the one at Hercules, and widespread adoption by other communities will be contingent on its proven reliability and competitive costs. At present, the AquaCell system involves sufficient risks that it might not have been adopted even in Hercules were it not for the town's large revenue base and its desire for greater control over its future population growth.

Federal Policy.–Federal policy has promoted the adoption of alternative wastewater treatment technologies since the establishment of the Environmental Protection Agency's Innovative and Alternative Technology (I/A) Program in 1978. Congress may wish to extend this program, which is due to expire at the end of fiscal year 1981, or to expand the financial incentives it has made available to municipalities and regional sewage agencies. In particular, only $15 million has been earmarked for R&D under the I/A Program; increased research, full-scale demonstrations, and information dissemination would be desirable features of an expanded I/A Program.

Community Energy Generation (ch. 9)

Small-scale hydroelectric projects can make a potentially significant contribution to the Nation's energy supply. The U.S. Army Corps of Engineers estimates that U.S. hydroelectric capacity could be increased almost threefold simply by installing additional capacity at existing sites and installing new generating equipment at dams that currently produce no electricity.

Local and National Significance.–Locally developed energy sources, like the recommissioned damsites in Wareham and Woonsocket, represent the revitalization of local resources that have fallen into disuse. The electricity generated by these projects can be applied to local energy needs, either for cutting the costs of municipal services (such as streetlights, schools, and sewage treatment), for attracting industry to the area, or for sale to local utility companies. In Woonsocket, the nearby Tupperware plant has also begun plans to renovate their own dam for industrial purposes.

Critical Factors.—Public participation does not seem to have been a critical factor in either of the case studies, although the Woonsocket project required local voters to approve a bond issue. Both projects have general support from local residents, but misconceptions about the size and potential uses of the projects have been widespread in both communities. Both towns had existing damsites, which gave the projects a sizeable capital cost advantage. Woonsocket also made effective use of Federal grants as seed money for attracting conventional financing. Wareham, on the other hand, has held out for almost total grant financing, and this has held up the completion of the

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project. The economics of local hydroelectric projects, in these communities and elsewhere, will also be affected by the rates paid by local utility companies for the power they produce. Recent Federal legislation will help to assure equitable rates.

Federal Policy .–Existing Federal programs of technical and financial assistance for feasibility studies, planning, and construction seem to be working effectively, particularly when the grants are used as seed money to reduce risks and attract conventional financing. The Corps of Engineers has conducted an extensive survey to identify damsites that might be converted or recommissioned; it has also issued a manual to assist communities in performing preliminary feasibility studies. The Public Utilities Regulatory Policies Act of 1978 requires public utilities to buy or wheel power from these projects, but the economic viability of the projects will be vitally affected by the wheeling and purchase rates that are to be established by State utility commissions by February 1981. In addition, current Federal policy favors the development of hydroelectric sites by municipalities and cooperatives. This may constitute a disincentive to the development of some sites by industry and investor-owned utilities, although they too are eligible for Federal grants and considerable private development has been taking place.

Health Care Systems (ch. 10)

Local health centers, prepaid health plans, and well-care programs may be able to reduce the costs and increase the effectiveness of health care delivery in communities throughout the Nation.

Local and National Significance.–The organizers in Hyde Park-Kenwood wanted to develop a community-controlled health care center as an alternative to the fragmented and inadequate health services on Chicago's South Side. Although the issue of community control is still unresolved, they have achieved some of their objectives—notably those of increasing the availability of primary health care and reducing its costs. In addition, their programs of preventive medicine and health education could help to improve the general health of the community. Widespread creation of health maintenance organizations in other communities could have a significant impact on the enormous cost of health care in the United States. The resources available in Hyde Park-Kenwood would not be available in most inner-city areas, however, and entirely different approaches will probably be required in rural areas.

Critical Factors.—Public participation was important to the development of the center, particularly in its financing: the organizers were able to raise $110,000 through the sale of debentures to community residents. The center is now operating in the black, largely due to the cost-cutting incentives offered by prepaid health care plans. There remains some conflict over community versus medical governance of the center, and there are problems in this and some other locations due to State medical practice laws that discourage community control of health care organizations.

