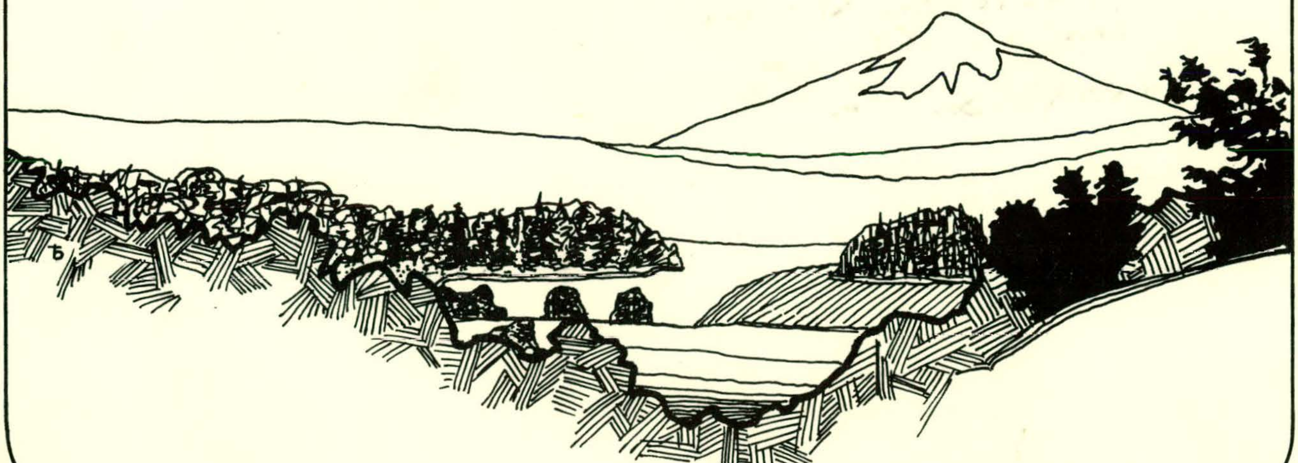
SOLAR 78 NORTHWEST

Conference Proceedings

July 14·15·16

Portland, Oregon



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Oregon Dept. of Energy
111 Labor & Industries Bldg.
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SOLAR 78 Steering Committee

Douglas R. Boleyn, P.E.
Energy Management Consultant
Portland General Electric

William C. Church, AIA
Architect

Donald J. Davey
Energy Conservation Officer
Bonneville Power Administration

Dr. Jean F. Delord
Professor of Physics
Reed College

Richard L. Durham
Special Projects Officer
U.S. Department of Energy
Richland

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The Architects Forum

Jill Goodnight
Research Specialist
Battelle-HARC
Seattle

Marion Hemphill
Acting Energy Advisor
City of Portland

Suzi Hosch
Coordinator of Emerging Energy Sources
Washington State Energy Office

Lee Johnson
Editor, RAIN: Journal of Appropriate Technology

Alan D. Kiphut
Solar Specialist
Oregon Department of Energy

James P. Leshuk, P.E.
Consulting Engineer

Richard A. Lowell
Assistant Vice-President, Appraisal Department
Benj. Franklin Federal Savings and Loan Association

Walter E. Pollock
Supervisor, Energy Conservation and Resource Development
Oregon Department of Energy

John S. Reynolds
Professor of Architecture
University of Oregon

Mary Lawrence
Conference Coordinator

INTRODUCTORY REMARKS

The summer of 1977 marked a quantum leap forward for solar enthusiasts in the Pacific Northwest. The Solar 77 Northwest Conference was a huge success, and relayed the fact to the general public that renewable resources and the techniques to use them were here - all that was needed was for more people to begin taking that first step toward a solar transition.

Needless to say, lots of folks have taken that step during the past year and, as a result, Solar 78 Northwest took a slightly different format. In order to respond to the growing public demand for sound energy management, it is absolutely essential that architects, engineers, contractors, planners, and government officials are informed about renewable energy technologies which are ready for implementation today. Judging from the responses of over 800 Conference attendees, it is clear that Solar 78 Northwest helped all of us take another giant step toward achieving rational energy use in our society.

While the three Conference days were a complete success, the real measure of value will become evident somewhere down the road. How soon will these technologies be readily available and accessible to all? How soon will renewable energy sources enter into everyday decision making? How much longer before "alternative" is dropped and solar, wind, biomass and geothermal resources are considered "conventional"?

Your support of Solar 78 Northwest is greatly appreciated - your personal involvement in spreading the results will be even more important. We hope the following pages are of some assistance.

SOLAR 78 NORTHWEST
PROCEEDINGS SUB-COMMITTEE

Lee Johnson
Al Kiphut
Jim Leshuk

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

NORTHWEST STATES - POLICY AND PROGRAMS AFFECTING SOLAR DEVELOPMENT

OREGON'S SOLAR PERSPECTIVE

by

Fred D. Miller, Director
Oregon Department of Energy

The use of solar energy will clearly account for a significant portion of the energy needs of the United States and the State of Oregon by the turn of the century. A recent report by President Carter's Council on Environmental Quality states that solar could provide 25 percent or more of the nation's total energy demand by 2025 -- depending largely on the priority given to solar energy utilization by federal and state government. In Oregon, several legislative measures have established a framework through which the use of solar energy is being promoted.

(1) In 1975, HB 2202 established a ten year property tax exemption for solar energy systems. This exemption was extended to 1996 in conjunction with the passage of SB 339 in 1977.

(2) In 1977, SB 339 established a tax credit program for the installation of alternative energy devices (solar, wind, geothermal) provided that the device meets 10 percent of the total energy demand of the building and is certified by ODOE prior to installation. This program gives the homeowner a tax credit equal to 25 percent of the system cost, up to a maximum credit of $1,000. To date more than 100 solar installations have been certified and are currently being installed.

(3) SB 477, passed in 1977, provides for a low interest loan program for eligible Oregon veterans who purchase and install solar energy devices. The loan limit is $3,000 added to a home mortgage, currently at a 5.9 percent interest rate.

(4) State enabling legislation for solar zoning was passed in 1975 with HB 2036, as one approach to providing solar access for solar energy users. This was modified in 1977 and currently allows county planning commissions to recommend solar ordinances to governing bodies. A more comprehensive approach to this issue is now being prepared for the next legislative session.

In conjunction with these specific legislative actions, the Department of Energy, along with U of O and OSU is actively promoting the use of solar energy by distributing information pertinent to specific applications. We have just recently completed the Oregon Solar Planning Study, are currently involved in the preparation of a solar economics study, and are working with the Department of Commerce on a Solar Code. Several concepts are now being put into bill form to expand the scope of SB 339, provide low interest loans for solar installations, evaluate state-owned buildings for potential solar retrofit, and provide for solar access.

We are at a unique point in energy history, and with our abundant hydro-electric power base, are fortunate to have this grace period during which we can make a smooth transition to renewable energy sources. The people of Oregon are rapidly moving in this direction, and our role as a state agency is to respond to this need and facilitate the implementation of alternate energy technologies.

SOLAR IN THE STATE OF WASHINGTON

by

Ray Anderson, Washington State Energy Office

In the State of Washington, we have as a goal accelerating the early and widespread use of solar energy technologies. In the past year and a half, we have begun taking significant steps to implement that goal.

In 1977, the state legislature passed SSHB 388, which exempted solar energy systems meeting any minimum HUD standards from property tax assessments for seven years. No claims may be filed after December 31, 1981.

With the assistance of the Solar Planning Office West, our solar advisory group, the University of Washington, and DOE, we have initiated a solar planning program, which produced the framework for a solar plan for the State of Washington, and suggested projects to accelerate the commercialization and use of solar in our state. The projects were melded with those of twelve other Western States, and were submitted to DOE for implementation through Western SUN.

Western SUN will provide each state with tools to continue the planning process and information/education programs to raise awareness and answer solar related questions. It will also support solar demonstration projects throughout the region. We are sure that by cooperating with other states, especially those in the Northwest, we can enhance each of our efforts to act effectively.

Citizens interested in promoting solar use can get involved in solar planning through serving on, or interacting with, the Washington Solar Advisory Group. Legislation can be affected by interacting directly with members and committees of the State Legislature, and by working with solar organizations such as the Western Washington and Inland Empire ISES Chapters. Community solar demonstrations can be promoted by individual homeowners and businesses incorporating solar into their buildings, and by community groups cooperating on local projects. All of these activities are needed to facilitate a shift toward widespread use of solar energy.

SOLAR ENERGY INCENTIVES IN IDAHO

by

Kirk Hall, Idaho Energy Office

Two recent actions by the Idaho Legislature provide for incentives for the development of alternative energy devices, including solar installations, and for the protection of solar access through the purchase of solar easements.

Alternative Energy Devices

Chapter 212, 1976 Session Laws, Section 63-3022C, Idaho Code, allows an individual taxpayer to deduct from taxable income the following amounts actually paid or accrued in the installation of a solar device serving at a place or residence: 40% of the amount attributable to the construction, reconstruction, remodeling, installation or acquisition of the alternative energy device; and 20% per year thereafter for a period of three years, provided that the deduction not exceed $5,000 in any one taxable year.

An alternative energy device is defined as: "any system or mechanism ... using solar radiation, wind, geothermal resource ... or wood or wood products primarily to provide heating, to provide cooling, to produce electrical power, or any combination thereof ... A built-in fireplace does not qualify ... unless it is equipped with a metal heat exchanger ..."

The Idaho Tax Commission estimates that income tax deductions in 1976 and 1977 equalled $7,762,392. That figure, however, includes deductions for the installation of insulation, for which that same Act allows. No data is currently available with respect to 1978 returns.

Solar Easements

Chapter 6, 1978 Session Laws, Title 55, Idaho Code, provides a means to obtain solar easements, provides for the requirements for an instrument of conveyance of a solar easement upon the sale of real property and declares an emergency to exist which brings the Act into full force upon its passage and approval. It was passed by the 1978 Legislature.

An easement is defined as: "A right of use, falling short of ownership, and usually for a certain stated purpose." (Sec. 50-1301, Idaho Code).

"The easement may be obtained for the purpose of exposure of a solar energy device to sunlight ... shall be created in writing, and shall be subject to the same conveyancing and instrument recording requirements as other easements."

"A solar easement shall be presumed to be attached to the real property on which it was first created, and shall be deemed to pass with the property when title is transferred to another owner."

WESTERN SOLAR UTILIZATION NETWORK (WSUN)

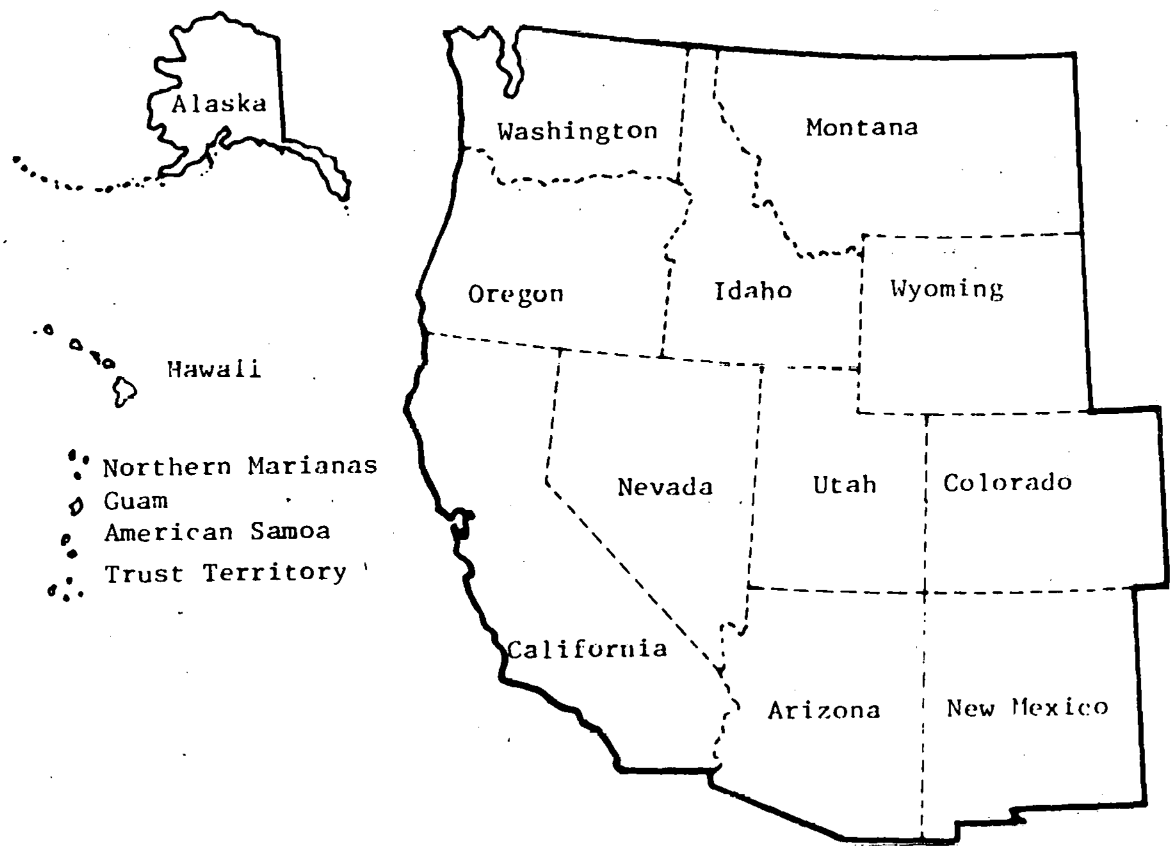
The following is the executive summary from " A Solar Energy Plan for the Western Region" as prepared in March 1978 for the US DOE under contract to the Solar Planning Committee (governors' designees from the 13 Western States), assisted by the Solar Planning Office-West. It is the summary of the negotiating document for Western Sun, and not necessarily an exact description of programs which Western Sun will be contracted to undertake.

Discussion Panel Moderator: Rick Morgan, Oregon Department of Energy

Panel members: Ray Anderson, Washington State Energy Office
Lonn Liffick, U.S. Department of Energy, Region X
Jeannie Ford, Physics Department, University of Oregon

Figure 1.1

MAP OF THE WESTERN REGION



Alaska • Arizona • California • Colorado • Hawaii • Idaho • Montana

Nevada • New Mexico • Oregon • Utah • Washington • Wyoming

(Hawaii also represents Guam, Commonwealth of the Northern Mariana Islands, American Samoa, and Trust Territory of the Pacific Islands)

Executive Summary

A SOLAR ENERGY PLAN FOR THE WESTERN REGION

Thirteen Western States*, as the result of a nine-month planning effort, recommend a plan for encouraging the use of solar energy in the West and an implementing organization to carry out the plan. This summary describes how the plan was developed, the programs and projects comprising the plan, overall cost estimates, and the structure of the proposed implementing organization, Western Solar Utilization Network (Western SUN).

Section 1 Background and Evolution of the Plan

This Solar Energy Plan for the Western Region is the collective product of representatives of the governments of 13 states, developed by and for those states based on their circumstances and needs. The plan is not the product of a central organization.

In the spring of 1977, the Energy Research and Development Administration (ERDA) announced the award of a contract to Midwest Research Institute to establish and operate a Solar Energy Research Institute (SERI) at Golden, Colorado. At about the same time, ERDA invited the governors of the various states to form regional organizations to plan for regional solar energy programs. Representatives of Western Governors elected to approach the matter as a group rather than delegate the task to a central entity. To make this feasible, they requested a nine month planning period rather than the shorter period originally indicated by ERDA and favored by representatives of some other regions.

ERDA agreed and approved a grant for a nine-month planning effort, July 1, 1977 to March 31, 1978. Western Interstate Nuclear Board (WINB), established by an interstate compact and ratified by the legislatures of 12 of the 13 states involved (and offering eligibility to the thirteenth state, Hawaii), served as the contracting agency. The contract vested control of the planning in a Solar Planning Executive Committee composed of six of the 13 state representatives designated by their governors. The 13 representatives composed the Solar Planning Committee with an advisory role. In the course of the planning effort, the 13-member

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*Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. Hawaii also represents Guam, The Commonwealth of the Northern Marianas, American Samoa, and The Trust Territories of the Pacific Islands.

Solar Planning Committee actually assumed and shared with the smaller Solar Planning Executive Committee full responsibility for the effort.

The contract also established the Solar Planning Office--West (SPOW) to provide staff services. It employed a temporary staff of seven professionals and two support personnel which assisted the states when requested and undertook the work of shaping various state recommendations into the actual text of this plan, as directed by the Solar Planning Committee.

The contract with ERDA, responsive to a proposal submitted by the 13 states, provided that an organization in each state designated by the state would receive a sub-contract to collect information, make recommendations for a regional plan and prepare a report on behalf of the state. Of the total funds awarded to the Western Region, 49.5 percent was forwarded to those state contractors for fulfillment of their subcontracts and an additional four percent was provided to pay expenses for members of a Solar Advisory Group in each state.

The Solar Energy Plan for the Western Region sprang from these grassroots origins. Subcontractors in each state selected by Solar Planning Committee members--in some cases state agencies and in other cases state universities or state research institutions designated by the states--drew on the advice of Solar Advisory Groups and engaged in evaluations and assessments leading to individual state recommendations for the plan.

The Solar Planning Committee met approximately monthly to coordinate activities among themselves and with the staff of SPOW and to make decisions. Also present at five of these meetings were the principal investigators responsible for conducting the efforts specified in the state contracts.

Preliminary state recommendations for the plan were delivered to SPOW early in December 1977. The SPOW staff collected and categorized nearly 400 projects suggested by the states. These were reviewed by the Solar Planning Executive Committee in mid-December and from this review the Executive Committee selected a preliminary list of approximately 40 projects for further refinement.

Following directions given by the Solar Planning Executive Committee, the SPOW staff produced a first draft of this plan in mid-January 1978.

The Solar Planning Committee and principal investigators from the states reviewed this first draft, recommended additions and eliminations and a number of revisions. On the basis of this guidance, the SPOW staff produced a second draft early in February, and again there was a meeting of the SPC and the principal investigators for further review.

Again, changes were recommended, leading to the preparation of a third draft completed on March 3, 1978. It was submitted to and approved by the Western Interstate Nuclear Board, subject to minor modifications, on March 9.

The Solar Planning Committee undertook a final review on March 10. Following this review, the staff made minor changes as directed by the Solar Planning Committee and editorial corrections and refinements to produce this plan.

(Principal investigators participated in reviews only of the programmatic section of this plan, as presented in Section 2; they did not participate in decisions regarding the recommended implementing organization, described in Section 3 or in deliberations on cost estimates, in Section 4.)

Section 2 Recommended Programs

This plan, subject to alteration and refinement as increased experience and circumstances dictate, consists of 40 projects in six programmatic areas recommended for initiation within the first fiscal year. The programmatic areas are established as a convenience and are not intended to compartmentalize the work. Extensive interlocks are found between various projects in various programmatic areas.

The plan does not propose basic research, since research ordinarily is not regional in nature. The region may in the future wish to recommend research if it is peculiar to the West and if it is not being carried out elsewhere.

The plan does not involve efforts in high-technology, long-term applications such as ocean thermal energy conversion, solar thermal-electric generation, and photovoltaic cell development, these being more appropriate for management at the national level.

The plan emphasizes efforts to accelerate the use of at-hand or near-at-hand technologies. Attention is given particularly to passive (and hybrid) solar space heating and cooling, water heating, wind energy conversion, and biomass conversion. The climatic characteristics and the resources of the West, as well as the state of the art, make these solar technologies particularly suitable for implementation.

Nearly all of the proposed projects provide for information and education delivered to the general public and key members of the institutional infrastructure, such as state and local government personnel, builders and developers, and mortgage lenders. (Many projects are purely informational or educational in nature.)

Western planners believe that the role of conveying information to potential consumers of solar energy and the deliverers of solar energy devices, designs, and applications is particularly suitable for regional, state, and local, as contrasted to national, management. Commercialization of solar energy ultimately takes place at specific sites involving specific consumers making business transactions with specific purveyors with the approval of local building code officials and other local authorities, thus the need for grassroots participation.

Certain aspects of solar energy development and implementation can be directed best by the Federal government. But there are powers vested in state and local governments which are particularly pertinent to solar applications. Construction blueprints and specifications are approved or disapproved by local authorities. Property tax assessments are made by municipalities, counties, and school districts. State law usually establishes parameters within which these local officials operate.

Public utilities are regulated by state commissions, with franchises and some operational rules established by municipalities. Utility regulation can provide incentives or disincentives to solar use. States and localities provide most of the nation's elementary and secondary education and a major portion of higher education. States, local governments, and school districts are major constructors of new buildings and major consumers of energy; they can provide many demonstrations of solar energy use.

Western planners, being state-oriented, are particularly cognizant of the roles of state and local governments and have attempted to shape this program to emphasize these roles. Seven projects in this plan address state and local government roles. They are Projects 2.4.1, 2.4.2, 2.4.3, 2.4.4, 2.6.1, 2.6.4, and 2.5.3.

Emphasis is placed on certain technologies:

Biomass Conversion. Technologies are at hand for several forms of biomass conversion, and in many cases the economics already are favorable, but there is a lack of knowledge of this potentially large contribution to the nation's energy supply. Use of this resource for energy also can reduce environmental pollution and reduce a waste disposal problem. Five projects in this plan directly address biomass conversion (2.3.6, 2.3.7, 2.3.8, 2.3.9, and 2.3.10).

Passive and Hybrid Heating and Cooling. Active solar space heating has received a lion's share of national attention, both from government and from private entrepreneurs. The technology is well advanced; the deterrents are economic, institutional and informational in nature. This plan addresses the informational and institutional deterrents. But in the view of Western solar planners, passive solar heating and cooling, or a hybrid application of passive design combined with active contribution, holds the greatest potential for economical application in Western climates. Passive applications have not received sufficient attention.

This plan proposes four projects to advance passive and hybrid heating and cooling (2.5.1, 2.5.2, 2.5.3, and 2.5.4).

Water Heating. Active solar water heating (and in some climates passive) is an at-hand technology which presently appears more economically feasible than space heating and cooling. Further, solar heating of water can make a worthwhile impact on the nation's energy balance. In warmer Western climates, such as in Hawaii, southern Arizona, and parts of Nevada and California, space heating requirements are low or nil, while water heating requirements are the same as elsewhere. Solar heating of water in this region can make a near-term contribution to the United States energy supply.

One project in this plan (2.5.5) directly applies to water heating and several others contribute.

Wind Energy Conversion. In many areas of the West winds are regular and predictable. Both small wind machines for farms and isolated localities and large wind machines for electric generation may be practical at numerous coastal and high plains sites.

Three projects (2.5.8, 2.5.10, and 2.5.12) address wind power use, and Project 2.5.9 may involve wind uses.

Space Cooling. The wide range of Western climatic areas includes much of the Sun Belt where space cooling presently places heavy demands on electric power supplies. While solar space cooling technology (except for passive) is not so well-advanced, and while the economics of space cooling presently are forbidding, the national benefits from solar space cooling could be indeed substantial. Therefore, this plan includes Project 2.5.11 to stimulate development of space cooling.

Section 3 Recommended Organization

It is recommended that the Solar Energy Plan for the Western Region be implemented by the Western Solar Utilization Network (Western SUN), which has been established by executive orders of the governors of several of the 13 states, conforming to the terms of a supplemental agreement pursuant to Article VII of the Western Interstate Nuclear Compact. This compact has been recognized by Federal legislation and ratified by the legislatures of 12 of the 13 participating states. The agreement permits participation also by North Dakota, South Dakota, and Nebraska, should any of these states desire to join and do not participate in another regional solar organization as recognized by the Department of Energy.

The terms of this agreement provide that control of Western SUN will be vested in a board of directors, the individual members of which will be designated in a manner to be determined by the governors of each state, with each state having one vote.

This board has the power to enter into contracts with the Federal government. Subject to contractual obligations with the Federal government, the board has authority to employ an Executive Director who, in turn, will employ a staff.

The proposed functional organization of Western SUN includes five divisions--Plans, Programs, and Budget; Analysis and Evaluation; Management and Coordination; Commercialization; and Administration--reporting to an Executive Director and Deputy. At the time of submission of this plan, a search for the Executive Director was well underway. Employment of an Executive Director, acceptable to the Department of Energy, could take place as early as April 1978.

The Western SUN will employ 57 persons--31 professionals and 13 support personnel in the central office plus 13 state liaison people--by the end of the first fiscal year of operation, if all projects recommended in this plan are implemented. If not all projects are approved for implementation, the size of the staff will be adjusted accordingly.

Western SUN will disperse its work widely throughout the region through contracts with private entities, public agencies, and participating states. The Western SUN central office will serve as a contracting agency and will not establish or maintain organic laboratory facilities nor, in general, conduct in-house the effort contemplated in the proposed projects. Particular emphasis will be placed on coordinating projects and tasks with SERI, the other regions, DOE contractors and, of course, with the appropriate DOE offices.

States, or entities designated by states, will be the contracting agencies for several projects. This is in keeping with the Western SUN philosophy that the most effective execution of many of the projects can best be made by governmental entities close to the people.

The Solar Planning Committee selected the general area of Portland, Oregon for the central office of Western SUN.

Section 4 Cost Estimates

Cost estimates for implementation of this plan during its first fiscal year are provided in Section 4.0, which is bound into a separate volume. The total projected costs for the first year are $15,209,800, of which $13,789,000 is for fulfillment of the contracts provided for in the recommended projects and $1,420,800 is for operation of Western SUN.

These total costs are based on implementation of all the recommended projects. If only a portion of the projects is approved by the Department of Energy, both project costs and Western SUN central office costs will be reduced accordingly.

PASSIVE AND HYBRID SOLAR HEATING

DAVID WRIGHT

David Wright, A.I.A.
Environmental Architect
Sea Ranch, California

Passive Solar Architecture

Passive solar architecture relates to energy conservation in a number of ways. Microclimate design tailored to local environmental influences dictates the architectural and solar tempering approaches including: siting, form, material use, and system suitability.

Traditionally, throughout the world, man has designed structures that are well suited to local conditions. Some excellent examples of extreme variation in climate and design approach exist in neighboring communities of a western province of Saudi Arabia. Closer to home, in the American southwest, the early inhabitants built dwelling complexes which illustrate many features of applied microclimate design. We can learn a great deal about conservation and survival from architecture of the past.

Contemporary solar architecture has its roots in early 1970 houses built in New Mexico. Three projects show the development and variation of one approach to direct gain passive solar and low energy structures for particular microclimates in a specific climate zone. Over 90 percent heating can be accomplished with simple methods using natural systems in even harsh climates, at building costs comparable to conventional structures.

Experience gained in several residential designs for the southwest was applied to an extremely different microclimate on the Northern California Coast. The result is a 94 percent heated and cooled-manually controlled passive solar home. This architectural statement demonstrates the possibilities of self-sufficiency and logic in form, which could influence our design approach to modern architecture.

The potential use of passive systems in most life zones of the world is both widespread and very cost-effective. With the gaining experience in designing for specific microclimates and with the development of in-progress experimental materials, passive solar architecture should prove to be the first consideration for energy-efficient structures world-wide.

RULES OF THUMB FOR PASSIVE SOLAR HEATING

by

J. Douglas Balcomb
Los Alamos Scientific Lab
Los Alamos, NM

The following "Rules of Thumb for Passive Solar Heating in Northern New Mexico: were published in the"New Mexico Solar Energy Association Bulletin", Volume 2, numbers 5, 6 and 7 by J. Douglas Balcomb of Los Alamos Scientific Laboratories.

Rule of Thumb #1

"Two to three feet of south-facing double glazing should be used for each BTU/^{o}F-hr of additional thermal load (i.e., exclusive of the glazing). This will give 70% to 80% solar heating in northern New Mexico (Los Alamos) for a building kept within the range of 65^{o}F to 75^{o}F."

An example may clarify the use of this rule. The first and most essential step is to calculate the heat load. This serves not only to provide a necessary number, but also to emphasize the important components.

Suppose that we have a building having the following characteristics:

Floor Area	1320 ft^2 (22 ft north-south by 60 ft east-west)
Walls	2- by 6-inch frame, 8-ft high, R-19 batts celotex siding
Roof	Shed roof over attic, 8-in. loose-fill insulation
Windows	Double panes (east, west, and north walls), 5% of wall area
Foundation	Slab on grade, 2-ft-thick perimeter insulation (R-10)

Suppose further that, after assuming a series of R-values, we find the following:

Walls	R = 22.0 (U = 0.045)

Ceiling R = 31.0 (U = .032)

We then determine the overall products of U & A:

Opaque walls	790 ft^2 x 0.045 =	36
Ceiling	1320 ft^2 x 0.032 =	42
Windows	42 ft^2 x 0.55 =	23
Perimeter	164 ft^2 x 0.17 =	28
Total Conductance (BTU/h-^{o}F)		129

Notice that this calculation does not include the south (60-ft) wall which is to be the collector.

Now we must add in infiltration. With ample caulk as well as proper attention to weather-stripping, vestibules, and dampers on fireplaces and vents, the throughflow might be reduced in cold weather to one-half of the air exchange per hour. Since air has a specific heat of about 0.014 BTU/ft^3-^{o}F at our altitude, the additional heat required to warm this throughflow of air is 0.014 x 10148 ft^3 x 0.5/h = 71 BTU/h-^{o}F.

Now we can use the Rule of Thumb. For 70% solar heating, we estimate that 2 ft^2 of south double-glazing is needed for each BTU/h-^{o}F of heat load, which leads to 2 x 200 = 400 ft^2 of glazing.

Fortunately, this is less than the 480 ft^2 of available south wall area. The remaining 80 ft^2 will probably be needed for glazing supports, end walls, doors, etc.

This house will never freeze if sufficient thermal storage is used. It will be about 70% solar heated if auxiliary heat is used to keep the interior above 63^{o}F, but it can be 100% solar heated with some tolerance and the use of sweaters. A better solution might be a small wood stove to add cheer and warmth on those snowy winter evenings.

It should be pointed out that there is a large difference between single and double glazing, primarily due to the huge heat loss at night through single-glazed windows.

Movable insulation can be used to reduce heat losses at night and still let solar energy in through the glazing during the day. The expected gain due to the use of good movable insulation is shown in Figure 8, page 62 of LA-UR-77-1162, by the dashed curves. Note that the use of single glazing now becomes viable whereas it was not very interesting without the movable insulation. In order to determine these curves, an R-value of 10 was assumed between the hours of 5 p.m. and 8 a.m. Such a value would be difficult to achieve with any sort of curtain or folding panel arrangement (due to edge leakage), although it could be achieved with beadwall or a tight-fitting panel. However, most of the gain associated with the movable insulation can be obtained with less than this ideal. For example, one-half of the advantage gained by placing R-10 insulation over double glazing at night could be achieved with R-3.3 insulation.

Rule of Thumb #2

"A thermal storage capacity of at least 30 lbs of water, or 150 lbs of masonry or rock should be used for each square foot of south glass. This storage should be located in the direct sun. If it is not located in the sun, four times more storage is needed."

Thermal storage prevents the building from overheating during sunny days. The sun's heat raises the large mass of material a few degrees in temperature rather than raising a small mass of building air and fabric to a high temperature. This has two benefits: 1) it greatly increases comfort, and 2) it provides a means of saving heating until night.

Thermal storage also works in the summer to provide a means of saving nighttime coolness into the day. More precisely, the excess heat accumulated in the daytime is absorbed in the building mass and then surrendered to the environment at night. This "flywheel" effect is responsible for the legendary ability of adobe buildings to remain cool in the summer. In effect, such buildings average the temperature over the entire 24 hours of the summer day.

In order to be most effective for winter solar heating, thermal storage mass must be absorbed directly by the mass for storage, as in the case of a water wall or Trombe wall. In such a case, the temperature variation of the storage mass may be approximately twice the temperature variation of the building air. If, instead, the storage mass is indirectly heated (by building air which has first been heated by the sun), then the temperature variations are usually about one-half those of the building air. Consequently, direct thermal storage will hold roughly four times as much heat as indirect storage for the same air-temperature variation. The preceeding example can be used to illustrate how these principles might be applied.

The building has the following characteristics:

Floor Area	1320 ft^2 (22 ft north-south by 60 ft east-west)
Walls	R-22
Roof	Shed over attic, R-31
Windows	Double-glazed (east, west, and north) 5% of wall area
South Wall	400 ft^2 of double glazing, 80 ft^2 opaque (R-22)

The thermal load can now be determined:

Opaque Walls	790 ft^2 x 0.045 =	36
Ceilings	1320 ft^2 x 0.032 =	42

Windows (E, W, N)	42 ft^2 x 0.550 = 23
Perimeter	164 ft^2 x 0.170 = 28
Infiltration	10148 ft^2 x 0.014 x 0.5 = 71
Subtotal (BTU h^oF)	200
South Glazing	400 ft^2 x 0.55 = 220
South Opaque Wall	80 ft^2 x 0.045 = 4
Total (BTU/h^oF)	424

The Rule of Thumb indicates that we should use either 30 x 400 = 12,000 pounds (1440 gallons) of water or 150 x 400 = 60;000 pounds of rock or masonry for direct thermal storage.

What happens on a clear winter day? The solar radiation transmitted through the south wall is roughly 1400 BTU/ft^2 over an 8-hour period for a total of 400 x 1400 = 560,000 BTU. If the average ambient temperature is 30^oF and the average room temperature is 75^oF, then the losses over this period total only (75-30) x 424 x 8 = 152,000 BTU. The excess heat to be stored is then 560,000-152,000 = 408,000 BTU.

Where should the thermal storage mass be located? This is largely a matter of architectural design and personal preference. Returning to the example, suppose that the designer specifies 15, dark brown, vertical 14- by 24-in adobe columns evenly spaced along the south side just behind the glazing; a 6-in concrete slab floor, and 35 ft. of 8-in-thick interior adobe mass walls which are 8-ft-high. For an interior air temperature rise of 15^oF, we might expect the following situation:

Storage	Mass (lb)		Temperature Rise (^oF)		Heat Capacity		Stored Heat
Columns	33,600	x	30	x	0.2	=	202,000
Floor (S)	36,000	x	15	x	0.2	=	108,000
Floor (N)	63,000	x	5	x	0.2	=	63,000
Walls	22,000	x	3	x	0.2	=	35,000
Total	154,600						408,000

This heat is returned to the building at night. If the average outside temperature is 5^oF during the remaining 16 hours of the day and average inside temperature is 65^oF, then the heat loss is (65-5) x 45 x 16 = 407,000 BTU.

Rule of Thumb #3

"Shading of south windows should be used to reduce summer and fall overheating. One effective geometry is a roof overhang which will just shade the top of the window at a noon sun elevation of 45^o and will fully shade the window at a noon sun elevation of 78^o."

Rule of Thumb #4

"The best thickness of a Trombe wall is from 12 to 16 inches. The masonry should have a high density - at least 100 lb./ft^3. Thermocirculation vents can be used to increase daytime heating but will not increase nighttime minimums. Vents should have lightweight passive backdraft dampers or other means preventing of reverse flow at night."

SOLAR RADIATION STATIONS IN THE PACIFIC NORTHWEST

by

M.S. Baker, H.D. Kaehn
Solar Energy Center
University of Oregon

IDAHO

	LOCATION	DATA	EQUIPMENT	AGENCY
1.	Boise	Global, Direct	Pyranometer Pyrheliometer	National Weather Service Boise, Idaho (208)
2.	Boise	Global	Pyranometer	Intermountain Gas Boise, Idaho 83707 (208) 377-6000
3.	Pocatello	Global	Pyranometer	
4.	Idaho Falls	Global	Pyranometer	
5.	Boise	Global; Tilt; Tracking w/tube shield	Pyranometer	Boise State Univ. Dept. of Engineering Boise, Idaho 87325 (208) 385-1011
6.	Bruno	Global	Pyrenometer	Computerized Farming Nampa, Idaho (208) 467-5796
7.	Idaho Falls	Global; Direct; Diffuse; Tilt	Pyranometer Pyrheliometer	Idaho Nat. Eng. Lab. Idaho Falls, Idaho 83401 (208) 526-2328
8.	Kimberly	Global	Pyranometer	Snake River Research Kimberly, Idaho 83341 (208) 423-5582
9.	Moscow	Global	Solar cell	Univ. of Idaho Dept. of Engineering Moscow, Idaho (208) 885-6554
10.	Raft River	Global; Direct	Pyranometer Pyrheliometer	E.G.G. Idaho Falls, Idaho 83401 (208) 526-1783
11.	Rexburg	Global; Tilt (45°)	Pyranometer	Ricks College Rexburg, Idaho 83440 (208) 356-1142
12.	Aberdeen	Global	Pyranometer	
13.	Wilder	Global	Pyranometer	Bureau of Reclamation Boise, Idaho (208) 384-1176
14.	Rupert	Global	Pyranometer	

Oregon

LOCATION	DATA	EQUIPMENT	AGENCY
1. Banks	Global; Tilt	Pyranometer	
2. Carty West	Global	Pyranometer	Portland General Elec. Energy Programs Portland, Or 97204 (503) 226-8478
3. Gladstone	Global; Tilt	Pyranometer	
4. Pebble Springs	Global	Pyranometer	
5. Salem	Global; Tilt	Pyranometer	
6. Grants Pass	Global; Tilt		Pacific Power & Light Portland, Or. 97204 (503) 243-4866
7. Portland	Global; Tilt	Pyranometer	
8. Tigard	Global; Tilt		
9. Corvallis	Global	Pyranometer	O.S.U./N.W.S Corvallis, Or. 97330 (503) 754-2745
10. Klamath Falls	Global	Pyranometer	
11. Portland	Global	Pyranometer	
12. Redmond	Global	Pyranometer	
13. Medford	Global; Direct	Pyranometer Pyrheliometer	
14. Corvallis	Global	Pyranometer	Oregon State Univ. Dept. of Mech. Eng. Corvallis, Or 97331 (503) 754-4646
15. Newport	Global	Pyranometer	
16. Garden Valley	Global	Pyranograph	Douglas Co. Water Resources Roseburg, Or. 97470 (503) 672-3311
17. Melrose	Global	Pyranograph	
18. Myrtle Creek	Global	Pyranograph	

LOCATION	DATA	EQUIPMENT	AGENCY
19. Bend	Global	Pyranometer	
20. Charleston	Global	Pyranograph	
21. Coos Bay	Global	Pyranometer	Univ. of Oregon Solar Energy Center Eugene, Or 97403 (503) 686-3623
22. Eugene	Global; Tilt (60°); Direct	Pyranometer; Pyrheliometer	
23. La Grande	Global	Pyranometer	
24. Whitehorse Ranch	Global	Pyranometer	
25. Burns	Global	Pyranometer	Squaw Butte Exp. Sta. Burns, Or. 97720 (503) 573-2064
26. La Pine	Tilt	Solar Cell	Pacific N.W. Bell Portland, Or. 97204 (503) 224-6261
27. St. Helens	Global	Pyranograph	Reichold Chemical Inc. St. Helens, Or. (503) 397-2225
28. Coos Bay	Tilt	Pyranometer	Boeing Seattle, Wash. (206) 773-0640
29. Stayton	Global; Tilt (90° w/reflector)	Pyranometer	
30. Portland	Global	Pyranometer	Lewis & Clark College Dept. of Physics Portland, Or. 97219 (503) 244-6161

Washington

	LOCATION	DATA	EQUIPMENT	AGENCY
1.	Bainbridge Island	Global	Pyranometer	
2.	Findley Lake	Global	Pyranometer	University of Washington Dept. of Forestry Seattle, Wash. 98195 (206) 543-4345
3.	Mt. Rainier	Global	Pyranometer	
4.	Medical Lake	Global; Diffuse, Photometric	Pyranometer	
5.	Seattle	Global; Diffuse, Photometric	Pyranometer	
6.	Fort Steilacum	Global; Diffuse, Photometric	Pyranometer	Univ. of Washington Dept. of Forestry Seattle, Wash. 98195 (206) 543-4345
7.	Seattle	Global	Pyranometer	Univ. of Washington Dept. of Atmospheric Sciences Seattle, Wash. 98195 (206) 543-4584
8.	Seattle	Tilt (60°)	Pyranometer	Seattle City Light Seattle, Wash. (206) 625-3553
9.	Edmonds	Global	Pyranometer	Snohomish P.U.D. Everett, Wash. (206) 259-9661
10.	Juanita	Tilt (60°)	Pyranometer	Boeing Seattle, Wash. (206) 773-9636
11.	Arlington	Global; Tilt, Tilt w/shadowband	Pyranometer	Ecotope Seattle, Wash. 98112 (206) 322-3753
12.	Camano Island	Global	Pyranometer	Puget Power & Light Seattle, Wash. (206) 454-6363
13.	West Roosevelt	Global	Pyranometer	Pacific Power & Light Portland, Or. 97204 (503) 243-4224
14.	Olympia	Global	Pyranometer	Evergreen State College Physics Dept. Olympia, Wash. 98505 (206) 866-6009

LOCATION	DATA	EQUIPMENT	AGENCY
15. Vancouver	Global; Diffuse	Pyranometer	Bonneville Power Admin. Portland, Or. (503) 234-3361
16. Richland	Global	Pyranometer	Sigma Research Richland, Wash. (509) 946 4161
17. Richland	Global	Pyranometer	Olympic Engineering Richland, Wash. 99352 (509) 942-7416
18. Hanford	Global	Pyranometer	Battelle N. W. Atmospheric Sciences Dept. Richland, Wash. 99352 (509) 942-7416
19. Rattlesnake Mt.	Global	Pyranometer	"
20. Othello	Global	Pyranometer	Computerized Farming Othello, Wash. 99344 (509) 488-9291
21. Spokane	Global	Pyranometer	Washington Water & Power Spokane. WAsh. 99220 (509) 489-0500
22. Seattle-Tacoma	Global, Direct	Pyranometer	National Weather Service Seattle-Tacoma Airport
23. Winthrop	Global	Solar cell	Alternative Energy Winthrop, Wash.
24. Friday Harbor	Global	Pyranometer	Univ. of Washington College of Fisheries Seattle, Washington

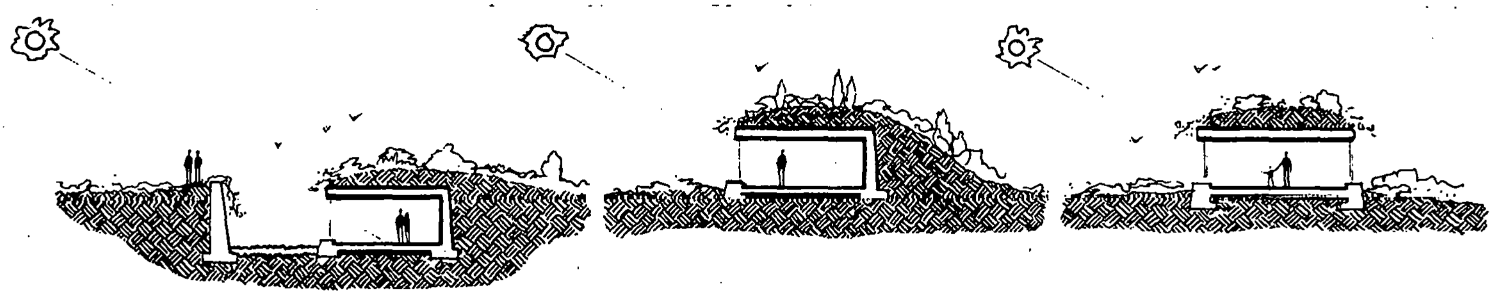
PRINCIPLES FOR GOING UNDERGROUND

by

Dave Deppen

The attractions of underground architecture include land conservation, long-lasting structures and reduced fuel use. But the biggest news usually seems to be that those advantages are possible in bright, sunny buildings with beautiful views out across the landscape.

How is this possible? Well, it's because under ground buildings have earth-covered roofs and have protecting earth at most outside walls, but they need not be deep below grade. We can build underground in any of the ways shown in these cross-sections.



A number of do's, don'ts, new opportunities and possible mistakes stand out when we plan to go underground. Here are some of the most common ones which need to be considered.

LAND

The best sites are ruined land. Ideal places are eroded, logged over, scarred, full of asphalt or in the ugliest parts of the cities. If you are lucky enough to find such a place, you'll often pay a lower price and have the great experience of nurturing a once dead area back into a beautiful green place. The underground office where I used to work was built on a scab of land 20 feet from a 6 lane freeway, but the interiors were quiet as a hush and today the place looks like a tropical oasis.

It's essential to build above the water table. That means determining the highest (not average) level that ground water may reach at the building site. Sources for that information are test borings by a soils engineer, the Soil Conservation Service and sometimes observant neighbors. Land with high water tables is often ideal for building on grade then berming earth around the sides and over top of the structure. A real respect for the ways of moving water is important. Working with it, not against it, saves many worries.

CODES

I'm not aware of any building code requirement that is a problem for well-designed underground buildings. The Uniform Building Code requires openable windows (or outside doors) in bedrooms. The reason is fire exits. That's fine. We wouldn't want these rooms without safe ways out. Natural light is required throughout most rooms of a house. Since underground houses can easily be designed to look out to open vistas, courtyards and light wells, that's fine too.

DESIGN

A primary source of ideas for a good design is the unique features of a particular site. Every site is a little different and the greatest satisfaction comes from tirelessly working with the special opportunities and limitations that a particular piece of land provides. I'm always amazed at how even the sites which seem to be so faceless and dull at first have a wealth of information for us when we start observing closely (and do our homework).

Likewise, a plan designed for one site can never blindly be built on another site. All sorts of embarrassments can happen when that's attempted: slopes go the wrong way, trees pop up in unexpected places, and all of the previous careful planning for the wise use of sun and breezes goes haywire.

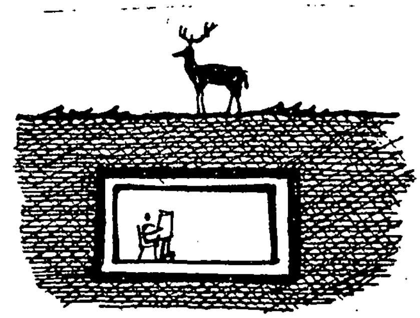
Gently and inconspicuously tucking the building into the site can provide beautiful results. An underground building can achieve a wonderful repose on the land. Beware of jarring retaining walls, overbearing garage doors and other features that would mar that sense of repose. Really good underground buildings have ways of presenting themselves to us in a very graceful manner.

Design takes time. Many people, charged up with the excitement of going underground, want to start digging right away! That enthusiasm is great, but the crucial design decisions that will shape the face of the land for better or worse for many lifetimes and effect thousands of dollars must go through a lot of churning and hard re-evaluation. Using land for any kind of building is a really awesome responsibility.

To simplify is crucial. This is sometimes a bitter lesson. The temptation to go overboard is very common on a first underground project. It is often puzzling to see the complicated roofs, huge maze-like floor plans, and extensive gadgetry proposed for many first projects. The more we discipline ourselves toward simple, but well thought out buildings, the better the results will be.

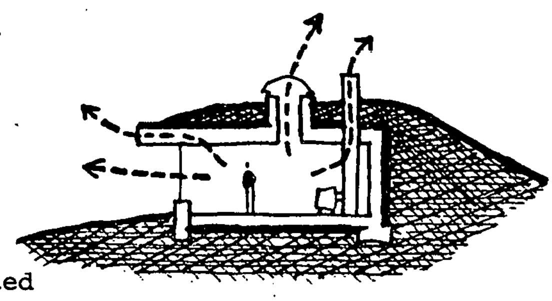
A real delight about going underground is that the building changes for the better as the years go by. Wildlife makes itself at home. Trees mature. Vines grow. The succession of native plants keeps us alert to the seasons. Don't worry if on move-in day the building looks somehow unfinished. It is unfinished. But the rest of the work will now be done by nature.

HEAT LEAKS

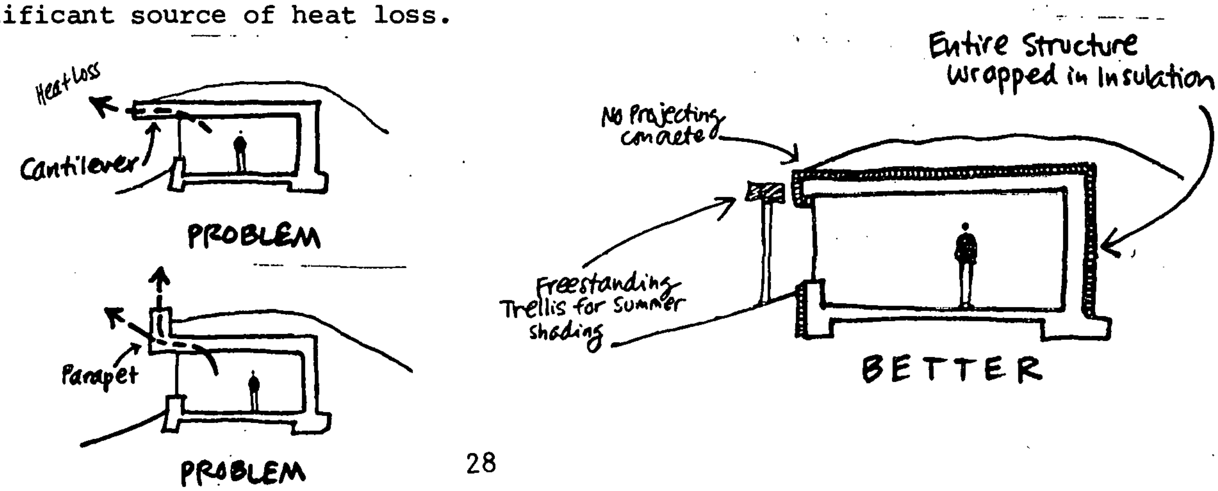


Often when we think about the energy efficiency of underground buildings we conjure up images of a stable 55° environment that hardly needs any fuel.

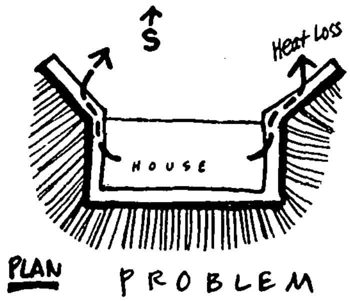
However, when we get to designing a building in which we want to live or work, the picture changes. We might put in lots of windows and skylights for light and view. We put in the doors. We put in vent pipes for the plumbing and flues for any back-up heating equipment. Suddenly we find that the design is poked quite thoroughly full of holes. Also, the earth cover on the roof is quite shallow now in an effort to trim structural costs. No constant 55° up there! And somehow the structure usually begins to bristle with heat bleeding projections. The building now has heat leaks galore. Here are some ways we cut down all that anticipated loss.

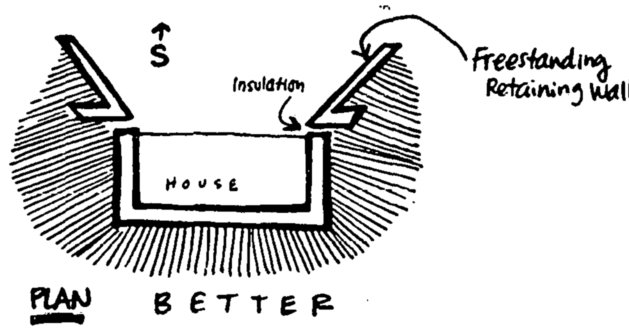


Avoid cantilever roof slabs and parapet walls. They are very tempting to use. The designers of the (current) first generation of underground buildings learned the lesson well: those projections are a significant source of heat loss.



Avoid retaining walls that are extentions of the building's structure. These bleed heat, too.





Evaluate the need for skylights very carefully. Conventional skylights are notorious for their potential water leaks and have a way of letting heat pour out in the winter and in in the summer.

Insulate well around the entire building. Earth will not do the job by itself. Earth is great at moderating temperature around a building and protecting it from scouring winds, but for insulation value the commercial boards must be used.

MATERIALS

It's a pleasure to work with materials for underground construction. That's because they're so substantial. They have to be. Everybody hates the thought of all that digging to make repairs. Actually, a whole new way of thinking has to be used when judging materials. We're building for very long periods of time and must ask ourselves over and over: "What will be the condition of this material in 100 years?" The discipline which comes from asking that question is somewhat maddening.

Superior underground waterproofings are much more costly than shingles, but they sure last longer. It's important to only use waterproofing products which the manufacturer specifically recommends - in literature - for underground use. Most any waterproofing application must be treated as a "system" using the primers, edge treatments and accessories as recommended by the manufacturer. Many waterproofings - while resistant to liquid water - are not resistant to water vapor. For underground uses, we need resistance to both. Of the many liquid and sheet waterproofings, my favorite for many applications is 1/16" butyl rubber sheets. The sheet form has the advantage of a manufactured uniform thickness. No matter what waterproofing is used, the crucial factor is the quality of the workmanship during installation.

Rigid insulation boards all around the structure and in contact with earth must be selected with one overriding concern: they must be of a type which will not eventually soak up water. Some of the rigid insulations now used in the ground in homebuilding will soak up water over time and thus become worthless.

TRICKY TRANSITIONS

The materials that go completely underground can be planned in a quite straightforward way. Likewise, the materials which cover the building's above ground surfaces are straightforward. The real challenge comes when we must consider the transitions between the underground and above ground areas. The most common of these transitions occur (1) at the fascia where the earth-covered roof and an exposed wall meet, (2) on vertical walls near grade level, and (3) at isolated windows and doors in an earth bermed area. These transitions are more vulnerable to leaks and material deterioration than the straightforward underground and below grade areas. They are also areas where costs can skyrocket due to the flashings, sealants and blocking involved , as well as the extra fitting time involved. It's important to keep these transitions to a minimum. Always designing in 3 dimensions with a watchful eye on all earth contouring will help keep the transition areas manageable.

HUMIDITY

Humidity levels need be no special problem in a properly designed building if we remember a few basics. In a new building curing concrete releases moisture into the air. This means a dehumidifier is usually necessary for perhaps the first 2 years as the structure drys out. After that time the dehumidifier may be used as required by weather conditions. Remember that most conventional buildings are annoyingly dry in the winter heating season. Our goal must be to produce the most healthy humidity levels.

LANDSCAPING

A reasonable depth of earth cover on a roof often ranges from 1-1/2' to 3'. At less than 1-1/2' the soil is prone to dry out too quickly in the summer. Over 3' the structural support costs become quite high.

Grading all slopes away from the building is a must. There should be gentle slopes on rooftop areas to prevent ponding. General site slopes toward the building must be diverted before they reach the building, usually by gentle drainage swales. Otherwise the building may be subjected to undue water pressure.

Deep mulching on top of the soil provides a lightweight covering that helps retain soil moisture, prevents erosion and provides a protective cover for the host of young plants establishing themselves on the roof and berms. Ideal mulches in this case are those that blend with the landscape and decompose rather quickly. No bark chunks!

Rooftop plantings may include some transplanted native shrubs and small trees (depending on the design of the structure) with the major portion of the roof allowed to go through the natural succession that determines what's best suited for that place. Yes, it takes a bit of courage to let that happen, but the watering, inevitable replacing and tending to exotics which don't belong there isn't really very sensible. Our spirits soar when the first wildflowers appear. They're hardy, cheery and colorful. It's hard to imagine better rooftop citizens.

FURTHER READING: Underground Designs by Malcolm Wells, 1977

Sparta Passive Solar House - Andrew Laidlaw

During the summer and early autumn of 1977, Andrew and Augusta Laidlaw built a passive solar home with Jim Bourquin, in Sparta, Oregon. Located 35 miles northeast of Baker, Sparta, a once roaring gold town, is now a dirt crossing where the high desert sage meets the Ponderosas of the Wallawa Mountains.

The 160 acre plot offered two springs, a cat-scrape road, no electricity but the wind for eventual power, along with numerous rodents and snakes, and that hot summer sun. The choosen site lay in a slight eastern slope- below the main spring, where the road was near, the soil deep and the views arresting.

It was mutually felt that the house should be warm and draft free in winter, cool in summer, rodent and reptile free at all times, small, unobtrusive, and inexpensive. We had just finished building a passive solar greenhouse in Noti, Or. and felt that this would be another good application for sunk-in-the-ground , thermally massive construction.

The house was designed with three seperate areas of temperature: cold storage for food,a cool sleeping space, and a comfortable living area.

The cistern room, for food storage, is a concrete walled root cellar, dug about 10 feet into the ground, behind and below the main living area. The two 300 gallon cisterns, dug a further 6 feet, act as additional thermal ballast, as well as being the water storage-purification system. Water, seeping into draintile in 2 graveled trenches, is conducted into a 300 gallon collection box. The line from the bottom of the collection box runs downhill to the first cistern, where the flow is regulated by a gate valve. (Two offshoot lines provide irrigation water for the garden between the spring and the house.) A small pipe near the top of cistern 1 leads to the second tank, where water is pumped to the kitchen or to a holding tank for a solar water heater, not yet completed. A small runoof pipe into the front field allows for the constant movement of water, thus clarifying it. Inbedded in the top of one of the cisterns is a "tuff tub" which stores the most perishable groceries for several days. Because of the spring water flowing around it, and the heavily insulated lid, the tub retains a 40-50 F. temperature, while the cistern room remains about 35-60F.

The sleeping area is a light-framed room above the cistern room and front porch. Its many windows and door onto a future back deck, allow for good air circulation in summer. Insulated from the living area below, it remains cool in winter, yet heat can be regulated by opening the door to the solar living area.

The living area, a 12' x 22' kitchen-dining-living room with a 4' x 10' L to accomodate a reading corner, appears to be quite spacious because of its high ceiling and the glass south side.

Set into the bank 8' on the prevailing westerly wind side, it opens out to ground level on the East, creating a blusterless microclimate on the front porch.

The living area is a concrete shell: a 4" slab floor, a southern concrete wall rising to 4' and continuing as glazing at 45 to the ridge, 8' concrete walls to the north and west, and a fenestrated east wall opening to the porch.

The mass walls are concrete poured into forms of rough sawn lumber and vibrated, leaving the wood texture as a finished surface. Thus the 17 tons of mass is the primary structural element and critter control. The drawback of the solid smooth mass is the decreased air-mass heat transfer, further reduced by the lack of an assisting fan.

Two inches of extruded styrofoam between 2x4 sleepers insulate the mass from the ground. Galvanized roofing, caulked at all joints, shield the insulation from rodent nesting and water penetration. Further protection is provided by gravel and drain tile.

The concrete slab has 1" brick pavers covering the kitchen-utility areas. Square particle board, varnished to 'immitate' cork, softens the appearance of the remainder of the room.

Southern glazing is 160 square feet of glass set at a 45 angle. This consists of 9 34"x76" sheets of home-made thermopane. This module became a major design consideration, for the patio lites, from which they were made, were purchased on a 'deal'. Being tempered glass, they could not be cut. The thermopane was made by sandwiching a 1x1, grooved to hold silicone caulk, between two sheets of glass. Silica Gel, a chemical used to remove moisture, was placed in a punctured copper or PVC tubes within the module. A final coating of silicone caulk sealed the wood and glass together, ideally. The southern surface, in the desert sun, or in snow reflected light, became hot enough to cause the gel to reemit the moisture; thus, the windows fogged.

However, the shutter system, not installed until this spring, seems to have solved this problem along with another major concern this winter- glare. Bright light, reflected off the winter landscape caused "snowblindness." In addition, the heat loss at night was considerable.

The principal criteria in designing the shutters, in addition to providing winter evening insulation, was to shade the glazing in the summer, while still providing a view. This necessitated the shutters being outside the building. They were constructed of 2" styrofoam cased between two thin layers of plywood, covered with galvanized metal on the top, and painted white on the bottom. A horizontal beam above the plane of the roof surface, reminiscent of an automobile "spoiler", was used to attain enough mechanical advantage (or decrease mechanical disadvantage) to be able to lift the shutters with a hand operated winch.

The ventilation system consists of 3 operable windows to the East, and a "flusher" on the West. The "flusher" is a tringular wall panel, 2' on a side, where the rafters meet the ridge above the concrete wall. Heavily insulated and tight in winter, the panel opens in summer to either suck the hot ceiling air out, or to flush the room with the prevailing breeze.

Winter circulation consists of either opening the windows, or the door to upstairs. There is presently a problem of heat stratification. Ceiling temperatures reach 100 F, particularly when the wood cookstove, the only additionaly heat source, is in use. Eventually this excess warmth will be used in heating the upstairs area through ceiling vents.

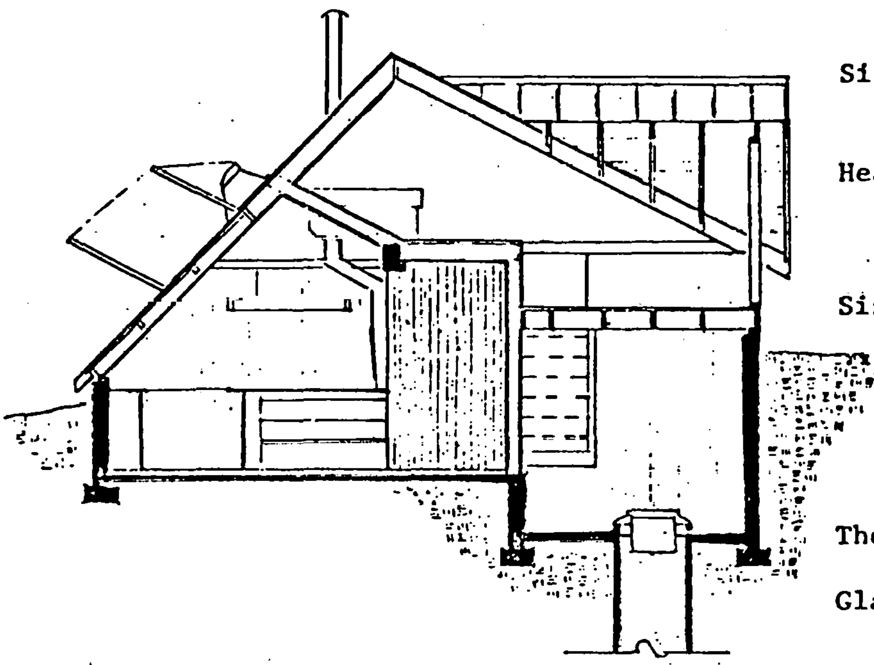
Conclusions:
The house performs very well. It is warm in winter, and being sunk in the ground, is not at all drafty. It should be even more comfortable next winter with the shutters. The thermal mass and shading shutters work exceptionally well for summer cooling, as does the triangular panel. Using the building to create a microclimate for the porch to the leaward, is very effective. It is pleasant to sit outside here, but when you turn the corner or the house, a cold wind greets you.

Certain of our design decisions, however, could be improved upon in future applications. The angled glass, with external shutters for shade, create detailing and operational problems that could be greatly simplified with vertical glazing. The south wall of the living area is exposed thermal mass. Although this area works well for summer cooling, it is a bit cold to sit next to in winter. It remains about 10 cooler than the other mass surfaces. We hope the light underside of the shutters will reflect low inter sun onto this surface, partially alleviating the problem.

One of the most attractive aspects of living in this house is the very bright yet filtered quality of the light inside. After becoming accustomed to this cheery atmosphere, we find the interiors of most conventional home dark and depressing.

Sparta Solar House - Andrew Laidlaw, designer

2019 N. 16
Boise, Id. 83702



Site: Sparta, Or. 35 miles NE of Baker, in Wallawa Mts.

Heating System: Passive Solar, wood cookstove, as auxillary. No electricity available

Size: 500 sq. ft. includes:
- Cistern room for food storage.
- 300 sq. ft. passive solar living-dining-kitchen area.
- sleeping area with heat by convection from living area.

Thermal Mass: 17 tons concrete

Glazing: 160 sq. ft. 45° due South

Performance: * no shutters.
Insulating shutters installed 5/78

Average w/ stove

	high	low
Inside:	79	45.3
Outside:	35	25.4

Average w/out stove

	high	low
Inside:	70	45.5
Outside:	42	28.5

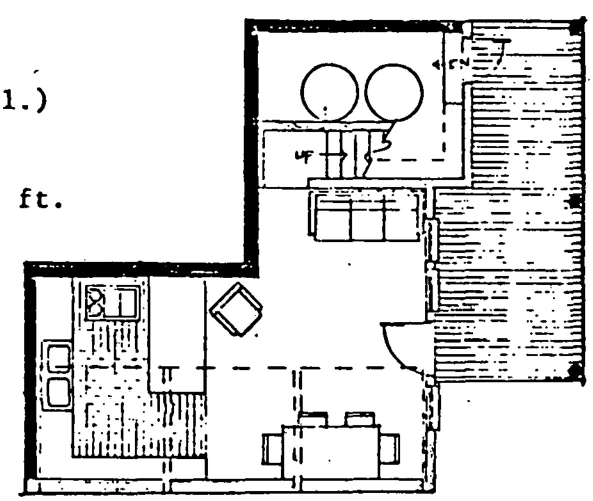
*Clear Day Cycle (Average, 5 day)

	high	low
Inside:	81	41.5
Outside:	34.8	19.4

Cloudy Day Cycle (Average, 5 day)

	high	low
Inside:	77.3	50.2
Outside:	36.7	30.8

Cost: $5,000 (includes spring devel.)
500 sq. ft. - $10 / sq. ft.
Mass wall: $3.47 / sq. ft.
Floor w/ brick: $1.89 / sq. ft.



EXPERIMENTAL EVALUATION OF THE REFLECTOR-COLLECTOR SYSTEM

H. D. Kaehn, M. Geyer, D. Fong, F. Vignola
D. Lanning and D. K. McDaniels
Solar Energy Center
University of Oregon
Eugene, Oregon 97403

1. INTRODUCTION

The first person to make use of a large reflector in an optimally oriented flat-plate collector system was H. Mathew of Coos Bay, Oregon. The performance of this solar house has been monitored since 1974 by the University of Oregon Solar Center; their analysis show a significant overall improvement in the useful energy collected over that expected for a simple flat-plate collector in the usual orientation [1].

The success of the Mathew solar house motivated us to make a theoretical study of the performance of a reflector-collector system when exposed to the direct component of the incident solar flux. Elementary considerations show that the optimum goemetry for winter operation of a reflector-collector combination has the collector oriented perpendicular to the reflector. This conclusion was verified by detailed calculations performed on an instantaneous basis [2]. The light gathered by the reflector-collector system was found to be 50-60% greater than that gathered by the simple flat-plate collector.

It was also found that the optimum reflector orientation for winter operation at 45^{o}N latitude was almost horizontal, but was a strong function of the time of day. To rectify this, a calculation of the reflector-collector system performance averaged over the entire day was made [3]. The optimum reflector orientation and the effects of finite reflector dimensions were determined in this way for winter operation assuming a direct beam.

In a forthcoming paper [4] the contribution of the diffuse component of the incident solar radiation to the light gathered by a reflector-collector system has been analyzed. It was found that the enhancement in the diffuse light gathered by a typical reflector system is about 1.1 times that gathered by an ordinary collector system.

In the final analysis it is the enhancement in the useful heat gathered by the reflector system over the standard collector configuration which is of most interest. In the paper in which we presented the calculation of the enhancement for the diffuse radiation, we also calculated the enhancement in the useful heat output using a simplified simulation model. It was found that if the solar system provides 2/3 or more of the total heating load then the useful heat obtained with the reflector system over an entire heating season is 40-50% greater than that obtained with a simple flat-plate collector.

While calculations of the usable heat output are valuable, there still exists a need for experimental evaluations under actual operating conditions. Our calculations above used monthly average radiation values, and this approach can only approximate the actual operating conditions. In addition the empirical procedures for estimating the mix of direct and diffuse components are only approximate at best. Also, the diffuse radiation is not truly isotropic as assumed so that the actual light enhancement for this component is greater than assumed. This paper describes the experimental arrangement used to make a direct comparison of the heat collected by the reflector-collector system with that of a standard collector configuration. A brief review of the theoretical analyses is given in the next section. The experimental system and mode of operation are described in section 3. The last section describes preliminary results from the data collected over the past winter and spring.

2. THEORETICAL BACKGROUND

The solar radiation collected by a reflector-collector system consists of that part collected directly by the collector and of an almost equal portion (for an optimally oriented system) contributed by reflection from the reflector onto the collector. In order to evaluate the relative performance of the reflector system as compared with that for a standard flat-plate collector configuration, we have calculated the ratio of the light collected by the reflector system to that collected by the standard collector (tilted at latitude + 15^o). We called this the enhancement factor $P_D(t)$, for the direct solar beams. For times near solar noon, the calculation gives a maximum enhancement factor of about 1.5 for a geometry in which the reflector is oriented almost horizontal and the angle between the reflector and the collector is about 100^o.

An important parameter for the reflector configuration is the orientation angle of the reflector. At 45^oN latitude the above calculations shows the optimum geometry, has the optimum reflector oriented slightly upwards at solar noon, with the topimum orientation moving appreciably downward as the time away from noon increases. To correct this ambiguity and to provide a more realistic calculation it was necessary to calculate an average daily P_D by calculating the total light gathered by the reflector system over an entire day and dividing by the same quantity calculated for the standard collector [3]. It was found that the optimum winter orientation has the reflector oriented at about 5^o downward from the horizontal. Including the finite reflector dimensions in this calculation shows that if R/L = 2 and W/L = 3, the loss in light gathered relative to that obtained with an infinite reflector is less than 5%. For this reason, the dimensions in the experimental reflector system described below were chosen to closely approximate these values.

Before any realistic calculation of the useful heat output of the reflector system can be made, it is also necessary to know the enhancement factor for the collection of the diffuse component of the incident solar radiation. It is shown in Ref. 4 that the enhancement factor for the collection of diffuse radiation (assumed isotropic) is,

$$P_d = \frac{\rho_r I_r + I_o(\pi/2)(1 + \cos\theta_T)}{I_o(\pi/2)(1 + \cos\theta^oT)} \qquad (1)$$

For a horizontal reflector and a vertical collector, the increase in diffuse light collected due to the reflector just compensates for the loss of diffuse light due to orienting the collector vertically and $P_d = 1.01$ (using a reflectance of 0.8). If the opening angle is increased to 105^o the overall enhancement for the diffuse component goes to about 1.1. Furthermore, if account is taken of the fact that ρ_r may have been chosen too low since some of the non-specular reflection goes in the forward direction then the enhancement for the diffuse component becomes even larger. Once both the direct and diffuse enhancements were known, the total intensity of radiation incident upon the absorber plate of the reflector collector system was calculated from information about the direct and diffuse contribution to the simple collector.

The useful heat output was then calculated using the simplified procedure of Swanson and Boehm [5]. This model includes the effect of storage size in a realistic manner, and includes appropriate correction factors to insure that their simplified procedure, using monthly insolation averages, agrees with more detailed simulation calculations. For reasonable storage capacities and for solar systems which provide more than 2/3 of the total heating load, it was found that the enhancement in useful heat obtained with the reflector systems is over 1.4.

3. EXPERIMENTAL ARRANGEMENT

The finite size reflector calculations show the importance of having R/L = 2 or larger, and W/L = 3 or larger. For this geometry the time-integrated analysis predicts that the direct radiation collected is less than 5% below that obtained with an infinite reflector. In order to achieve this geometry it was necessary to construct our own flat-plate collectors. The two collectors for the comparison measurement were constructed to be exactly identical. Before going on to describe the overall apparatus, we include a brief description of the construction details of the collectors.

The collector frame was made of wood because it was easy to handle, inexpensive and provided a rigid support. Care was taken to protect the wood frame against moisture and other weathering effects. All joints were caulked with a material which can stand extreme temperatures. All external surfaces were treated with a wood sealer and covered with two coats of enamel. No trace of weather damage has appeared in over 1 1/2 years of operation.

The absorber plate was made of copper in order to minimize corrosion problems since water is used as the heat exchange fluid. A grid of 1.25 cm. diameter rigid copper tubing was fastened together using a high melting point silver-bearing solder. The copper tube grid was attached to the back of a copper absorber plate (0.55 mm. thickness) by soldering in order to insure good thermal conductivity between the plate and the tubing. Black paint (3M Nextel Black Velvet) with an absorptance of 0.95 was applied to the front of the absorber.

The collectors were double glazed using 0.32 cm thick clear HERCULITE tempered glass. The spacing between the glass plates and between the inside glazing and the absorber plate is about 0.95 cm. to reduce the heat loss through the back of the collector, an 8.9 cm layer of fiberglass insulation (R-11) was placed directly underneath the absorber plate. Beneath this was placed a 2.5 cm thick layer of technifoam insulation (R-9). The latter was used because of its compact size, appropriate insulation properties and rigidity. Both collectors have a height L = 67 cm and a width W = 187 cm, and the ratio W/L = 2.8.

The reflector is comprised of individual square glass mirror tiles 30.5 cm on each side. The back-surfaced mirrors are 0.25 cm thick and have a measured specular reflectance of 0.8 for a near normal beam of direct solar radiation. The complete reflector is 215 cm wide and 184 cm long giving a maximum R/L of 2.7 which can be masked in order to study a smaller R/L.

3.1 SYSTEM OPERATION

A schematic representation of the experimental system for the reflector-collector testing program is shown in Fig. 1. The system was constructed to follow closely the NBS standards for flat-plate collector testing. Two collector systems were designed so that a direct comparison of the useful heat output of the reflector-collector system with that of a standard collector system could be made. The reference collector is mounted at 60^{o} to the horizontal plane, while the collector for the reflector system is oriented at 85^{o} to the horizontal. The reflector is mounted at 5^{o} below the horizontal plane.

The support frame was designed to be quite strong as the collectors weigh 100 kg each. UNISTRUT was chosen for this purpose because of its strength and because no welding was required in constructing the support structure. The back section of the support structure was used to house all of the electrical equipment. It was also designed to help stablize the support for the upper collector and to provide support for a roof to protect the monitoring and auxiliary equipment from precipitation.

The system operates as follows: Water is driven by a circulation pump through the pipelines to the two collectors. The flow rates in the two pipelines can be varied independently by adjusting balance valves, and the rate of flow in each line is monitored by a flowmeter. The water temperature is monitored by platinum Resistance Temperature Detectors (RTD) as it enters the collectors. The water then collects the heat from the absorption plate and the exit temperature are also monitored by RTD's. The water from both collectors is then mixed and the acquired heat is eliminated by running the return water through a heat load comprised of a pair of automobile heaters connected in parallel. The fans in the heaters are regulated so that the water returns to the storage tank at a nearly constant temperature. The water is reheated if necessary to maintain a constant inlet temperature to the collectors. The entire system is closed. Other features include the use of an RTD to monitor the ambient temperature and a pyranometer mounted in the plane of the standard collector to monitor the incident solar radiation. All data is fed to a 10

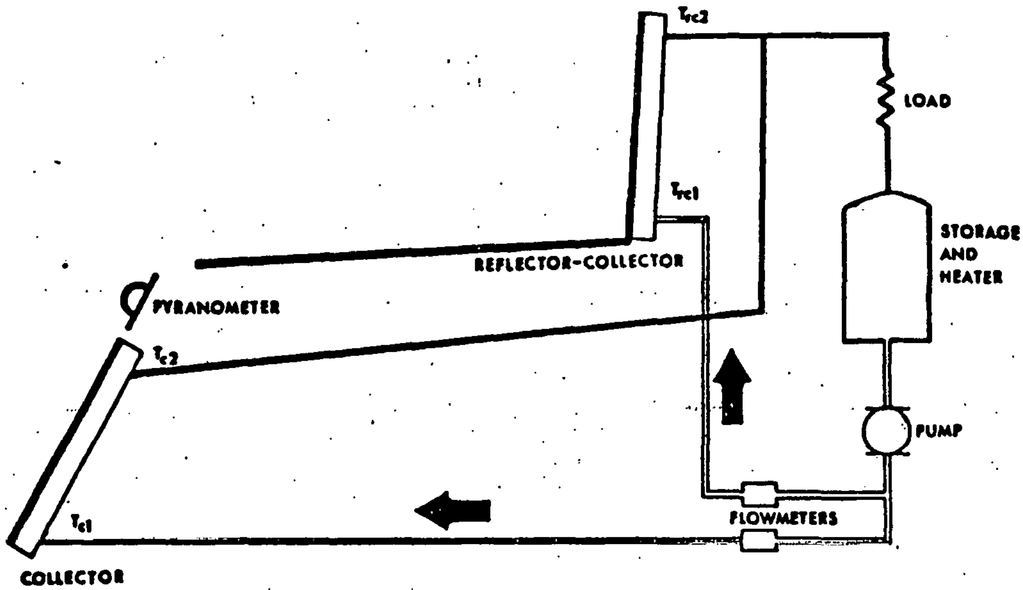


Figure 1. Schematic drawing of the system layout for the experimental tests of the performance of the reflector-collector system.

channel Data Logger which stores the information on punched paper tape. This data is transferred to magnetic tape, which can then be read into the University of Oregon PDP-10 computer for analysis.

Several problems were encountered with the instrumentation system. The most severe was electrical interference caused by the heating and ventilation equipment for the science building which is located on the floor below the experimental setup. It was necessary to enclose the RTD leads in copper water pipe and the transmitter output leads in steel conduit to reduce electrical pickup to an acceptable level. Another significant problem was due to the design of the purchased temperature transmitters. In trying to reduce the electrical noise, a passive filter was added to the output signal of the transmitter. This caused oscillations in the transmitter circuitry leading to erratic output signals. This problem was solved by isolating the output of the transmitter using an instrumentation amplifier. A filtering stage was then added to reduce noise.

4. ANALYSIS

The flowrate and the inlet and outlet temperature of each collector are measured at five minute intervals. The insolation incident on the plane of the 60^{o} collector is also recorded using an Eppley P.S.P. pyranometer mounted above the collector. These measurements are recorded on a punched paper tape along with the date and time. The direct component of the solar radiation measured with an Eppley NIP and the global radiation are simultaneously recorded on strip chart recorders.

At present only a partial analysis has been completed of the data recorded since 1 January 1978. The useful heat output of each collector is calculated over hourly and daily periods using the following relation,

$$Q = \int m\, C_p\, (T_2 - T_1)\, dt \text{ for } T_2 > T_1. \qquad (2)$$

The inlet temperature is T_1 and the outlet temperature is T_2. The mass flow-rate is determined from the turbine flowmeter readings. The usable heat enhancement is obtained hourly $P_Q(t)$ and daily P_Q by evaluating the ratio of heat collected by each collector. The hourly and daily efficiency for the standard collector is determined by dividing the heat collected Q_c by the collector area A and taking the ratio with respect to the solar flux H_{60} measured by the tilted pyranometer. The preliminary results for selected days are shown in Figs. 2 and 3 and listed in Table 1. The hourly data are integrated from 30 minutes before the hour until 30 minutes after the hour indicated. The data for January 27, 1978 are indicative of results expected for clear day winter operation.

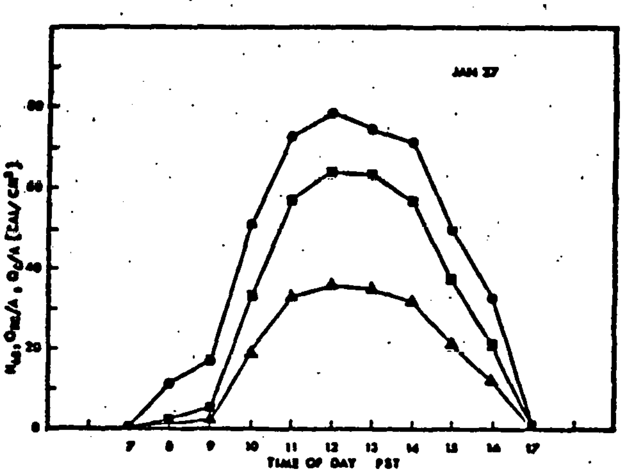


Fig. 2. The January 27, 1978 performance data for the reflector collector system Q_{RC}/A ■ and the collector system Q_C/A ▲. Also shown is the integrated solar radiation measured at a 60° tilt H_{60} ●. All data are integrated from 30 minutes before the hour to 30 minutes after the hour.

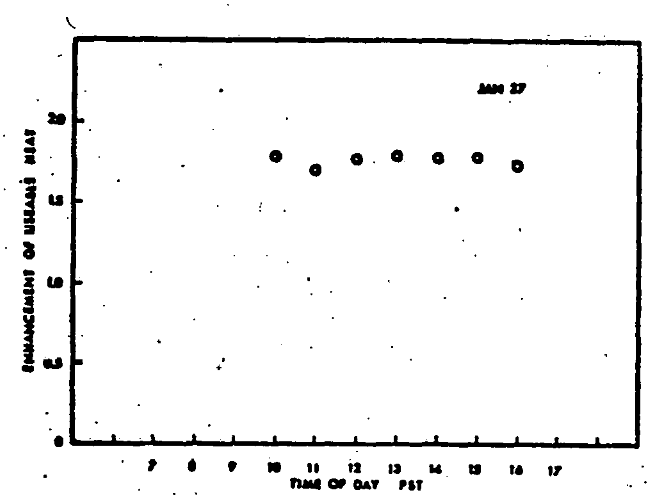


Fig. 3 The enhancement of usable heat for a reflector-collector system with respect to a collector oriented at a 60° tilt angle. Results shown are for the data plotted in Fig. 2.

In Figure 2 the incident solar radiation on the inclined plane H_{60} (upper curve) rises to the clear sky levels after the early morning overcast disperses. The usable heat output of the standard collector (lower curve; shown as Q_c/A for comparison with H_{60}) rises abruptly at 10 AM and collects heat with an instantaneous efficiency at noon of 46% and a daily efficiency of 42%. During this day the inlet temperature to the collectors was maintained between 40°C to 50°C. The average ambient temperature was 15°C.

The reflector-collector system (middle curve in Fig. 2; shown as Q_{RC}/A) collects considerably more usable heat. This is displayed in Fig. 3 where the enhancement of usable heat $P_Q(t)$ for the hours of sunshine is nearly constant at about 1.8. The enhancements for the early morning hours are not shown due to the large experimental uncertainty resulting from dividing two small uncertain quantities. However, the estimated experimental error ($\pm$ 1 cal $cm^{-2}hr^{-1}$) is negligible for the periods of full sun (the errors lie within the data symbol for the noon value). A very stable differential temperature measurement is required in order to accurately evaluate the low insolation responses.

Table 1. Performance data for selected days in early 1978.

Date	Q_c/A [cal-cm^{-2}]	H_{60} [cal-cm^{-2}]	N_c	Q_{RC}/A [cal-cm^{-2}]	P_Q
1-27	193	462	0.42	341	1.77
1-28	0	41	0.0	0	--
1-29	0	33	0.0	0	--
1-30	98	275	0.36	175	1.79
1-31	12	100	0.12	15	1.25
2-7	26	110	0.24	41	1.58
2-8	15	86	0.17	24	1.60
2-9	59	203	0.29	92	1.56
2-17	6	82	0.07	5	.83
2-18	30	142	0.21	33	1.10
2-19	67	226	0.30	93	1.39
2-20	20	132	0.15	26	1.39
2-23	39	142	0.27	54	1.38
2-24	47	184	0.26	62	1.32
2-25	31	166	0.19	34	1.10
3-12	124	322	0.39	157	1.27
3-13	127	392	0.32	168	1.32
3-14	210	517	0.41	281	1.34
3-15	136	422	0.32	178	1.31
3-16	180	504	0.36	242	1.35

Table 2. The enhancement for the direct component of solar radiation calculated for the dimensions used in this experiment.

Date	P_D	Date	P_D	Date	P_D
1-21	1.50	5-21	0.48	9-21	0.99
2-21	1.36	6-21	0.37	10-21	1.29
3-21	1.11	7-21	0.42	11-21	1.47
4-21	0.74	8-21	0.63	12-21	1.53

Preliminary values are reported for other days during January, February and March in Table 1. Most of days are characterized by broken cloudiness and considerably lower insolation. In these cases, there were clear intervals where most of the usable heat was collected for the day. The enhancement is highest in January and decreases in the following months as expected. This is consistent with the values for the enhancement of the direct beam radiation P_D[3] displayed in Table 2 for the system dimensions used in this experiment. The enhancement for usable heat will be larger than the optical enhancement during periods of full sun for the months where $P_D > 1$ because the additional light gathered by the reflector is usually all converted into useful heat. The experimental results are consistent with theoretical estimates [4].

5. NOMENCLATURE

A - area of the collector

L - vertical length of the collector

W - horizontal width of the collector

R - reflector length

I_o - incident diffuse solar radiation

I_r - diffuse radiation reflected onto collector from a perfect reflector

ρ_r - specular reflectance of reflector

θ_T - tilt angle of the collector with respect to the horizontal plane for the reflector - collector system

θ^o_T - tilt angle of the collector with respect to the horizontal plane for the reference collector

P_D - enhancement of direct radiation

P_d - enhancement of diffuse radiation

H_{60} - incident total radiation on a 60^o plane

Q_c - heat gained by the collector of reflector system

Q_{RC} - heat gained by the collector of reflector system

N_c - efficiency of standard collector

P_Q - enhancement of useful heat Q_c/Q_{RC}

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ARCHITECTURAL DESIGN WITH WINTER OPTIMUM REFLECTOR-COLLECTOR GEOMETRY

John S. Reynolds, Professor of Architecture, University of Oregon, Eugene, Oregon 97403
M. Steven Baker, Research Associate, Solar Energy Center, University of Oregon

ABSTRACT

Winter optimum geometry for reflector-collector (R-C) performance at 45° N Latitude is a nearly vertical south-facing flat plate collector with a larger, nearly horizontal reflector. There are extensive architectural design consequences of this nearly-90° angle between two potentially large, flat and highly reflective surfaces, particularly when they are elevated to improve access to the low winter sun. Winter optimum R-C geometry is useful for space heating and as the winter configuration for a variable tilt DHW collector. The reflector enhances both passive and active collection.

Various solutions to the architectural integration of these surfaces are illustrated. Design principles include: (1) framing the collector, (2) intercepting glare from the collector or reflector surface, (3) utilizing the strong upward-directed light from the reflector, (4) extending the reflector surface to serve added purposes, (5) contrasting a smaller R-C near eye level with a larger R-C further away, and (6) using the nearly-90° angle elsewhere in the building.

1. INTRODUCTION

Winter optimum geometry for collector-reflector (R-C) performance at 45° N Latitude has been demonstrated to be a nearly vertical south-facing collector with a larger, nearly horizontal reflector (Mathew solar house at Coos Bay, Oregon 1968) (1), and subsequent theoretical analyses by the staff at the University of Oregon Solar Energy Center (2), (3). There are extensive architectural design consequences of this not-quite-90° angle between two potentially large, flat and highly reflective surfaces, particularly when they are elevated to improve access to the low winter sun. The authors regularly encounter reactions from architects and laypeople to this combination as being "awkward", "ugly", or "unduly dominant."

Included here are some design principles which aid the integration of R-C surfaces in buildings, and some illustrations of these principles as developed by architectural design studios taught by Professor Reynolds. The dimension and tilt angle terminology are illustrated in Fig. 1.

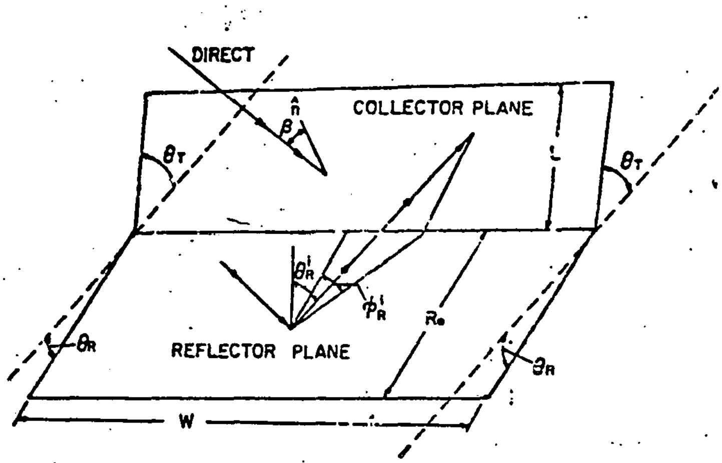


Fig. 1. Dimensions and tilt angles. Note that the angle of the reflector relative to the horizontal, θ_R, is positive when the reflector slopes downward from the collector base. (2), (3).

2. R-C PERFORMANCE ADVANTAGES

The winter-month insolation on near-vertical south-facing surfaces at 45° N is significantly enhanced by the presence of a near-horizontal reflector, as shown in Fig's 2 and 3. Enhancement shown is relative to the insolation received by a typically oriented collector (Latitude + 15°). Passive solar applications utilizing large areas of vertical south glass are obvious candidates for reflector enhancement, as are active flat-plate collectors.

While such winter optimization most clearly benefits space heating systems, it also is applicable to the winter position of a variable-tilt domestic hot water (DHW) collector. In summer, however, the R-C system receives less insolation, as shown in Fig. 4. This can be beneficial to space heating systems in preventing overheated collectors, but is obviously detrimental to DHW systems unless the collectors' tilt is variable.