Federal Policy.—Existing Federal programs have effectively encouraged the establishment of health maintenance organizations in a large number of communities. However, there has as yet been no review of the impact of the public participation requirements of the Health Maintenance Organizations Act of 1973, Congress may also wish to investigate means of addressing the barrier posed by State medical practice laws.

The Technologies From a Local Perspective

The preceding profiles show that the projects had widely varying objectives and suggest that their significance can be quite different when viewed from the national perspective instead of the local. Thus, no simple judgment of "success" or "failure" can be applied: each case must be enamined from both points of view.

Viewed broadly, local development is not always simply a question of economic growth as conventionally measured. Efficient and cost-effective municipal services—the goal of several of the projects—are a necessary underpinning to local development, as is the availability of health care and a healthful, pleasant environment. Similarly, it is not sufficient to ask whether the projects created *new* employment. In one case study, jobs have been saved that otherwise would have been lost–certainly as important as the creation of new jobs. Other projects have aided the continued operation of existing enterprises—the small family farm.

Creating employment and new industry was not the principal objective of the projects examined. Nevertheless, some of the projects provided help in severely depressed areas by creating jobs and by providing training or retraining for the unemployed. Often, however, these jobs and training programs were limited to the construction phase of the projects and did not represent permanent employment opportunities. Some of the projects did improve the viability of existing enterprises (small farms). Others could create significant opportunities for small business—the home-improvement and construction sector is notable in this connection.

One real significance of these projects from a local perspective is their potential for reducing—or at least stabilizing—the real costs of community services. The following are some examples taken from the case studies:

1. *Waste management and resource recovery.—*
   - *reduce* the operating costs of secondary wastewater treatment;
   - use municipal solid waste as a fuel to generate steam for use in the downtown area;
   - recover materials from municipal wastes, including compost and water as well as aluminum, glass, iron, and steel;
   - reduce the volume of sludge and other residues that must be disposed of; and
   - reduce the air, water, and land pollution associated with waste management.
2. *Energy.–*
   - *reduce the energy* consumption of wastewater treatment facilities;
   - develop new sources of energy for municipal services and local industrial use; and
   - recommission abandoned or underutilized energy-generating facilities for local use.
3. Health *care and social services.—*
   - increase the availability of primary health care;
   - reduce the cost of medical services; and
   - provide community activities for the elderly and the handicapped.

The technologies for residential housing address the energy efficiency of the local housing stock, thereby reducing the costs of owning or renting a home. The technologies for small-scale agriculture address the variable costs—energy for machinery and farm buildings—that farmers have the most control over. By stabilizing or reducing the farmer's production costs, these technologies might make the difference in helping to keep him in business. The farmers' market and other direct-marketing strategies, by creating or expanding local markets, likewise improve the farmer's return on investment and thereby improve the economic viability of the small family farm.

The Technologies From a National Perspective

Perhaps the most important aspect of these technologies from a national perspective is their transferability–the degree to which a technology that was successfully developed in one community can be replicated in other communities throughout the Nation. This preliminary study includes only a few case studies, and for this reason it is difficult to draw any firm conclusions on this subject. Several of the case studies suggest that the success of some development projects was due to unique local resources; but even in those cases it is possible to learn valuable lessons about the factors that might be important to the success or failure of similar projects elsewhere. These critical factors will be addressed in the next section.

If the development projects examined in the case studies were replicated by a large number of communities throughout the Nation, their combined effects could make a significant contribution to achieving national goals in the following three sectors:

- *Community services.* —The correction, upgrading, and expansion of the Nation's wastewater treatment facilities through conventional approaches may be beyond the resources currently available to the Federal, State, and local governments. Alternatives such as the Solar AquaCell may provide more cost-effective solutions. Similarly, the contribution of hydroelectric power to the Nation's energy supplies could be substantially increased by installing additional capacity at existing small-scale damsites like Woonsocket's that are currently unused or underutilized. The staggering costs of health care, which may soon consume 15 percent of the gross national product, might also be cut by prepaid health care plans and the diffusion of community health care centers such as Hyde Park-Kenwood.

- *Residential energy conservation.—The* residential sector accounts for over 20 percent of annual U.S. energy consumption. Americans have already responded to the changing energy situation by reducing the direct consumption of energy in their homes, but dramatic further savings are possible: conservation measures that are cost effective against current energy prices could save the energy equivalent of the total production rate of Alaska's North Slope. This potential energy savings is particularly important in view of the number of new houses that must be built in the next 20 years, but considerable savings are also possible for existing housing stock through energy-saving retrofits such as attached solar heating greenhouses. By reducing the demand for energy in this important sector, technologies like those examined in this study could, on a national level, not only help to stem the rise in the total costs of housing but also reduce the need to develop costly new sources of energy.
- *Small-scale agriculture.*–By reducing energy and other production costs, and by increasing the prices that farmers receive for their produce, these production technologies and marketing approaches can improve the economic viability of the small family farm. They can also help to promote agricultural land retention and help to ensure local food supplies in the event of an oil embargo, natural disaster, or war.

From a national perspective, the potential bill for some of the services examined, such as wastewater treatment, is so high that any reduction in their cost might free up significant resources for other national needs. In several other cases, the technologies represent an updating of approaches that were in use before the era of cheap and plentiful energy supplies. While they are unlikely to become more than a partial alternative to centralized or large-scale technology, they can help to broaden and diversify the Nation's "technology mix."

Critical Factors

The relative uniqueness of some of the projects, which might limit their transferability, is largely a result of special conditions or community resources. In some instances the resources were financial: passive solar houses, for instance, are being built primarily in the custom housing market for middle- and high-income families; similarly, the Solar AquaCell wastewater technology involves substantial risks, and might not have been built had it not been for the city's revenue base. In other cases the special resources were human: the Hyde Park-Kenwood organizers, for instance, could draw on the considerable resources available through the University of Chicago community and the local tradition of cooperative action; in the case of the New Life Farm, the success of the project depended in large part on the special contributions made by a charismatic leader. In still other communities, the special resources were material: Wareham and Woonsocket both had existing damsites at which to install hydroelectric generators, and Akron had an existing distribution system for the steam created by burning refuse.

Despite the unique elements found in some of the projects, however, a number of common factors seems to be important in the success or failure of each case, as well as in their likely transferability to other communities.

Public Perception and Participation

In municipal undertakings, such as the Akron RES, the low-head hydroelectric projects in Wareham and Woonsocket, and the Hercules AquaCell facility, public participation was not a major factor. Greater participation by local residents in the planning of the projects, however, might have encouraged consideration of alternative approaches; for example, Akron might have decided on a turnkey development rather than assuming the risk itself. Public participation seemed to be important to the success of such community undertakings as the health care center in Hyde Park-Kenwood and the various farmers' markets. In the case of individual undertakings, such as the solar applications in the Small Farm Energy Project, the passive solar houses, and the attached solar greenhouse retrofits, a high degree of public interest and participation was—almost by definition—essential to the success of the projects.

Technical Information and Expertise

Availability of technical information and expertise was found to be crucial to the successful planning, construction, and operation of all the projects. The Cheyenne Community Solar Greenhouse offered an example of the difficulties that can arise when this information and expertise is lacking.

In the larger projects, city planners and consulting engineers demanded reliable data on the capital costs and technical performance of the technologies. Where such detailed information is not yet available, as was the case with the AquaCell, high contingency fees and difficulties in securing financing must be expected. For less complicated community projects, on the other hand, the needs for information are simpler and can often be met through "networking," as was the case in the organization of the farmers' markets in the Boston area, In the case of individual undertakings, the greatest need is for personal, hands-on experience in the design and construction skills needed to build the installation. This experience was provided effectively by community workshops in the case studies of solar heating greenhouses in New Mexico and farm energy systems in Nebraska. Comprehensive programs of instruction, practical experience, and individual technical assistance—used in Morehouse Parish, La., as well as Cedar County, Nebr.–appear to be the most effective mechanism for transferring technical information about the simpler technologies.