3. OBSTACLES TO R-C ARCHITECTURAL INTEGRATION

Most serious obstacles to the integration of R-C arrays into architectural form are their large areas and their nearly-90° angle relationship. It may seem common for a vertical wall to be met at its base by a ground plane that slopes gently away from it. When this ground plane is highly reflective however, at least three problems arise. First, it is not at all typical, and therefore attracts attention. Second, it can readily become the source of intense reflections, either to passersby or especially to occupants behind the windows whose solar collection it is enhancing. Third, it is (if made of common, relatively inexpensive materials) easily made dull by abrasion, and is therefore unavailable for traffic of any kind, unlike common ground planes near buildings. Further, a reflector at grade is more likely to be shaded by vegetation or nearby buildings or hills, making this R-C location of dubious long-term value in more densely settled areas.

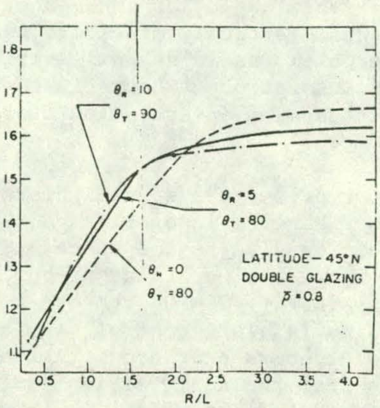


Fig. 2. Enhancement in direct beam radiation gathered for the collector-reflector system compared to that of a Latitude + 15° collector. Shown as a function of reflector length, these calculations were performed for January. (Curves for December and February would be almost identical.) For vertical glass (θ_T=90), added reflector length becomes less cost-effective at about R/L=1.7. (3)

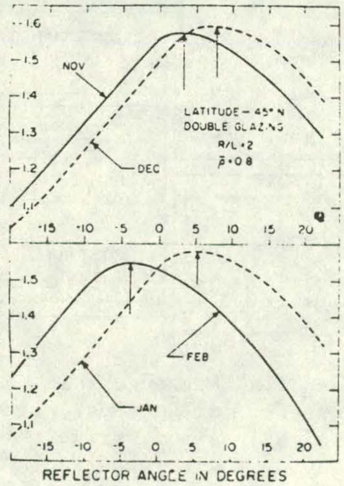


Fig. 3. Optimum reflector tilt angles, as they vary by winter month. Note that R/L=2 was assumed, as an approximation of the optimum R/L from Fig. 2. (3)

Comparing the insolation available to an R-C system to that of a typically sloped collector (at Latitude + 15°) over an entire year, it is evident in Fig. 4 that enhanced insolation for the R-C system begins about September, and ends in March. For Seattle and Brussels (the more northerly locations), the November through March insolation incident upon the R-C collector is 35% greater than that for the typically sloped collector.

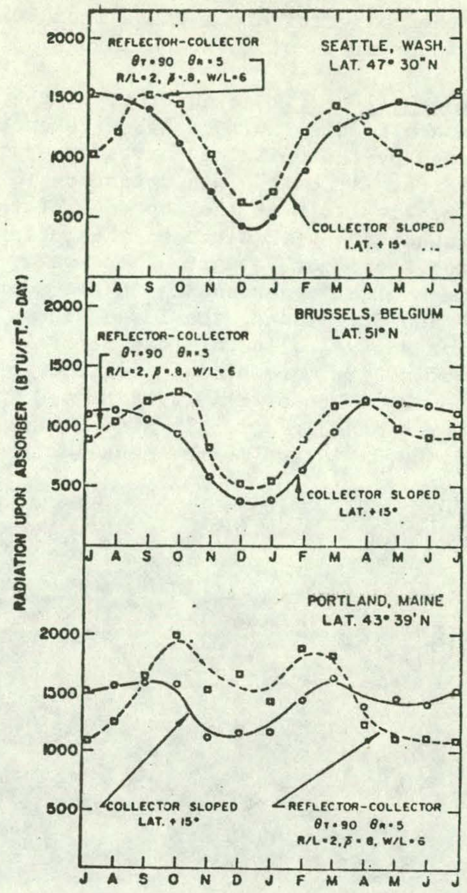


Fig. 4. Comparison of total insolation upon the absorber plates of reflector-collector systems and more typically sloped flat plate collectors, for three northern locations. (4)

As a R-C system is elevated for better access to low winter sun, it encounters the obstacle of presenting an unfamiliar silhouette. The gentle sloping reflector roof surface is certainly common, but not the abruptly rising nearly-vertical glassy collector at its north edge. There is little precedence in architecture for this particular silhouette.

Further, the advantages of a variable-tilt reflector (or collector), evident in the monthly changes of optimum tilt shown in Fig. 3, easily become architectural disadvantages. A surface that is both large and highly reflective is particularly difficult to integrate into a building if its position can vary relative to all other surfaces. Protecting such a surface against excessive wind forces or snow accumulation, in any of its possible positions, can be difficult as well.

4. DESIGN PRINCIPLES FOR R-C INTEGRATION

The six principles discussed below are but the beginning of a collection of such approaches to R-C architectural integration. The models illustrated are those of third, fourth and fifth year architecture students at the University of Oregon.

Typically, the collector areas range from 20% to 30% of the floor areas of these buildings.

4. 1. Framed Collector. In contrast to the "billboard" approach to displaying a large collector, a frame formed by the building serves several purposes. First, it calls less attention to the collector, particularly if the top edge of the collector is not the silhouette of the building. The collector seems more a part of the wall, and less of a mechanical appurtenance on the roof; see Figs. 5 and 8. Second, the large glassy areas of passive or active collectors can be broken up into areas of a size more closely related to the building plan by means of repeating frames, as is shown in Fig. 6 and Fig. 11. It has a third advantage to be discussed in the next section.

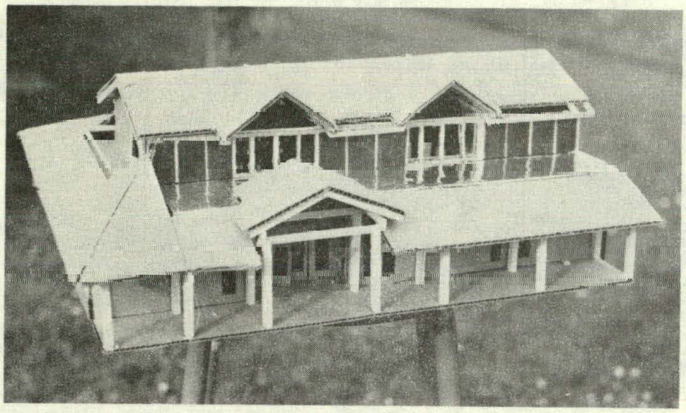


Fig. 5. An older style community hall is provided with a small active collector-reflector system, framed by its porch roof below and the gable dormers of its main roof above. The reflector and most of the collector are not visible from the ground. Project: William Ryals.

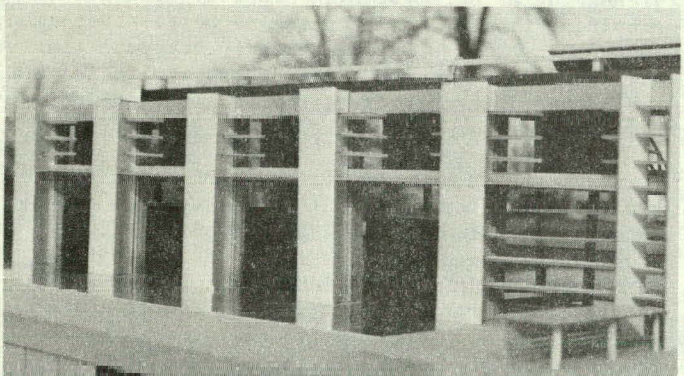


Fig. 6. South facade of a project to house a school of architecture. The large passive (thermal storage wall) collectors (middle of photo) are served by horizontal reflectors; a horizontal view window runs just below the continuous overhang. Smaller active collectors above this overhang are also aided by its reflector surface. Dominant vertical fin walls separate and frame the collectors, and intercept sideways reflected light. Project: Hans Ettlin.

4. 2. Glare Control. As the frame around a collector becomes more three dimensional, its projection in front of the collector surface affects the insolation. The frame intercepts sun at hours further from noon, and also intercepts the reflected light that is relatively great at these unfavorable angles of incidence. Where glare from near-vertical collectors becomes a potential problem (as in densely settled areas), the loss of insolation at hours further from noon may be offset by the interception of troublesome glare.

The reflector presents a special glare problem, where it is enhancing insolation on the window of a direct-gain passive heated space. This can also occur where collectors occur below windows or decks, as in Fig. 7. On the other hand, the reflector aids in glare control, in that it intercepts glare at hours near noon. At these times, reflections from the near-vertical collector plunge downward and almost due southward from the collector surface. The reflector intercepts this light, and directs it upward. In summer, this upward direction is quite steep, making annoyance of neighbors much less likely.

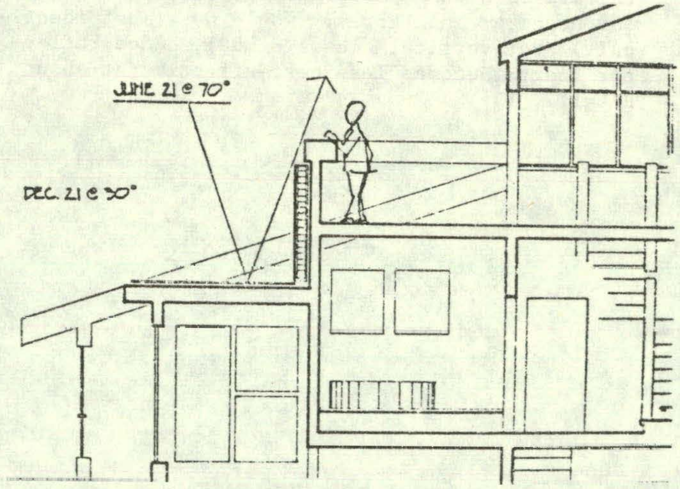


Fig. 7. Use of a thickened railing to prevent view of the reflector surface. Light from the reflector which does not strike the collector is directed away from eye level on the deck. A wide railing (or window sill) can completely block the close-range view behind it, thus preventing view of the reflector surface at any time. Project: Henry Kunowski.

4. 3. Utilize Upward Light. The strong upward component of light from the reflector surface, where it is not a threat as glare, can produce unusual results both on the exterior and interior of the buildings, Fig. 8. Detailing on the undersides of surfaces (such as soffits) is made more visible, and strong light on the ceilings of rooms is of benefit to deep penetration of daylight to such rooms' interiors. When the reflector is sometimes covered by a thin film of water,

the resulting patterns of dancing reflected light can attract considerable attention to the indoor surfaces they illuminate.

Use of reflectors in direct gain systems is limited by glare problems, except for clerestory openings above eye level. The reflector-clerestory combination, with the resulting illuminated ceiling, is a promising application for passive system design.

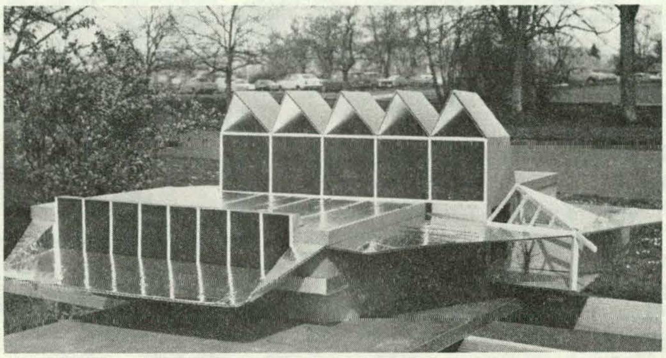


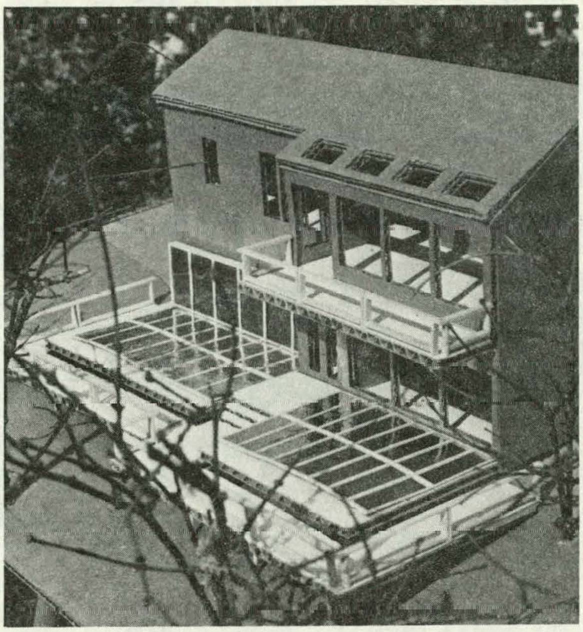
Fig. 8. The larger collector and reflector on this project for an airport terminal produce strong upward light that illuminates the under side of the folded-plate roof. Thus, instead of darker shadows as ceiling planes, the upward directed light on the ceiling inside is almost as strong as the shafts of direct sun. Glare is no problem, as these windows are well above eye level. Project: Layne Mitchell.

4. 4. Multi-purpose Reflector. The integration of a reflector into the other roof surfaces of a building may be made easier by sharing its shiny quality. When several roof surfaces are reflective, the reflector itself is no longer unique (as in the cover of the entrance in Fig. 8. foreground).

When location on the ground produces a highly visible reflector, this reflective quality may be utilized somewhat as a "reflecting pool" is used, to argument a vertical object of interest - often the collector itself - beyond (Fig. 9).

Fig. 9. Project for a cinema and office building complex. The large reflector (left) rises from grade, enhancing insolation on the vertical collector. The arriving movie-goer sees the collector mirrored in its surface. (Glare into the eyes of departing patrons is a potential problem!) Project: Mary Liang and Brent Pilip.

The reflector may be brought indoors, where it directs light to otherwise-dark spaces. The same roof whose exterior surface is a reflector may have an interior ceiling also reflective, achieving both a deeper penetration of daylight and a ceiling of unusual interest. Or the reflector may be made seasonal, as in Fig. 10.



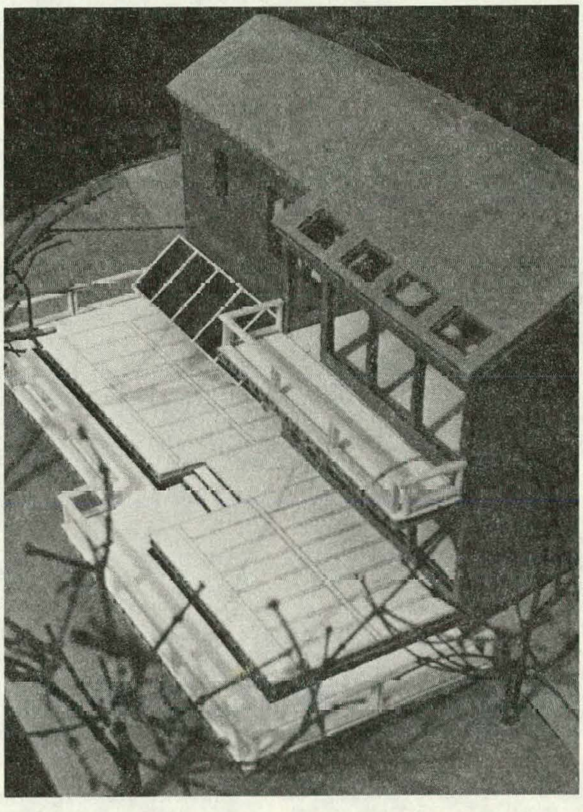
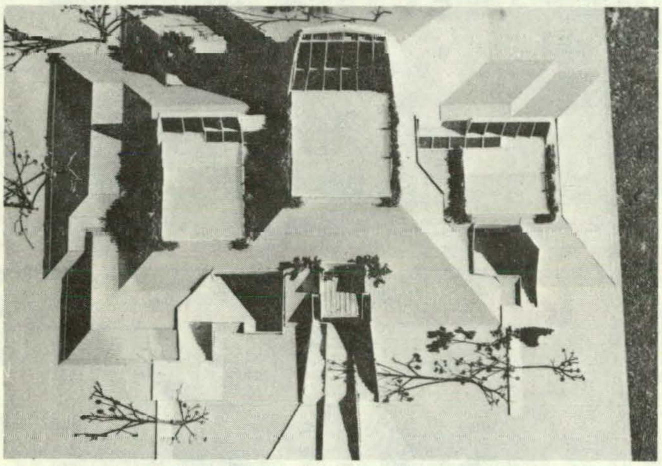


Fig. 10. Seasonal reflectors. In winter (a), extensive reflector surfaces enhance both an active collector and a direct-gain lower-floor space. In summer (b), the collector pivots to a more advantageous tilt, and the reflector panels flip over to the underside of what is now an extensive deck for summer recreation. Project: Eric Hoff.

4. 5. Smaller R-C at eye level. The last two principles involve integration by repetition; the R-C geometry becomes familiar by appearing more than once. A very large R-C application can be introduced by a smaller R-C more in scale with people, near eye level (as was done in Fig. 8). The semi-underground church project (Fig. 11a) uses a very small R-C at the entrance (lower center photo) and intermediate R-C systems at either side of the major R-C (shown in elevation, Fig. 11b).



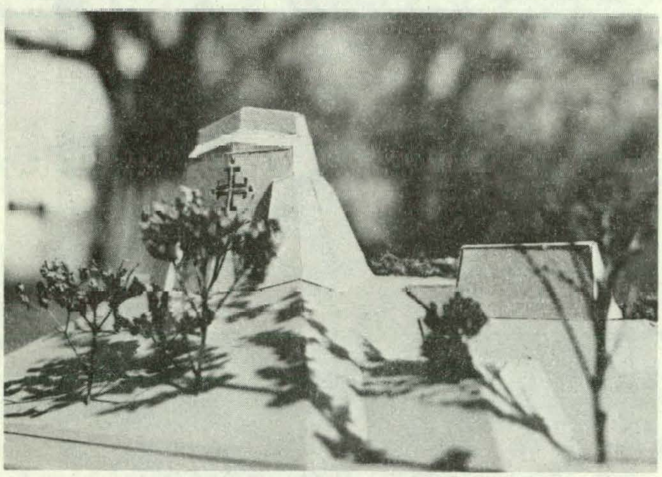


Fig. 11. A Semi-Underground Church. The gradual slopes of the earth berms rise to the much steeper slope of the collectors that form the silhouette of this building. The reflectors are framed (and concealed) by low shrubs. Some of the reflected light enters skylights, where its intensity can enhance the color of stained glass. Most of the reflected light enters collectors. Project: Paul Smith.

4. 6. Repeat R-C geometry elsewhere. The nearly-90° angle may reappear on either exterior or interior to reinforce the intentional use of this unusual angle. A rooftop R-C may be particularly visually helped by a repetition of this angle in the silhouette; a version of this is shown in Fig. 11b. Again, the advantage of several, rather than just one, R-C is apparent; not only is the size smaller and more likely to be in scale with other elements of the building exterior, but the repetition is helpful in making less a display and more an integration of the collector and its reflector with the building they serve.

ACKNOWLEDGEMENTS

The nearly vertical collector-nearly horizontal reflector's successful performance is well demonstrated by Henry Mathew's design for his home in Coos Bay, Oregon (1968). The staff at the University of Oregon Solar Energy Center provided both theoretical analyses (see references) and continuing encouragement to the design studios. There are several other R-C studio projects which were omitted in consideration of limitations on this paper's length.

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AGRICULTURAL/INDUSTRIAL PROCESS HEAT

SOLAR HEATED GREENHOUSES

by

Marsha Mackie - Yamhill County Energy Office
Bill Mackie - Oregon Dept. of Energy
Tim McGee - Seattle, Washington

AREN'T ALL GREENHOUSES SOLAR HEATED?

It's true that all greenhouses use the sun. But not all greenhouses use the sun as a source of heat. In fact, because of the way they are designed, traditional greenhouses often require large inputs of energy and can be costly to heat. Remember -- solar radiation is free!

WHAT MAKES A SOLAR GREENHOUSE DIFFERENT?

Short-wave solar radiation (sunlight) enters every greenhouse. Inside, it is absorbed by plants, pots, earth and benches and re-radiated into the greenhouse environment in the form of long-wave solar radiation (heat). The object of a solar heated greenhouse is to keep as much of this sun-generated heat as possible inside the greenhouse. Two ways to accomplish this are by preventing heat loss and adding thermal mass. Traditional greenhouses do not address either of these concepts.

HOW DO YOU PREVENT HEAT LOSS?

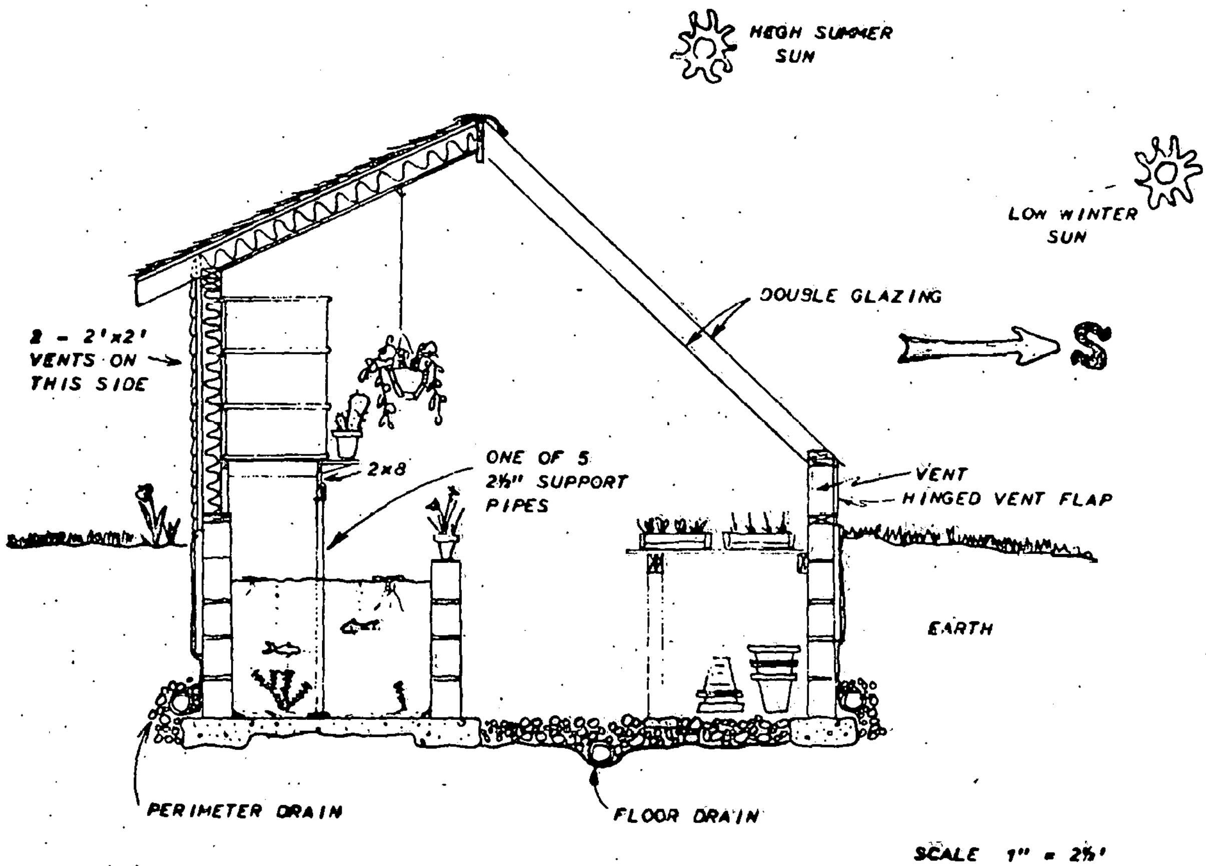
Glass is a very good conductor of heat. This means that much of that precious solar heat collected in the greenhouse will pass right back out through the glazing (glass, plastic, or fiberglass) unless measures are taken to stop it. First -- limit the glazing to only the southern exposures. This will allow you to pick up most of the direct radiation, but will at the same time prevent most of the heat loss. Also, two layers of glazing will allow only half the heat loss as a single layer. Second -- be sure all other exposures are well insulated. Most Northwest greenhouses have 3½" of fiberglass insulation (or the equivalent) in the east, west and north walls and in the ceiling. Some are even recommending 6". Finally -- minimize outside air infiltration by plugging all leaks and cracks. Go around with a caulking gun and patch every spot which might be a potential air leak.

WHAT IS THERMAL MASS?

Thermal mass can be any material which has the ability to store heat. Heat storage is necessary to keep night temperatures from dropping too low. And we in the Northwest are all too familiar with those days when the sun never shines. Thermal storage can help carry the greenhouse through those times. The most common heat storage materials are water and rocks, and there are a number of innovative ways in which these can be incorporated into a greenhouse design. One of the easiest is to fill black 55-gallon drums with water. (Black absorbs more heat than light colors.) Some greenhouses have included ponds for heat storage which can double as fish-farming tanks. Rock walls can not only serve as heat storage, but make an attractive greenhouse interior. One greenhouse in Oregon has filled a bin on the north wall with rocks, held in by chicken wire.

DO SOLAR GREENHOUSES HAVE ANY SPECIAL PROBLEMS?

Unless you want to have a back-up heat source, it's not possible to keep the temperature as closely controlled as in some greenhouses. Cool weather crops may be the best choices. Adequate light levels may also be a problem because only one side is glazed. Using reflective material or white paint on the interior surfaces will help. Lack of CO_2 can also be a problem when inside-outside air exchange is restricted. Some greenhouse gardeners have dealt with this by raising rabbits, worms, or even chickens in their greenhouse. Others have simply added a compost heap.



FOR FURTHER READING

The Solar Greenhouse Book Edited by James McCullagh, Rodale Press, Emmaus, PA. 18409, $8.95.

Survival Greenhouse by James B. Dekorne, Walden Foundation, P.O. Box 5, El Rito, New Mexico, 87530, $8.95.

The Food and Heat Producing Solar Greenhouse: Design, Construction, Operation by Rick Fisher and Bill Yanda, John Muir Publications, P.O. Box 613, Santa Fe, New Mexico, $6.

Organic Gardening Under Glass by George and Katy Abraham, Rodale Press, 33 E. Minor St., Emmaus, Pennsylvania 18409, $8.95.

NORTHWEST GREENHOUSE PUBLICATIONS

Noti Solar Greenhouse: Performance and Analysis, Center for Environmental Research, School of Architecture and Allied Arts, University of Oregon, Eugene, OR. 97403. $2.

Two Solar Aquaculture-Greenhouse Systems for Western Washington, Tilth, Rt. 2, Box 190-A, Arlington, WA. 98223. $2.

Solar Heated Greenhouse, Bill and Marsha Mackie, 835 Fleishauer Lane, McMinnville, OR. 97128. $2.

FARMSTEAD UTILIZATION OF SOLAR ENERGY

By Martin L. Hellickson
Department of Agricultural Engineering
Oregon State University

The adaptation and utilization of solar energy will become an increasingly important alternative to fossil fuel energy consumption as the cost of conventional fuels continue to increase and supplies diminish.

Many applications of solar energy are either presently feasible or are bordering on becoming economically feasible. Positive fossil fuel savings have been demonstrated in several areas including: solar grain drying; heating of greenhouses, residences, and livestock confinement structures; and large scale pumping of irrigation water. Widespread adoption and utilization of solar energy requires a coordinated effort of education and familiarization. Meaningful demonstration applications of solar technology are vitally needed to increase fossil fuel savings and to adapt solar technology.

Dairy operations in Oregon exhibit opportunity for the demonstration of fossil fuel energy saving modifications. As an attempt to remove the conspicuous absence of an actual demonstration solar collector on the OSU campus and to gain valuable experience and information from monitoring the operation of a solar collector system, approximately 100 sq. ft. of solar collectors will be erected at the OSU dairy center. The solar collector system will be used to heat water for the sanitization and clean up requirements in the dairy. Objectives of this research include: a) a complete cost of material summary for the solar collector system, and b) the determination of the quantity and temperature of water that can be accumulated from the solar collector system under mid-Willamette Valley conditions.

Maintaining a reliable water supply in remote range land grazing areas of the United States is a perennial problem of livestock producers. Acute drinking water shortages during drought frequently result from total dependence on runoff to fill livestock watering dams.

Many of these areas exhibit positive potential as agriculturally productive land. Ample supplies of groundwater suitable for irrigation and livestock watering lie within a few feet of the earth's surface. The development of a simple solar powered pump that will lift small quantities of water to the surrounding ground surface would present a great technological advance in these areas.

Specific objectives included in this solar energy research project include the design, the construction and testing of a simple solar powered apparatus that will develop torque or shaft power such that it may be adapted to a simple water pump.

A model size apparatus will be developed and tested to determine the feasibility of developing torque as a result of heating a bimetallic coil.

Attached to the coil will be a mass which during the heating process will be deflected through a distance. This will cause an imbalance with an identical mass directly across the center shaft of the apparatus. The net torque resulting from the mass being deflected will be the product of the net level arm and the mass.

ACUREX CONCENTRATES ON SOLAR ENERGY

Ed Rossiter
Acurex Corporation/Aerotherm Division
485 Clyde Avenue
Mountain View, CA 94042
(415) 964-3200

ABSTRACT

Several thermal applications for solar systems are described, including irrigation pumping, process hot water, and process steam. The design and construction of the 25-hp solar irrigation system at Willard, New Mexico is discussed in some detail. Some aspects on the economics and costs for systems are presented.

INTRODUCTION

The most important part of any solar system is the solar collector, since the collector dictates the performance of the system. In thermal applications such as a domestic hot water system, a flat-plate collector ordinarily will generate temperatures from 110° to 140°F, while a concentrating collector can generate much higher temperatures -- up to 600°F -- on a practical basis.

The Aerotherm Division of Acurex Corporation has worked in the fields of thermal sciences and thermal system engineering since 1965. As part of a broad attack on the many problems which were caused by the energy crisis, the Aerotherm Division began working in the field of solar energy about 2-1/2 years ago with emphasis on cost-effective solar systems which require high temperatures.

One of our major objectives in solar energy was to find a reliable solar collector made of readily available materials that would provide a cost-effective solar system. We investigated the market and found that no single high-temperature collector met these criteria. Therefore, we began a design task for a high-temperature collector that would be used in the most cost-effective solar system possible. Our analyses indicated that a parabolic-trough concentrating tracking collector would meet this criteria. But it had to be designed for an industrial-grade system to provide long, reliable service that meets the usual industrial investment criteria.

We completed our design and now manufacture a parabolic-trough concentrating collector which we feel is industrial-grade equipment. Our collector is analogous to an industrial-grade air-conditioning system as opposed to less rugged home air-conditioning systems. The collector is targeted for the industrial and commercial markets.

Of course, there are other high-temperature collectors on the market. However, it is difficult to compare a parabolic-trough concentrator to other types of collectors strictly according to temperature. Collectors based on different design criteria do not necessarily cover the

Printed in U.S.A.

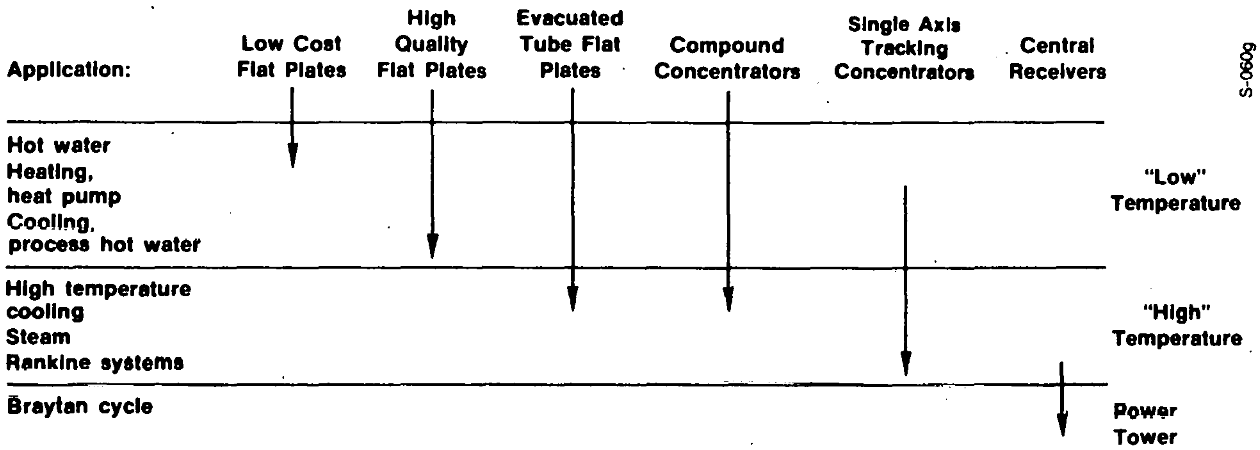


Figure 1. Solar collector.

same temperature range as a parabolic-trough concentrator. Figure 1 indicates the operating temperature ranges of various collectors on the market. This particular figure is subjective, and only gives a very rough comparison. However, as shown, parabolic-trough concentrators (which are examples of tracking concentrators) cover a temperature range from approximately 140°F up to 600°F. Many important industrial and commercial applications require temperatures within this range and are ideal candidates for using solar energy. Examples include generating process hot water at 200°F, generating low-pressure steam at 350°F, and heating working fluids from 450°F to 600°F that can operate organic Rankine cycle systems. Acurex has worked on several solar applications in the past few years. Two systems are already installed (or are in the installation process) while others are still in the design stages.

The economics of high-temperature industrial solar systems are not easy to define, since all industrial or commercial solar systems tend to be custom designed. Even though solar energy is basically a simple concept, using a high-temperature solar system for industrial processes is new to the industrial and commercial marketplace. Industry is not familiar with the designs of solar systems for generating high temperatures. In addition, contractors and installers are also unfamiliar with high-temperature solar systems. None of these problems are insurmountable. The initial cost of industrial solar systems, a major obstacle to implementing high-temperature solar systems, will drop as the industry and contractors become more familiar with solar energy and accept it for industrial applications.

In addition, solar energy cannot be treated as an expense item such as fuel oil or coal. Solar energy is a renewable resource, but requires a larger capital expenditure than conventional energy sources. Capital and operating costs will become more acceptable as industry gains experience and, hopefully, Government allows sufficient investment and tax incentives.

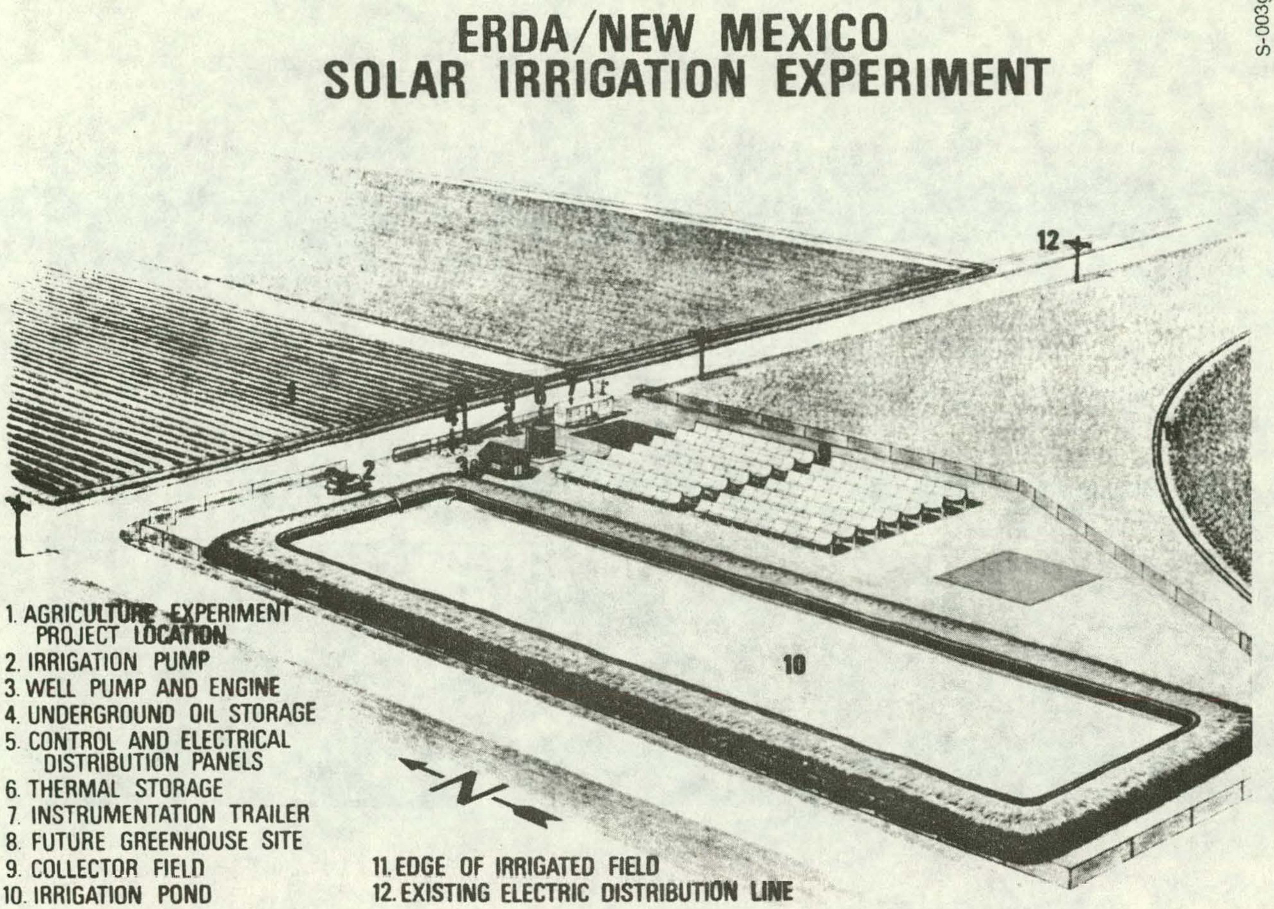


Figure 2. ERDA/New Mexico solar irrigation experiment.

A SHALLOW-WELL IRRIGATION SYSTEM

One of the solar systems that Acurex has worked on is a shallow-well irrigation system near Willard, New Mexico. This system is owned by New Mexico State University and was installed by Sandia Laboratories. Acurex provided the collector field for this project. Figure 2 is an artist's version of the field, showing the basic elements of the system. Figure 3 is a photograph of the actual collector field.

Figure 4 shows a block diagram of the system. The design operating temperature of the field is 420°F. The primary working fluid for the collector field is a high-temperature heat transfer oil. After passing through the collector field, the primary working fluid passes through a heat exchanger boiler to vaporize Freon. The Freon is then expanded through a Barber-Nichols organic Rankine cycle turbine, which provides approximately 25 hp shaft power.

The pump operates at a well depth of approximately 75 feet, and is used to fill a holding pond (shown in Figure 2). Water from the pond is pumped out to the field with a conventional, diesel-engine pump. One way to extend this system would be to increase the solar field for pumping the water from the pond to the varous fields. The system is designed with storage capacity so it can operate without sunlight for approximately 12 hours when the storage system is fully charged.

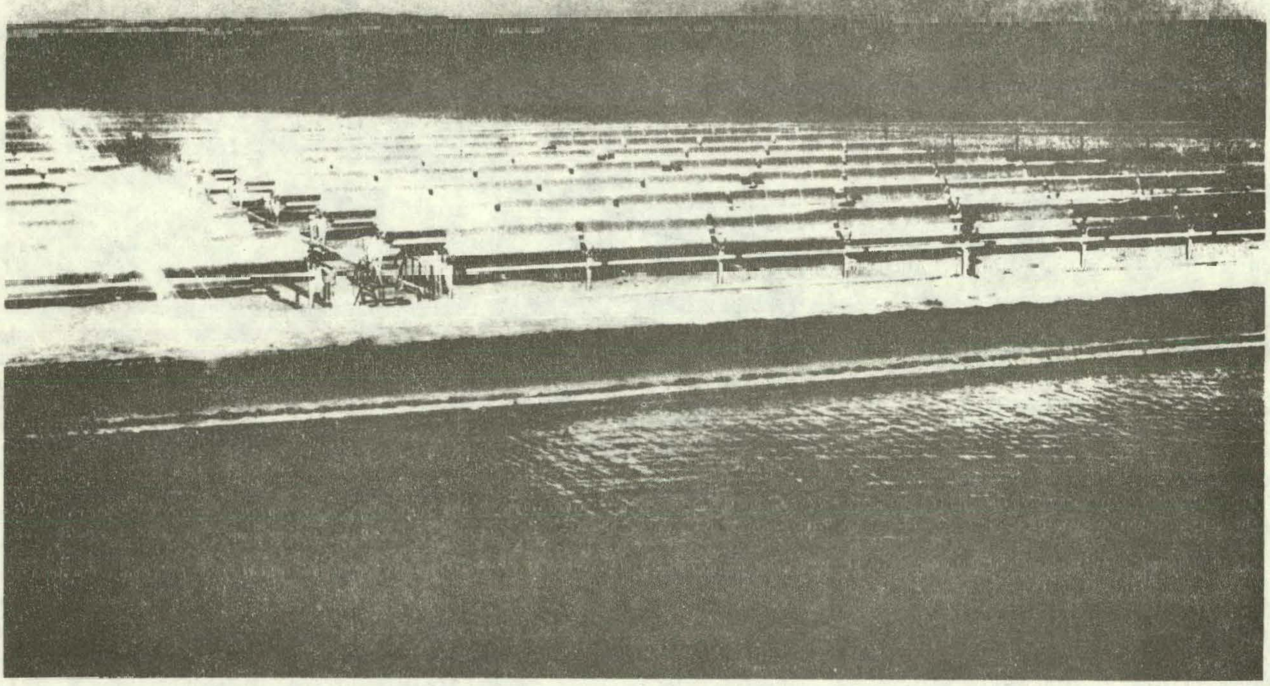


Figure 3. Concentrating solar collector field.

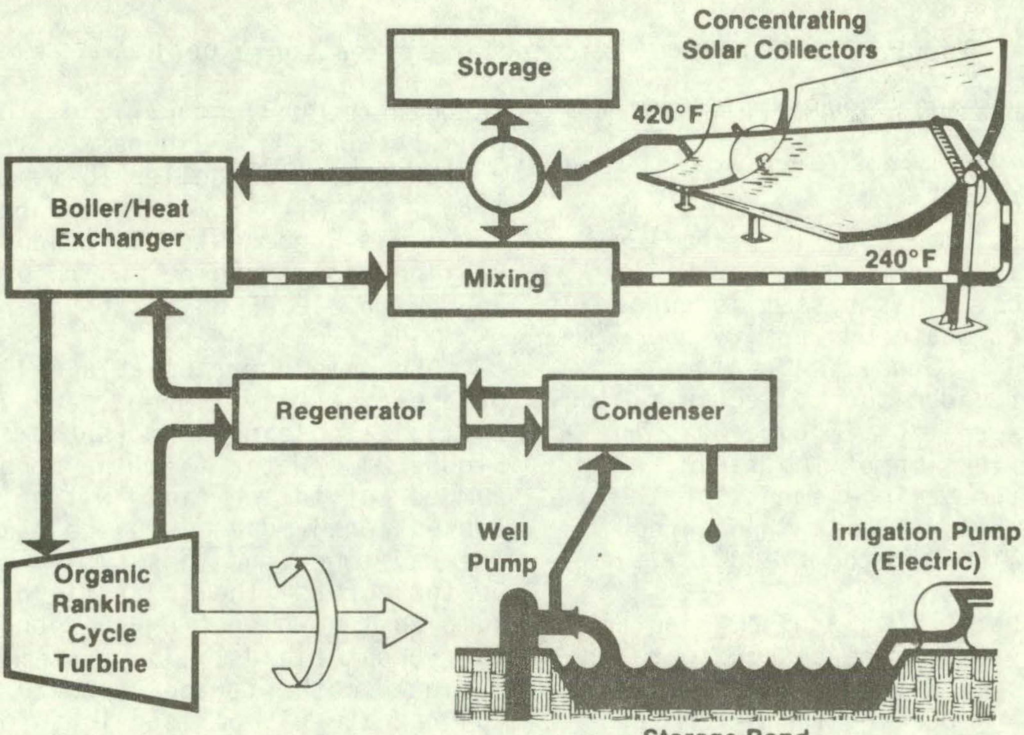


Figure 4. Shallow well irrigation system.