Essential Resources

The availability of essential resources—material and human, tools and labor—was found to be the most unique factor in these projects. For this reason, it is also likely to affect their transferability to other communities. The apparent lack of resources in a community, however, is less of a barrier to the development of these projects than it might at first seem. The unpromising resources in Morehouse Parish (almost total reliance on cotton) and Rutland (very little local vegetable production) were eventually overcome through the efforts of determined and imaginative organizers. This is not quite a case of pulling a rabbit out of a hat, however; only an outsider would conclude that necessary resources are not available. The lesson seems to be that a great deal can be done if resources are developed and managed from within the community, and in some cases—the manure digester, for example–a promising technology can be based on what might seem the least promising resource base (hog manure and depleted farmland).

Financing

The forms of financing used in the projects were as varied as the financial needs involved. Grant-financed projects appear to work best where initial seed money is required, either to attract more conventional financing (as in the case of Woonsocket) or to allow the project to become self-supporting (as in the case of the farmers' markets). The projects were less successful, or encountered a new set of problems, when they became dependent on total or continued grant financing. For one thing, they have a continuing need to attract new grants, which may require the staff to invest its time in fundraising instead of project management; for another, grant funding is frequently tied to specific projects rather than being available for general and administrative expenses. The latter may cause the project staff to become involved with a number of disparate efforts, instead of concentrating its time and attention on the success of a central program. The Bronx comporting project encountered both of these problems, but the organizers were able to overcome them (to some degree) through "consortium funding''-by seeking smaller grants from a large number of donors, they avoided becoming too dependent on a single source. In Wareham, on the other hand, the organizers' insistence on financing their whole project through grants has led to delays in the completion of the hydroelectric project.

In the smaller scale projects, the success of the Small Farm Energy Project shows that cost-sharing funds can be very effective in encouraging the adoption of some technologies. This and other projects also demonstrate that grant funding for community workshops can be highly cost effective, because of the high leverage they achieve in disseminating information and practical skills and in encouraging independent efforts within the community. Many of the residential projects were financed out-of-pocket by individuals, and tax credits and low-cost loans (including loans from utility companies) can effectively encourage these investments.

The development of larger scale technologies, like the Solar AquaCell, can be impeded considerably by the current state of the venture capital market. In large municipal projects, such as centralized resource recovery or small-scale hydropower or wastewater treatment, intervention may also be required to reduce financial risk in order to attract conventional financing. These, too, are cases where Federal and other grants can be productively used as seed money.

Some of the projects became self-supporting in a fairly short time; the farmers' markets are the best example of this, but they also have much smaller capital requirements than most of the other projects. Other projects—notably the Bronx Frontier Development Corp.–have the potential to support themselves in time, although in the case of the Bronx this probably will require raising tipping fees to competitive levels. Some projects, on the other hand, are not profit-oriented and are unable to become self-supporting. Community service projects like the Cheyenne solar greenhouse are the best example of the latter, and their cost effectiveness must be evaluated in comparison with alternative mechanisms for delivering the same social services.

Institutional Factors

Some of the projects were opposed, at least initially, by professional and commercial interests; others encountered difficulties due to institutional resistance or outright opposition. Professional resistance seemed to derive from a demand for better and more reliable performance data; the reluctance of the engineering profession to accept the AquaCell technology is a good example, as is the building industry's reluctance to accept new housing designs. In other cases, local commerical interests opposed a project that they thought might become a competitor (as in the case of a greenhouse operator in Cheyenne) or might be detrimental to local business (as in the case of the Rutland farmers' market); these fears usually proved unfounded, however, and in other cases (notably Ravinia) the business community was an important promoter of a project. Financial institutions were hesitant about financing some of the projects, particularly resource-efficient housing. Some of the projects also experienced opposition (or at any rate insensitivity) from regulatory and other government agencies; building codes and waste-management guidelines are a particular source of difficulty for some technologies.

One institutional arrangement that can promote the adoption and diffusion of these technologies is networking—establishing links between existing delivery systems and public interest groups—which was used successfully by city and State agencies in Boston and Baltimore. In most cases, the assistance of the Federal Government was effective, although in some cases it could have been improved, as will be discussed below.

Federal Policy

A wide variety of Federal policies and programs have contributed, directly or indirectly, to the development and adoption of these technologies; the individual chapters contain extended discussions of these programs. Criticisms of these Federal programs concern the extent, coordination, and management of these programs, rather than their formal objectives. These criticisms, and proposals for addressing them, are also discussed in the individual chapters.

The pattern that emerges from the case studies suggests that there are four principal areas in which Federal programs for local development might be modified and improved:

- data gathering and analysis;
- information dissemination;
- technical assistance; and
- financial assistance.

Data Gathering

The technologies examined in the case studies were found to be at varying stages or development, but they all seemed likely to profit from a more concentrated effort to gather reliable data on the design, cost, performance, and/or reliability of the technology itself, as well as on the particular community's experience in applying it. In the case of technologies that are still in the experimental stage, this information is vital to their further development; the gathering of such data was seen to be the central objective of several of the projects, including the Solsearch Conserver Home and the New Life Farm biogas digesters. Other case studies involved technologies that had been successful in laboratory- or pilot-scale demonstrations, but were being applied for the first time in a full commercial- or municipal-scale facility; in these cases—which included the food-producing solar greenhouse, Recycle Energy System, large-scale composting, and Solar AquaCell wastewater treatment—the acceptance of the technology by other communities will depend on the demonstrated reliability and cost-effectiveness of the pioneer installations. In still other cases, the local development project involved the innovative application of a proven technology, as in the onfarm solar applications. Finally, some of the projects involve variations on technologies that have been in use for some time, and which could productively be subjected to a comprehensive comparison with one another and with more conventional approaches; the future dissemination of this category of technologies, which includes several varieties of passive solar houses, farmers' markets, and health maintenance organizations, could be assisted by this kind of evaluation and comparison.

It should be noted, however, that most of the local development projects that were examined in this study were not designed with the specific purpose of providing technical demonstrations of the technologies involved or gathering technical and other data on those technologies. In addition, there are special difficulties involved in the gathering of reliable data at facilities that are currently in use by the community or, in the case of projects undertaken by individuals, currently occupied. The behavior of the occupants has a considerable influence on the performance of energy-efficient houses, for instance; similarly, the staff of the Cheyenne greenhouse, like the busy farmers in Cedar County, Nebr., have had neither the time nor the equipment to conduct detailed monitoring of their solar installations.

Options.–There are a number of steps that can be taken by Federal agencies and local project organizers to ensure that adequate data gathering and analysis is in fact carried out. These steps include, but are not limited to, the following:

- *Modify project* design. -Federal agencies can encourage grant applicants to include a strong data-gathering component in the design of their projects, where possible. In some cases this may require additional funding or the earmarking of a portion of the project's funds specifically for data-gathering.
- *Redirect existing* research.–In some cases what is needed is not *more* data but a different *kind* of data, particularly social science data. Human behavior is a significant but uncontrolled variable in some projects. Occupants of solar-heated houses, for instance, may have to open and close vents or tolerate wide tem-

perature swings. Similarly, Federal research has traditionally been oriented toward the science and engineering underlying resource recovery; future efforts might productively investigate the human aspect, such as incentives that would promote source separation by individual households.

- *Support and expand Federal monitoring projects.*—The National Center for Appropriate Technology has begun two projects to monitor the performance of different solar greenhouse designs. Similar projects might be undertaken by other Federal agencies to provide assistance for monitoring the performance of other projects, including direct-marketing strategies and energy technologies for small-scale farmers.

Information Dissemination

Even when a technology is fairly well developed and data have been gathered by one developer, its diffusion can be impeded if other potential developers are unaware of the project or unable to obtain detailed information on design, costs, and performance. In some cases this will cause communities to overlook a promising alternative or to waste time and money in an unnecessary duplication of efforts that have already been carried out elsewhere. In other cases it will result in resistance from engineers and financial sources who, in the absence of reliable technical and economic information, consider the project too risky. In a few cases this might cause the failure of a project because its organizers were unaware of the problems, and solutions, that have been discovered in similar projects elsewhere.