Acurex assisted Sandia Laboratories in installing the collector field.

We encountered several problems, and we describe their solutions. One problem was connecting the receiver to the system manifolds. Because the receiver in a parabolic-trough concentrating system rotates with the reflector surface, the connection between the receiver and the stationary system manifolds must also rotate. We initially chose a swivel fitting that was a high-temperature, quick-disconnect fitting. However, Sandia Laboratories found that the high-temperature heat transfer oil was not truly compatible with the seals and, in addition, wind-blown sand caused these fittings to bind. Therefore, the connection was changed to a flexible, high-temperature hose which we now have adopted as our standard connection. This experience has been verified by others involved in high-temperature solar systems. We believe that hoses will provide more reliable operation than swivel fittings. Even though hoses must be replaced periodically, maintenance and replacement costs for swivel fittings would be higher.

Another problem we encountered was the technique used to connect the receiver sections. Initially, we used a brazed connection. However, very small pin holes in the brazing flux were a problem using the high-temperature oil. Therefore, we have gone to a TIG (Tungsten Inert Gas) welded-joint construction.

A third problem was some breakage of the outer glass tubing around the steel receiver. Our design for the receiver consists of an inner steel tube with a selective black-chrome coating; this tube is surrounded by an outer Pyrex glass sheath to reduce convective losses. (Without the outer Pyrex sheath, convective losses could become serious at high temperatures and very serious under wind situations.) However, since the thermal expansion coefficient for the glass sheath and the inner coated steel receiver are not identical, different thermal expansions had to be allowed for in the design. Some of the Pyrex tubing cracked under thermal expansion because of improper design of the support structures. This problem has been corrected by modifying the support flange and the packing material at the support structure to better compensate for the thermal expansion of the glass. Since the system is not an evacuated tube system, the steel receiver tube can expand freely from a center support at the middle of the collector row.

Another problem we encountered was with the tracking system (see Figure 5). Until recently, one of the more common objections to a tracking collector has been the operation of the tracking control system -- the system which focuses the collector optimally on the sun under a variety of insolation and environmental conditions. Tracking systems have had problems focusing properly under conditions with low insolation and/or sparse cloud cover. For example, the system might focus on a "false" image by focusing on a cloud that is reflecting the sun. We experienced this problem and solved it by connecting a radiometer to the field collector system control panel. When the total insolation falls below a certain level (which is field adjustable), tracker power is disconnected, and the field ceases tracking, eliminating the "hunting" problem.

This Acurex tracking system is extremely versatile. It has several logic modes available to the user: a focus mode, a stow mode in either rotational direction, a desteer mode in which the collector will track about 5° off-focus for a minor overtemperature condition, in all

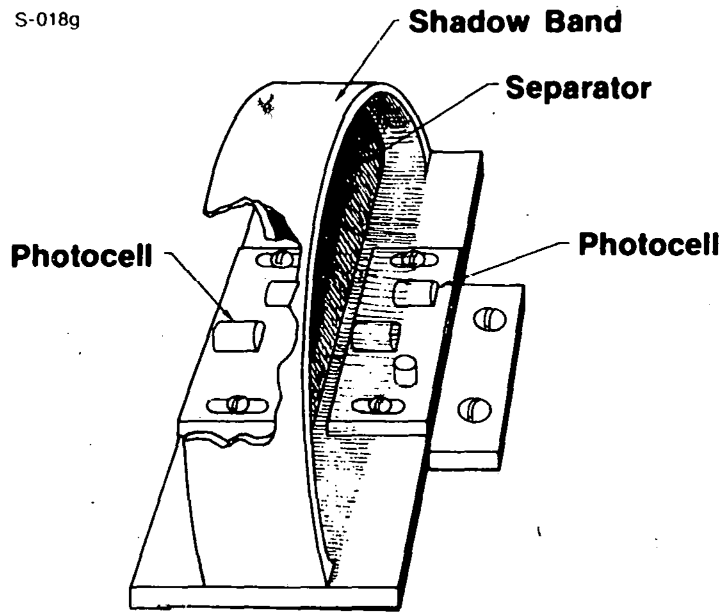


Figure 5. Tracking electronics.

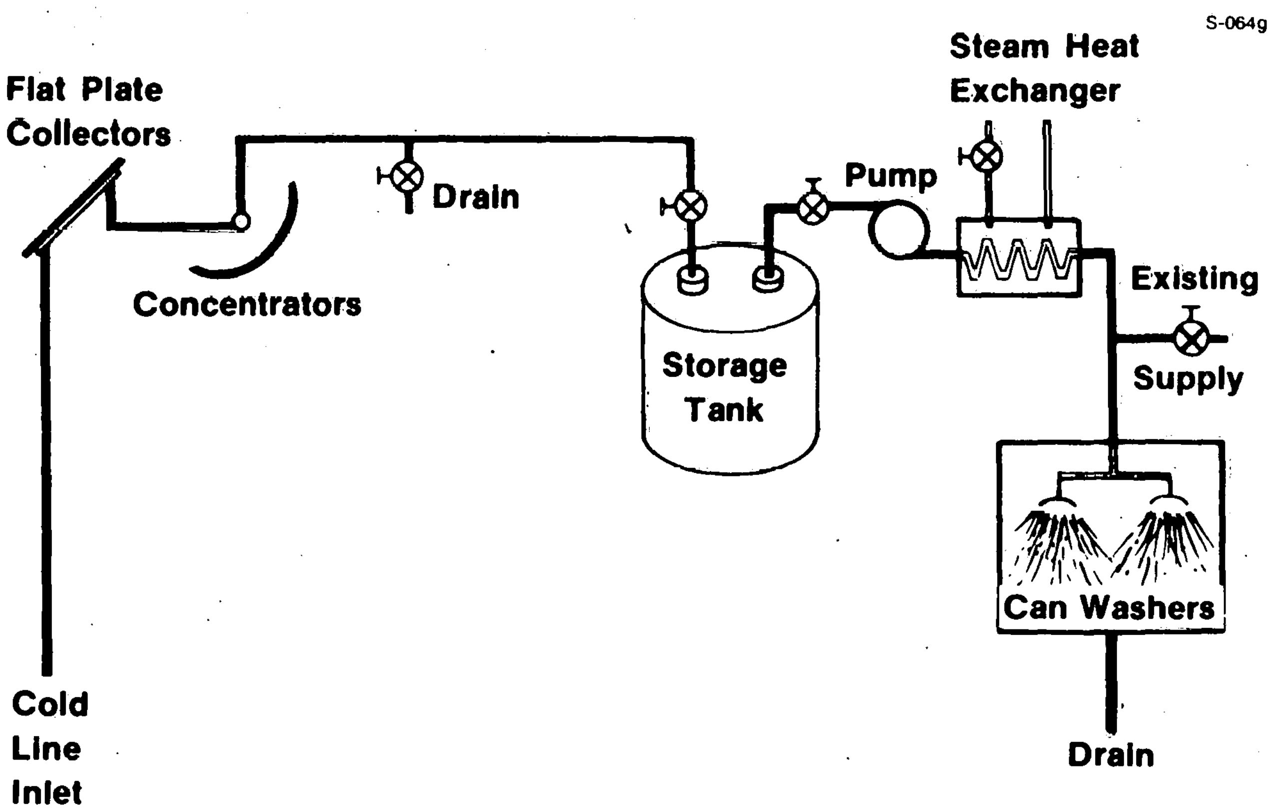


Figure 6. Solar process hot water system.

cases drawing a minimum amount of power for tracker operation. In addition, the system is also fully compatible with "open-loop" control, in which a computerized central system controls the field. The system is fully compatible with computer control commands, that is, standard computer logic levels. In sophisticated systems, overall efficiency can be increased if the system focus is determined by a memory that knows the exact position of the sun at any time of the year.

PROCESS HOT WATER APPLICATIONS

Acurex is working on two solar applications for high-temperature process hot water; one is for a soup plant, the other for a hotel. We designed and are currently installing a system at the Campbell Soup Plant in Sacramento, California for washing cans prior to canning soup. Figure 6 shows the system block diagram. The temperature from the solar system is controlled by a series of digital valves which regulate the flow through the collector field.

One unique aspect of this system is that it is a mix of both flat-plate collectors and parabolic-trough concentrators. The flat-plate collectors are used as preheaters to raise the temperature of well water from ambient up to about 140°F. The concentrators then heat water from 140°F to about 190°F. Further details of the system are included in one of the appendices of this paper.

We chose a mixed field instead of using only one type of collector because our analysis (as part of the system design) showed this to be the most cost-effective system for this application. For a different application, a mixed field might not be most cost effective. Even for this application, a mixed field might not be chosen today since there have been cost reductions in manufacturing the concentrating collector. During the actual system installation, we found it was difficult to install two types of collectors for one solar application. This may have a bearing on future field designs, but part of the difficulty can be attributed to the lack of experience in installing industrial solar systems in general. We anticipate that when contractors become more experienced in installing industrial solar systems, some of this difficulty can be eliminated.

The field was installed on the roof of an industrial building -- which was not as easy as it would appear. In this application, we were fortunate to be able to utilize the main roof support beams as the collector support. We used an A-frame support for the collector anchored on the support beams. However, many roofs of industrial buildings are not stressed to handle the loads of a concentrator system. Although the distributed load of the Acurex concentrator system is not large (on the order of 5 to 6 pounds per square foot), point loads may require additional stressing of the roof -- which could be expensive. Roof stresses are an important consideration when proposing an industrial system design. It may be less expensive to install the collectors on the ground and increase the system manifold run than to pay a larger price for stressing the roof to handle the collector load.

Acurex is also involved in a new project to provide hot water (140°F to 180°F) for a hotel complex on the island of Hawaii. We will supply the collector system to provide hot water not only for domestic purposes, but also for the laundry and the kitchen (see Figure 7). This application is a good example of using concentrating collectors where one might assume flat-plate collectors would be more appropriate. On a dollar-per-Btu

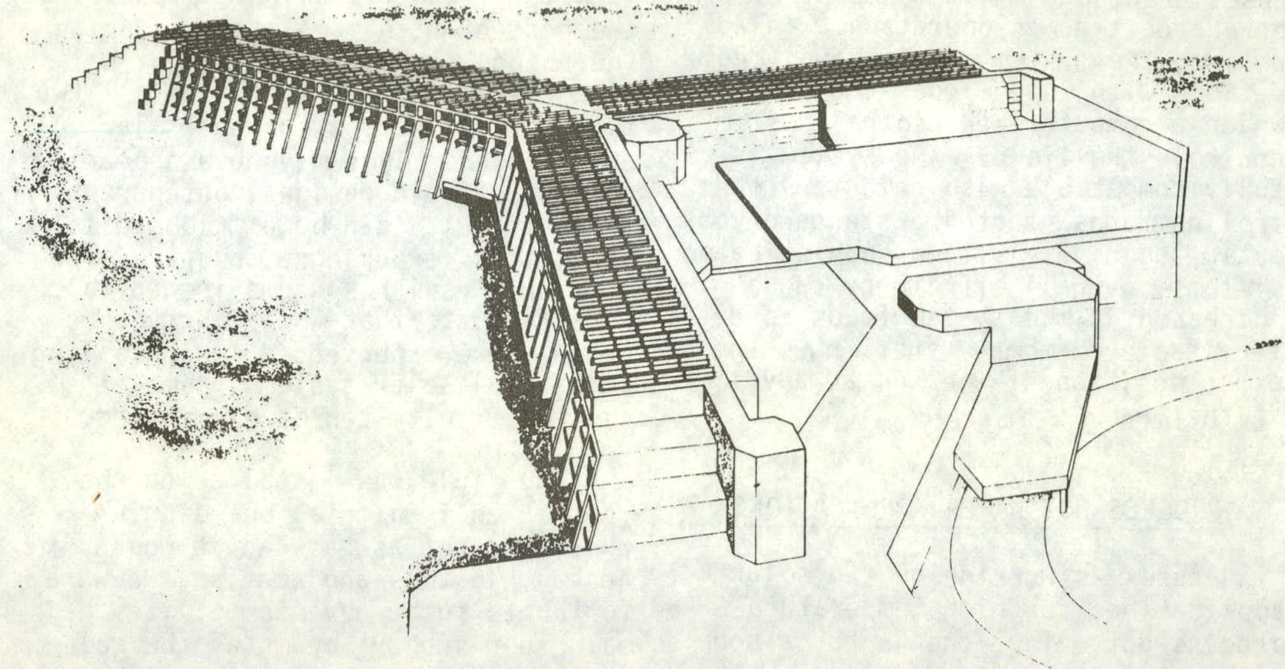


Figure 7. Artist's conception of solar system for hotel models.

basis, a concentrator system was clearly the most cost effective for this application and geographic location, even though the temperature requirements seem modest.

This particular system will be installed near the sea. Because the reflector material for our collector is anodized aluminum reflecting sheet, there has been some concern that the reflector sheet would degrade seriously in a marine environment. However, salt spray would only slightly affect the collectors, located a few hundred yards from the sea, since significant amounts of spray are not carried far enough inland. This is based on observing the effects on similar building materials in this environment. New protective transparent coatings are expected to appear on the market in the near future and if they prove reliable, they could easily be used to protect against salt spray if it were to become a problem.

STEAM GENERATION

Acurex is currently preparing a solar system to provide low-pressure steam for gauze bleaching at a Johnson & Johnson plant in Sherman, Texas. Generating steam using a concentrating collector is probably one of the most straightforward solar applications. This particular application will not require a heat exchange system for the collector field as did the shallow-well irrigation system. Boiler-treated water will be used in the primary solar fluid loop. Water flows through the collectors, reaching a temperature of approximately 345°F and a pressure of approximately 120 psi. This water is eventually flashed to steam for the bleaching process. Figure 8 shows a block diagram of the system.

Since this application appears to be straightforward, we do not anticipate any new problems with the

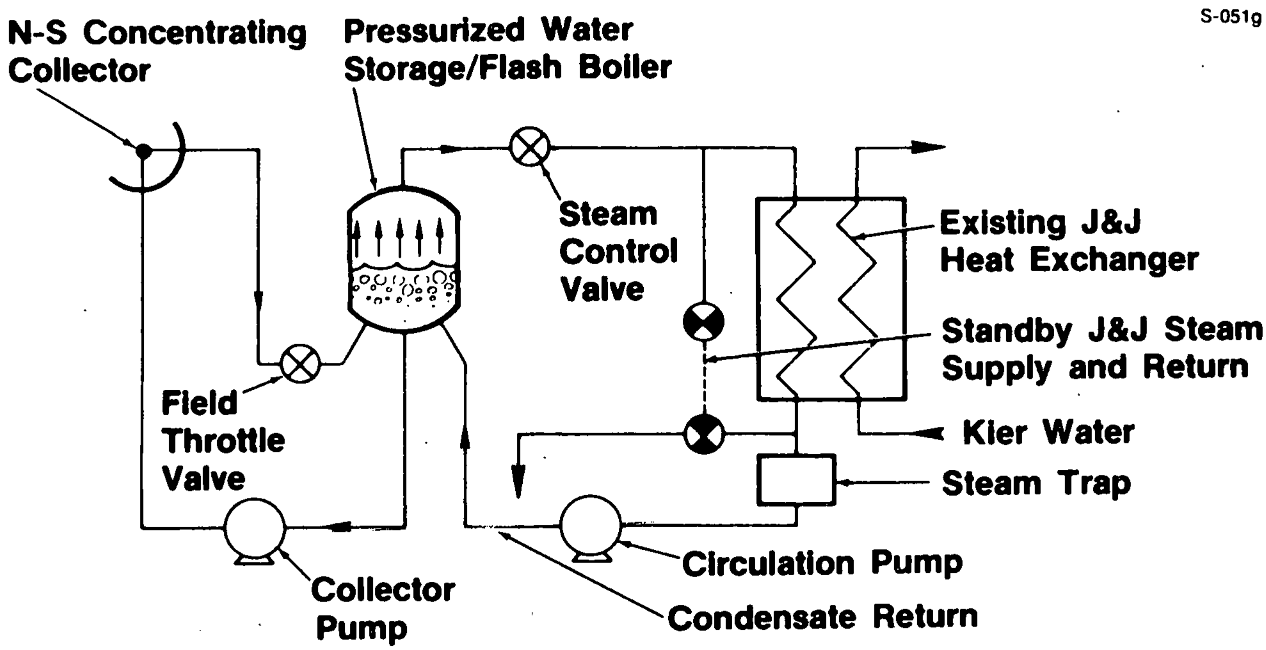


Figure 8. System schematic.

collector field. However, we must be careful that the system interfaces properly with the industrial process as it presently operates. One of the difficulties in implementing solar energy in the industrial and commerical markets is that it is not entirely clear whether designing a system to retrofit to an existing process or designing a new overall system from the beginning, including the actual process design, would be better. A solar-powered "boiler" system will not necessarily be identical to a fossil-fuel-fired boiler system.

ECONOMICS AND COST

Although Acurex has some experience in industrial and commercial solar energy systems, it is not easy to discuss the economics of these systems in general, since no two applications are identical. The objective for an industrial solar system design should be to minimize system costs. Normally, costs of a thermal solar system are given in terms of dollars per Btu. Costs for thermal systems are determined by the overall system engineering, not the engineering for the system components individually. Of course, for any application, different engineering costs will be incurred since industrial and commercial solar energy systems are essentially custom designed. Hopefully, this situation will change in the future when solar energy technology is more widely disseminated. However, the final criteria should always be to provide the most cost-effective system possible.

For a system using an Acurex parabolic-trough concentrating collector, we would not normally anticipate any significant modifications or engineering changes to the basic collector design for a particular application. We have found that some special requirements, such as for special quality control to trace the source of material or special flexible hose fittings, may increase the cost at most by $1 to $2 per square foot. Therefore, any requirements unique to a particular application would not significantly alter the basic cost of the collector on a per-square-foot basis.

Currently, there is some agreement in the industry that the cost of a high-temperature collector system (including collector foundations, manifolds pumps, etc.) for installations on the ground are approximately $26 to $29 per square foot. One of the major advantages of the Acurex collector is a minimum number of connections to the system manifolding for a large area -- two connections for 480 square feet of collector aperture area. However, the cost range does not cover total system cost which may involve peripheral equipment such as absorption chillers, turbines, or anything else which requires high-temperature fluid input. Therefore, for a large-scale solar project, the collector system will only be a portion of the total system cost -- possibly as low as 30 to 40 percent of the total.

Pre-establishing a basic system cost for any particular application is almost impossible to do at this time. "Hard" prices for installation cannot be generalized since installation costs vary widely depending on location and the local labor rates. Table 1 is a summary of estimates for a solar collector field using the Acurex concentrator and assuming a field size of 40,000 ft^2, with 20-foot spacing between rows. The costs for assembly, foundations, etc., were estimated using labor rates in the Phoenix, Arizona area. These costs were also based on estimated labor hours for an installation on level ground with sandy (or worst case) soil conditions. The figures shown in Table 1 are estimates, and can vary significantly depending on labor rates, the field site, and the particular application at hand (i.e., required temperatures, pressures, etc.).

Maintenance costs (Table 1) must also be considered when making a financial analysis for a solar system. Maintenance for a solar system may only mean a slight increase in normal maintenance for a particular industrial process if a maintenance team is already in place for a particular industrial or commercial application. In addition, if the project is anticipated only to have a 10-year payback, then replacing the reflector material and hoses in that period may be unwarranted. Therefore, these costs should be eliminated from the life-cycle analysis, significantly reducing expected maintenance costs over the life of the solar system. The investment analysis for a truck or car is analogous. The cost of a new engine is not included if the car is only expected to be used 5 years.

One of the maintenance concerns which arises often is the amount of effort required to clean a collector during normal operation. A simple, rugged collector may only need a hosedown washing. The Acurex collector, with an anodized aluminum reflector, may not be optimal from a reflectance point of view, but it is rugged, reliable, and very cost effective in terms of maintenance. It is easy to wash, withstands rough handling, and also (because of our particular design) the reflector surface is easy to replace if any serious damage does occur.

The industry probably will turn to a more standard design for high-temperature collectors in the future, and all collectors currently available probably will not survive. This should solve another objection to solar systems -- the availability and high cost of the various collector materials. If the industry standardizes one concentrating collector design or design type, the demand for collector materials will be high and manufacturers can easily obtain sufficient quantities of these materials at reduced costs due to high volume.

CONCLUSION

Although all aspects of high-temperature solar systems using an Acurex Concentrating Collector have not been described, some basic elements of our experience have been detailed. The basic philosophy of Acurex in the industrial and commercial solar energy business is to provide the most cost-effective solar energy system possible, using the most reliable and rugged materials available. Acurex Corporation is minimizing its involvement in developing newer and more sophisticated materials for solar energy systems. We have chosen to use common materials, such as steel, aluminum, and glass for our concentrator to minimize difficulty in implementing industrial and commercial solar systems.

ACKNOWLEDGEMENTS

Acurex wishes to acknowledge the support of ERDA and, in particular, Sandia Laboratories, for support and cooperation in the projects discussed in this paper.

APPENDIX A: SOLAR-POWERED, SHALLOW-WELL SYSTEM

DESCRIPTION

Today, there are several hundred thousand shallow-irrigation wells on farms and ranches in the southwestern states of California, Arizona, New Mexico, and Texas. The pumps on most of these wells are powered by fossil fuels, primarily natural gas. Inevitable increases in the cost of these fuels -- and the threat of shortages -- may make many of these wells unprofitable to operate in the foreseeable future.

To explore solar energy as a way of driving these wells, Acurex Solar Concentrating Collectors are being used in an experimental solar-powered irrigation system near Albuquerque, New Mexico. Sponsored by the Energy Research and Development Administration (ERDA) and the state of New Mexico, the project is designed to prove that solar energy is a technically and economically sound source of power for supplying water to America's agriculture.

Currently available technology is being used in all components of the experimental solar system. Performance data from this system will prove that the concept is feasible, and guide the commercial production of similar solar-powered irrigation systems in the near future.

A field of Acurex Concentrating Solar Collectors supplies the power for the solar irrigation system. These collectors heat an oil-like transfer fluid which remains stable at high temperatures. When this fluid reaches 216°C (420°F) a valve opens and the heated fluid flows either to a heat storage tank or directly to a boiler/heat exchanger.

In the boiler/heat exchanger, heat from the transfer fluid changes Freon R113 to a gas which reaches 163°C (325°F) and 1517 kPa (220 psi). This high-pressure gas drives a turbine which powers a well pump. Water is pumped into a plastic-lined storage pond to be used for irrigating.

The entire solar irrigation system is a closed-loop system. The heat transfer fluid and the Freon R113 are both recycled to be used repeatedly.

APPENDIX B: SOLAR INDUSTRIAL PROCESS HOT WATER SYSTEM

DESCRIPTION

Acurex and Campbell Soup Company, under ERDA sponsorship, are working together to investigate how solar energy can be used to heat water for industrial applications. Acurex first made a thorough study of the hot water needs at the Campbell Soup Company's plant in Sacramento, California. Following this study, Acurex designed a solar waterheating installation that will supply hot water at the required temperature of 190°F.

The solar-heated water will be used to wash empty and full soup cans on one of many parallel can-washing lines. An adjacent line will be used for comparison. The system is currently being built and will be operational in the very near future. It will be tested for a full year to provide complete information on efficiency, reliability, and operating costs.

DESIGN

Acurex's solar field design uses an optimum mixture of flat-plate and concentrating solar collectors. The flat-plate collectors are single-glazed with a nonselective surface on the metal absorber. These flat-plate collectors will preheat the water. Final heating will take place in the trough-shaped parabolic concentrating collectors.

The installation will supply 190°F water at a rate of 12,000 gallons per day during the peak season. At other times during the year, the same amount of water will be supplied at a lower temperature. This water will be brought up to the required 190°F by a steam heat exchanger. A storage tank will be used to ensure that hot water is available for two 8-hour shifts.

TABLE 1. COLLECTOR FIELD COSTS, 40,000 FT2
(see text for assumptions)

COLLECTOR FIELD INSTALLATION COSTS
(per ft of collector aperture area)

Collector hardware	$13.69
Installation supervision	1.11
Shipping (rough est. only)	0.65
Assembly labor	4.00
Foundations[a]	4.50
Manifolds, pumping	3.90
TOTAL INSTALLED FIELD COST	$27.85

MAINTENANCE COSTS
(per 84-foot row -- eight collector modules)

Normal maintenance per year	6.5 hours
Washing per row	1/3 hour
Material	$20.50 per year

REFLECTOR AND FLEX HOSE REPLACEMENT
(every 10 years) $58.00

Note: All costs in current (August 1977) dollars.

[a]Foundations costs are often not included in the purchase of a collector system. Foundations are provided by the organization with responsibility for site preparation. This organization is often not the collector manufacturer.

T-609

Heat Pumps and Solar Cooling

by
David P. Hartmann
System R&D Engineer
Bonneville Power Administration
Portland, Oregon

to be presented at Solar 1978 Northwest
Sheraton Hotel, Lloyd Center
Portland, Oregon
July 14, 1978

Interest in alternative energy sources for use in heating and cooling substations began in 1973 at Bonneville Power Administration. You will recall that 1973 was a very poor rain and snow year for the Columbia Basin and extensive conservation measures had to be taken to permit the available hydro generator capability to meet load.

Use of waste heat from power transformers had been done earlier at Hydro Quebec headquarters in downtown Montreal. In winter, the buildings make-up air was used to cool the buildings power transformers. The transformers waste heat provided preheating of the subzero outside air during the winter. In Chicago, Commonwealth Edison used building supply water to cool power transformers in five substations installed in Sears Tower. Here the transformer's waste heat preheats the incoming water for domestic hot water needs. Seattle City Light is investigating heating the Pacific Science Center with transformer waste heat from a nearby station. This study has EPRI funding.

Transformers are inherently very efficient. Their efficiency ranges up to 99.96 percent or even better. However, when one considers a 250,000 kilovoltampere transformer, even 0.1 percent losses represent 250 kW of available waste heat. The problem is that this heat is expelled of near-ambient temperature from the transformers oil-to-air cooling radiators. Further, American National Standards require that the top oil temperatures of the transformer never exceeds 55°C above ambient. Since the Portland-Vancouver area experiences a winter peak load, and because there is less sunlight available in winter, it appeared suitable to test a heat pump which uses the power transformer's waste heat to improve its coefficient of performance to provide warm water to a fan-coil unit to heat the Ross Control House.

Two methods could be used for drawing heat from the transformer cooling oil and transferring it to refrigerant in the heat pump circuit. The first would be to put the oil in heat exchange with water and in turn use the water to warm the heat pump refrigerant. An intermediate water loop, or other low pressure intermediary was needed, to insure that leakage would always be out of the transformer since oil contamination would have catastrophic results. The second method, which was selected, was to avoid the oil circuit completely and put a conventional plate-fin coil into the air stream leaving the oil cooler. Table I gives a summary of numerical information selected as a design point. Under these conditions, it will be seen that about 350,000 Btu/hour are rejected, warming a 10,000 cfm airstream from 21^{o}F to 54.5^{o}F. About 55,000 Btu/hour will be extracted by the air coil, as designed, sufficient to supply full heat requirements to the Control House at a 99 percent probable design temperature.

Table I

Prototype Energy Retrieval and Solar System

Input Data for Design Point

Ambient Air Temperature	21°F
Transformer Load	67%
Transformer Size	250 MVA
Oil Temperature	68.5°F
Heat Rejection, Oil Radiator	361,500 Btu/hr
Air Temperature, Leaving Radiator	54.5°F
Air Flow Rate	10,000 cfm

Air Coil Data

Coil Dimensions	58' x 58' x 3 1/2
Rows	2
Spacing, Face	2 inches
Row	1.5 inches
Fins	12.95 inch^{-1}
Saturated Suction Tempurature	42.1°F
Capacity	55,000 Btu/hr

Vacuum insulated glass solar collectors are used to gather available winter solar energy for storage in a 4300 gallon water tank for back-up for the heat pump system. The heat pump and solar collectors were installed during the summer of 1977. May 15, 1978, marked the beginning of the heating season. First winter performance was marked by several compressor failures, some instrumentation problems, but almost no electric resistance heat was needed, since the heat pump and the backup solar system performed well.

A 15-ton specially designed solar lithium bromide absorption water chiller was installed at Ross during January 1978 to provide air conditioning. The heat pump runs in reverse mode with water cooling as a backup to the absorption chiller. The design of this chiller includes a special vacuum spray evaporator chamber which permits successful absorption cooling with solar-heated water as the energy source. This solar heated water may be as low as 170°F and still it provides sufficient energy to cool the building. Table II shows the expected summer performance of the solar collector array.

Table II

Owens-Illinois Sunpak-SSR Collector Array
35 Panels, 30° Angle, Flow 1.7 Gal/Ft^2-Hr 25% Glycol

Average Daily Performance

	Available Insolation Btu/Day-Ft^2	Estimated Heat to Chiller Btu/Day	Potential Cooling to Storage Ton-Days/Day
June	1396	684,000	2.38
July	1676	925,000	3.21
August	1598	880,000	3.06
September	1179	578,000	2.01

Percentage cooling load by solar
TRANSYS, "Average" weather = 100%
cooling load by solar.

Admittedly, the Ross Control House is not a severe test of the absorption chiller because the building cooling load is not 15 tons. Thus, it is possible to run the chiller for short periods of time during warm sunny weather and store the chilled water (at 46°F) in the 4300 gallon tank. The air-coil fan unit is then fed chilled water from storage to maintain comfortable conditions for the workers in the Control House. Solar cooling began during the week of May 15. With the variable Pacific Northwest summer climate so far, we have experienced good results in cooling either with the solar absorption unit or the reverse-mode heat pump. Table III shows the load calculations for the Ross Control House.

Table III

Ross Control House

Load Calculations

Floor Area, Conditioned Space	2760 Ft^2
Annual heating Load	1.39×10^8 Btu/Season
Building Load	30,000 Btu/Degree Day
Annual Cooling Load	2.34×10^7 Btu/Season
Heat Pump, Heat to Load	99%
Heat Pump, Seasonal C.O.P.	-6.2 Expected Above 3
Absorption Chiller, Output	2.76×10^7 Btu/Season

In a separate undertaking, BPA has agreed to field test a 25-ton organic Rankine cycle heat pump for heating and cooling BPA's Redmond Maintenance Building. This unit uses Freon vapor (thus the organic cycle) heated from solar hot water to run a very high speed (up to 60,000 rpm) specially designed turbine compressor. This compressor does the work needed for the heat pump. Because the compressor and a special high-speed backup electric motor are all on the same gas-bearing-supported rotor, efficiency of this unit is quite high. Installation of this unit, along with double-glazed solar collector field of 5000 square feet will begin in early calendar year 1979 (Jan-April). This heat pump is a development from the NASA/DOE cooperative effort to develop commercial solar heating and cooling systems.

A related plan is being considered by BPA and DOE's Division of Solar Heating and Cooling to install a second generation solar absorption chiller at BPA's Big Eddy Control House near The Dalles, Oregon. This control house has a large year-round cooling load and because of the desert climate, better year-round insolation. The objectives of the second solar absorption chiller project are to get a more optimized design into the field for testing. To be more optimized, the energy efficiency is being raised and construction/installation labor and costs are being lowered. The factory assembly and test of a skid-mounted module with smaller more efficient pumps and motors and minimal requirements for field assembly and control system hookup should help make this system more nearly competitive with existing electromechanical units.

Reference

1. "Prototype Energy Retrieval and Solar System," Dr. D. P. Hartmann and Dr. Wendell Biermann, Energy Systems Division, Carrier Corporation, Presented at the Solar Outlook 1978 Conference, Washington, D.C., March 11, 1978.

SOLAR ECONOMICS

AN ECONOMIC ANALYSIS OF PACIFIC NORTHWEST ACTIVE SOLAR HEATING SYSTEMS

G.L. Liffick, U.S. Department of Energy, Richland, WA.
H.L. Parry, Battelle Northwest, Richland, WA.

INTRODUCTION

In May 1978 the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency released a report entitled "Solar Energy for Pacific Northwest Residential Heating" (available from U.S. Department of Energy, 915 2nd Ave., Seattle, WA. 98174). Part of that report dealt with the economic viability of different residential uses of solar energy in the Pacific Northwest. This paper will discuss the analysis performed in the report to evaluate the economics of active solar heating systems for swimming pools, domestic water and residential living spaces.

Solar Swimming Pool Heaters

Solar swimming pool heaters are the most widely used of all solar heating systems in the country. Figure 1 shows a typical schematic for a pool heating system. After pool water is pumped through a standard pool filter, it passes through the collector array and then back to the pool. Manual or automatic valves allow the collectors to be bypassed on very cloudy days or at night if it is desired to keep the filter running. The circulation pump is generally the standard pool pump supplied as part of the filter system. The pool itself acts as a heat storage and distribution system.

Swimming pool heaters represent an ideal application of solar energy for several reasons:

1. Swimming pools are generally used from late spring to fall when the largest amount of solar radiation is available.

2. Because of the low temperatures and pressures involved, solar pool heaters can use very simple, low-cost, unglazed collectors, often made of plastic.

3. The relatively low collector operating temperature results in high collector operating efficiency.

Sizing a solar heating system for a swimming pool is a fairly simple operation. Because variations in pool

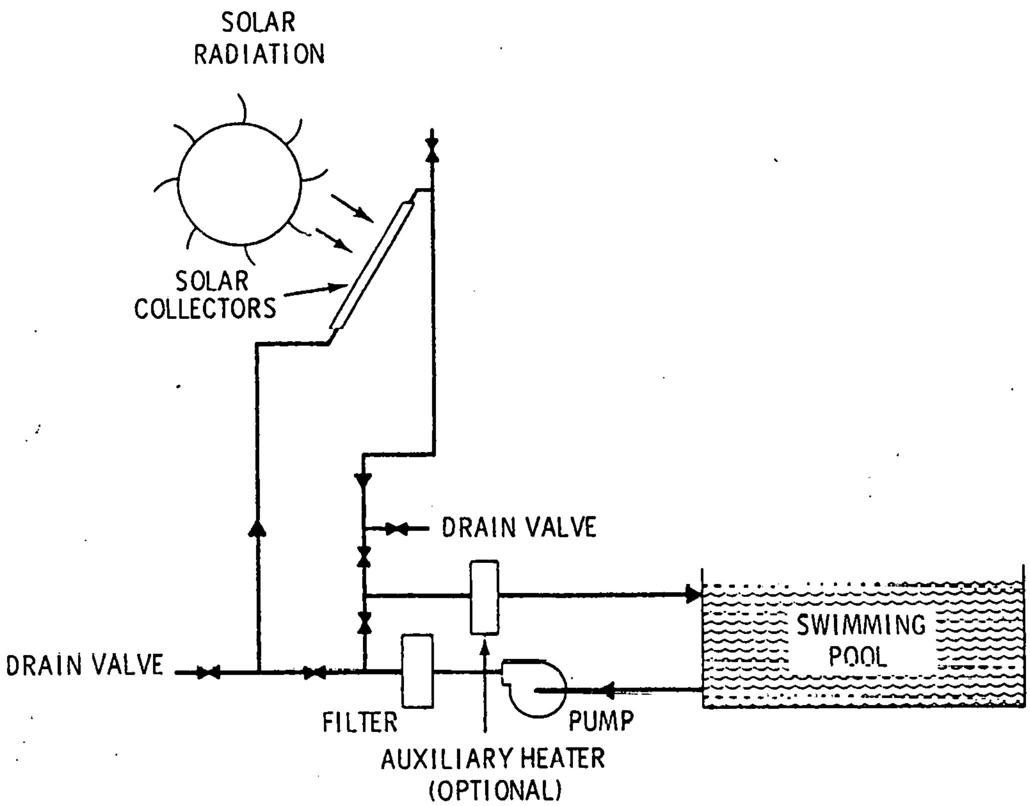


FIGURE 1. A Solar Swimming Pool Heating System

temperature are not a serious problem and because collectors are inexpensive, sizing of a collector system for a pool is not as critical as for a house. For this reason, detailed procedures for sizing pool heaters have not been developed. Instead, the general rule-of-thumb has been to use a south-facing collector area of 50 to 75% of the pool surface area.

A detailed economic analysis of solar pool heaters is difficult because so much depends upon the practices and values of the pool owner. How warm does he want his pool? Does he object to temperature variation during the swimming season? How long a swimming season does he desire? Is he willing to cover his pool at nights to minimize heat loss? However, it is possible to perform a very simple analysis which will give an indication of what the expected payback periods might be for different cities in the Pacific Northwest.

Table 1 shows the amount of energy that 1 ft^2 of 30° slope, south facing, swimming pool collector, operating at 60% efficiency (typical for a pool collector), might gather during a season from April 1 through September 30.[1] The table also shows the equivalent value of that energy if it were provided by electricity at rates of 1.0, 2.0 and 3.0 cents/kWh (1 kWh = 3413 Btu). It is then simple enough to compare the energy value of 1 ft^2 of collector to the cost of buying and installing that 1 ft^2 of collector to determine the approximate number of years it will take to pay for the system. As an example, if electricity costs 2.0 cents/kWh, the value of 1 ft^2 of pool collector in Corvallis, Oregon, is about $1.06/season (from Table 1). If the pool collector system costs $4.00/ft^2 to build and install, the system should pay for itself within 4 years ($4.00/$1.06 saved each year = 3.77 years). Note that this very simple analysis does not take into account escalating energy costs, the value of alternative investments, possible tax credits, maintenance costs, or energy wasted if the solar system is turned off because the pool is warmer than a particular owner desires. Consequently, it should be used only as a very rough guide. However, the table does show that pool heaters can collect a considerable amount of energy during the swimming season throughout the Pacific Northwest and can recover their initial cost in a fairly short period.

TABLE 1. The Estimated Average Seasonal Value of 1 ft^2 of Swimming Pool Solar Collector in Various Cities

City	Net Energy Collected	Value for Different Electric Rates 1¢/kWh	2¢/kWh	3¢/kWh
Corvallis, OR	53 kWh	$0.53	$1.06	$1.59
Medford, OR	67 kWh	0.67	1.34	2.01
Seattle, WA	55 kWh	0.55	1.10	1.65
Spokane, WA	65 kWh	0.65	1.30	1.95
Boise, ID	68 kWh	0.68	1.36	2.04

Season from April 1 to September 30.
Collectors facing south at a 30° slope.
Assumed 60% collector efficiency.

Active Residential Space and Water Heating Systems

An economic analysis of four different solar heating and/or hot water applications has been performed for eleven Pacific Northwest locations. This paper gives results for two of those locations - Boise, Idaho and Corvallis, Oregon. Results for Twin Falls, Idaho; Astoria, Oregon; Klamath Falls, Oregon; Medford, Oregon; Friday Harbor, Washington; Pullman, Washington; Richland, Washington; Seattle, Washington; and Spokane, Washington can be found in the DOE report discussed in the Introduction.

The four applications considered at each location were:

1. solar hot water system installed in new construction,[a]
2. solar hot water system installed in an existing structure,[a]
3. solar space heating and hot water system in new construction, and
4. solar space heating and hot water system installed in an existing structure.

FCHART, a computerized design tool developed by the University of Wisconsin, was used to perform this solar system economic analysis. The methodology for the analysis is similar to that used in Solar Water and Space Heating,[2] a report prepared by the Mitre Corporation for the Division of Solar Energy, DOE, November 1976. Certain variables used in the MITRE analysis have been changed to better reflect Pacific Northwest conditions. Table 2 lists the input variables used for this analysis. Figure 2 shows the system being analyzed. The results of these analyses are curves relating solar system cost and the cost of electricity to the Years-to-Break-Even for a cost optimized solar system. Years-to-Break-Even is the time it takes to recover 100% of the initial cost of the solar system through savings in electricity costs considering both inflation and interest charges. The cost of the solar heating and hot water systems are compared to electric resistance heating (baseboard units or electric furnace) costs and electric water heaters. It should be noted that each solar system was sized to minimize the Years-to-Break-Even, that is, to be as cost effective as possible.

Future electricity costs are based on DOE (formerly the Federal Energy Administration) projections published in the

(a) Different loan conditions were used for new construction and modifications to existing structures (see Table 2).

TABLE 2. FCHART Variables

Variable	Description
Variables Common to All Analyses	
Type of Solar System	The liquid system shown in Figure 2.
Collector Orientation	South facing
Solar System Costs	System costs of \$5, \$10, \$20 and \$30/ft^2 were used. These are the incremental costs of the entire solar sytem (collectors, controls, piping, storage, etc.) divided by the collector area (ft^2). The incremental cost of the solar system is the cost above the conventional heating and/or hot water systems.
Storage	1.8 gal/ft^2 of collector area.
Loan Conditions	For new construction a 25-year loan at 8-1/2% annual interest was used. For solar systems added to existing structures the loan was 10 years at 10% annual interest.
Alternative Investment Opportunity	It was assumed that if an individual does not buy a solar system this money could be invested at 8-1/2% (before taxes).
Electrical Energy Costs	Current electricity costs of 1.0, 2.0, 3.0, 4.0, and 5.0 cents/kWh were used. These costs were based on FEA projections published April 15, 1977, in the Federal Register.
Operating Costs	An annual cost of 1% of the system cost was used to provide for maintenance and increased insurance. Inflation of 6%/year was applied to these costs.
Income Tax Rate	A combined Federal State income tax rate of 30% was used.
Property Tax	It was assumed that solar systems would be exempt from property tax. This has occurred in Oregon and Washington.
Salvage Value	It was assumed that at the end of 15 years the solar system has no salvage value (i.e., does not increase the value of the building).
Heating and Hot Water System Variables	
Collector Slope	56° from horizontal
Type of Collector	Double-glazed copper tube collector with $F'_R(\tau\alpha)_n = 0.70$ and $F'_R U_L = 0.83$.(a)
Thermal Load	Building heat loss of 527 Btu/hr/°F. With an outside design temperature of 18°F this would result in a 26,350 Btu/hr heating load (68°F inside). Hot water load as below.
Hot Water System Variables	
Collector Slope	46° from horizontal.
Type of Collector	Single-glazed copper tube collector with $F'_R(\tau\alpha)_n = 0.75$ and $F'_R U_L = 1.00$.(a)
Hot Water Load	80 gal/day heated from 60°F to 140°F.

(a) $F'_R(\tau\alpha)_n$ and $F'_R U_L$ are parameters used to describe the efficiency of solar flat plate collectors.

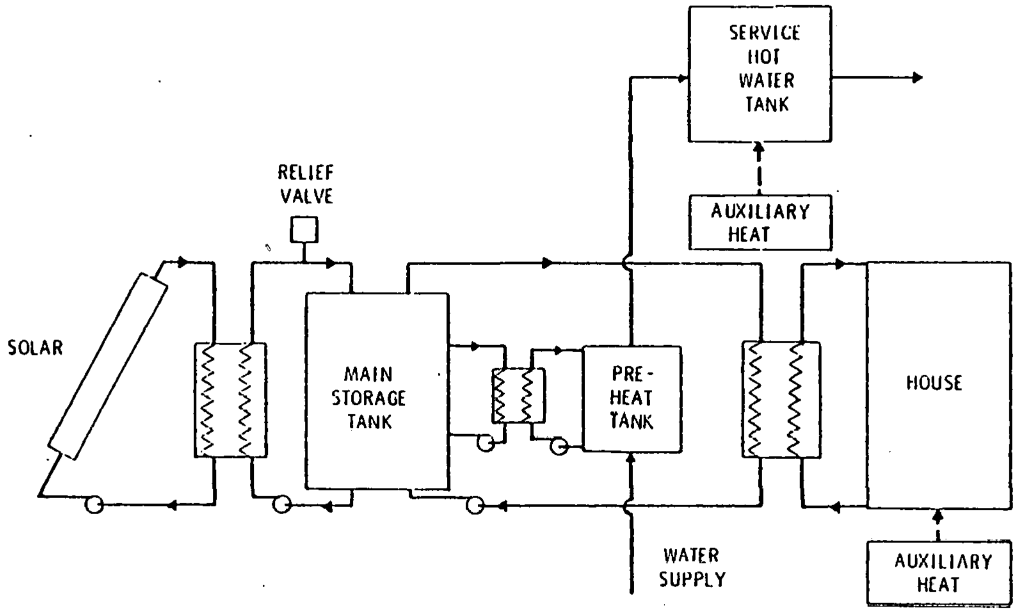


FIGURE 2. Schematic Diagram of a Liquid-Based Solar Space and Water Heating System

April 15, 1977 Federal Register. Since these projections do not include inflation, they have been increased by 6%/year. The combined rate of increase in electricity costs averages 8%/year over the next 15 years, with the years 1977 through 1981 having approximately an 11%/year increase. Of course, the rate increases of individual utilities will vary depending on their future cost of electricity. For this analysis the DOE combined rate of increase in electrical costs was then applied to each of the five present electrical cost figures (1.0, 2.0, 3.0, 4.0 and 5.0 cents/kWh). Electricity costs in the Pacific Northwest are currently between 0.8 and 2.5 cents/kWh. The 3- to 5-cents/kWh electricity costs are included to show how the Years-to-Break-Even will change at higher electricity costs.