Options.–The problem of information dissemination can be addressed through a number of measures—local, regional, and national—including but not limited to the following:

- *Encourage networking.*–The establishment of networks, through which local and regional groups with related interests are able to share information and expertise, has been effective in organizing farmers' markets in the Boston area and for disseminating information on small farm systems in Nebraska. Federal agencies, particularly those like the Agricultural Extension Service and Community Services Administration that have extensive local representation, are in a good position to encourage the establishment of similar networks to spread information and share experience among local groups, State agencies, and Federal programs throughout the Nation.
- *Establish regional demonstration* Projects.—The case studies have shown that local demonstration projects are particularly effective in stimulating a community's interest in innovative technologies and, more significantly, in promoting the adoption of those technologies by other local residents. This was particularly true in the case of the Small Farm Energy Project in Nebraska, but could also be seen in the interest stimulated by several of the resource-efficient houses. The creation of regional research and demonstration centers, such as model energy-efficient farms at State experimental stations, could also help to generate information on the effectiveness of integrated systems of farming techniques and farm energy technologies.
- *Encourage information* exchange.-The Federal Home Loan Bank Board has conducted four workshops on energy-efficient housing as part of its efforts to encourage local savings and loan associations to include conservation requirements in their home loan programs; this program, however, had no legislative mandate. The Resource Recovery and Conservation Act of 1976 called on the Environmental Protection Agency to organize a similar program of information exchange between different levels of government, and between government and private industry, on the performance of available resource recovery systems; however, sufficient funds were not appropriated to implement this program. The Federal Government could contribute to the diffusion of a number of these technologies by creating and funding a more extensive program of regional panels and seminars at which local bankers, homebuilders, engineers, urban planners, and other interested parties could be exposed to recent developments in their fields. By disseminating the necessary information on design, reliability, and costs, this approach could be useful in overcoming institutional

and financial barriers to the adoption of the technologies by other communities.

Technical Assistance

Even when reliable design and performance data are available, the development of a particular project will not be possible unless and adequate skill base exists, or can be developed, in the local community. This can be a problem even with the simplest of projects, although the skills needed for planning and building an attached solar greenhouse, for instance, can be taught rather easily. Often, however, these skills are relatively complex, and difficulty of acquiring them can be a barrier to the success of the project. In the case of the larger municipal projects, even the expertise needed for planning the project or determining its feasibility are beyond the means of a given community.

Options.—There are two basic approaches to this problem: technical assistance and skill transfer. The former usually involves greater Federal involvement and greater expense; the latter usually costs less and benefits the community more, since the skill base will remain in the community after the completion of the project. The following represent a range of options for technical assistance:

- Workshops.—For the simplest of the projects, particularly those that are to be built by individual homeowners or farmers, the community workshop approach is highly effective. This was the case with the attached solar greenhouse in both New Mexico and Wyoming, where small groups of neighbors can together to learn by doing: they planned and built a greenhouse on the home of one of the group members, thereby learning the skills that they would need to plan and build their own greenhouses later. This approach was also successful in demonstrating the technology in the local community, and it was often the stimulus for additional installations.
- *Training programs and seminars.--The* Small Farm Energy Project in Nebraska demonstrated the effectiveness of programs of lectures, seminars, and discussion groups in exposing local residents to a wide variety of potential applications for their farms. The training programs conducted by the organizers of the Cheyenne greenhouse allowed local residents to plan and build their own facility; it also provided marketable skills and work experience for local high school students. A similar program in Bethel, Alaska, was part of the curriculum of Kuskokwim Community College.
- *One-on-one technical* assistance.—Personalized, individual attention from organizers and outside experts was useful in providing specific help to farmers both in building solar installations in Nebraska and in organizing a farmers' market and ancillary projects in Morehouse Parish, La. The existing extension program of the Departments of Energy and Agriculture could be used as a mechanism for this form of assistance.
- *Computer models and other planning aids.–* Some communities lack the expertise for planning large municipal projects, and for other communities the expense of detailed feasibility studies may be prohibitive. Technical assistance in these cases might include manpower for conducting site evaluation and other preliminary studies of the local resource base. However, the same assistance can be provided in the form of handbooks showing how local groups and municipal governments can conduct a low-cost, "quick and dirty" feasibility study. In some cases, notably that of small-scale hydropower projects, computer models have been developed for this purpose; Federal agencies have also prepared feasibility and planning manuals for farmers' markets and community health care centers. Local groups could be assisted greatly by the development of similar technical and organizational guides for energy-efficient housing and farm systems, resource-recovery systems, and wastewater treatment facilities. These aids would allow local communities to conduct their own evaluations and planning, without the need for extensive Federal involvement or funding.
- *Expert assistance* panels.—The Resource Recovery and Conservation Act of 1976 directed the Environmental Protection Agency (EPA) to provide State and local governments with teams of technical, financial, marketing, and institutional specialists to assist them in