The University of Wisconsin has shown that a FCHART analysis of a liquid system reasonably approximates the performance of a similar air system.(3) Therefore, although the Years-to-Break-Even curves developed for each location were based on a liquid system, they may also be used to approximate a system using air as the heat transfer fluid.

Accurate prediction of the performance of a solar heating system is made very difficult by the fact that performance is dependent upon the local weather -- not just the weather in the local region, but the weather at a given building site. The weather parameters most affecting a solar system's performance are the following:

1. solar radiation, which determines the energy available for collection,

2. ambient temperature, which helps to determine the amount of energy needed for heating and the efficiency of the collection system, and

3. wind speed and direction, which also help determine the energy needed and the collection efficiency.

The difficulty in making accurate performance predictions for a solar heating system at a specific site is not as serious as it might seem. Most cost effective solar systems for the Pacific Northwest will not provide 100% heating and will need to have an auxiliary heating unit capable of maintaining an adequate living environment. Consequently, there should not be undue hardship if a system does not provide all of the heat predicted.

The procedure for using the Years-to-Break-Even curves is as follows:

1. From your utility bill or by calling the local utility, determine your average cost of electricity in cents/kWh.

2. Calculate the total incremental system cost per ft^2 of collector for the proposed solar system. The total incremental system cost of the solar system is the cost above the conventional heating and/or hot water system cost, and includes the cost of all components, installation, labor, sales tax, etc. If you are eligible for a federal or state tax credit or rebate, subtract this amount from the total incremental system cost. Divide this "net" cost by the ft^2 of collector area. Typical values for commercially installed solar systems are \$20 to \$30/ft^2 of collector. Do-it-yourself systems are typically \$10 to \$20/ft^2 of collector.

3. As shown in Figure 3, find your cost of electricity (2 cents/kWh), draw a vertical line up to the total system cost/ft^2 of collector curve (\$20/ft_c^2), and from that point draw a horizontal line over to the vertical axis to determine the Years-to-Break-Even. In this example for Boise, Idaho, it will take approximately 12 1/2 years before electricity savings equal the additional cost of a solar hot-water

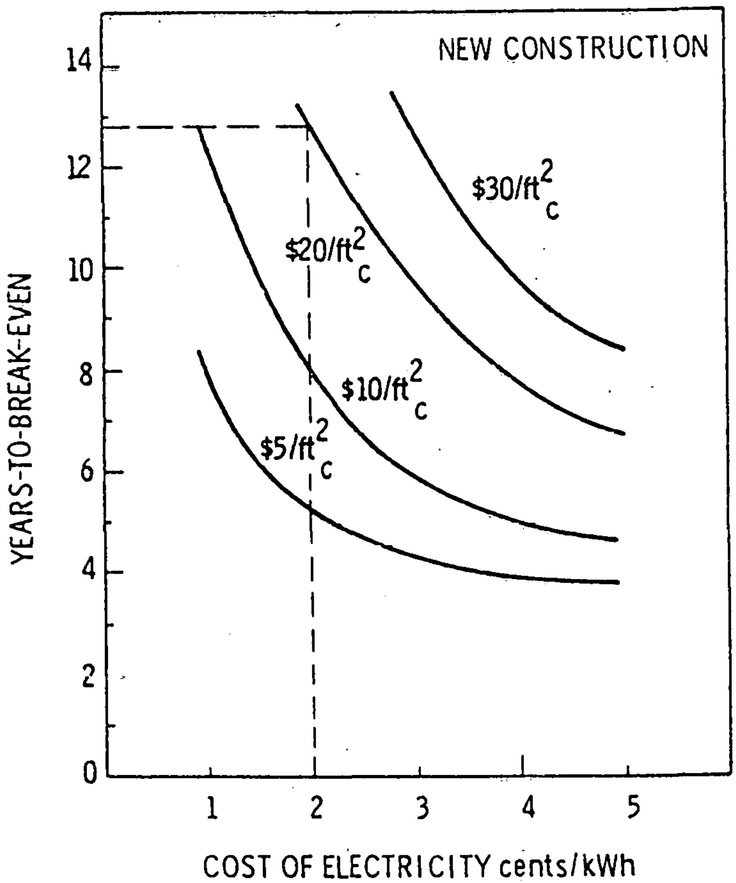


FIGURE 3. Hot Water System, Boise, Idaho

system. Note that for heating systems, solar systems are compared to electric resistance heating (baseboard units or electric furnace).

4. Collector cost curves not shown, such as $15/ft$^2_c$, may be estimated (interpolated) between the existing curves. However, the curves cannot be extended (extrapolated) to lower electricity costs. The optimal solar systems in the blank areas either require more than 15 years to break even or will supply less than 40% of the total energy requirements.

Figures 4 and 5 show the Years-to-Break-Even of cost optimized solar systems in Boise and Corvallis based on the assumptions in Table 2. The ranges of collection areas and energy supplied by the cost optimized system are shown in Tables 3 and 4. It should be stressed that although the values shown are felt to be typical, they should be used only as guides, not fixed design values. Each potential solar system should be individually analyzed after the preliminary design has been completed.

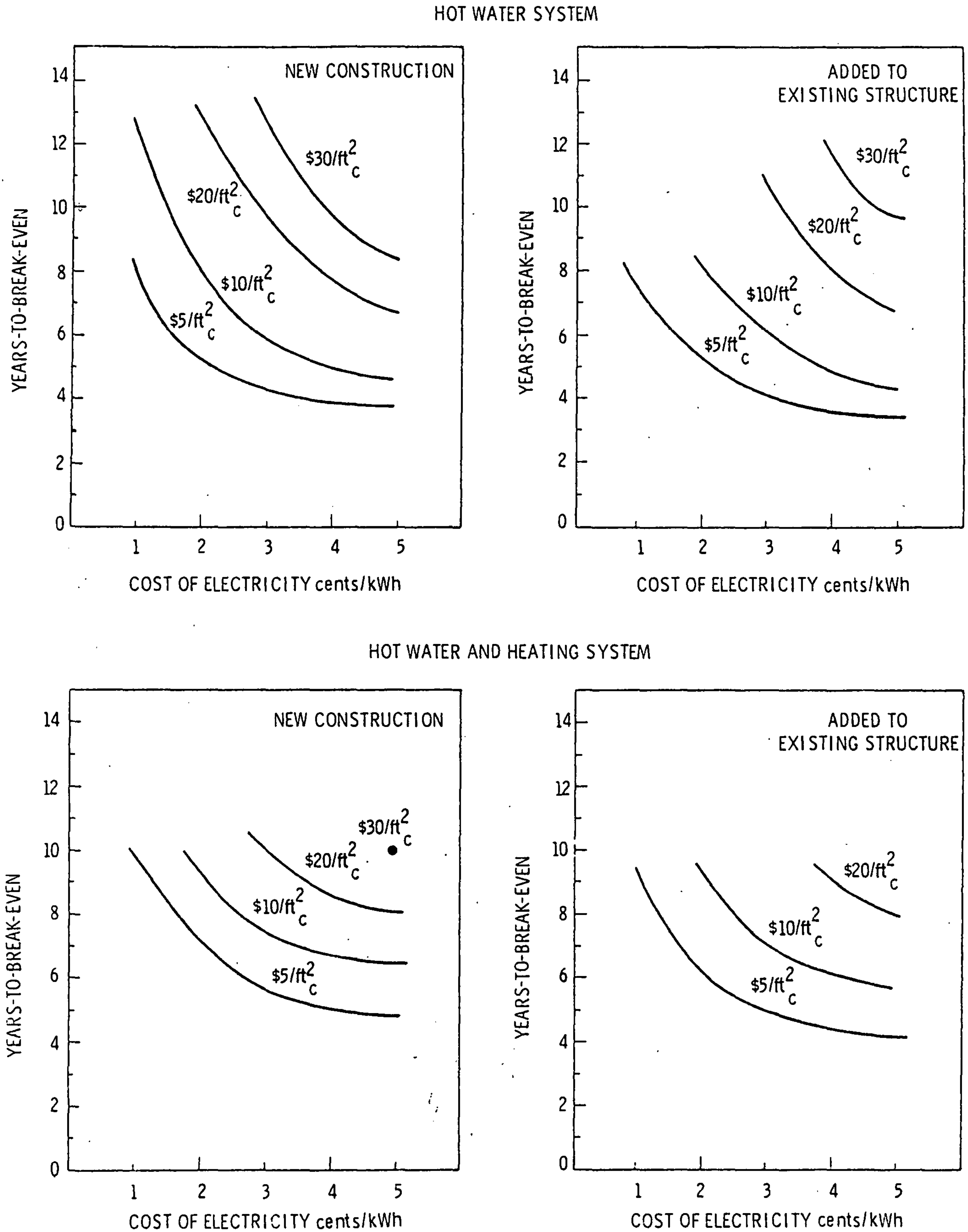


FIGURE 4. Economic Analysis for Boise, ID

TABLE 3. Economic Analysis for Boise, ID[a]

A. Percent Energy Supplied by Solar System

Solar System Cost $/ft^2	Energy Cost cents/kWh	Hot Water: New Construction	Hot Water: Retrofit	Hot Water and Heating: New Construction	Hot Water and Heating: Retrofit[c]
5	1	73	65	53	41
	2	81	77	70	62
	3	92	83	78	72
10	1	50	(b)	(b)	(b)
	2	73	65	53	41
	3	79	75	65	55
20	2	50	(b)	(b)	(b)
	3	68	54	41	(b)

B. Range of Optimized Solar Collector Areas (ft^2)

Solar System Cost $/ft^2	Energy Cost cents/kWh	Hot Water: New Construction	Hot Water: Retrofit	Hot Water and Heating: New Construction	Hot Water and Heating: Retrofit
5	1	75	60	305	195
	2	100	85	560	425
	3	155	105	780	605
10	1	40	--	--	--
	2	75	60	305	195
	3	90	80	460	330
20	2	40	--	--	--
	3	65	45	200	--

(a) FCHART data is based on information from the National Climatic Center, Asheville, NC. Boise data should be generally applicable to the Snake River Valley from Mountain Home, ID north to Huntington, OR.
(b) Less than 40%.
(c) Added to existing structure.

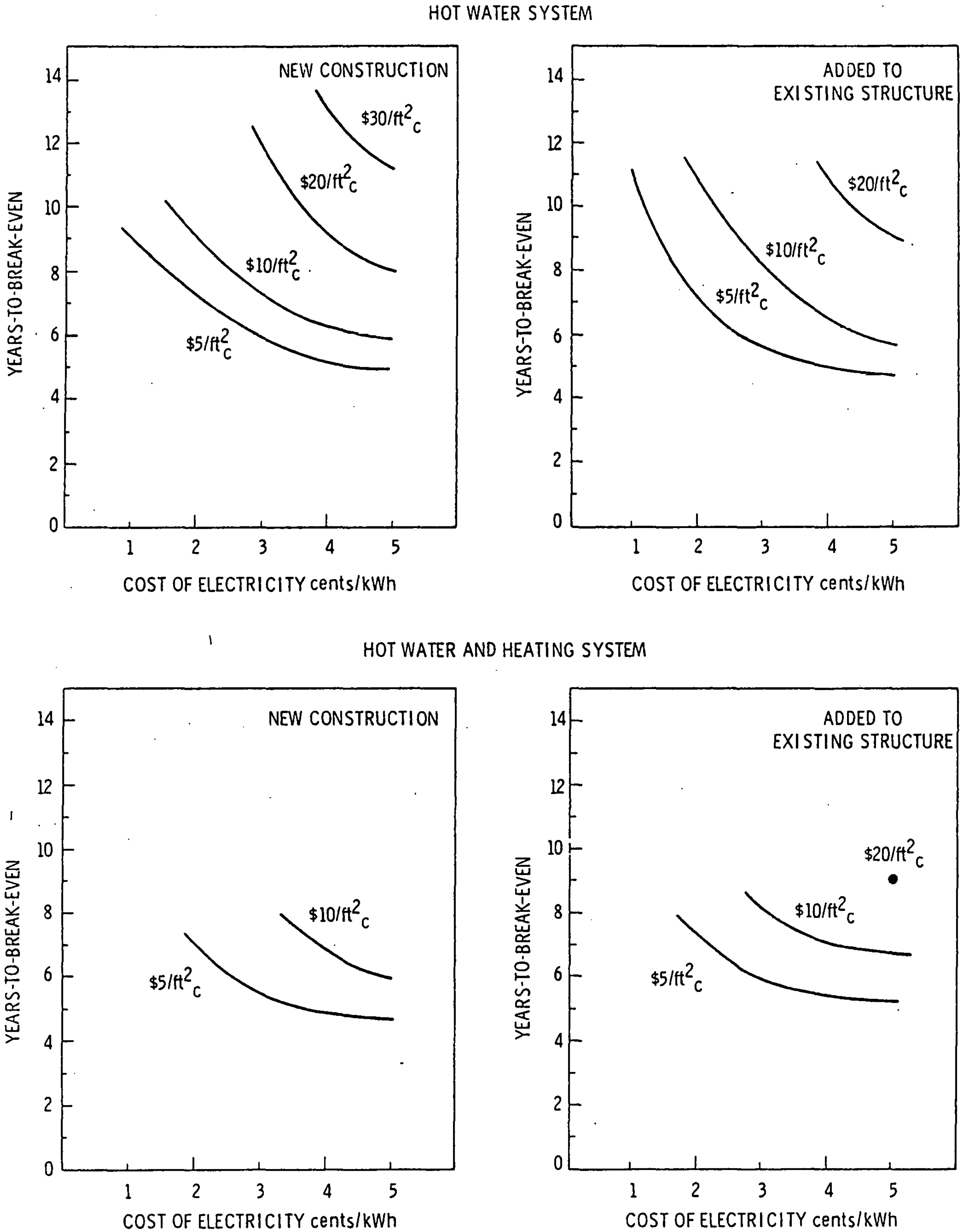


FIGURE 5. Economic Analysis for Corvallis, OR

TABLE 4. Economic Analysis for Corvallis, OR[a]

A. Percent Energy Supplied by Solar System

Solar System Cost $/ft²	Energy Cost cents/kWh	Hot Water: New Construction	Hot Water: Retrofit	Hot Water and Heating: New Construction	Hot Water and Heating: Retrofit[c]
5	1	56	45	(b)	(b)
	2	69	63	56	47
	3	96	80	63	57
10	2	56	45	(b)	(b)
	3	63	58	48	(b)
20	3	48	45	(b)	(b)

B. Range of Optimized Solar Collector Areas(ft^2)

Solar System Cost $/ft²	Energy Cost cents/kWh	Hot Water: New Construction	Hot Water: Retrofit	Hot Water and Heating: New Construction	Hot Water and Heating: Retrofit
5	1	70	50	--	--
	2	110	90	445	315
	3	255	165	620	480
10	2	70	50	--	--
	3	90	75	330	--
20	3	55	50	--	--

(a) FCHART data is based on information from the National Climatic Center, Asheville, NC. Corvallis is located adjacent to the coastal range on the west side of the Willamette River Valley and data for it are probably directly applicable only to the immediate area. However, these curves can used as a guide for the Willamette Valley from Eugene north to Portland.
(b) Less than 40%.
(c) Added to existing structure.

CONCLUSIONS

An analytical evaluation of the economics of active solar heating systems for swimming pools, domestic water and residential living space shows that all three can be cost effective in the Pacific Northwest when compared to electricity. Swimming pool heaters at a price typical of commercially installed units (i.e., $\$4/ft^2$ collector) can pay for themselves in well under 10 years. However, for domestic water and space heating systems to have acceptable pay back periods they must be very low in cost ($\$5$ to $\$10$ per ft^2 of collector for the total installed system). This indicates that while a low cost do-it-yourself system may be economically viable, the cost effectiveness of commercially installed systems at $\$20$ to $\$30$ per ft^2 of collector is marginal. Of course it should be recognized that cost-effectiveness is only one factor affecting the homeowner's decisions to install an active solar heating system. Issues such as prestige, energy consciousness, the environmental ethic, and the desire to minimize our nation's dependence on foreign oil may well be of greater importance to many homeowners than pure economics. Also legislative measures to reduce the effective cost of active solar heating systems through tax credits and refunds can have an overnight effect on the economic attractiveness of such systems.

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ECONOMICS OF RESIDENTIAL SOLAR HEATING (ACTIVE SYSTEMS)
IN THE PGE SERVICE AREA

by Roy Josi, P. E.
Space Conditioning Consultant
Portland General Electric Company

INTRODUCTION

There is much confusion evident regarding the feasibility of solar heating in the Northwest. Many people have "written off" this energy source as practical in this region because of the apparent abundance of "liquid sunshine" and overcast weather. Other people adamantly dispute this viewpoint and claim that all forms of solar heating are economical today.

This paper is from a study that attempts to quantify solar economic feasibility in the PGE service area.

"Passive" solar heating which employs the structure itself to collect and store solar energy using natural convection, conduction, and radiation phenomena is very feasible in the PGE service area. This study, however, is limited in scope to "active" solar heating systems - those which employ electrical and/or mechanical energy to facilitate the collection and storage of solar energy.

In addition, institutional barriers such as solar zoning, building codes, financing opportunities, etc., are not treated in this paper.

Economic studies discussed in this report use PGE Schedule 7 (residential) rates of 2.4¢ per kilowatt-hour under Tariff E-9, effective November 1977.

Economic Analysis of Solar Heating

Later sections of this report discuss economic analyses of solar swimming pool heating, solar domestic water heating, and a combination of solar domestic water heating and space heating in the PGE service area. The analyses of the latter two involve the use of a solar simulation and optimization computer program developed by the University of Wisconsin Solar Laboratory entitled "FCHART".

Life-Cycle Economics

The initial cost of heating equipment (and most everything else we purchased) used to be practically the only factor in deciding the type of system to install in a residence or building. The cost of energy because it was inexpensive played a small role in that decision.

Now energy costs are rising and necessarily have to be considered when analyzing the lifetime cost of owning and operating any heating system, especially a solar heating system. Equipment costs are still important if you are contemplating a solar heating system, but so are maintenance costs, financing costs, depreciation, salvage or trade-in value, and fuel costs.

Therefore, consideration not only of initial investment costs, but also the operating and maintenance costs of that equipment during its lifetime, constitutes what is called "life cycle costing".

Initial Cost Considerations

All of the above discussion is not to say that first cost of a solar heating system is not an important consideration - it is. It is, in fact, a very important component of life-cycle economic analyses.

When first cost of the solar heating system is discussed, it is important to clarify what is being talked about. In solar heating there is a wide range of available technology - all the way from the person who makes his own system out of recycled material and installs it himself, to the person who employs an architect or engineer to design a system using commercially available components and then has a contractor install the system. Obviously, the first type of system has profound first cost advantages over the second type. However, other owning and operating costs may be affected by this choice of approach - namely the usable lifetime of the system, system performance degradation over time, maintenance costs, and system reliability.

All of these factors must be included into an analysis in order to determine the lowest owning and operating cost over the life of the system.

Non-economic Factors

Economic life-cycle cost factors are not the only driving forces behind purchasing decisions for solar heating systems - especially for the homeowner.

Other factors which motivate these decisions are: desire for some self-sufficiency, pioneer spirit, conservation concerns, desire for some sort of hedge against inflation, appreciation of home for resale purposes, and a desire for decentralization of energy resources.

"Optimized" Solar Heating Systems

The analyses, discussed in this paper, of solar domestic water heating systems and combination solar space heating and domestic water heating systems are intended to quantify the life-cycle economics of "optimized" solar heating systems. There are also analyses of the sensitivity of certain critical variables as those variables differ from these "optimized" values. Some familiarity with the meaning of life-cycle cost terminology and solar terminology is necessary to be able to interpret the analyses. A review of "Appendix A - Glossary of Terms" will help in this regard. The definition of "optimized" system can also be found in this Appendix.

The results of any such life-cycle economic analyses are, of course, only as accurate as the accuracy of all the input parameters. When you study the impact now of events that will take place for 20-30 years into the future, one must either be an accurate prophet or make the confession of mortality and therefore make the best assumptions possible for a large number of unpredictable "things". Some of these unpredictable "things" are inflation rate, rate of solar backup fuel escalation, maintenance costs, system life, and yearly and lifetime system performance. The assumptions made in these analyses are largely "educated best guesses". The interpretation and the use of the results must bear this "softness" in mind.

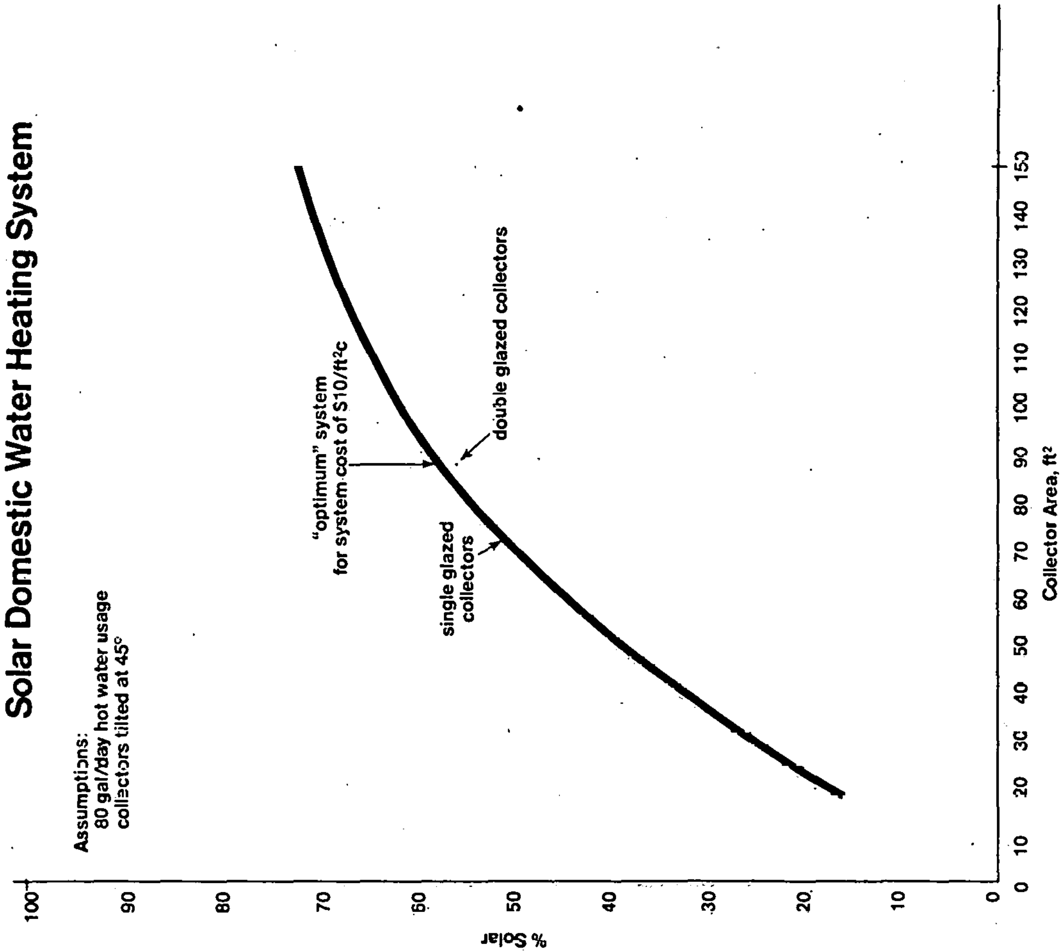
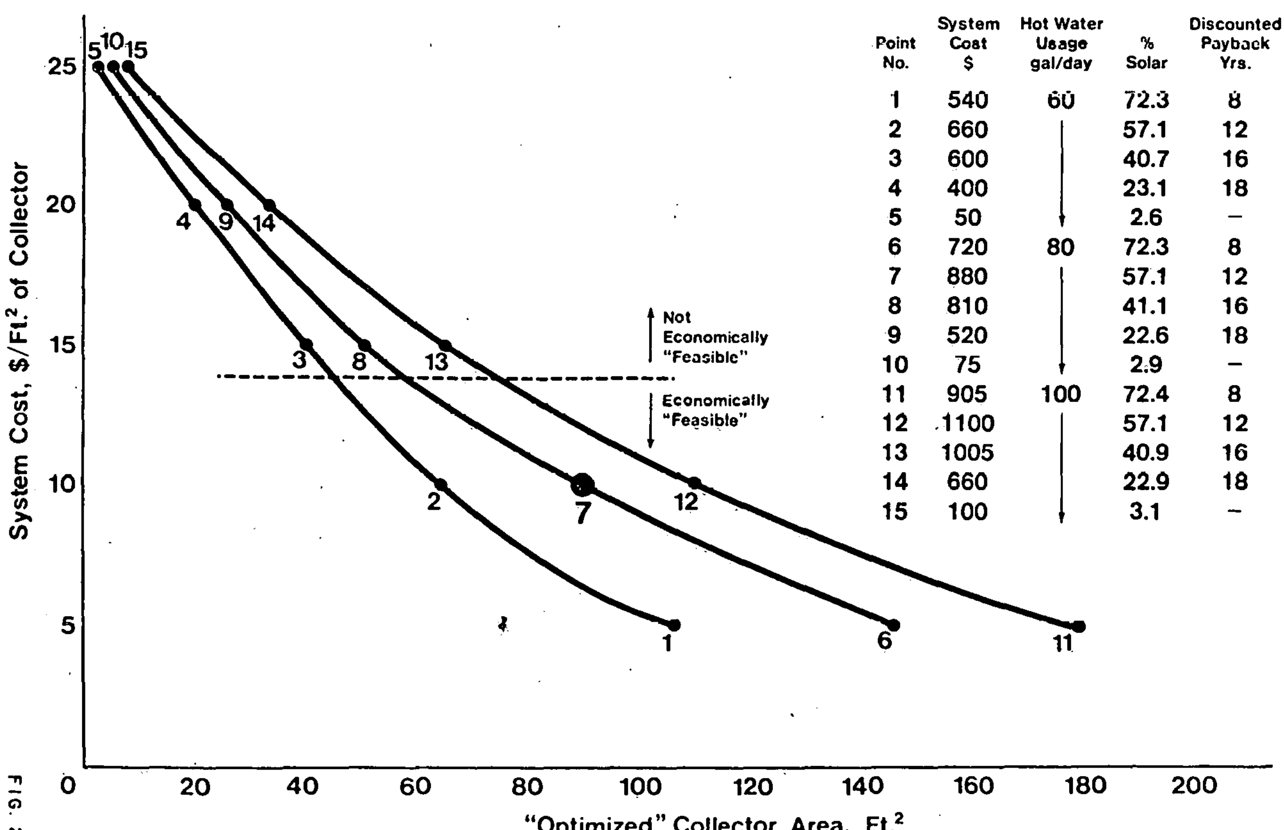


FIG. 1

"Optimized" Solar Domestic Water Heating System



Point No.	System Cost $	Hot Water Usage gal/day	% Solar	Discounted Payback Yrs.
1	540	60	72.3	8
2	660	↓	57.1	12
3	600		40.7	16
4	400		23.1	18
5	50		2.6	–
6	720	80	72.3	8
7	880	↓	57.1	12
8	810		41.1	16
9	520		22.6	18
10	75		2.9	–
11	905	100	72.4	8
12	1100	↓	57.1	12
13	1005		40.9	16
14	660		22.9	18
15	100		3.1	–

FIG. 2

SOLAR SWIMMING POOL HEATING

Assumptions

For these systems, the analyses assume the following:

- Unglazed plastic or metal collectors facing true south at a 30-degree tilt from the horizontal.
- Pool heating season from April 1 - September 30.
- 60-percent seasonal collector efficiency.

Results

For the above assumptions, these systems will produce approximately 55 kilowatt-hours of energy per sq. ft. of collector worth $1.32 under PGE Schedule 7, Tariff E-9 rates effective November 1977.

Typical system costs today per sq. ft. of collector are:

- $.50-$3.00 for "do-it-yourself" systems.
- $3.00-$5.00 for commercially available systems.

It is evident that simple paybacks within five years can be expected for solar swimming pool heating systems in the PGE service area.

SOLAR DOMESTIC WATER HEATING

Assumptions

For these systems, the analyses assume the following:

- Portland weather data.
- Single-glazed collectors facing true south tilted 45 degrees from the horizontal.
- Solar storage of 1.8 gallons per sq. ft. of collector.
- 20-year economic study.
- 6-percent inflation rate.
- 35-percent combined State and Federal income tax rate.
- PGE's residential rates and escalation estimates (8.3 percent per year).
- 3-year loan at 10 percent, 10-percent down payment.

- 1.5 percent of initial investment per year for maintenance and insurance.

- 6-percent discount or yield rate.

Results

Figure 1 shows how the performance of a solar domestic water heating system varies as the collector area increases. For instance, by doubling the collector area from 40 sq. ft. to 80 sq. ft., the percentage of solar contribution increases from 33 percent to 54 percent. Increasing to 120 sq. ft. increases the performance to about 65 percent. As you can see, there is an optimum "knee" to the curve above which the incremental "cost/benefit" advantage is lost. At a system cost of $10 per sq. ft. of collector, this optimum collector size is about 90 sq. ft. This figure also shows that for year-round domestic water heating single-glazed collectors are a little better than double-glazed.

Figure 2 displays data from 15 FCHART runs to attempt to determine quantitatively the economic feasibility of three typical family sizes. The hot water consumption assumed is 20 gallons per day per family member. Therefore, the bottom curve assumes a family of three; the middle curve, a family of four; and the top curve, a family of five. Five different solar system cost-investment amounts were assumed for each family varying from $5 per sq. ft. of collector to $25 per sq. ft. of collector. This covers the entire range of do-it-yourself to contractor-installed systems. Each of the 15 points plotted represents the "optimum" (see Appendix A for definition) collector area and solar percent contribution for each assumed system cost and family size. The horizontal dotted line is the break-off of economic feasibility (based upon our definition in Appendix A). It turns out to be about $14 per sq. ft. of collector area in all three cases. This in essence says that if you can install a system for $14 per sq. ft. or less then it is economically feasible.

One important caution or clarification is called for at this point - these costs do not include State or Federal tax incentives. They only represent your own out-of-pocket costs. The effect of adding these incentives is to raise the horizontal line of economic feasibility. In other words, total system costs of more than $14 per sq. ft. of collector area can be spent and still be feasible, but only $14 per sq. ft. of your own money. Tax incentives as they now stand are discussed later in this paper.

COMBINED SPACE AND DOMESTIC WATER HEATING SYSTEMS

Assumptions

For these systems, the analyses assume the following:

- Portland weather data.

- Double-glazed collectors facing true south and tilted 60 degrees from the horizontal.

- solar storage of 1.8 gallons per sq. ft. of collector.
- 30-year economic study.
- 6-percent inflation.
- 35-percent combined State and Federal income tax rate.
- PGE's residential rates and escalation estimates (8.3 percent per year).
- 30-year mortgage at 8.5 percent, 10-percent down payment.
- 1.5 percent of initial investment per year for maintenance and insurance.
- 6-percent discount or yield rate.

Results

Figure 3 shows how the performance of a combined solar space and domestic water heating system varies as the collector area is increased. For instance, by doubling the collector from 300 sq. ft. to 600 sq. ft. the percentage of solar contribution increases from 40 percent to 60 percent. Increasing to 900 sq. ft. of collector only increases the performance to 69 percent. The optimum collector area (at a cost of $15 per sq. ft. of collector) for our set of assumptions is about 253 sq. ft. of collector, yielding a solar contribution of 37 percent. For these combined systems, double-glazed collectors are better than single-glazed.

In our performance of economic analyses using FCHART, certain values of collector azimuth, collector tilt, and storage capacity were assumed. Figures 4-6 display what happens when you independently vary these quantities, one at a time, holding everything else constant. In other words, how sensitive is the performance of a combined solar heating system to changes in these three variables? Maybe your home is oriented 30 degrees west of south, rather than true south, and you would like to know how much this penalizes you. Or you would like to know what doubling the storage capacity does to benefit you. Maybe your roof isn't tilted 60 degrees from horizontal. A study of these three figures should throw more light on the criticality of these variables.

Intuitively, it should be obvious at this point that combined solar space and domestic water heating systems have difficulty being as economically feasible as solar domestic water heating systems. The main reason is that at the time the energy is needed most (winter for space heating) the solar resource is also the lowest. This fact is illustrated very vividly in Figure 7.

Figure 8 displays data from 15 FCHART runs to attempt to determine quantitatively, the economic feasibility of combined solar space and domestic water heating systems for three classes of residences. The hot water requirements assume a family of four (80 gallons per day total consumption), living in

Solar Space and Water Heating System

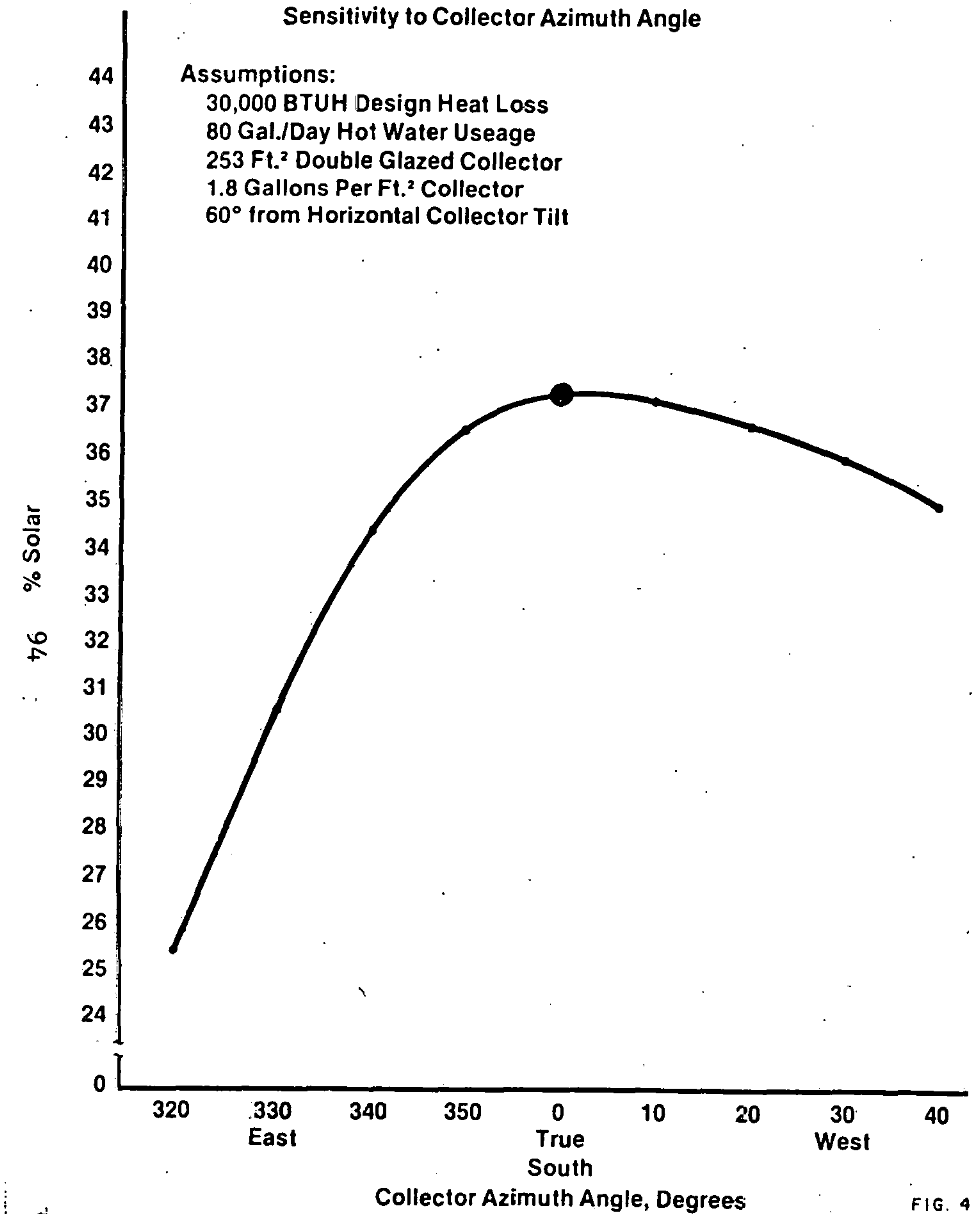
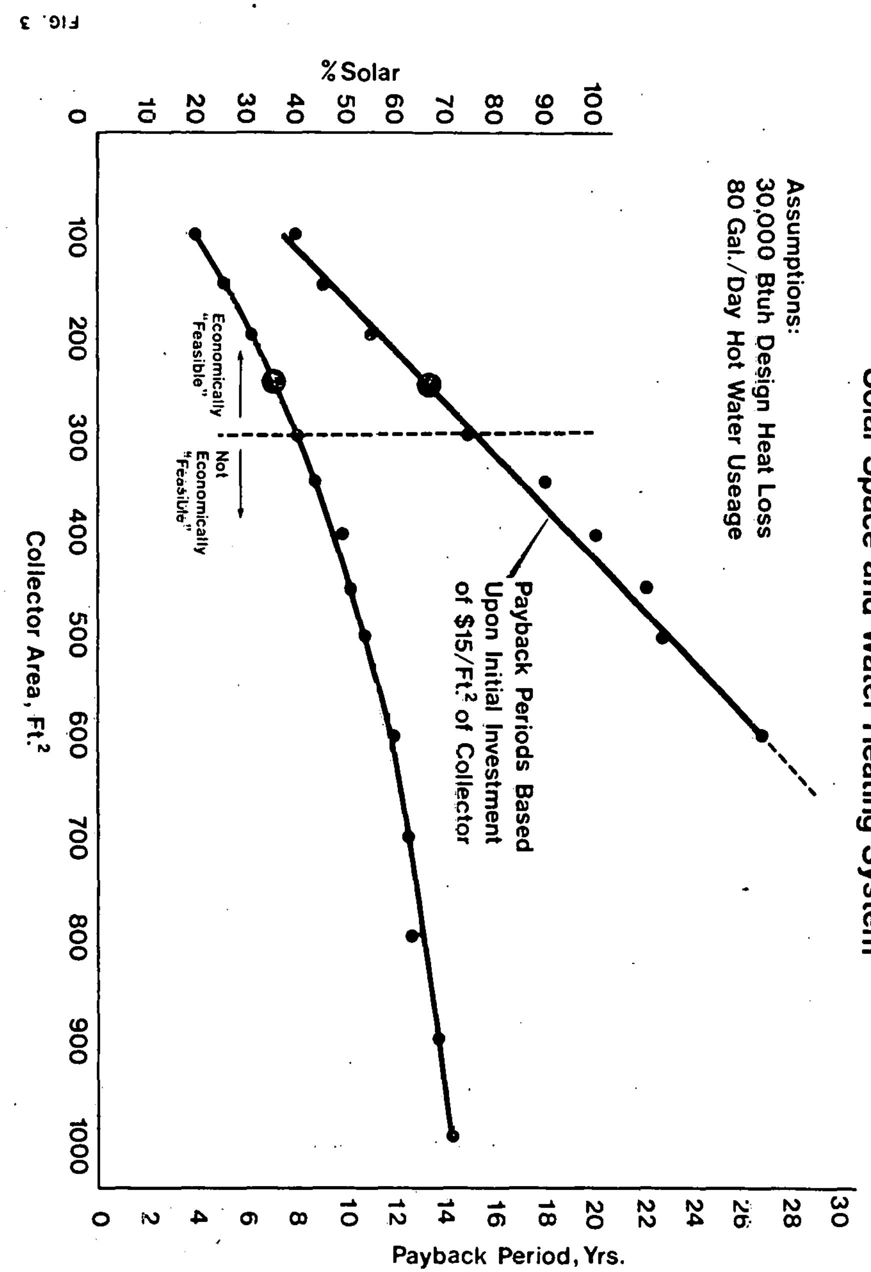


FIG. 4



Solar Space and Water Heating System

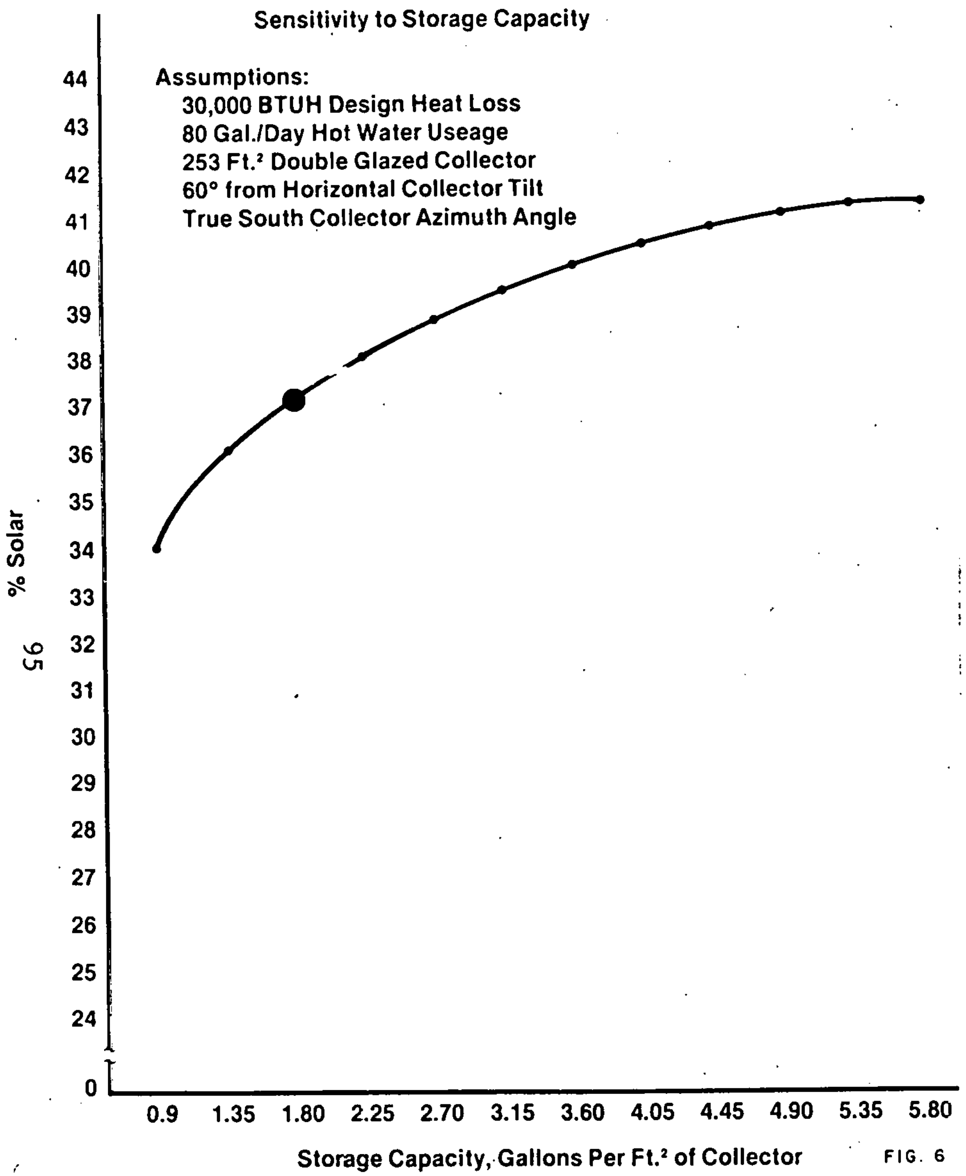


FIG. 6

Solar Space and Water Heating System

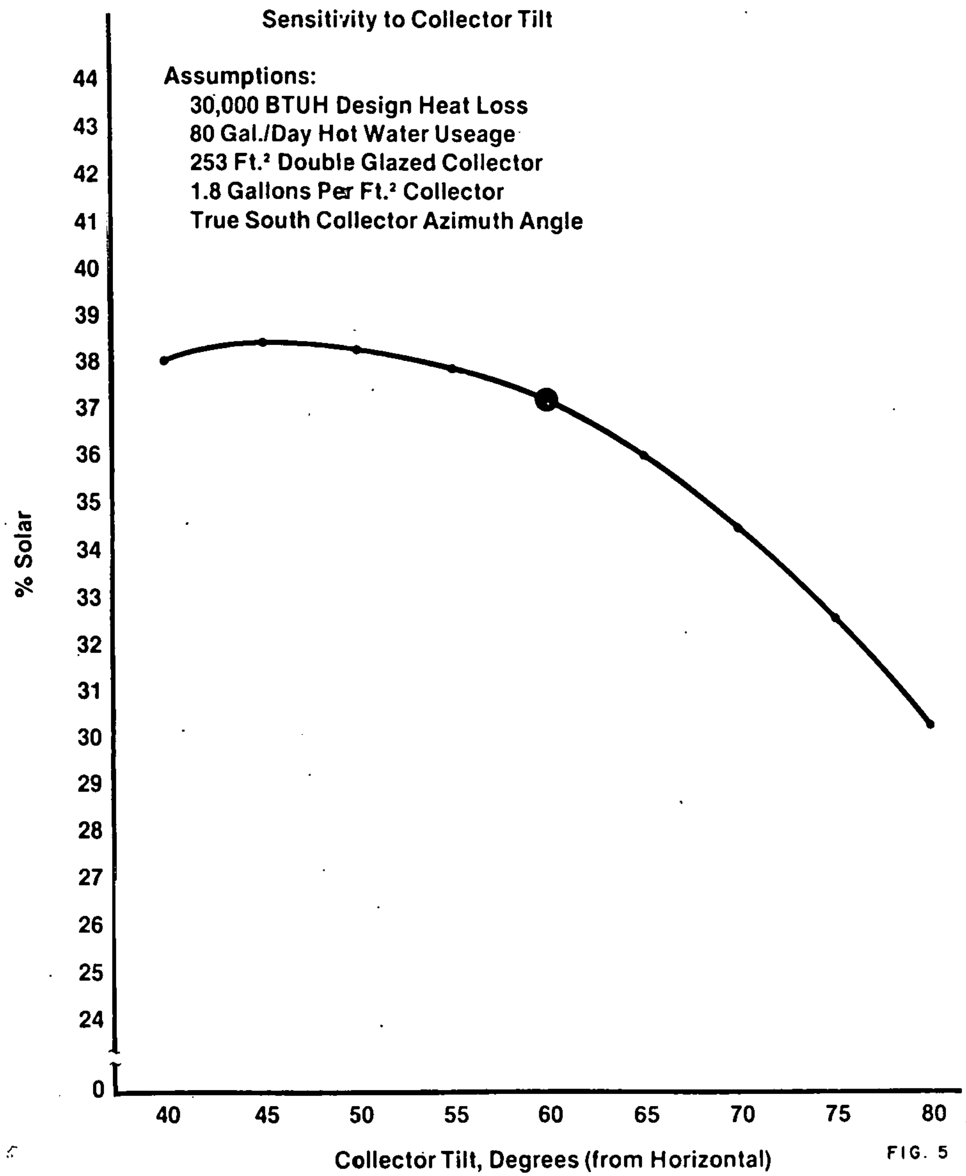


FIG. 5

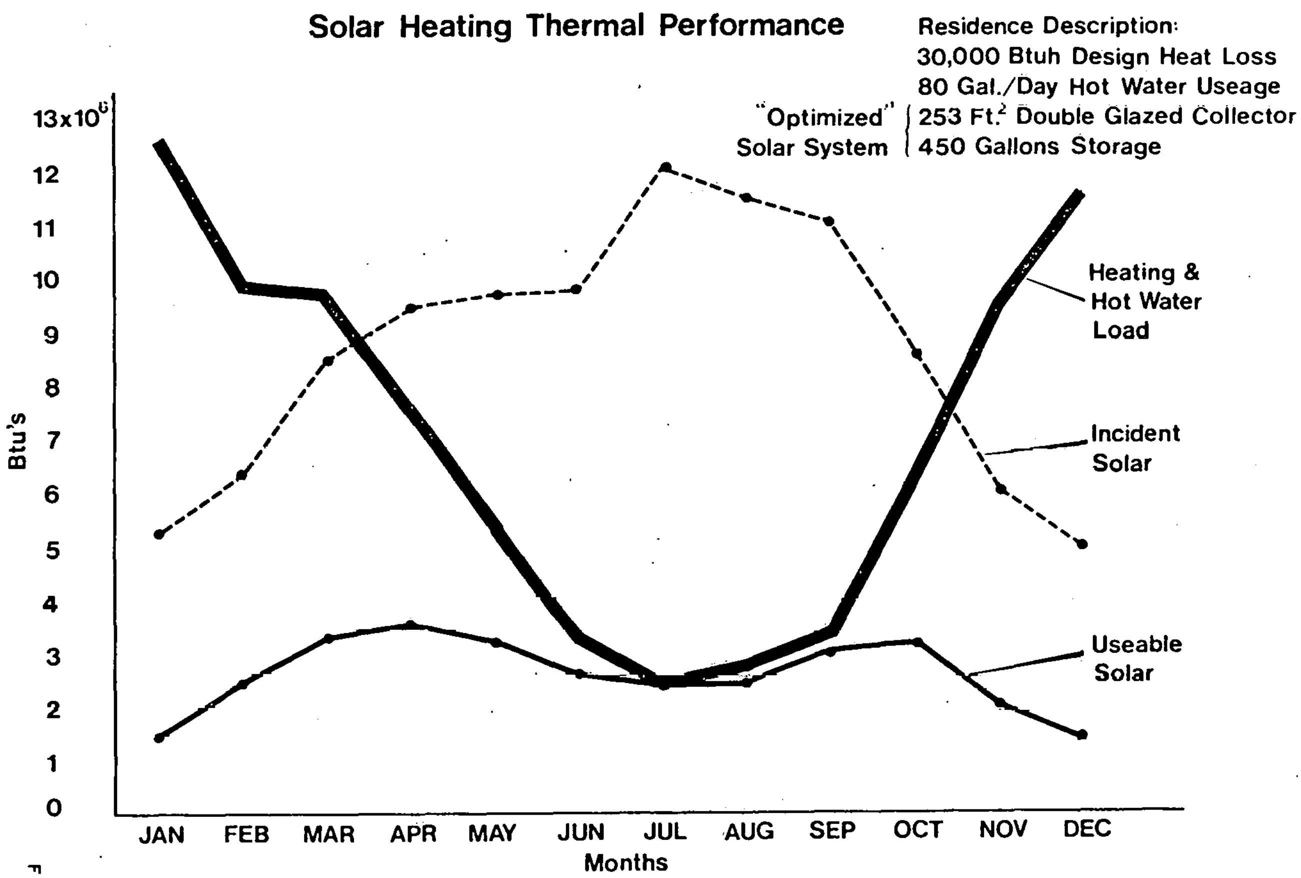
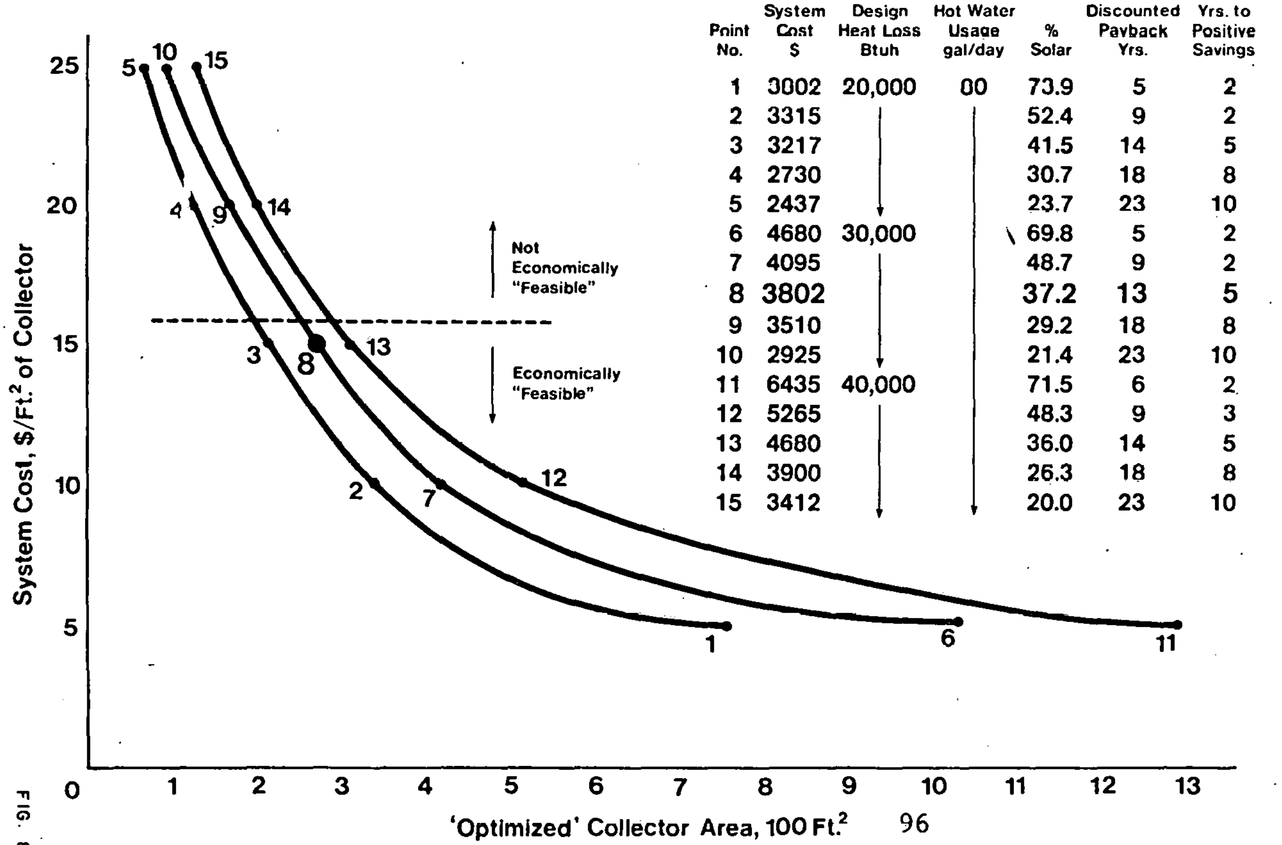


FIG. 7

"Optimized" Solar Heating Systems



Point No.	System Cost $	Design Heat Loss Btuh	Hot Water Usage gal/day	% Solar	Discounted Payback Yrs.	Yrs. to Positive Savings
1	3002	20,000	00	73.9	5	2
2	3315			52.4	9	2
3	3217			41.5	14	5
4	2730			30.7	18	8
5	2437			23.7	23	10
6	4680	30,000		69.8	5	2
7	4095			48.7	9	2
8	3802			37.2	13	5
9	3510			29.2	18	8
10	2925			21.4	23	10
11	6435	40,000		71.5	6	2
12	5265			48.3	9	3
13	4680			36.0	14	5
14	3900			26.3	18	8
15	3412			20.0	23	10

FIG. 8

residences with three different typical design heat losses. Design heat loss is the space heating requirement at what is called the design outdoor temperature. For Portland, the ASHRAE (American Society of Heating, Refrigeration, and Air Conditioning Engineers) Handbook of Fundamentals lists 24°F as the design outdoor temperature. This means that for 97.5 percent of the total hours of December, January, and February, temperatures equalled or exceeded 24°F. For a total of about 54 hours during these same three months, temperatures dropped below 24°F. The three typical design heat losses chosen were 20,000, 30,000, and 40,000 Btu's per hour. These numbers do not have as much to do with the size of the residence (although there is a connection) as they do with the thermal efficiency (i.e., glass types, areas, and insulation levels) of the residence. Five different solar system cost-investment amounts were assumed for each residence, varying from $5 per sq. ft. of collector to $25 per sq. ft. of collector. This again covers a range of do-it-yourself to simple contractor-installed systems. Many more elaborate systems cost in excess of $25 per sq. ft. of collector, but as you can see from Figure 8, the economics of $25 per sq. ft. systems don't "pan out" too well. Therefore, no attempt is made to analyze systems that cost more than $25 per sq. ft.

Each of the 15 points plotted represents the optimum collector area and solar percent contribution for each assumed system cost and class of residence. The horizontal dotted line is the break-off of economic feasibility. It turns out to be about $16 per sq. ft. of collector area in all three cases. This in essence says that if you can install a system for $16 per sq. ft. or less, it is economically feasible.

Again, one important caution or clarification is called for at this point - these costs do not include State or Federal tax incentives. They only represent your own out-of-pocket costs. The effect of adding these incentives is to raise the horizontal line of economic feasibility. In other words, total system costs of more than $16 per sq. ft. of collector can be spent and still be feasible, but only $16 per sq. ft. of your own money can be spent. Tax incentives as they now stand are discussed later in this paper.

The definition of an "optimized" solar heating system as given in Appendix A as that system size which minimizes the present worth of yearly costs with the solar-assisted system over the period of the analysis. Another way of saying this is that system size which maximizes the present worth of solar savings. All 15 points plotted on Figure 8 are for optimized systems.

A question may come up - how critical is it to install an optimized solar heating system? Figure 9 attempts to demonstrate this for a solar system costing $15 per sq. ft. of collector for a residence with a design heat loss of 30,000 Btu's per hour. The optimum system has a collector area of 253 sq. ft. and results in a present worth of solar savings over a 20-year period of about $3,300. This system results in a solar contribution to space heating and domestic water heating of 37.2 percent per year.

If the present worth of solar savings were reduced 10 percent to about $2,970, a range of collector area from about 175 sq. ft. to about 360 sq. ft. can be selected. This is quite a large range of values; however, for this residence at the assumed solar system cost, solar system sizes above 300 sq. ft. do not pay back soon enough to be called economically feasible.

The essence of the conclusion to the above-posed question is that exact optimization of a solar heating system is not that critical within plus or minus 100 sq. ft. of collector area up to the economically feasible limit.

Another point can be made by careful observation of Figures 8 and 9. From Figure 9 for $15 per sq. ft. systems, the range of solar percentages for economically feasible systems is about 41 percent or lower. Higher solar percentages cannot be considered economically feasible based upon our definition. By studying Figure 8 again, the lower the system cost, the higher the optimized solar percentage. For $10 per sq. ft. the solar percentage for the same residence (30,000 Btu's per hour) is 48.7 percent, and for $5 per sq. ft. the percentage is 69.8 percent. For the three residences, the cutoff of economic feasibility (Points 3, 8, and 13) reveal solar percentages of 41.5 percent, 37.2 percent, and 36 percent, respectively, for optimized systems.

In our economic analyses of these combined solar heating systems, we made certain assumptions (listed under "Assumptions"). Four of those assumptions related to maintenance and insurance costs, mortgage rate, yield or discount rate, and electricity escalation rate. The assumptions were "best guess" and were reasonable. However, how sensitive are our results to variations in these assumptions?

Figure 10 shows plots of these four variables as each is changed, keeping all other variables constant. The big "square" and "dot" on each of the four plots is the value that has been assumed and used all through our analyses. For each plot, the left vertical axis is payback in years, and the right vertical axis is present worth of solar savings over the entire period or the analyses. Each of the four variables are changed and plotted in increments of 1 percent. Careful observation reveals that as maintenance and insurance costs are changed, dramatic differences in payback and present worth of solar savings occur. The same is true of electricity escalation. Values change much less dramatically for variations in mortgage rate and discount rate; therefore, it can be concluded that life-cycle cost analyses of solar heating systems are very sensitive to variations in and assumptions of maintenance and insurance costs, and backup or auxiliary energy escalation rates. They are not very sensitive to variations in and assumptions of mortgage rate and discount rate.

This conclusion can be extrapolated one step further - when analyzing a solar heating system, recognize that your investment option is most affected by minimizing first cost as well as maintenance and insurance costs. These two things can be mutually exclusive - in other words, putting in an inexpensive system may result in a higher yearly maintenance cost or vice versa; however, this does not have to be true.

Also recognize that your investment option is very definitely affected by the conventional or backup energy costs, and it is also very definitely affected by the future escalation rate of those energy costs over the life of your system.

Penalty for Not "Optimizing" Solar Heating System

Point No.	System Cost $	System Cost $/ft²	Design Heat Loss Btuh	Hot Water Usage gal/day	% Solar	Discounted Payback Yrs.	Yrs. to Positive Savings
1	1500	15	30,000	80	18.9	8	2
2	2250				26.0	9	3
3	3000				31.9	11	4
4	3802				37.2	13	5
5	4500				41.1	15	6
6	5250				44.8	18	7
7	6000				48.1	20	8
8	6750				51.1	22	9
9	7500				53.9	23	10
10	9000				58.5	27	12

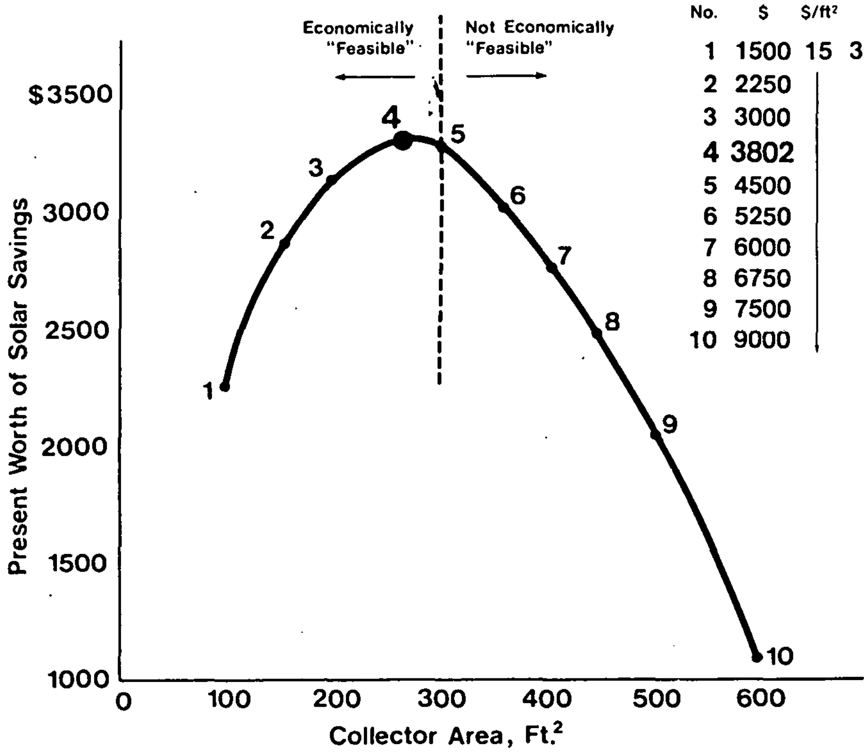


FIG. 9

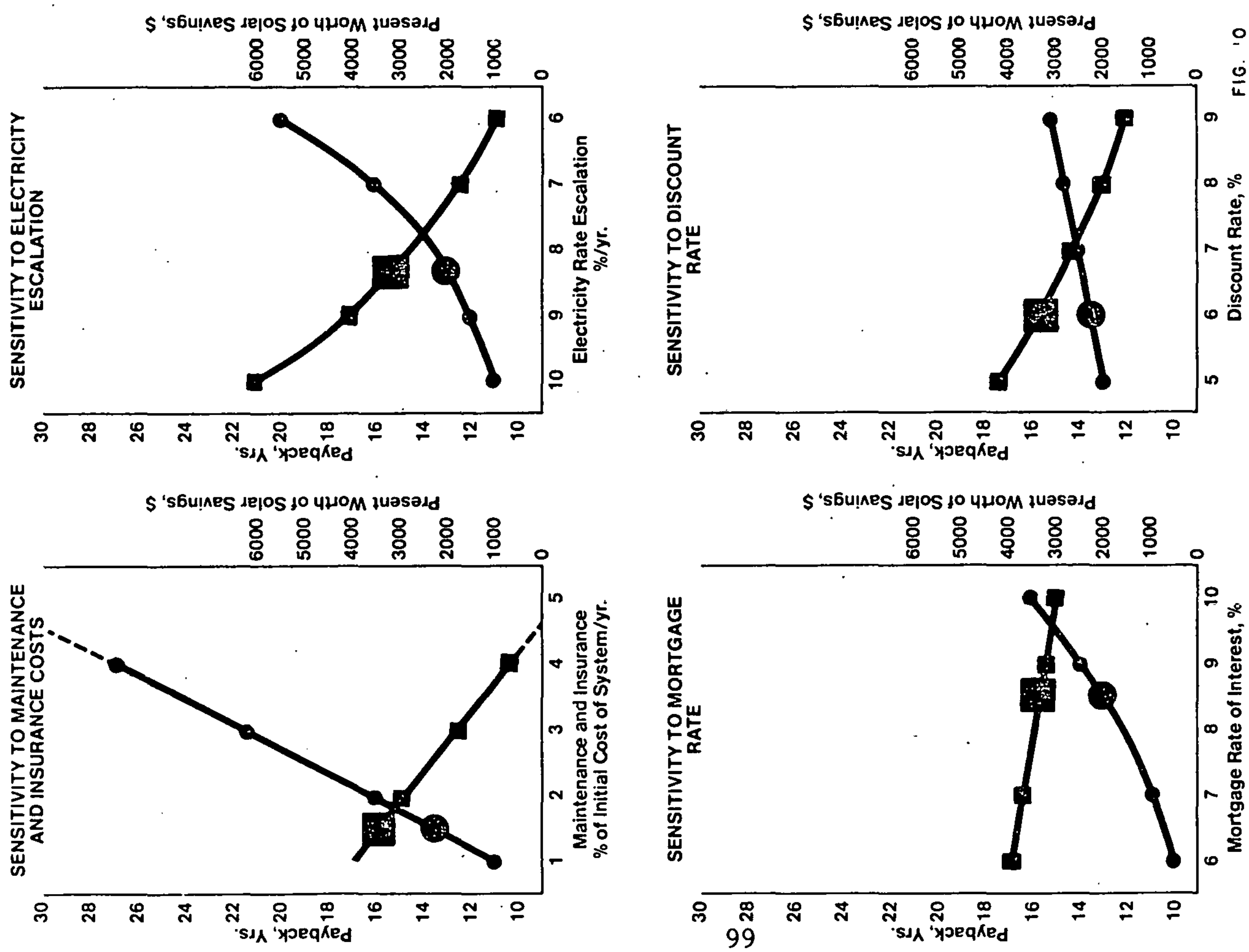


FIG. 10

Finally, your investment option is not profoundly affected by the mortgage or loan rate of the money you borrowed to finance the system installation. It is also not affected significantly by your yield rate (the minimum rate of return you require on your investment).

SOLAR INCENTIVES

State of Oregon

The 1977 State of Oregon Legislature passed S.B. 339 which provides a tax credit to any Oregon homeowner who installs a solar, wind, or geothermal energy device in his principal or secondary residence. Twenty-five percent of the investment cost, or a maximum of $1,000, may be claimed, provided the alternative energy device meets minimum performance criteria set up by the Department of Energy and has been certified by the Department. Taxpayers are eligible for only one credit per year and must claim it during the year the device has been certified. If the amount of credit exceeds the taxpayer's liability, the credit may be claimed for five successive years until it is fully used. The credit took effect the tax years after January 1, 1978.

Solar swimming pool heating system providing 10 percent of the dwelling's total energy requirement may also, upon certification, qualify for the tax credit.

Also under S.B. 339, property equipped with solar energy heating or cooling systems is exempt from ad valorem property taxation, and the exemption applies to any installation made on or after January 1, 1976, but before January 1, 1998.

S.B. 477 applies to all veterans intending to install solar, wind, or geothermal energy devices in their homes. A loan of up to $3,000 may be granted provided the alternate energy device will meet or exceed 10 percent of the total requirements of the home. Along with the Department of Veterans' Affairs, the Department of Energy is establishing the minimum performance criteria for systems that will use these standards to certify the devices.

Veterans are also eligible to obtain a tax credit for alternate energy devices under S.B. 339.

Federal

While Congress has been considering the National Energy Act for over a year, no final action has yet occurred. The major stumbling block has been the inability of the House and Senate conferees to agree to a plan for the deregulation of natural gas prices; however, there are a number of provisions in the legislative package related to solar energy programs which have been generally agreed to by the conferees.

One of those provisions is the solar income tax credit which will be available to homeowners - 30 percent of the first $2,000 of expenditures, and 20 percent of the next $8,000, for a maximum tax write-off of $2,200.

Equipment qualifying for the tax credit includes heating, cooling, and hot water units, as well as wind systems.

Another provision of the pending legislation would give industries and businesses an additional 10 percent tax credit above the regular 10 percent investment tax credit for installing solar and wind devices to provide heating, cooling, and for biomass conversion systems.

When the Federal tax credit is passed, both State and Federal tax credits can be taken by a homeowner. The following table shows the total effect (if the Federal tax credit is passed in its present form):

Investment	State Tax Credit	Federal Tax Credit	Out-of-Pocket Expenses
$ 1,000	$ 250	$ 300	$ 450
2,000	500	600	900
3,000	750	800	1,450
4,000	1,000	1,000	2,000
5,000	1,000	1,200	2,800
6,000	1,000	1,400	3,600
7,000	1,000	1,600	4,400
8,000	1,000	1,800	5,200
9,000	1,000	2,000	6,000
10,000	1,000	2,200	6,800

CONCLUSIONS

- Solar swimming pool heating is economically feasible now with paybacks less than five years, and in some do-it-yourself cases, one swimming season.

- Solar domestic water heating is very close to economic feasibility even for contractor-installed systems (do-it-yourself systems in many cases already are economic). Maximum system costs of about $14 per sq. ft. of collector of a homeowner's own money can be spent. State income tax credits (in existence) and proposed Federal income tax credits combined will about double this maximum investment amount, and most systems on the market today fall within this amount.

- Combined solar space heating and domestic water heating systems are not economically feasible (even with the tax credits) unless a good percentage of the system is do-it-yourself. Some simple contractor-installed systems may fall into this category also. Passive solar space heating systems can be economically feasible today. Maximum system cost of active combined systems of about $16 per sq. ft. of collector of a homeowner's own money can be spent. State and proposed Federal income tax credits increase the maximum amount on a sliding scale, and this definitely helps economic feasibility, but not with the same impact as for domestic solar water heating systems.

- Solar percentages of 35 percent to 50 percent look better, both from a technical and economic standpoint for domestic water heating and space heating systems, unless the system costs are $10 per sq. ft. or less. At these lower costs, "optimized" systems contribute more than 50 percent of the requirements.

- Life-cycle economic feasibility is very sensitive to changes in the input variables of maintenance and insurance expenses, backup fuel costs, and escalation in the backup fuel costs. It is also very sensitive, of course, to first cost. Changes in discount rate and mortgage rate do not affect the feasibility as significantly.

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APPENDIX A

Glossary of Terms

- Cost With Solar - For each year of a study this is the sum of the annual mortgage payment, annual solar backup fuel payment, and annual insurance and maintenance payments minus any annual income tax savings (property tax for the solar system is excluded in Oregon).

- Cost Without Solar - For each year of a study this is the annual cost of conventional fuel minus any tax savings.

- Depreciation - While yield is return on investment, depreciation is the return of the investment. It is a yearly paperwork charge using a particular acceptable method (i.e., straight line, declining balance, some of the years digits, etc.) to account for recovery of the investment.

- Discounted Payback Period - This is the time required before the cumulative present worth of yearly solar savings becomes positive.

- Discounted Rate of Return - What you earn with money invested in the solar system.

- Economic Feasibility - Everyone has his own ideas of what determines economic feasibility. Consistent with the ERDA report, DSE-2322-1, "An Economic Analysis of Solar Water Heating and Space Heating", two criteria of cost effectiveness are chosen for this study:

  - Positive savings within 5 years
    or
    Payback within 15 years

  These criteria were chosen because they appear to have the most meaning for an ordinary property owner.

  Positive savings will be of primary importance if the decision maker assumes that the unpaid mortgage for the solar system can be recovered upon the sale of the building. Positive savings can be viewed as similar to "dividends" paid on investment or interest paid on savings; however, taxes will not have to be paid on solar dividends whereas they would have to be paid on income from savings or investment. Thus the dividend which a solar system might return in the form of savings is a very important factor for a perspective buyer considering his cash flow position.

  Payback is commonly used by investors to measure when the capital cost has been entirely recovered. This criteria would be more attractive to a perspective owner who does not believe the remaining equity in the solar system could be recovered in a resale.

- Effective Federal-State Income Tax Rate - State income taxes paid are deductible on federal returns; therefore, the effective Federal-State income tax rate is calculated as:

Effective rate = Federal rate + State rate - (Federal rate x State rate)

Appendix A - Glossary of Terms

- Inflation Rate - Annual rate of increase in cost of items such as taxes and insurance.
- "Optimized" Solar System - The collector area of a solar system which minimizes the present worth of yearly cost with the solar-assisted system over the period of analysis.
- Payback Period - After the discounted payback period, assuming all further positive yearly solar savings at an interest rate equal to the discount or yield rate, payback occurs when this accumulated sum equals the remaining principal on the mortgage.
- Percent Solar - The fraction of the total system load (space heating and/or domestic water heating) supplied by the solar energy multiplied by 100.
- Positive Savings - The year in which the solar system first becomes profitable. This is when the annual yearly cost without solar exceeds the yearly cost with solar.
- Present Worth of Solar Savings - This is the value of yearly solar savings in today's dollars. Each year solar savings are "discounted" back (using the yield or discount rate) into today's dollars and then summed. This results in the present worth of solar savings over the entire period of the economic analysis.
- Savings with Solar - This is the difference between the cost without solar and the cost with solar.
- Solar Backup Fuel Escalation Rate - Annual rate of increase in the cost of the backup or auxiliary fuel used to supplement the available solar energy.
- Yield or Discount Rate - The annual rate of return which you make with your money in your best investment opportunity. This equals the real rate of return plus the general inflation rate. For the typical home owner the real rate of return is 1 to 2 percent, for business 3 to 4 percent.

RJ/kwD51.11B17

PNL-2410
UC 59
Executive Summary

AN ANALYSIS OF FEDERAL INCENTIVES USED TO STIMULATE ENERGY PRODUCTION

An Executive Summary

to
Division of Conservation
and Solar Applications
Department of Energy
Washington, DC 20545

by
B. W. Cone, D. L. Brenchley, V. L. Brix,
M. L. Brown, K. E. Cochran, R. J. Cole,
M. G. Curry, R. Davidson, J. Easterling,
A. G. Fassbender, J. S. Fattorini, Jr.,
B. Gordon, H. Harty, C. McClain, D. D. Moore,
W. J. Sheppard, S. Solomon

March 1978

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Pacific Northwest Laboratories
Richland, Washington 99352

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UNITED STATES DEPARTMENT OF ENERGY
Under Contract EY-76-C-06-1830

Printed in the United States of America
Available from
National Technical Information Service
United States Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151

Price: Printed Copy $____*; Microfiche $3.00

*Pages	NTIS Selling Price
001-025	$4.50
026-050	$5.00
051-075	$5.50
076-100	$6.00
101-125	$6.50
126-150	$7.00
151-175	$7.75
176-200	$8.50
201-225	$8.75
226-250	$9.00
251-275	$10.00
276-300	$10.25

AN ANALYSIS OF FEDERAL INCENTIVES USED TO STIMULATE ENERGY PRODUCTION

An Executive Summary

The amount of solar energy that reaches the earth's surface every two weeks is equivalent to all of the known reserves of coal, gas, and oil. Yet, the use of this energy source to generate electricity and heat and cool buildings is negligible.

Debate over solar energy's role has caused policy makers to speculate on the reasons for the large difference between present and potential uses of solar energy. These reasons appear to be buried in complex technical, economic, legal, institutional, and political interrelationships. An improved understanding of forces that have shaped the existing energy budget may provide insights for the future.

The purpose of this research was to analyze past and present federal incentives to production of various energy sources and thereby assist the Division of Solar Energy, Energy Research and Development Administration, in the study and recommendation of federal incentives for the development of solar energy. The research was divided into five parts: a survey of current thought about incentives for solar energy production; the theoretical approach to analyzing and characterizing incentives; a generic view of the energy incentive-creating landscape for 1976; analysis of the major energy sources (nuclear, hydro, coal, oil, and gas) along their trajectories from exploration to waste management, including their costs in 1976 dollars; and insights into potential incentives for solar policy.

Economic, political, organizational, and legal viewpoints were considered in formulating the typology of incentives. The following eight types of incentives were identified:

1) Creation or prohibition of organizations that carry out actions.

2) Taxation exemption, or reduction of existing taxes.

3) Collection of fees for delivery of a governmental service or good not directly related to the cost of providing that good or service.

4) Disbursements in which the Federal Government distributes money without requiring anything in return.

5) Requirements made by the government backed by criminal or civil sanctions.

6) Traditional government services provided through a nongovernmental entity without direct charge (i.e., regulating interstate and foreign commerce and providing inland waterways).

7) Nontraditional government services such as exploration, research, development and demonstration of new technology.

8) Market activity under conditions similar to those faced by non-governmental producers or consumers.

GENERIC INCENTIVES

Using this typology of federal actions, incentives provided during FY-1976 were identified on a generic basis. Fifty-eight organizational components spent an estimated $9.97 billion conducting energy-related activities. Expenditures of individual organizations ranged from $2.51 billion, spent by the Tennessee Valley Authority (TVA), to negligible amounts. The TVA, the Energy Research and Development Administration, and the Rural Electrification Administration (REA) Capital Investment Program accounted for 70% of the incentives expended. Thirty-four departmental agencies administered $4.46 billion in energy programs. Eleven Senate committees had jurisdiction over energy-related organizations, the largest of which, the Energy and Natural Resources Committee, had jurisdiction over 18 organizations with a total outlay of $6.04 billion. Fourteen House committees had jurisdiction over energy-related organizations; these included the Government Operations Committee, which had jurisdiction over 29 organizations with a total outlay of $9.06 billion.

Organizations emphasizing market activity spent 62% of all funds. Exploration, research, development, and demonstration accounted for 28%. Organizations whose primary action involved requirements backed by criminal and civil sanctions spent 5%. Only one organization was involved in altering the tax structure.

Fifty-five percent of the $9.97 billion was directly related to incentives involving electricity, mostly for market activities. Of the remaining 45%, $2.39 billion was expended for incentives to the nuclear industry. The oil industry received $1.25 billion. Coal and gas received less than one-half billion each. The solar energy industry received less than $100 million in incentives directed specifically toward energy-producing industries.

NUCLEAR INCENTIVES

Incentives for nuclear power are estimated to have cost the Federal Government between $15.3 billion and $17.1 billion over the past 30 years. This was about 13% of total federal incentives to stimulate energy production. The Civilian Reactor Development Program (CDRP) used approximately 70% of the research and development dollars. The Liquid Metal Fast Breeder Reactor (LMFBR) program has received $2.9 billion through the CRDP. The cost of regulating the civilian reactors ($1.2 billion) and the investment in the enrichment plants ($1.7 billion) were included in the total costs.

The total costs of incentives to the nuclear industry do not take into account several nonquantifiable incentives, namely the cost of the Price-Anderson Act (a legislative action which removed the liability insurance roadblock) and federal uranium policies. No way was found to quantify them.

HYDRO INCENTIVES

The estimated cost of incentives to hydroelectric power (and associated transmission) ranged from $9.2 billion to $17.5 billion. This is about 10% of the total federal incentives to stimulate energy production. In the development of hydropower, the government has acted as a market entity at each step of the production-consumption cycle. All of the incentives used to stimulate hydro energy production would, therefore, be categorized as market activity. Two procedures were used to quantify the incentives. For the first, return on investment from power revenues and costs of construction, operation, maintenance, management, and regulation of dams (that could be allocated to power development) were calculated. For the second, subsidies provided by (a) the low interest rates and (b) the exemption of power revenues from taxes were calculated on the basis of the differences between federal and private industry costs. Using the first procedure, it was estimated that the costs of incentives were $12.3 billion for hydroelectric generation and $5.2 billion for electric transmission. With the second, the costs were $7.2 billion and $2.0 billion, respectively.

COAL INCENTIVES

The depletion allowance has been the single largest incentive to increased coal production. It amounted to $3 billion between 1954 and 1976. Traditional services, which include facilities to aid the water-borne movement of coal, amounted to $1.8 billion between 1957 and 1976. The nontraditional services of research, exploration, development, and safety accounted for $1.7 billion of incentives.

OIL INCENTIVES

Incentives to oil production were considered as two categories: 1) exploration and production and 2) refining and distribution. Exploration and production was defined to include the search for and recovery of both crude oil and natural gas, so that incentives to the exploration and production of one of these energy sources acted as an incentive to the other. However, refining and distribution was limited to petroleum conversion.

An estimated $77.2 billion has been expended for incentives to the oil industry. This was 60% of the total federal incentives to stimulate energy production. The largest incentive to the petroleum industry was the reduction of existing taxes through intangible drilling expensing and the percentage depletion allowance. This incentive amounted to $40 billion. The second largest category, disbursements, included stripper well price incentives, incentives for new oil, and subsidies for tankers and pipelines. The estimated value of disbursements from 1921 to 1976 was $30 billion. Traditional services, such as the maintenance of ports and waterways to handle oil tankers, accounted for $4.7 billion. Research and development and data collection by the Geological Survey and Bureau of Mines accounted for $1 billion of incentives. Requirements and market activity accounted for an insignificant percentage of the total cost of incentives to oil.

NATURAL GAS INCENTIVES

An estimated $15.1 billion was expended for incentives to the natural gas industry between 1954 and 1976. This was 12% of total incentives to energy production. Most of the incentives were in the form of exemptions or reductions of existing taxes. Intangible drilling expensing and the percentage depletion allowance accounted for $11 billion. Disbursements in the form of wellhead price controls were the second largest category, accounting for $3.5 billion. Requirements, nontraditional services (which included data from the Bureau of Mines and the Geological Survey) and market activity accounted for $0.3 billion.

CONCLUSIONS

In the years since 1918 the Federal Government has expended $123.6 to $133.7 billion for incentives to stimulate energy production. A precedent therefore exists for the Federal Government to spend or forego large sums to increase energy production.

Considering the sums of the columns of Table 1, it can be seen that oil received the largest share of incentive funds. Possible reasons are 1) a large percentage of the population enters the oil market, at the gasoline pumps, each week; 2) oil has been commonly assumed to be difficult to find and in relatively limited supply; and 3) oil is perceived by the average citizen as necessary for a desirable lifestyle. The great value placed on oil by the public makes legislators sensitive to an assured supply.

Coal received the smallest percentage of incentives. The reasons may be: 1) coal has supplied energy over the longest period of time; 2) it is thought to be available in abundant quantities; and 3) coal is perceived as an inconvenient and dirty fuel. It therefore commands less political popularity.

TABLE 1. An Estimate of the Cost of Incentives Used to Stimulate Energy Production, in Billion 1976 Dollars

	Nuclear	Hydro	Coal	Oil	Gas	Total
Taxation		1.7	3.0	40.5	11.3	54.0
Disbursements	1.2			30.3	3.5	33.8
Requirements		0.03	0.04	0.6	0.2	2.43
Traditional Services			1.8	5.0	0.1	6.9
Nontraditional Services	12.4-14.2		1.6	0.8		14.8-16.6
Market Activity	1.7	7.5-17.5				10.9-19.2
Totals	15.3-17.1	9.2-17.5	6.8	77.2	15.1	123.6-133.7
Percent of Total Incentives	13%	10%	5%	60%	12%	100%

Incentives for gas, nuclear, and hydro power have received intermediate amounts of funding. Production of gas is strongly related to the production of oil and the creation of incentives to increase oil production is correlated to that for gas. Incentives to the nuclear industry could result from 1) a strong puritan ethic which valued the making of something useful out of an investment conceived for destruction, and 2) a recognized need for new power sources. This was manifested as a dream of the future and articulated by the Joint Committee on Atomic Energy. The driving forces behind federal expenditures for hydro power were largely social, as part of the taming of a raw land with flood control, irrigation, and recreational facilities.

Considering the sum of the rows of Table 1, it can be seen that 42% of the total cost of incentives could be categorized as the action of levying a tax or the exemption or reduction of an existing one. Taxation is relatively easy to administer, has an immediate financial impact on those affected, is flexible, and is expedient. Approximately 26% of the cost of incentives was in the form of disbursements for which the Federal Government received no direct or indirect good or service in return. Disbursements have a long history as a tool to encourage or induce the American public. The Federal Government allocated 12% of the money expended to create incentives for energy production through nontraditional services such as exploration, research, development, and demonstration. Though popular in promise, nontraditional services are not as flexible as taxation and disbursements. One reason for this is the limited size of the research community, which cannot be readily expanded. Twelve percent of the total expenditure for incentives to increase energy production involved government market activities such as TVA. These, too, are inflexible.

Creation or prohibition of organizations, collection of fees, requirements, and traditional services have not been emphasized as incentives to increase energy production. Such incentives are often unpopular. When they are potentially feasible, as in the case of creating the TVA, they must be acted upon quickly.

The analysis indicates two apparent rationales for incentives: 1) promotion of a new technology during its early stages and 2) payment of the difference between the value of an activity to the private sector and its value to the public sector. The support of nuclear energy represents an example of the first justification. Examples of the second are rural electrification (REA), economic development (TVA), flood control (dams), and price controls (oil, gas, and coal). If solar policy were developed according to these rationales, three-fourths of the action would focus on taxation and the disbursement of money for which no goods or services are received in return. It would appear that these incentives should affect the technical elements of solar energy production for which consumers most often enter the marketplace.

During the course of the analysis, incentives were identified which did not have a quantifiable cost to the American taxpayer. Examples of these are the Price-Anderson liability indemnification for nuclear power, the Connally Hot Oil Act, the Interstate Oil Compact Commission, and the Natural Gas Act of 1938. An analysis of the results of such incentives in which the Federal Government assumes responsibility and risk could lend considerable insight to the formulation of a strategy for solar development.

In conclusion, a precedent exists for utilizing federal incentives to increase energy production. Design of national energy policy which considers the results of federal investment in incentives to increase energy production could be an efficient basis upon which to integrate current and impending technology, existing energy stocks, and consumer requirements and preferences. The conclusions of micro-economic solar energy feasibility studies could be inconsequential without a comprehensive understanding of the costs and results of incentives to increase energy production. This is so because of the disparity in rationale between the Federal Government and the private sector. The Federal Government need not predicate national policy on short-term, micro-economic analysis. As confirmed by this study, federal justification is predicated on long-term goals met with the aid of new technology and supported by social values of the nation. If it is socially desirable and technologically feasible to increase solar energy's share in the national energy budget, the paramount policy question is one of selecting an incentive strategy and determining the government's level of investment in it.

EDUCATION/INFORMATION PROGRAMS

OVERVIEW

Jill Goodnight, Moderator

If solar applications are to be adopted in the Northwest, a market must develop for them. This market is influenced by a number of things, among them the price of conventional fuel and people's expectations of future pricing policies; the presence of a solar infrastructure of designers, installers, architects and engineers, dealers, and repairmen; the availability of credit for both the developing solar business and the end user; governmental regulations such as building codes and zoning ordinances; and the general level of awareness of solar's ability to impact energy usage today.

The education and information function is a critical component of each of these market-developing elements. Information programs must be organized on many levels and addressed to many publics. Numerous ways of educating and informing our Northwest public on solar issues and events presently exist: college and university course offerings; integration into other levels of our formal educational systems; specially focused media such as Rain and Cascade magazines; general media coverage by local newspapers and television stations; private efforts of solar consultants and other energy-related firms, including utility programs; state energy office outreach programs; local and regional solar energy associations; and Solar '78 Northwest itself.

Among the problems which solar information programs face is coordination of efforts by existing organizations. Another is the continuous gathering and updating of solar data--without project performance reporting and analyses useful to particular group needs, our "publics" will find the information without value: whereupon the best coordinated information network would be of little use. Financial support is a key factor in developing the technical data base.

The regional solar commercialization center to be developed in Portland is designed to address these needs on a state-by-state basis. A discussion of Montana's plans to implement a solar commercialization plan is published in the July 1978 issue of Solar Age.

Follow-up on other Northwest information activities and the regional center (Western SUN) can be expected at the Solar '79 Northwest conference a year from now. In the meantime, the papers which follow are examples of existing solar education programs funded at the state and federal levels which are noteworthy both for their individual accomplishments and for the contribution which they will make when integrated into the regional information network developed through Western SUN.