developing comprehensive plans for waste management and resource recovery. EPA's Technical Assistance Panels Program provided staff and consultant expertise in these areas to over 160 communities in 1978 and 1979. A similar program has been planned for DOE's Energy Extension Service. The establishment of similar assistance programs by other agencies might be useful in promoting the consideration, adoption, and construction of local projects for wastewater treatment, energy generation, and health care.

Financial Assistance

Some of the technologies had the virtue of low cost, which allowed them to be developed by local communities without major Federal assistance. In several of the case studies the costs of the project were minimal and the project rapidly became self-supporting. This was particularly true of the farmers' markets and some of the energy-saving retrofits for residential and farm buildings. Other projects, although they promise to cut total costs over the life of the installation, required initial investments that might be beyond the resources of some communities or involved technical and economic risks that could make conventional financing difficult or impossible to obtain. This was found to be true in the case of the larger municipal projects, such as resource recovery, wastewater, and hydroelectric installations. Given the potential expense of these municipal services on a national level, and the potential benefits of developing innovative methods of delivering them, it might be appropriate that the Federal Government intervene to reduce the financial risks and burdens they might impose on local communities. At issue is the form that this intervention should take.

Options.–Several of the local development projects examined in the case studies could be replicated by other communities without Federal financial assistance. But even in cases where Federal assistance is necessary, there are several ways in which the degree or amount of this assistance can be held down. These measures include, but are not limited to, the following:

- *Technical risk* reduction.—Federal efforts to gather and disseminate reliable information on the technologies (see above) can also reduce the financial risks of the projects and prevent costly planning errors. Data-gathering efforts might include programs to determine the capital and operating costs of existing installations; this information could then be disseminated to financial institutions through regional workshops like those conducted by the Federal Home Loan Bank Board. Particular attention—and where necessary, expert assistance—should be given to the collection of cost-benefit and lifecycle cost information.
- *Financial risk reduction.*–Current Federal programs for innovative and alternative wastewater systems include risk guarantees for the correction or modification of facilities that do not work properly, at no cost to the local government. Similar guarantees might encourage the consideration of other alternative technologies. Tax-free bonding would also improve the financial profiles of some municipal undertakings.
- *Earmarked and set-aside* funds.-Federal appropriations for research, development, demonstration, and construction of municipal facilities might set aside a certain portion of the funds specifically for the adoption of innovative and alternative technologies.
- *Subsidzed loans.*—The Solar and Conservation Bank, recently established within the Department of Housing and Urban Development, provides low-cost loans for conservation retrofits and solar features in new housing. The Farmers' Home Administration provides similar loans for rural housing, and the Federal Home Loan Bank Board encourages local savings and loan associations to include energy-efficiency requirements in their home loan programs. These efforts might be expanded and/or extended to include other technologies.
- *Tax credits and other incentives.*–Eligibility for Federal tax credits, such as the Residential Energy Credit, might encourage the adoption of several of the smaller technologies. Current Internal Revenue Service guidelines do not allow credits for attached solar greenhouses, for instance, and extension of the credits to include farm installations might also promote

the more rapid adoption of biogas digesters and onfarm solar installations like those developed in the Small Farm Energy Project.

- *Stimulate markets.*-Federal procurement guidelines, such as those promulgated for recycled steel, might ensure a market for locally grown produce or for materials recovered from municipal waste.

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