OREGON DEPARTMENT OF ENERGY
PROGRAMS IN OREGON'S
COMMUNITY COLLEGES

by

Jim Thompson
Conservation Specialist
Oregon Department of Energy

Oregon's 13 community colleges, geographically spread throughout the state, provide a unique opportunity to reach homeowners with energy information. ODOE efforts have been designed to aid them in developing the capability to provide that service.

Over the past year we have taken 3 approaches:

1. Home Weatherization Classes for Homeowners

2. A Solar Training Workshop for Community College Instructors

3. A Demonstration Energy Information Center

Home Weatherization Classes were initiated by the ODOE in July and August 1977 in all 13 colleges. Four electric utilities (Idaho Power, Pacific Power and Light, Portland General Electric and the Springfield Utility Board) provided expert instructors from their conservation staffs. The classes discussed insulating, weatherproofing, storm window construction, furnace maintenance and other energy and cost saving ideas for the do-it-yourselfer. Information on Oregon's Weatherization Tax Credit was also presented. Many of these classes ran more than once in each college and a number of colleges have elected to offer the classes on a regular basis.

A Solar Training Workshop attended by 25 instructors from 12 colleges was held at Linn-Benton CC in March 1978. Instructors were selected by their colleges on the basis of their background in related fields and their interest in teaching solar classes to homeowners. Experts in solar energy education were chosen by the ODOE to conduct the 3-day session. The workshop consisted of classroom sessions covering technical information, an overview of solar energy, and information about Oregon's Solar Tax Credit as well as workshop sessions during which participants constructed a solar water heater. The workshop concluded with installation of the system on a home that had been plumbed to receive it by employees of the Benton-Linn Community Action Agency. Following this workshop several colleges have offered solar classes this spring and summer with more planned for the coming year.

A Demonstration Energy Information Center at Linn-Benton CC is being partially supported with ODOE funds. The Mid-Willamette E.I.C. will provide classes and workshops on energy topics, offer an energy reference library and operate a referral service to direct people to sources of information and assistance. The ODOE will monitor the results of the project to evaluate the possibility of expansion of the energy information center concept to other community colleges.

Energy Technician Training Programs. In the coming year the Oregon Department of Energy and the Oregon Department of Education will cooperate on a program to evaluate the viability of establishing energy conservation and/or solar technician training programs through one or more of the state's community colleges.

A technician training advisory committee is presently being formed to assist with this process. The committee's responsibilities will consist of the following:

1. Evaluation of similar, existing programs in other parts of the country

2. Determination of program options that are viable for Oregon (e.g. "energy conservation technician", "passive solar technician", "active solar technician", etc.)

3. Definition of content of each recommended program

4. Investigation of employment potential for graduates of each recommended program

5. Determination of the resources needed for a successful program (i.e. physical plant needs, academic personnel requirements, etc.)

6. Briefing interested community colleges on the committee's findings

Upon completion of the committee's work, interested colleges will be encouraged to develop proposals for offering one or more of the recommended program options. The best of these proposals would then be approved by the Department of Education and the Educational Coordinating Commission.

This process is designed to:

1. Eliminate unnecessary duplication of effort

2. Discourage poorly conceived, inappropriate programs from being proposed, and

3. Prevent "unsuitable" community colleges from wasting time and energy developing programs they could not implement

The goal is to establish within the next year or so one or more high-quality, enduring technician training programs to meet the ever-growing needs of Oregon's energy consumers.

TRAINING AND TECHNICAL ASSISTANCE IN APPROPRIATE TECHNOLOGY FOR WASHINGTON STATE WEATHERIZATION PROJECTS

by

Birny Birnbaum
Grant County Community Action Council
Moses Lake, WA

BACKGROUND:

Grant County Community Action Council's experience with solar energy information and education is a result of a training program it developed for the weatherization projects in Washington State. Most community action agencies in Washington State have a weatherization project. The community action agency directs federal monies, chiefly from Community Services Administration(CSA), into the localities for anit-poverty efforts. The CAA is an umbrella agency for numerous anti-poverty and social programs. One such program is the weatherization program, created to lessen the impact of high energy costs upon the poor.

The bulk of a weatherization program's activities has been insulating and weatherproofing low-income peoples' homes. But, since its inception about four years ago, the mandate of the weatherization program has evolved from simple weatherization to overall energy conservation. Sensing the evolving nature of weatherization activities will require new skills, Washington State and CSA Region X set aside part of the training monies for weatherization projects for "training & technical assistance in appropriate technology",

What is "appropriate technology"? In the T&TA grant context, appropriate technology(A.T.) was meant to by synonomous with solar energy technologies. We percieve A.T. as more than just tools or techniques; A.T. represents a set of values and goals to design our tools, insititutions and social structures around.

Now comes the question,"Appropriate for what?" We come up with the concept of local self-reliance. We see the values at the foundation of our complex industrial technology - ever-constant growth and economic efficiency - themselves are part of the structural causes of peverty. The dominant technologies are characterized by tremendous concentrations of wealth, power and knowledge. These complex industrial technologies are designed by experts for experts and preclude participation or understanding by common people. These techniques, be they a nuclear reactor, a multinational corporation or a supertanker, justify these tendencies in the name of economic efficiency and a growing GNP.

The poor person is least able to cope with technological society. He or she hasn't the skills or access to skills necessary to enter into mainstream economic life. Dependencies upon experts are encouraged and developed. Decision-making for many facets of our lives falls to a select stratum of specialists. The root causes of poverty aren't just lack of material goods or money; rather, it is the powerlessness to affect or control the many forces which influence poor peoples' lives. This poverty grows in direct proportion to the size and power of corporate business, federal bureacracy and big labor. Handing out food, shelter or money doesn't alleviate poverty - the poor are still powerless to enter into the mainstream, but now have been temporarily appeased until their powerlessness prevents them from maintaining the material possessions given them.

Our anti-poverty programs must seek to aid poor people help themselves to gain greater control over the forces which dominate their lives. This implies implementing self-help programs in place of welfare-type handouts. The emphasis shifts to advocacy in place of direct services. The values of local self-reliance support this analysis and appropriate technologies are those tools and techniques which allow people to better determine the course of their lives and implement local self-reliance. The technologies appropriate to local self-reliance use local resources to make local products to fill local needs. They are relatively small in scale and promote participation by their users. They are low-cost and place but a small burden upon the environment. They allow men and women to work creatively using a certain tool or technique to enhance their abilities, not replace them. They offer greater equity because small scale and participation make them responsive to local needs and voices.

With this background, we can proceed to training for weatherization programs. Clearly, weatherization programs can be an appropriate tool for anti-poverty efforts. The key is how the programs are implemented. If weatherization is done by disinterested crews shoddily insulating and weatherproofing low income peoples' homes, we perceive a temporary bandage to the wounds of poverty. Another hand-out robs people of pride, self-esteem, innovative capabilities and the incentive for bringing themselves out of their poverty. Why should they? The Feds will give them food stamps, keep them warm, feed their kids in school and provide make-work jobs. Self-reliance is shunned and dependence is encouraged.

But weatherization programs implemented in a self-help manner with strong supportive services could allow poor people to moderate their energy demands - direct control over one critical aspect of their lives.

With this analysis in mind and a mandate to give training in appropriate technology, we developed a program to help weatherizers gain knowledge of and skills in self-help appropriate technologies which they could implement in their own localities.

PROGRAM

The goals of our 6-month training program were:

- To develop an understanding of and technical skills in appropriate technologies relevant to weatherization programs, and
- To develop a working knowledge of and continuing access to the varied resources needed by community-based groups such as the weatherization program.

The program had three components. The first was an overview of appropriate technology in the form of a day-long seminar. The purpose of this overview was to develop a framework - conceptual, political, economic and technical, - for weatherizers with which they could begin to evaluate their programs for effectiveness as anti-poverty efforts. The session included a talk on "Technology, Values and Appropriate Technology" a slide show- technical overview and a talk on "Appropriate Technology and Community Economic Development".

At the overview, we supplied bibliography and access material. We discussed methodologies for cataloging local resources in the hope of developing among the participants a sense of the vast resources at their disposal - be they local, state & federal economic resources, natural resources, information resources, or human resources.

Moving from the theoretical base of the overview, the second component of the training program was practical, hands-on training in specific appropriate technologies. We asked each weatherization project to develop a small local project which would reflect an understanding of appropriate technology, local needs and local resources. We scheduled workshops to develop work plans for these local a.t. projects and also to offer hands-on training in some appropriate energy technologies. We put on five 3-day workshops building solar greenhouses and solar water heaters and two 1-day workshops on woodstoves. We planned on-site visits to offer more localized training as needed.

Realizing the need for weatherization people to develop their own training capabilities, the third component of our training program was communications and information exchange. In addition to facilitating a network among weatherizers via a newsletter, we would provide various access materials as well as contact with prominent a.t. research and demonstration groups. Our hope in bringing weatherizers into direct contact with other groups working in appropriate technology around the region was to leave an on-going information/access network after our six-month training program had been completed.

RESULTS:

The appropriate technology training program was greeted enthusiastically by weatherizers around the state. 80-90% of the pojects were present at our introductory session. Talks by Ken Smith and David Morris introduced new and creative ideas to the weatherizers. The slides of solar technologies and the talk on community economic development introduced new possibilities to many weatherizers, and after slogging it out for years with quantitative bureaucratic goals, the program was a breath of fresh air for many weatherizers.

Despite the great enthusiasm, there weren't many local A.T. projects. Lack of time and funds were key reasons. Weatherizers, already overworked and tied to quantitative grant guidelines, didn't have the leeway to investigate new realms for their program.

Even so, the weatherizers took every opportunity to attend our workshops. Our workshops building solar greenhouses and water heaters prompted several weatherizers to write such projects into their next grant. Add two woodstove workshops to the five construction workshops and most weatherizers around the state had contact with some kind of decentralized, low-cost solar technology.

We supplied many information resources to all weatherizers and served as technical advisors when called upon. One important aspect of information exchange was a weatherizer's newsletter. Responsibility for this newsletter was assumed by the State Office of Economic Opportunity/Office of Community Development(OEO/OCD now called Planning and Community Affairs Agency-PCAA).

A brief comment. OEO, along with CSA Region X, administers money to weatherizers. OEO is charged with technical assistance to weatherizers around the state. They've developed most of the training programs the past four years. To say they've been ineffective is an understatement. Their ineptitude has hindered weatherizers for years. The newsletter has yet to materialize.

We feel the training program had some positive effects. Through it, most weatherizers were introduced to ideas of local self-reliance and appropriate technology. Folks attending workshops were unanimous in their praise and in the excitement generated by the hands-on training.

The combination of slide shows and solar system construction was found to be a great way to teach solar skills. Slide shows are relatively inexpensive, yet vividly illustrate any variety of topics.

Problems encountered by weatherizers are many and difficult, as well as being tangential to the focus of this conference. Yet, as a solar addition to a home is ineffective without great conservation measures, so must solar technology training occur in conjunction with conservation and weatherization technique training. This recommendation has been passed along to CSA. We feel the most important result of our program has been to document the feasibility and desirability of low-cost solar energy applications in anti-poverty programs.

BATTELLE'S PACIFIC NORTHWEST LABORATORY
SOLAR TECHNOLOGY TRANSFER PROGRAM

by

E. V. Werry

A U.S. Department of Energy-sponsored program has been underway sinc April 1977 to present information on technically feasible and economically competitive solar technology to Northwest organizations most likely to use it in the near future. The program was an early attempt by the federal agency to promote commercialization of those solar systems that are ready for the marketplace. As a precursor of the Regional Solar Commercialization Centers exemplified by Western SUN, its program will be folded into the Portland operations once these begin.

Called the Regional Solar Technology Transfer Program, Battelle Pacific Northwest Laboratories (PNL) is the program manager. The region primarily covers the states of Idaho, Oregon, Washington, and western Montana. In recent months tech-transfer activities have occurred in North and South Dakota particularly on the state government level.

Regional solar energy consultants in the private sector were contracted to assist the Battelle personnel in developing the education programs. A decision to emphasize passive solar design in their materials, which were focused primarily on heating and hot water applications, was made both because of its potential economic advantage and because a dearth of information on passive systems applicable to the Northwest user existed at that time. As the program developed, it became focused primarily upon two target groups: architects and lenders. The information needs of these groups were widely divergent and therefore two separate programs were designed. Substantial contributions to the necessary program content were made by the Energy Committee of the American Institute of Architect's, Seattle chapter, and representatives of several appraising and mortgage bankers associations in the Seattle area.

For the Seattle, architects, an intensive solar course was prepared with six 2-hour evening sessions and one all-day introductory seminar on passive systems and design. The all-day passive seminar was organized and taught under a sub-contract by John Reynolds and Steve Baker of the University of Oregon, and Ed Mazria of Albuquerque. The Seattle course material was later pared down to a two-day seminar and presented by Battelle staff members Ellwood Werry, Laird Parry, and Mike Morgenstern in Spokane and Bozeman through sponsorship of the local AIA and college systems. The seminars were open in these later sessions to community college and university staff, building contractors, engineers, and other interested persons. Plans have been made to hold the seminar in Portland on September 8 and 9, and in Boise at a date yet to be determined, but prior to the program's discontinuation in mid-September.

The material prepared for the lending and appraising communities was a much more streamlined introdution to the use of solar technologies in the building industry. It consisted primarily of a slide program and economic analysis of solar payback and valuation. The three-hour orientation was prepared and conducted by Ken Smith and Dave Baylon of the Ecotope Group in Seattle.

Unlike the response of the architectural community, which drew considerably over 150 potential registrants in Seattle although space was available for only 120, the lending and appraising societies were not nearly so aware of the sun's potential to warm their pocketbooks. Of the 50 who attended the two sessions that were held and filled out evaluation forms on the session, the majority had come out of personal, rather than professional, interest in solar heating.

It was pointed out in these sessions that the true need for solar information lay not with the lending and appraising professions directly, but with the county assessors required to implement solar property tax exemption programs. Placing a dollar value upon the amount to be exempted was presenting extreme uneasiness when no comparable market sales values could be found. The tech transfer effort in terms of valuation programming then turned to state departments of revenue and county assessors.

The response from this professional group was excellent: cooperative and interested, knowing that their solar knowledge would be challenged in just a matter of time. From meetings in Boise and Olympia (Salem felt that its tax exemption law posed no difficulty in administration for Oregon assessors), the theoretical basis for an assessor's manual on valuing typical solar heating systems--both active and passive--was developed by Dave Baylon of Ecotope Group.

A survey was prepared of other states in the U.S. with solar property tax exemption programs and how each handled the definition and eligibility of passive system components and made available to the participating departments of revenue. In Olympia, the regulations which precluded passive systems from elegibility were determined by the Dept. of Revenue to be contrary to the intent of the law, and new eligibility criteria are being drawn up. In Boise, although a solar property tax exemption was proposed but did not pass the legislature, the field documents designed by the state for county use have been amended to include a checkbox for "solar heating." This will be useful for future identification of solar structures for market comparison purposes.

Among the other activities undertaken by the Technology Transfer program were the following: 1) distribution to over 80 libraries in Washington, Idaho, Oregon, and Montana of sets of government-published solar reference documents; 2) short presentations to engineering societies, community groups, building officials, and builders on solar applications in the Northwest; 3) Sun Day participation through lectures and passive solar booths in Seattle, Olympia, Spokane, and Richland; 4) participation in planning and presentations for Solar '78 Northwest; and 5) general information service upon request.

Among the materials developed through this program is a set of videotapes with accompanying slides of the early Reynolds-Baker-Maxria passive seminar presentation in the fall of 1977. These will be made available at no charge to organizations and college for group showing. For further information, contact: Ellwood Werry, Battelle Pacific Northwest Laboratories, Richland, WA 99352; (509) 946-2345.

DISTRIBUTION OF SOLAR INFORMATION ON A STATE AND REGIONAL BASIS

by Kay Collins

Presented at Solar '78 Northwest Conference
July 15, 1978

Distribution of Solar information on a regional and/or state basis is not easy. However, it can be done. By using systems which are already available you are sometimes able to save precious time and money. To help make my points more clearly, I will give you some examples from the region in which I work, the Rocky Mountain Region.

This audience probably has a mixture of people, some who want to distribute information and those who want to receive it. I hope that I can help answer questions both ends of the spectrum might have. If not, please ask me questions at the end of the talk.

REGIONAL ENERGY/ENVIRONMENT INFORMATION CENTER

First I would like to use a couple of slides to explain what the Regional Energy/Environment Information Center is like and what our function is.

In June, 1977, the Regional Energy/Environment Information Center was developed at the Conservation Library of the Denver Public Library. It was placed there because of the experience of the personnel and accumulation of pertinent material. Some political problems were avoided by not placing such a center with one of the various federal agencies who are sponsors and funders.

The Department of Energy (then ERDA) and the Environmental Protection Agency provided the initial funds for the Center. They have since been joined by the National Agriculture Library. These agencies, plus the Departments of Interior, Commerce and Health, Education and Welfare, signed a cooperative agreement to work together in developing and assisting the Center. In this way they can work in a well defined manner and the region can hopefully receive a more integrated network of information collection and dissemination.

Initially we agreed to:

1. Answer questions about energy and the environment
2. Through the Department of Energy's RECON data bases provide computer produced bibliographies
3. Refer people to other sources of information when appropriate
4. In connection with this, to help identify experts in the fields of energy and environment.
5. Help locate and provide publications, when possible.

We have available a collect call number (303) 837-5994 to assist in receiving requests. If use increases sufficiently, a toll-free 800 number will be installed. We also have an FTS line into the Center which can be used to call people back, obtain publications or facilitate coordination of information.

We cover the 10 state Rocky Mountain-Plains states of:

Arizona
Colorado
Montana
Nebraska
Nevada
New Mexico
North Dakota
South Dakota
Utah
Wyoming

However, if questions come from outside this region and the local area is unable to help them, we will provide some assistance. We also collect information on more than just this region; what occurs elsewhere often affects or has implications for this region.

Establishing and implementing this system at first, sounds very easy. In fact, it is very difficult and a lot of learning, sharing and searching is going on as progress is achieved. However, the first regional experiment seems to be moving toward some success without multi-million outlays of capital.

I will first outline some of the problems and try to indicate some ways we are dealing with them.

The Rocky Mountain-Plains States are large and the populations scattered. There are few large towns or information centers. Small towns and big spaces make information dissemination more difficult. The needs are still there, however.

The obvious answer is to develop a network which utilizes existing libraries and information centers, reduces unnecessary duplication of materials and services and promotes necessary duplication.

We have found that most people prefer to use their local, handy library or sources of information. They often receive the same questions over and over. To assist them we will try to identify those questions and provide answers to them in the form of summaries or work with them to help them have available those tools which will answer the majority of questions received. We will also help as a back-up for those less requested questions and publications and try to help provide answers, photocopy, microfiche or interlibrary loan.

Through the Western Information Network on Energy (WINE) we are working to develop more formal lines of communication and cooperation than have existed in the past. WINE, by the way, encompasses the Pacific Northwest states. In fact, those of you who are interested, are encouraged to join. There are no membership fees, only cooperation.

WINE was established by a group of people in the West who were concerned about the growing proliferation of information centers and systems. They were (and are) competing for funding to do the same things while many worthwhile projects were going undone. Many of us felt that the time had come to begin cooperating as best we could and support each other for funding and in our regular working environment. We try to eliminate unnecessary duplication and begin to fill the the needs we can identify.

The Regional Energy/Environment Information Center fits into this by acting as a type of hub for activities and clearinghouse for information. We are trying to work with people in the region to obtain the information they need to answer questions they receive on a routine basis and to then be able to come to us for the back-up they need on those questions which might be very specialized. With our resources and the ability to refer people to other sources, we usually end up with satisified customers.

Let me give you a closer look at what we are in the process of establishing in Colorado. In cooperating with the Colorado Office of Energy Conservation, we are trying to establish a network which mainly utilizes existing libraries and information centers. The state is establishing a series of local energy offices to answer questions on energy. Solar is one of the most popular topics. These offices help tell how to gain their information, how to do their solar projects, who on the local level is available to assist them, etc. They work closely with the county expertise in areas where the centers are located. We are working to bring the extension agents, the office staff and the library network into closer cooperation. I recently went to Grand Junction and got these people together in one room. They generally knew about each other, but did not really work together. Through this meeting, they developed a much clearer view of what each was doing. Some demonstrations were given, and they have all been able to begin expanding their ability to distribute information to the user. For example, the library at Grand Junction and the local energy center have developed some cooperative buying programs on publications in order to expand the information available and eliminate some duplication. The library knows much better that we can run computer searches for them, that we have many unique publications available and we have already helped them identify some publications available free and how to obtain others they needed. The working relationship between all parties has progressed to that area of friendship that always help facilitate transfer of information.

Solar energy faces problems that some other subject areas do not face. Solar energy is a popular topic and our books are always checked out with a very long waiting list. People must come into the library and sit and read our reference copies. At the same time, we are unable to loan any of the books through interlibrary loan because they are never on the shelves but checked out to local users. We therefore try to refer the library or user to a place where they can buy their own copies. In Denver we have the EARS bookstore which specializes in solar energy (including wind, biomass, etc.). Not only do they have books, but they have paid for copyright on several solar articles from magazines, reprint these articles and sell them.

Other local bookstores will carry popular solar titles. Some of the groups in Colorado have worked to produce good products and are selling them. Most any bookstore will carry a good book which will sell. Some groups sell their own publications directly.

Our staff also tries to make people aware of the National Solar Heating and Cooling Information Center at the Franklin Institute. People can write or call there for some information. We will be working with this group to try to make more of this available on local area shelves.

This is only a quick summary of a few of the activities going on to help in the distribution of solar information. For those who need more information on our activities, please ask questions now and feel free to write or phone us for more details. We would like to welcome anyone interested in WINE to contact either me or Al Lefohn at Montana Energy Office of EPA in Helena, Montana. The more we work together, the more we can do to help each other.

Funding for fancy distribution systems is always fluctuating. Try to use existing systems whenever possible. People are familiar with them, use them and they tend to be long-term. Do not confuse your audience by trying to present them with too much information, much of it of poor quality; rather, try to make available good sources of information in a convenient fashion.

This does not mean I urge you to never by-pass a local area. Some people will never change or go outside their own doors. They are blocks to a good network. Try to work with them and work around them when possible.

Evaluate hotlines very carefully before going to one. There are so many of them across the country, people call them all and end up getting much the same thing from each one. Or they don't know which one to call and thus don't call any. We find the farmer in Eads would rather talk to the local librarian or extension agent than come to Denver or any other larger city, or make a phone call. He feels uncomfortable about calling. We are trying to establish a way that the farmer can get his information and feel comfortable about doing it.

By supporting the local institutions with useable information and backing them up when they get stumped, we feel that solar information will be much better distributed and more widely used.

Ecotope Group

2332 East Madison · Seattle, WA 98112 · (206) 322-3753

SUN DAY Report

Prepared By
Jane Howard
SUN DAY Coordinator

I. SUN DAY GOALS

Wednesday, May 3, 1978 was designated International SUN DAY by a coalition of unionists, small business people, farmers, environmentalists, consumer activists and public officials. The goal of SUN DAY was to increase the over-all public awareness of solar energy as a renewable resource technology and of the need to spend more money on implementing solar technologies. Public awareness will help build the public support needed to break down the barriers preventing the rapid development of this free, renewable and environmentally pure energy source.

In Washington State, the international solar energy celebration day occurred as a week of activities from April 28 to May 7. The direction of the activities was to encourage individual and social welfare through appropriate and thoughtful energy use. Activities were planned primarily as educational outreach to demonstrate the viability of solar energy in the Pacific Northwest, including possible aaplications of wind, bio - mass and hydro-based technologies. Conservation and solar measures that people can act on now were stressed by Ecotope Group. The SUN DAY activities were designed to elicit thinking, questioning, understanding and action concerning solar energy use and its production/distribution.

The types of activities that occurred during SUN DAY week were varied. They included: solar home tours, practical "hands-on" workshops, seminars, panel discussions, films, slide shows, fairs, speakers, cultural events, displays and sunrise ceremonies. These activities are listed below city-by-city. A short assessment of the success of these activities is included. A detailed evaluation of events will follow this report when response from organizers is received.

BELLINGHAM

Wednesday, May 3
Sunset celebration including music, dancing, New Games, volleyball, kite flying.

Thursday, May 4
Movies on the practical applications of solar energy in urban and rural environments, with a talk by James Alberi, professor and solar researcher at Western Washington State University.

Friday, May 5
Films and slide shows

Saturday, May 6
Alternative Energy Fair, including workshops on conservation, solar collectors, solar greenhouses, demonstrations of solar devices, music, games.
Speech by Representative Mary Kay Becker.

Sunday, May 7
Solar Home Open House -- 3 homes open to the public with guided tours.
SUN DAY slide show. A talk by Dr. Ruth Weiner, professor at Huxley College of Envirnonmental Studies.

Monday, May 8
Films and slides.

Success of Activities:
The solar home tours and the Alternative Energy Fair highlighted the SUN DAY activities. The attendance ranged from 30 participants on the tours to 700 in the park for the fair.

EVERETT

Saturday, April 29
Trip to Pragtree Farm, an organic vegetable farm using appropriate technology in such structures as a parabolic aquaculture/greenhouse, solar hot water heater and a composting toilet.

Monday, May 1
Film festival featuring "Diet for a Small Planet," dealing with the economic, ecological and nutritional values of animal vs. vegetable protein and how to use these values to the best advantage in diet. Speaker: Gary Lockhart, an herbalist.

Tuesday, May 2
"Pedal Power," follows the use of bicycle power in such diverse applications as grinding grain to pumping water.

Wednesday, May 3
"Solar Frontiers," examines three solar homes built by middle-income families.
Speaker" Giles Shepherd, instructor of Physics at Everett Community College.

Thursday, May 4
"Desert Cloud," a solar structure that self-inflates, rises from the desert floor in Kuwait, creating rain as water condenses on its underside.

Success of Acitivites:
Awaiting report from organizers.

TACOMA
Wednesday, May 3
Pre-dawn walk and sunrise breakfast.
Audubin Society and Sierra Club booths along with alternative energy demonstrations by Dr. John Randolph, University of Puget Sound.
Potluck dinner and sundial construction.

Success of Activities:
Organizers report 75-100 participants.

LONGVIEW

Wednesday, May 3
Energy Fair, including demosntrations of solar water heaters, solar ovens, and solar heating systems both passive and active. A local company that manufacturs pellet fuel for generating heat and electricity from organic matter exhibited along with 15 other exhibitors including storm windows and insulation installation demonstrations. Bonneville Power Administration also presented an exhibit.

Success of Activities:
The publicity was poorly handled. The attendance at the fair left something to be desired.

PORT TOWNSEND

Wednesday, May 3
Sunrise celebration; some inspirational playing with the sun using lenses and mirrors. A formal dedication of the Olympic Alternative Center and introduction of the events and workshops of SUN DAY week.
Public library display of resource materials.
"Solar Collector" workshop, including discussion on working principles and expected returns from solar heat collection and hands-on construction of a convective air-loop "window box" collector designed for low income, owner-built-and-installed applications.

Thursday, May 4
Continuation of library display.
"Solar Facts Workshop" -- local solar information and conservation facts presented. Solar greenhouse design explained and design computations worked through, including economic investment potentials.

Friday, May 5

Continuation of library display.
"Solar Buildings and Architecture" -- a lecture/seminar for presentation of information about the possibilities of, planning for and building of energy conserving and solar heated architecture for the Pacific Northwest.
Film showing several existing solar heated houses designed for the "Snowbelt."

Saturday, May 6

"Grass Roots Solar Energy Day." All-day program of speakers, demonstrations, displays and discussion about simple and inexpensive ways to use solar energy now. Included were presentations on organic gardening, wood stoves and wood heat, greenhouse growing, functional landscaping, beekeeping, and discussions with solar owner-builder George Van Dusen, professor at Peninsula College.

Success of Activities:

The week of activities held great interest until the end of the third and fourth days. Too many activities were scheduled consecutively. Approximately 40 participants attended each evening session.
"Solar Architecture" and sunrise dedication were the most effective.
The information was based on too many facts and figures for the participants to feel comfortable. Many missed the points being made due to the intensity of the technical information.

RICHLAND

Wednesday, May 3

Richland Science Center solar displays.
Tours of local solar buildings.

Success of Activities:

Publicity poor, attendance poor. No grassroots involvement by the community.
Sphere of awareness of participants was very high.

PORT ANGELES

Wednesday, May 3

Workshop covering the basic principles of design for an attached solar greenhouse. Included in the presentation was local climate and radiation figures with a discussion of ways to adapt solar designs to take advantage of local weather conditions. The solar greenhouse under discussion served as a model for demonstrating design and planning considerations for passive solar heating systems.
Lisa Steinman, student intern from Institute for Environmental Studies, University of Washington; Bruce Hanify, Clallam County energy auditor; Kathy Pape, energy coordinator for Clallam County; and Marian Meachum, Shoreline Commissioner and solar homeowner made presentations.

Success of Activities:

Awaiting report of organizers.

ELLENSBURG

Wednesday, May 3
College-based activities. Details yet to be provided by organizers.

Success of Activities:
Very good attendance reported.

MOSES LAKE

Wednesday, May 3
Seminar discussion on "Solar Energy and Energy Futures for Central Washington and the Northwest."
Some Love's Vision of Tomorrow media presentation.

Friday, May 5
Solar greenhouse open house

Success of Activities:
Poor attendance.

MONROE

SUN DAY Week
Tours of the 100,000 gallon methane digester at the State Honor Farm.

Success of Activities:
A dozen phone calls were received inquiring about methane and the plant, but no one came to tour.

SEQUIM

Wednesday, May 3
Solar information workshop on implementing solar energy systems for homes and gardens. Speaker on "How to Build a Solar Greenhouse, Particularly for the Sequim area."

Success of Activities:
Awaiting report from organizers.

SPOKANE

Saturday, April 29
Solar exhibition at Riverfront Park.

Sunday, April 30
Tours of solar homes and buildings

Success of Activities:
Awaiting report from organizers.

SEATTLE

April 8 - May 22
"Something New Under the Sun? Solar Energy for Washington," University of Washington extension class.

May 1-5
Youth workshops, Montlake Community Center.

April 28
Solar Home Slide Presentation, Seattle University, with Ken Smith of Ecotope Group.

April 29
Solar Home Open Houses, Washington Natural Gas in Juanita, Space/Time in Edmonds.

April 30
SUN DAY celebration in Gas Works Park. Solar exhibits, Micro-Environmental Research Group barge, Caribbean Superstars, Messengers Theater Group, New Games.

April 30
Tours of four Energy Conservation homes, Sand Point Park.

May 1
"The Soft Energy Path," lecture at Seattle University by Davis Straub of Ecotope Group.
"Energy and Law," Charlie McLane at Seattle University.

May 2
"Boeing's Solar Projects," Bill Beverly at Seattle University.
Solar Heated Homes in the Pacific Northwest -- slide show by WEES on Queen Anne Hill.

May 3
Slide show on solar in the Northwest by Randy Skoog of Ecotope, University of Washington. Also at UW, panel discussion with solar experts and "Conservation in Regional Electrical Energy Policy" workshop.
Pike Place Market (through May 6) feature SUN DAY chalk-talks and exhibits.
Ecotope Group demonstration solar greenhouse at Pike Place market.

May 4
"The Regional Power Plan," Dick Watson at Seattle University
Solar Heater Homes in the Pacific Northwest -- slide show and presentation by WEES' Tim Williams on Queen Anne Hill.

May 5
Solar home slide presentation at Seattle University.
Forum on solar energy, Montlake Community Center.

May 3 & 5
Home energy audits, Montlake Community Center.

May 2
Seminar on solar greenhouses at Montlake Community Center by Ecotope's Tim Magee.

May 4- 14
Department of Energy Traveling Energy Exhibit, Northgate Shopping Center.

May 5-6
Solar "Plumb-In," slides and hands-on workshop in connecting solar panels to a domestic hot water system. Ecotope Group

May 5-7
Hands-On Solar Greenhouse Workshop. Ecotope Group

May 6
Solar Home Open House, Space/Time, Edmonds. Solar home tours.

May 6
Solar Fair and exhibits, Montlake Community Center

May 6-7
Demonstrations, solar trades fair, family workshops at Pacific Science Center

May 12-14
Solar Water Heater Workshop,(Edmonds) Ecotope Group.

May 7
Solar Home tour.

Success of Activities:

<u>OLYMPIA</u>

May 5-7
Exhibits, films and displays at "An Exposition of Appropriate Energy Use," at The Evergreen State College. Included as feature speakers: Amory Lovins, Sim Van der Ryn, and John McBride.

III. SUCCESS OF ACTIVITIES

SUN DAY was a media event. The audience addressed was the general population which perhaps does not yet view solar energy as a significant issue. The events did not produce public action nor leave any feeling of moral oblication to participate in the activities -- as happened widely with Earth Day several years ago.

In general, attendance at events was moderate. For people who attended, however, the enthusiasm and interest expressed were high.

The most successful events were the solar home tours and the hands-on workshops. Seattle especially responded favorably to participatory events rather than to the more academically-oriented panel discussions and lectures.

Seattle University discussions were poorly attended. However, the May 3 panel and dialog workshops at the University of Washington were effective in drawing a crowd of interested and informed individuals.

The celebrational events reported success throughout the state in bringing people together. In Seattle, the Gas Works Park event attracted approximately 3,000 people. Bellingham and Port Townsend report that their sunrise celebrations drew crowds of interested solar enthusiasts.

IV. QUESTIONS AND CONCERNS

A group of five volunteers felt that an information sheet could facilitate individuals in finding financing for solar systems and could describe needed changes in state and federal laws that now form barriers to the use of solar technologies. This fact sheet, "Sun shine and the Law," is included with this report,and describes possible incentives (and removal of "dis-incentives")for solar utilization and investment.

Several individuals suggested the need for visible solar demonstration projects in the cities. Such model projects through media presentation and visibility in neighborhoods could assist people in understanding and adopting solar technologies. Volunteers and others also suggested that a regular public interest column in local newspaper and TV programs could do much to address solar energy issues and development.

The most-often-asked questions expressing people's concerns with solar technologies are listed below:

1. What is SUN DAY?

2. Why use solar energy?

3. Does it work in the Pacific Northwest?

4. How does it work?

5/ What are the current applications in the Pacific Northwest?

6. How much does it cost? Does it save enough energy to pay for itself?

8. Where can one get funding for small solar projects?

9. What about wind and other forms of solar energy?

10. Where can I learn more about the possibility of using solar energy for my home?

SUN DAY has uncovered the need for answering these questions for the general public. The on-going need to educate the public about the barriers to development of solar energy in Washington State is obvious. People are interested now and express an eagerness ot act, but are not sure oftentimes of the actions needed for realizing the use of solar energy soon. A focus for political and educational activities should be the major directional task of on-going SUN DAY organization.

The success of demonstration workshops, tours and other "hands on" experience with the technology strongly suggests that it is the presence of the technology itself, where it can be seen and felt and its operation clearly shown, have the greatest impact. It is also clear from the questions and doubts of people participating, that the Northwest's "solar inferiority complex" needs to be addressed clearly so that people can understand and begin to take action on the solar possibilities for this region.

It is clear that the federal government believes in the economic viability of solar energy utilization within the Pacific Northwest. From the response of the citizenry and the nature of their questions, it is essential that DOE and the State of Washington, in conjunction with local groups, engage in a large scale implementation, demonstration and commercialization project. The aim of such a project, for instance to install up to 1000 water heaters in the Region by July 1979 and to facilitate 50 to 1000 passive solar remodels, would provide a community-level experience of the technology to facilitate its understanding and increase its immediate use.

Additionally, efforts to expand and strengthen solar energy research in the Cascadia region should be made. The good work Region X DOE has done to bring good solar economic analysis to the attention and understanding of Northwest citizens should be continued. The presence of DOE and its report during SUN DAY week served to further public awareness that solar is an important and immediate issue of common concern.

The second chapter of this report will include concrete assessment of public participation in SUN DAY events, a critique of the varying modes of information exchange, and suggestions for on-going public education about solar energy.

OPPORTUNITIES FOR FINANCIAL HELP

OREGON'S SOLAR TAX CREDIT PROGRAM - THE FIRST 100 INSTALLATIONS

by

Alan D. Kiphut
Solar Specialist
Oregon Department of Energy

In 1977 the Oregon Legislature passed SB 339 - allowing homeowners to obtain 25% of the cost of an alternate energy device (solar, wind, geothermal) in the form of a state tax credit (up to a maximum credit of $1,000). This paper specifically describes the solar energy portion of the program. To become eligible for the credit, a homeowner must first file an application with the Department of Energy and have the device certified <u>prior</u> to installation. In order to qualify, the device must meet specific criteria established by the Department of Energy, which include providing at least 10% of the <u>total</u> energy demand of the dwelling. Using typical energy consumption figures for various building sizes and the F Chart computer program for solar system performance, tables were developed showing estimates of collector area needed to meet the 10% requirement (The table for space heating is reproduced below as Figure 1).

<u>Figure 1</u>

Estimated* Active Solar Collector Area or Passive Solar South-facing Glass Area for Space Heating Only (Collector assumed @ 60 degree tilt to horizontal; efficiency for Total Insolation Assumed at 30 percent for Oct.-April Heating Season)

Storage: Active Collectors -- 2 gal. water or 1/2 cu. ft. rock per sq. ft. collector. Passive designs -- 4 gal. water or 1 cu. ft. rock per sq. ft. glazing.

Approx. Residential Heated Area	(# Residents)	Zone I	Zone II	Zone III
1,000 s.f.	(2)	90 s.f.	70 s.f.	65 s.f.
1,500 s.f.	(3)	135 s.f.	100 s.f.	95 s.f.
2,000 s.f.	(3.5)	165 s.f.	125 s.f.	120 s.f.
2,500 s.f.	(4)	200 s.f.	150 s.f.	140 s.f.
3,000 s.f.	(4.5)	230 s.f.	175 s.f.	165 s.f.

*These are based on the estimates made by the Department of Energy. An individual determination may be made as to whether the 10 percent requirement is met, if an applicant feels their dwelling uses less energy or their collector is more efficient than assumed in the derivation of these tables.

The public response to this program has equaled our expectations, with 102 solar installations certified to date. The $80,000 which the state will spend in the form of tax credits to these homeowners is more than compensated for by the $500,000 they've poured into Oregon's young solar industry. Prior to the passage of SB 339, few solar energy systems had been installed, although a great deal of research and experimentation had taken place at the University of Oregon and Oregon State University. Figures 2 and 3 illustrate the dramatic changes which have occurred in the past few years.

Figure 2. Oregon Solar Installations - 1973

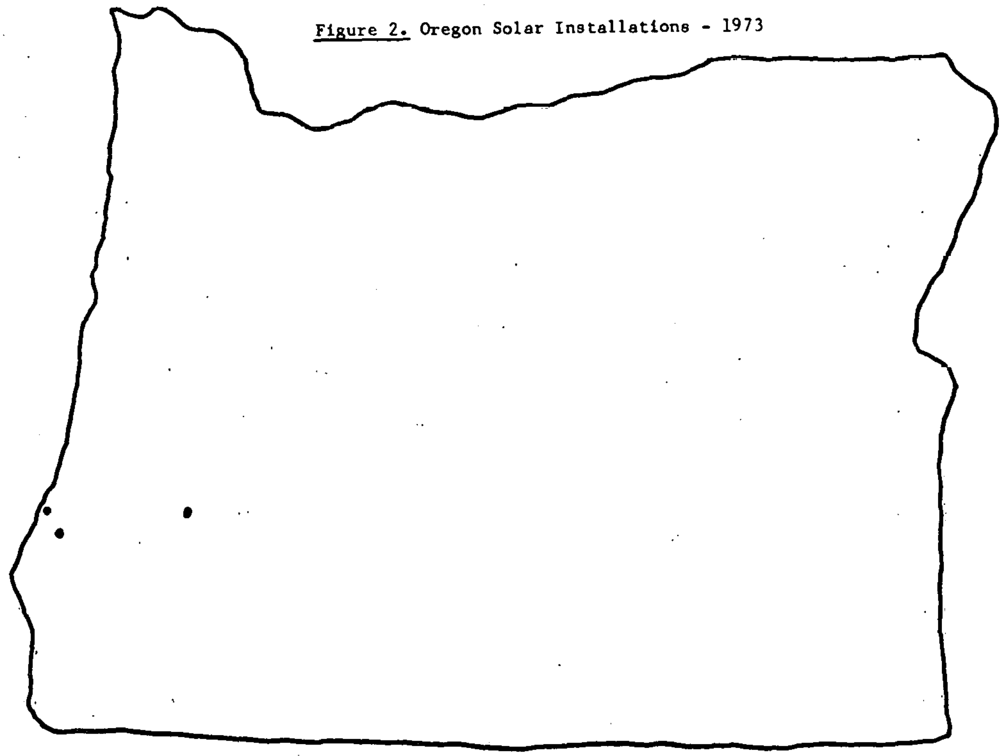
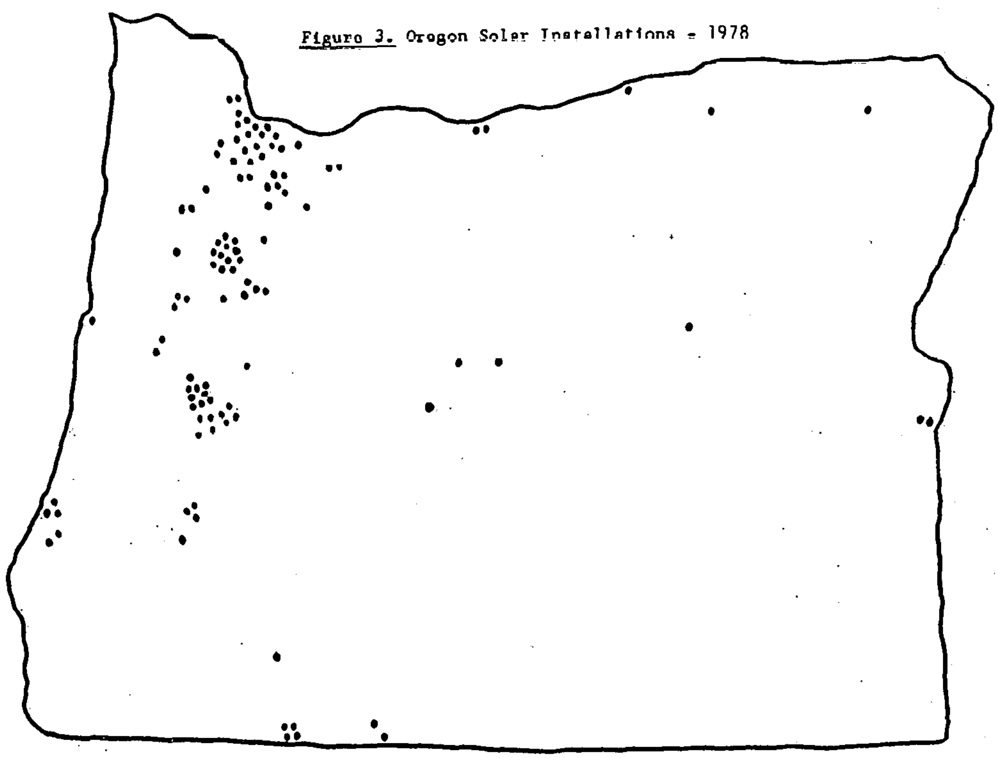


Figure 3. Oregon Solar Installations - 1978



The "economics" of solar energy systems continues to be a major topic of discussion, but will not be dealt with here in any detail. Let it suffice to say that "payback period", "rate of return" and other forms of economic analysis are only marginally acceptable and hardly deal with the complete picture, especially in light of existing federal subsidies to suppliers of conventional energy forms and the ramifications of continued reliance on imported fuels. Figure 4 outlines cost information for the first 102 solar installations certified by our department, illustrating a wide price range and a substantial degree of homeowner involvement. As might be expected, the average cost/ft^2 of an owner built and/or installed system is substantially lower than that of a commercially installed system. However, it should be pointed out that in almost all categories listed in Figure 4, the low cost commercially installed system is lower in price than the high cost owner built/installed system, illustrating that it is extremely important to see what's on the market before attempting the job yourself. Typically these numbers do indicate that the do-it-yourselfer is getting more collector area for the dollar.

SUMMARY/CONCLUSIONS

The Tax Credit Program has indeed been successful in stimulating public involvement in solar energy installations. As with any new program there are some bugs to be worked out, which we hope to correct during the next legislative session. The following are of major concern:

1. The combination of requiring prior certification and that the building be the owner's primary or secondary place of residence has basically ruled out the certification of solar spec homes. A "transfer of certification" clause will correct this situation.
2. Some solar domestic water heating systems have had trouble meeting the 10% criteria. Changing the requirement, for this use only, so that a system providing 50% of the energy used for water heating may be certified, will alleviate this situation.
3. The wide price range of systems installed has caused some concern about consumer protection. We are currently looking into the most appropriate method for handling this potential problem, along with the Department of Consumer Affairs.

Figure 4

COST DATA OF CERTIFIED SOLAR INSTALLATIONS

Type of System	Number of Installations	High Cost	Low Cost	Avg. Cost	Avg. Cost/Ft.[2]
PASSIVE SPACE HEAT					
Commercially Installed	9	$ 8,000	$2,690	$5,452	$15.36
Owner built and/or Installed	3	4,500	1,690	2,863	10.93
ACTIVE SPACE HEAT					
Commercially Installed	14	11,504	4,927	7,406	25.19
Owner built and/or Installed	2	5,925	2,700	4,313	5.88
HYBRID AND COMBINATION SYSTEMS					
Commercially Installed	32	17,295	2,600	7,806	18.80
Owner built and/or Installed	11	5,275	1,714	3,539	9.89
ACTIVE DOMESTIC HOT WATER					
Commercially Installed	16	3,000	1,060	2,160	31.82
Owner built and/or Installed	10	1,832	400	1,057	17.18
SWIMMING POOL HEATING					
Commercially Installed	6	4,250	1,620	2,800	9.26
Owner built and/or Installed	3	1,126	800	946	3.67

FEDERAL FINANCIAL ENCOURAGEMENT

by

Xerpha Borunda
National Solar Heating &
Cooling Information Center
P. O. Box 1607
Rockville, MD 20850
(800) 523-2929

When I majored in economics at Portland State, one of the first definitions we were taught was that economics is the study of limited resources and unlimited wants. Probably for that reason, economics is called the dismal science.

Now that you've all attended these wonderful sessions and are convinced that you want solar, I'm afraid that the dismal message of this panel is going to be that solar technology is more advanced than solar financing. In bringing you that message, I can only hope that you'll forget about the good old days when the messenger bearing bad news was beheaded and remember instead the sign over the bar in Virginia City: "Please don't shoot the piano player--he's doing the best he can."

I've been asked to present an overview of the financial encouragement available from the federal government, and although it's flattering to be reffered to as an expert, in the area of federal grants and proposals it's safer for me to say that I'm sharing with you the information of which I'm aware. Those of you who have participated in the proposal process should appreciate this more modest approach.

Actually the National Solar Heating and Cooling Information Center is a pretty complete source of such information and is specifically the central source for HUD and DOE/PON applications. But more about that in a minute.

Most of you have probably contacted the National Solar Information Center at one time or another. The Center gathers and disseminates information about solar energy uses, specifically about heating domestic water supplies and about residential space heating and cooling.

Incidentally, the National Solar Center maintains an extensive research library which includes computer hook-ups to NTIS and DOE-TIC. So don't hesitate to ask specific questions.

In discussing the financial encouragement offered by the federal government for solar energy use, there seem to be four more-or-less clearly defined areas:

1. R & D monies
2. Demonstration project grants
3. Federally insured loans
4. Tax incentives

Let us begin with a quick look at the status of research and development monies.

Research and development money--usually offered by a solicitation called a Program Research and Development Announcement (PRDA)--is expected to improve the technology or lower the cost of the existing technology in one of several areas, which currently include:

-Photovoltaics

-Solar thermal

-Wind

-Biomass

-Agricultural and process heat

Agricultural and process heat is used for such projects as grain drying; peanut, tobacco and forage drying; livestock production; green houses; and food processing. These are U. S. Department of Energy monies but they are administered by the U. S. Department of Agriculture. As Paul Scofield from Idaho pointed out yesterday, this program is currently moving from the R & D phase to the applications phase. The 1977 Agriculture Act appropriated some $20 million for grants for applications of the current technology. Watch for such a program which should be upcoming from USDA.

The second group of federal incentives are the demonstration programs which are estimated at spending $87 million in FY 1978, covering both residential and commercial applications.

In the public sector, the residential program is administered by the Department of Defense; the commercial program by Department of Devense and General Services Administration. These projects are often contracted and sub-contracted by competitive bid at the local level.

In the private sector, the residential demonstration program is administered by the Department of Housing and Urban Development, using competitive solicitations called Requests for Grant Applications (RFGAs). The commercial demonstration program comes directly from U. S. Department of Energy--whose money this all is--using competitive solicitations called Program Opportunity Notices (PONs). The way to receive these applications is to call the National Solar Heating and Cooling Information Center and ask to be put on the appropriate list.

DOE's Program Opportunity Notices are funded for five cycles, the third of which has just been awarded. The fourth PON cycle is currently scheduled for fall of 1978 and the fifth for fall of 1979. Again--these are for commercial--that is, non-residential--projects.

HUD's residential demonstration program is also funded for five cycles. Cycle 5 is scheduled for late 1978 or early 1979 and will be the last under the current funding.

These residential demonstration projects are funded to make up the difference between the total cost of the project with solar equipment and methods and the total cost of the project if it were using only conventional equipment or methods.

Applicants must be either builders who are building for the speculative market or quasi-public bodies such as housing authorities, community action agencies or tribal councils.

Within these stipulations, HUD has funded many types of solar installations: passive, active (air and water systems), hybrid (active and passive), integrated space and water, and retrofits.

Many of these completed projects are being monitored and the resulting information is the basis for the Intermediate Minimum Property Standards--the current federal guidelines for equipment and installation of solar energy systems.

Also from HUD, and also coming up soon--August 8, to be exact--is the Passive Residential Design Competition and Demonstration. It is a one-shot program in two parts:

The design competition is an open-to-anyone, free-for-all, awarding to the winners $2,000 for retrofit design and $5,000 for a new design.

The demonstration portion of this competition can be awarded only to a builder who has submitted an award-winning new construction design.

Coming soon, but not yet announced when I left Philadelphia on Wednesday, is the second of five cycles for a Request for Proposal (RFP) from Department of Health, Education and Welfare for solar heating and cooling of space and water for health care facilities. I have a name and address at Health Resources Administration for anyone interested--or you may get it, of course, from the National Information Center. Health Resources Administration does ask that any requests for applications be on health-care facility letterhead.

While we're previewing coming attractions, I'd like to just mention the Appropriate Energy Technology Small Grants Program which is currently, as I understand, scheduled to begin in Region X--this area--late in 1978. Basically all projects must be small scale and energy efficient. Watch for this one.

Now, having addressed the solicited proposals and competitions, I would like to mention that for those ideas which don't fit any of the above, you may always submit an unsolicited proposal to DOE or to the appropriate agency. And, in fact, if you've invented a more energy-efficient mousetrap, the National Bureau of Standards maintains an Office of Energy Related Inventions.

These grant programs, you've noticed, are mostly for professionals. For an average person to install solar devices or techniques the person to talk to is the man on my left--your friendly local banker. Some sources of federally insured money are available--all of which is administered at the local level. Most of these require adherence to the Intermediate Minimum Property Standards. There are funds insured by:

-FHA, Title 1 Home Improvement Loans for solar are for up to $15,000/14 years/12%

-FHA insured new construction now includes solar provisions

-FmHA has solar money available at local option

-VA will insure solar building and devices, but is much less specific than FHA--but then as you veterans know VA is always less specific

-CSA has money available for solar, specifically labeled for low-income housing and . . .

-SBA now has money available specifically for setting up a solar business

The other possibility for federal assistance at the personal level is, of course, tax incentives. You have already heard the administrative assistants of various Northwestern senators and congressmen discuss the bills that are proposed but not enacted. These would offer tax credits for investment, for solar and for conservation. These are proposed, and I would rather not discuss them. When I was growing up in this area and playing cow-pasture ball, the little fat kid who was the umpire couldn't be pushed into making a call. When asked if a pitch had been a ball or a strike, he'd reply "Until I calls 'em, they ain't nothin'." That's how I feel about legislation: Until it's enacted, it ain't nothin'.

I think you can expect tax credits of some kind. I think you expect to see extensions and additional funding for the existing programs. I think you can expect to see appropriate technology money for third-world nations available through USAID. And I think you can expect to see interest in the sexy projects like a solar-powered satellite.

There. Have I been too dismal?

Consider your alternatives:

Your local bankers can be quite responsive.

Your state government--expecially Oregon's--can offer you almost as much as the federal government.

You can always write to your congressman or senator.

Good luck with all that you--we--are trying to do. Thank you for the opportunity to be here today.

WIND ENERGY

SINGLE PERSON INSTALLATION OF SMALL WINDPLANTS

by Mark Lindgren
5211 S. W. Vermont
Portland, OR 97219

My aim with this paper is not to make installers out of all of you but to dispel any anxiety you might have about removing or installing a 600 pound wind generator atop a 65 foot tower and alone to boot. However if you do have a buddy it will make this simple task easier still.

With a few of the right pieces of equipment you can install a generator in 3-4 hours by yourself if the tower is already up. The safety equipment I recommend is a hard hat and a safety belt with two tag lines having large ladder clips. This allows one line to always be attached to the tower as you move around it. A carpenters tool belt is a real help too as it eliminates many trips up and down the tower for the right tool. However you will have many trips up and down the tower if you work alone. A vehicle with a power winch makes the actual lifting quite easy. Two snatch blocks guide the cables at the top and bottom of the tower. A 200 foot rope is vital for guiding the generator and for raising and lowering parts. An 11 foot gin pole of high strength and light weight is best when working alone. I use three adjustable cables with hooks on them; one as a safety on the gin pole, one for attaching the snatch block to the base of the tower, and one as a safety should you have to hang the generator on the tower for any reason. You also need a gin pole clamp to fasten the pipe to the top of the tower. I recommend an open trailer for transportation, as this allows the lifting vehicle with the winch to be independent of the plant for loading and unloading.

The first step in installation is to bolt the tower cap casting to the tower top. The cap should not be fully tightened so as to make sure the weight of the generator is on the tower top steel and not the cap bolts. The saddle is then slid into the cap with the thrust bearing. The next step is to establish the direction of the wind on the day of the lift; as you must mount the gin pole clamp and the gin pole to the leeward side on the left. The loop of the clamp would curl towards the right if you were facing the wind. The clamp is loosely installed and the gin pole is raised up and through the clamp, and bolted at its base to the left tower leg. The clamp is tightened and the pole is cabled for safety. The height of the gin pole should be as low as possible; 3-4 feet above the top of the generator saddle as the actual lift above the saddle is minimal. A snatch block is placed at the pole top and at the base of the left tower leg to which the pipe is bolted. This gives a straight vertical pull on the cable which is threaded through the top and bottom snatch blocks. The trailer is placed on the right hand side of the gin pole if you were facing the wind. The cable is hooked into the eye atop the wind generator and then the generator is winched up so the tail can be installed and tied to the plant in the "on" position with the pull out chain. Then the governor is bolted in place at the front of the generator. This allows for a smooth balanced lift. Guide ropes, preferably two, are tied to the front and rear of the plant. The rope can be wrapped around the vehicle bumper for pulling leverage. A trick here, if it is not terribly windy, is to shackle the long angle of the tail to the lifting cable and let it guide the generator up the tower to within four to six feet of the top. With the tail unshackled the plant is then hoisted one to two inches above the tower saddle, long guide bolts are substituted for the standard bolts and slid up through the saddle and screwed into the bottom of the generator. The plant is then lowered down and bolted up with the original bolts. The tail spring is installed next which puts the generator in the "off" position. The tower cap bolts are tightened and next the blades are bolted to the governor. If the blades are raised up through the center of the tower they are less likely to be damaged by hitting the tower steel.

With the right equipment and working safely installation or removal of a small windplant is a simple task that can be very satisfying even when done alone.

The following four pages from the Jacobs manual contains additional installation information.

INSTALLATION INSTRUCTIONS FOR THE JACOBS AUTOMATIC WIND-ELECTRIC PLANTS

INSTALLATION EQUIPMENT REQUIRED

HOISTING PIPE; PIPE CLAMP, FOR FASTENING PIPE TO TOWER; BLOCK AND TACKLE; ROPE TO HOLD UNITS AWAY FROM TOWER WHEN HOISTING.

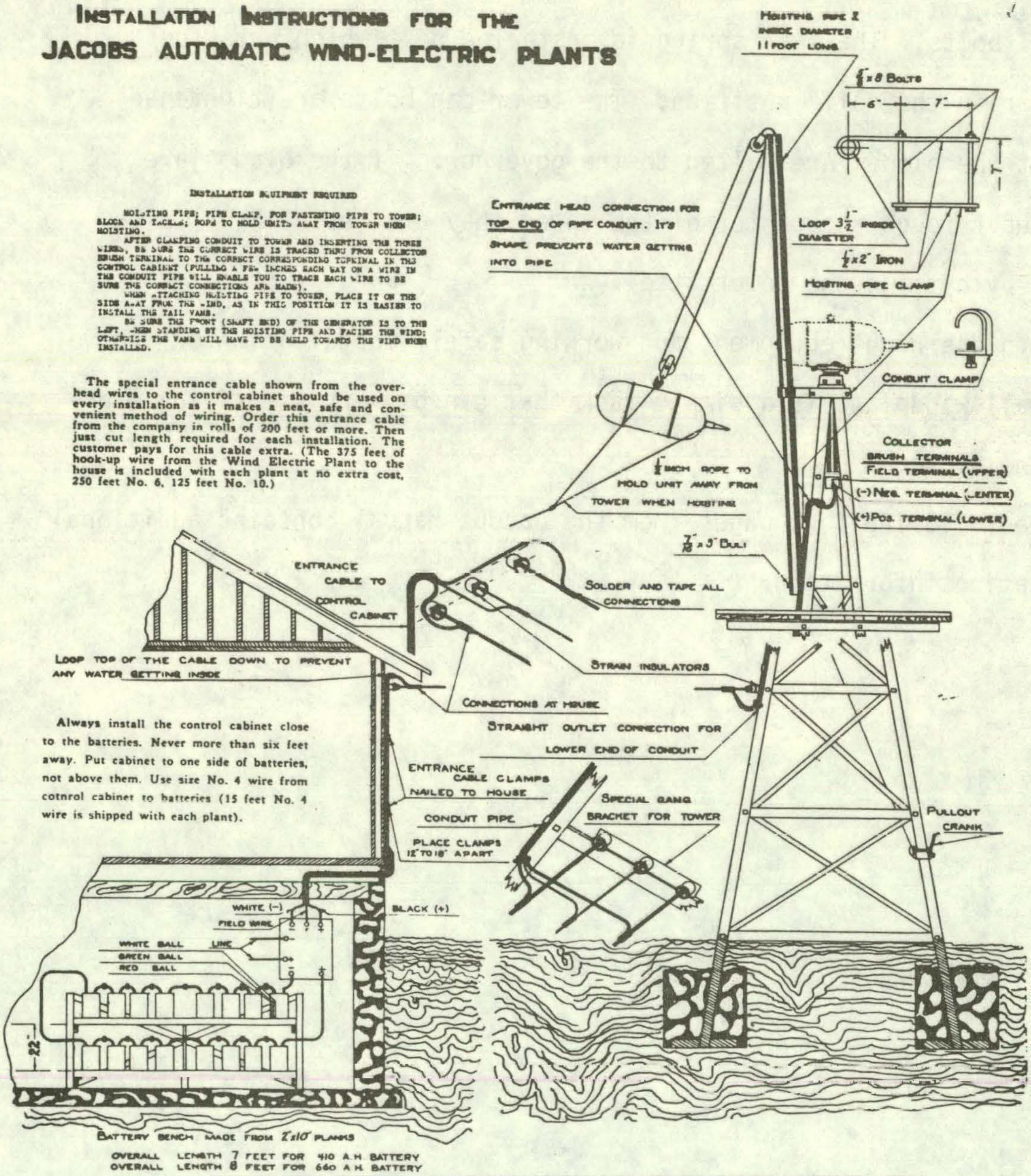
AFTER CLAMPING CONDUIT TO TOWER AND INSERTING THE THREE WIRES, BE SURE THE CORRECT WIRE IS TRACED THRU FROM COLLECTOR BRUSH TERMINAL TO THE CORRECT CORRESPONDING TERMINAL IN THE CONTROL CABINET (PULLING A FEW INCHES EACH WAY ON A WIRE IN THE CONDUIT PIPE WILL ENABLE YOU TO TRACE EACH WIRE TO BE SURE THE CORRECT CONNECTIONS ARE MADE).

WHEN ATTACHING HOISTING PIPE TO TOWER, PLACE IT ON THE SIDE AWAY FROM THE WIND, AS IN THIS POSITION IT IS EASIER TO INSTALL THE TAIL VANE.

BE SURE THE FRONT (SHAFT END) OF THE GENERATOR IS TO THE LEFT, WHEN STANDING BY THE HOISTING PIPE AND FACING THE WIND; OTHERWISE THE VANE WILL HAVE TO BE HELD TOWARDS THE WIND WHEN INSTALLED.

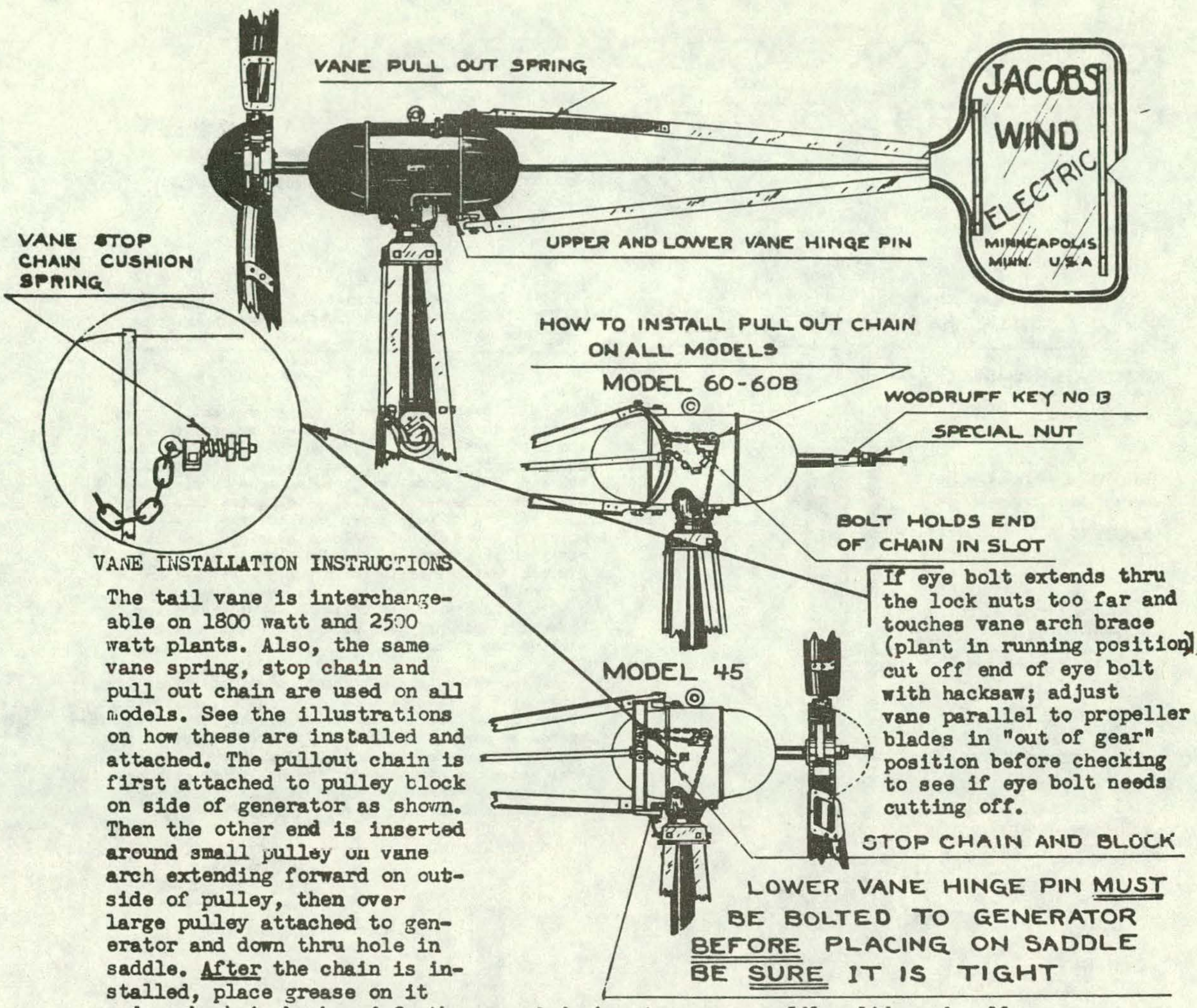
The special entrance cable shown from the overhead wires to the control cabinet should be used on every installation as it makes a neat, safe and convenient method of wiring. Order this entrance cable from the company in rolls of 200 feet or more. Then just cut length required for each installation. The customer pays for this cable extra. (The 375 feet of hook-up wire from the Wind Electric Plant to the house is included with each plant at no extra cost, 250 feet No. 6, 125 feet No. 10.)

Always install the control cabinet close to the batteries. Never more than six feet away. Put cabinet to one side of batteries, not above them. Use size No. 4 wire from cotnrol cabinet to batteries (15 feet No. 4 wire is shipped with each plant).



IMPORTANT **Always Give Serial Number When Ordering Parts**

VIEWS OF VANE MOUNTING AND CHAIN CONNECTIONS



VANE INSTALLATION INSTRUCTIONS

The tail vane is interchangeable on 1800 watt and 2500 watt plants. Also, the same vane spring, stop chain and pull out chain are used on all models. See the illustrations on how these are installed and attached. The pullout chain is first attached to pulley block on side of generator as shown. Then the other end is inserted around small pulley on vane arch extending forward on outside of pulley, then over large pulley attached to generator and down thru hole in saddle. After the chain is installed, place grease on it and work chain back and forth several inches to grease saddle slide and pulleys. Do not grease chain before inserting as it will not slide down chain tube.

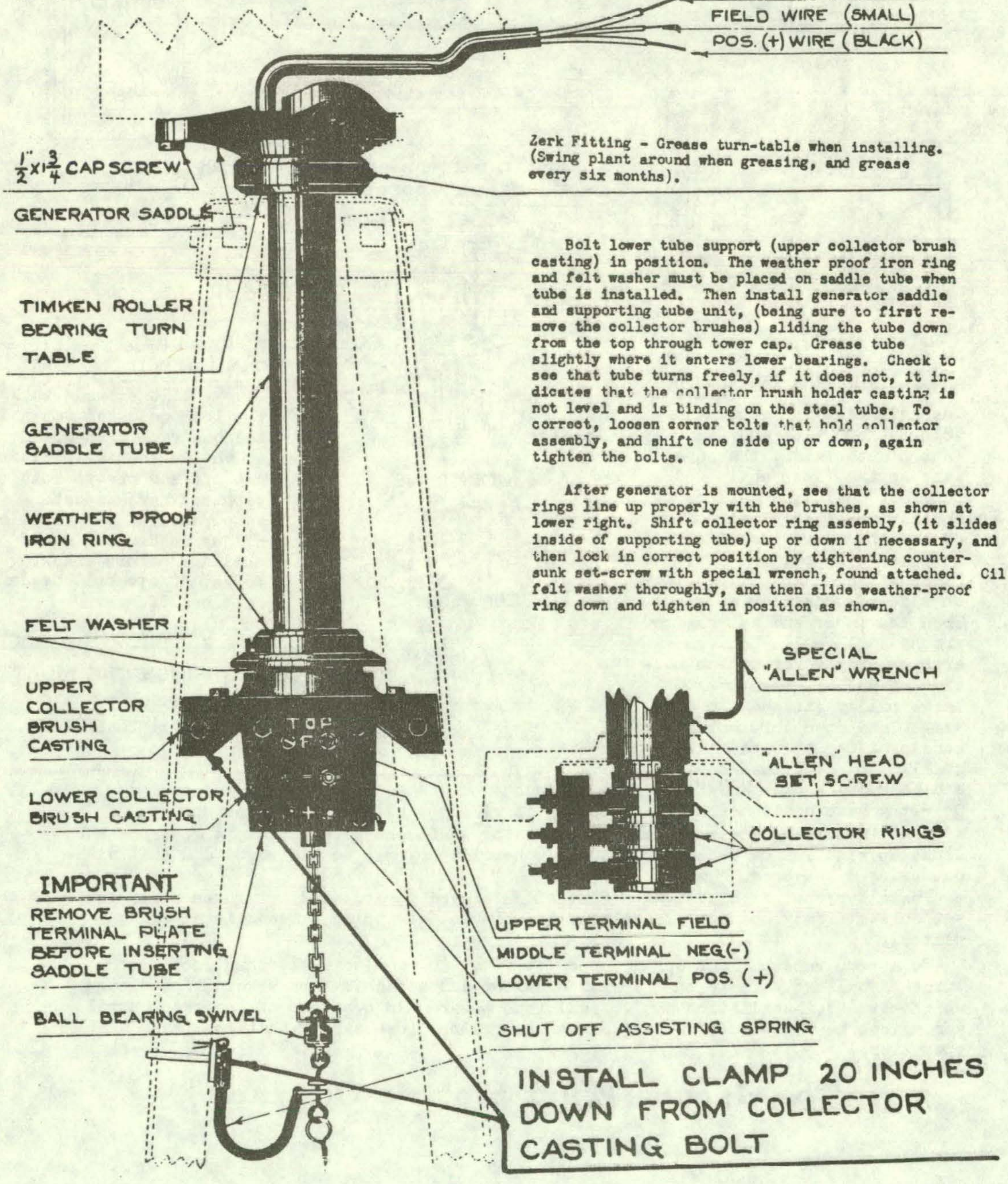
When installing governor head on generator shaft, be sure keyway in governor hub lines up with key on generator shaft. Otherwise key may be dislodged and lost without being discovered.

Install propeller blades with flat side forward toward wind. Tighten propeller set screws firmly but not excessively (to prevent stripping threads in aluminum plates).

To attach vane pullout spring, hook it first to vane bracket, then loop 3 or 4 turns of "baling" wire through spring end loop and attach a rope several feet long which permits installation man to pull rope toward him over top of generator until spring can be hooked over spring pin on generator. (Use safety belt for this operation.)

The Jacobs Wind Electric Co., Inc.

GENERATOR SADDLE ASSEMBLY AND COLLECTOR BRUSH UNIT



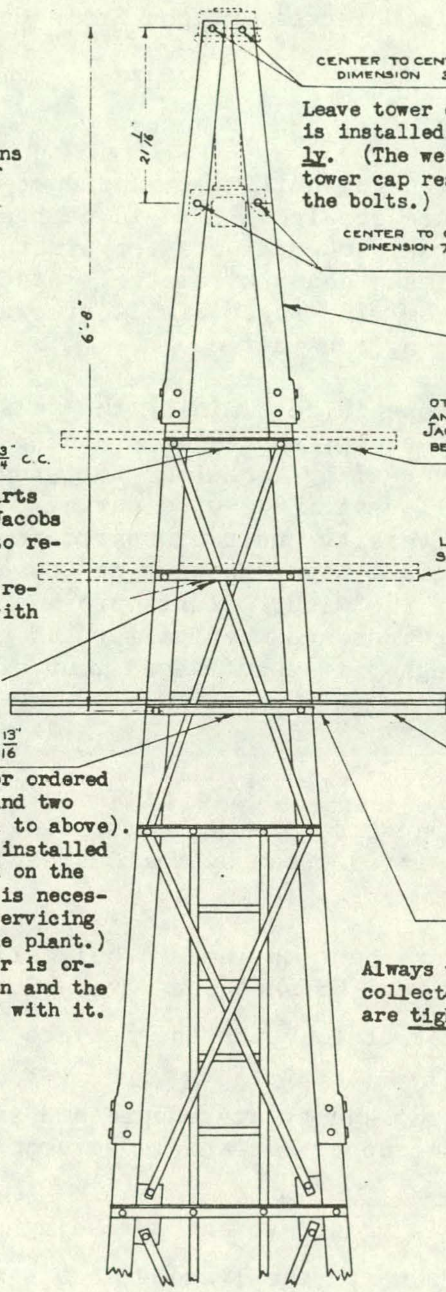
Zerk Fitting - Grease turn-table when installing. (Swing plant around when greasing, and grease every six months).

Bolt lower tube support (upper collector brush casting) in position. The weather proof iron ring and felt washer must be placed on saddle tube when tube is installed. Then install generator saddle and supporting tube unit, (being sure to first remove the collector brushes) sliding the tube down from the top through tower cap. Grease tube slightly where it enters lower bearings. Check to see that tube turns freely, if it does not, it indicates that the collector brush holder casting is not level and is binding on the steel tube. To correct, loosen corner bolts that hold collector assembly, and shift one side up or down, again tighten the bolts.

After generator is mounted, see that the collector rings line up properly with the brushes, as shown at lower right. Shift collector ring assembly, (it slides inside of supporting tube) up or down if necessary, and then lock in correct position by tightening countersunk set-screw with special wrench, found attached. Oil felt washer thoroughly, and then slide weather-proof ring down and tighten in position as shown.

STUB TOWER MOUNTING SPECIFICATIONS

M.R.M. PLATFORM INSTALLATION instructions and Jacobs stub tower specifications



Leave tower cap bolts loose until generator is installed. <u>Then tighten the bolts firmly</u>. (The weight of the plant insures the tower cap resting on corner rails and not on the bolts.)

Two of these short girts are included with a Jacobs stub tower, ordered to replace the platform angles which must be removed and discarded with the old platform.

Each Jacobs stub tower ordered includes a platform and two small girts (referred to above). The platform must be installed <u>only</u> at this location on the tower. (The platform is necessary for the future servicing and maintenance of the plant.) (When a complete tower is ordered the stub section and the platform are included with it.

Always use lock nuts on tower cap and collector casting bolts, and be sure they are <u>tight</u>.

TREES AS AN INDICATOR OF WIND POWER POTENTIAL

by

John E. Wade and E. Wendell Hewson
Department of Atmospheric Sciences, Oregon State University

INTRODUCTION

A necessary condition for utilizing wind energy is a knowledge of the strength and persistence of wind. This is particularly true here in the Pacific Northwest where in mountainous terrain the wind may vary considerably over distances less than a kilometer. Since power is proportional to the cube of the wind speed, it is crucial to know the strength of winds at sites being considered.

One of the first steps in determining the feasibility of utilizing wind as a source of energy should be a wind power survey, the purpose of which is to discover windy locations for wind power plant installation. This paper will describe a wind survey technique being developed by Oregon State University under a Department of Energy contract. The technique, called "Biological Wind Prospecting", uses plants as indicators of the strength of the wind. Plants provide a quick, at a glance, indication of strong winds and when calibrated by the degree of wind shaping provide a rough, first-cut assessment of wind power potential.

DEVELOPMENT OF THE TECHNIQUE

Putnam (1948) was the first to use vegetation as a tool in wind power surveys. He classified trees by various degrees of wind deformation which included:

(a) *Brushing*: the branches are bent to leeward only slightly, like the hair in a pelt which has been brushed one way.

(b) *Flagging*: the branches stretch out to the leeward and the trunk is bare on the windward side.

(c) *Wind clipping*: the leading shoots are suppressed and held to an abnormally low level. The upper surface is as smooth as a well kept hedge.

(d) *Tree carpets*: the tree is prostrate and spreading over the ground.

(e) *Winter killing and resurgence*: the leading shoots are killed during the winter.

(f) *Ice deformation*: the formation of ice on the branches in winter causes breakage, leading to a much branched "candelabrum" tree.

Putnam assumed that tree deformation was a function of the annual mean wind speed. He noted that some components of the annual mean wind speed may not contribute to tree deformation; for example, light winds will have little effect on tree form and occasional severe winds without breakage do not affect tree shape but contribute to the annual mean velocity. However wind turbines, he reasoned, react similarly using only speeds in a certain range. In addition, he found turbine output could be predicted from the annual mean wind speed because speed frequency distribution curves in New England are of the same statistical type. Therefore tree deformation should also be a function of the annual mean wind speed.

Putnam's technique, although based on fragmentary observations of trees and often only estimated wind data, showed good agreement between the degree of tree deformation and annual mean wind speed. Barsch and Weischet (1963) and Yoshino (1973) also found agreement between measured wind speeds and the degree deformation of trees. However, none of the above studies attempted to develop relationships between wind velocity and tree form.

In July 1976, Oregon State University initiated a similar study whose purpose was to calibrate in terms of wind characteristics various indices of wind effects on vegetation. These indices, when calibrated, could in turn be used as a first step in selecting sites for wind energy conversion systems.

The first year of the study began with the establishment of a library of information on the affects of wind on vegetation. In addition, five indices of wind affects on coniferous trees were developed and the calibration process was commenced. The results of the first year's research are described by Hewson et al. (1977) and Hewson and Wade (1977).

During the second year, the study of the relationship between the index values and wind characteristics was expanded to over 40 locations in Washington, Oregon, Nevada and California. The primary emphasis in this phase of the study was the calibration of two widely distributed species of conifers, Douglas-fir (Pseudotsuga menziesii) and Ponderosa Pine (Pinus ponderosa) in terms of annual mean wind speed.

Preliminary calibrations have been made on three indices:

Griggs-Putnam Index: a subjective rating scale similar to that developed by Griggs and used by Putnam (1948). The original index has been described earlier.

Deformation Ratio: an indicator of the degree of wind induced crown asymmetry and trunk deflection. The ratio is computed by measuring the angle formed by the crown and the trunk on the leeward side of the tree and dividing by the measured angle formed by the crown and the trunk on the windward side of the tree. The sum of this ratio and the quantity $\gamma/45$, where γ is the angle of permanent deflection of the tree trunk from the vertical, is defined as the deformation ratio, as illustrated in Figure 2.

Compression Ratio: a measure of the influence of wind on the formation of reaction wood and the resulting eccentric radial growth. The ratio is calculated by measuring the increment of growth on the lee side of the tree over some period of time during which winds have been measured and dividing by the increment of growth over the same period on the windward side of the tree (see Figure 3).

Two other indices have been examined but not calibrated. They are:

Shape Index: a measure of the relative influence of wind on apical (height) and radial growth. The index is computed by dividing the circumference of a tree at 1.5 m by its height.

Eccentricity: an indicator of the departure from circularity of the trunk of the tree. This index is computed by measuring the major and minor axes of the tree at 1.5 m and computing eccentricity.

These five indices are calculated from data collected in the field. At each experimental site wind data are being gathered so that the relationship between the wind and each index value can be determined. At many of the locations winds are being measured using recording anemometers and wind vanes, from which monthly averaged wind speeds and directions can be determined. The sites that have been chosen for study have been selected either because of the presence of wind deformed vegetation or because wind information and trees happen to be available in the same area. Wherever possible these shorter period wind measurements are being correlated with nearby longer period records to determine how representative the short period records are.

The procedure needed to develop index values for each tree involves first of all a physical examination of the tree and its environment which includes amount and direction of wind induced flagging, nearby sheltering vegetation which may affect tree form, and terrain influences that may affect stem shape. Measurements are made of tree trunk height and circumference for the Shape Index, major and minor axes of the trunk for the Eccentricity, and the altitude of the location where the tree is growing. A photograph is taken from a point perpendicular to the direction in which the tree is flagged for later laboratory analysis of the degree of wind flagging for determining the Griggs-Putnam Rating and the Deformation Ratio. For the Compression Ratio the tree is cored on the side facing the prevailing wind direction at breast height, 1.5 m, and also on the opposite side of the tree trunk. The two holes in the tree are plugged and the cores are mounted in blocks and labeled for laboratory analysis.

The final step in the field analysis may include the collection of needles, bark and a cone so that positive species identification can be made if necessary by a dendrologist. Up to the present time the study has concentrated on Douglas-fir and Ponderosa Pine, but eight other species of conifers have also been included.

The wind data are processed at Oregon State University to determine hourly, monthly and annual mean wind speed and the percent frequency of winds from each direction. Field data on each tree are processed and the indices defined earlier are calculated. Tree cores are sanded, polished, cross dated and measured for growth increment. The data on the tree rings are cross dated, as shown in Figure 4, to insure that the rings on each side of the tree are aligned and represent the year assigned.

RESULTS

Index values have been computed at 24 locations which have a year or more of wind data. Relationships between the indices G (Griggs-Putnam Index), D (Deformation Ratio), C (Compression Ratio) and $\bar{V}$ (the annual mean wind speed) are given in Table 1 along with r, the correlation coefficient, ME the mean error in the prediction of mean wind speed and P_{25} the percent of time the prediction error is likely to exceed $\pm$ 25%.

Table 1. Relationships between $\bar{V}$ and index values.

Index	Relationship	r	ME (%)	P_{25} (%)
G	$\bar{V} = 1.05G + 2.72$	.90	14	8
D	$\bar{V} = 0.9D + 3.00$	.88	15	21
C	$\bar{V} = 3.6C + 0.32$	.67	22	32

Mean predictive errors were calculated using a Jackknife statistical technique (see Quenouille, 1956 and Gray and Schucany, 1972). The technique involves dividing the sample into as many subsets as there are data points. Regression relations are calculated for each subset leaving out one of the data points. For each regression relation an error estimate is obtained for the point not included. In this way the mean predictive error for each data point is based on a regression equation which does not include that point. The mean error for all the data points is the mean error expected when using a regression relationship developed with all of the data points. In Table 2 and Figures 5 and 6 relationships are shown between the annual mean wind speed and the three indices.

Table 2. Relationship between the Griggs-Putnam Index (G) and the annual mean wind speed ($\bar{V}$) in m sec^{-1}.

G	$\bar{V}$
0	< 3.3
1	3.3 - 4.2
2	4.3 - 5.1
3	5.2 - 6.2
4	6.3 - 7.5
5	7.6 - 8.5*
6	8.6 - 11.0*
7	> 11.0*

* Estimated since data are not available for these speed ranges.

Relationships have also been developed between the percent of useable winds P and the indices (see Table 3). The percent of useable winds is defined as the percent of time the winds occur in the range

3.6 - 22.3 m sec^{-1} which is the speed range at which many commercial wind turbines operate.

Table 3. The relationship between P (percent of useable winds) and $\overline{V}$ (the annual mean wind velocity) in m sec^{-1} (other parameters are the same as in Table 1).

Index	Relationship	r	ME (%)	P_{25} (%)
G	P = 12G + 29	.90	15	8
D	P = 10D + 33	.84	19	21
C	P = 18C + 32	.60	32	41

The C index obviously has the greatest amount of error because asymmetric growth may be the result of a number of other factors not related to wind. However, if a large number of trees (six or more) are sampled at each location this error should decrease.

We have also found that coniferous trees in windy locations are shorter, have a greater circumference, trunks are generally egg shaped in a radial cross section with the narrow end pointed in the direction of the prevailing wind, and the direction of the crown and trunk asymmetry are strongly correlated with the prevailing wind direction.

During the next year research will focus on extending these techniques to both other coniferous and deciduous trees. Work is also proceeding in developing techniques for identifying wind deformed vegetation from aerial photographs. The use of aerial photographs would speed the process of selecting sites with good wind power potential.

CONCLUSIONS

Tree deformation appears to be a sensitive indicator of annual mean wind speed and direction and trees may be used to estimate both the annual mean wind speed (mean error $\pm$ 17%) and percent of useable winds (mean error + 22%). This technique could appropriately be used as a first stage in a wind survey prior to instrumentation with anemometers.

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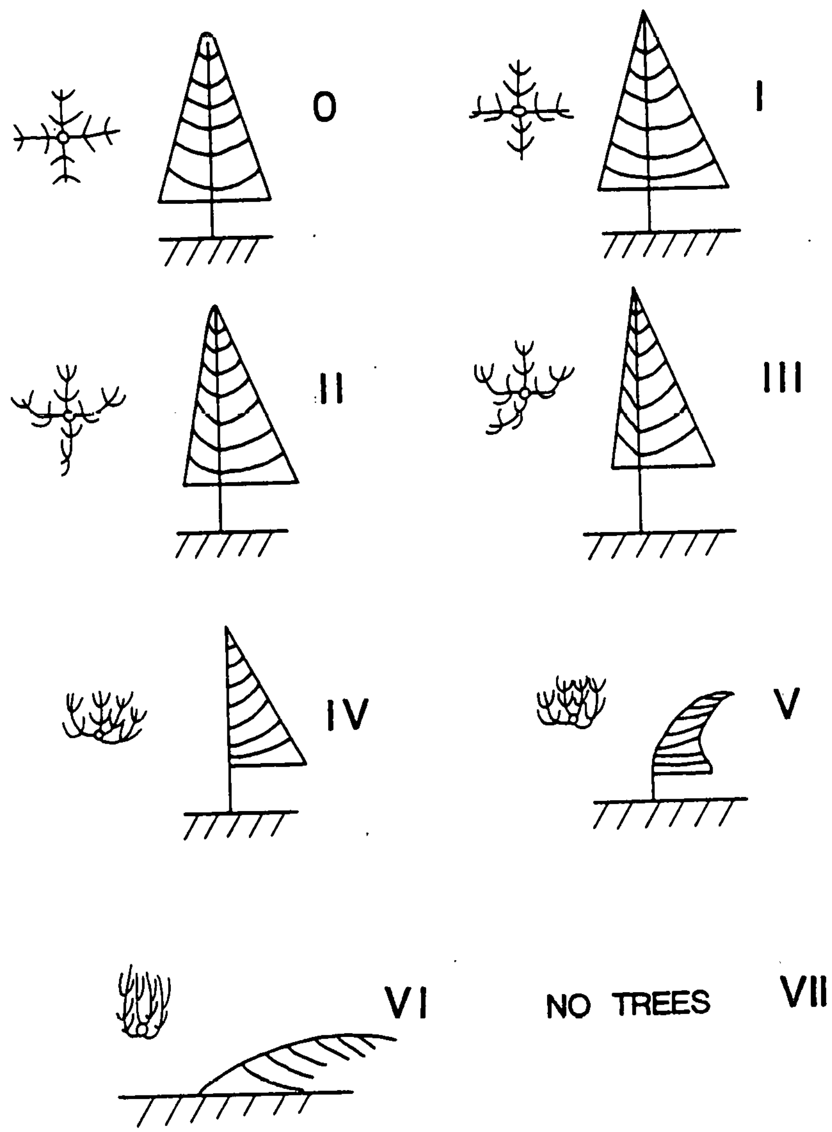

Figure 1. A representation of the Griggs-Putnam Index which is based on external wind deformation of coniferous trees.

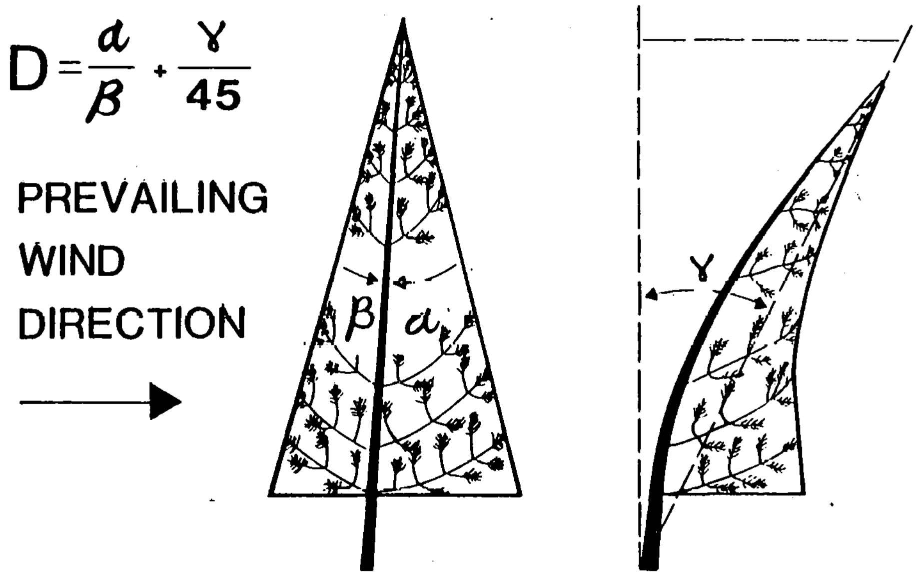

Figure 2. The Deformation Ratio measures the degree of wind induced crown asymmetry and tree trunk deflection. The ratio of α and β has a minimum value of 1 and a maximum value of 5.

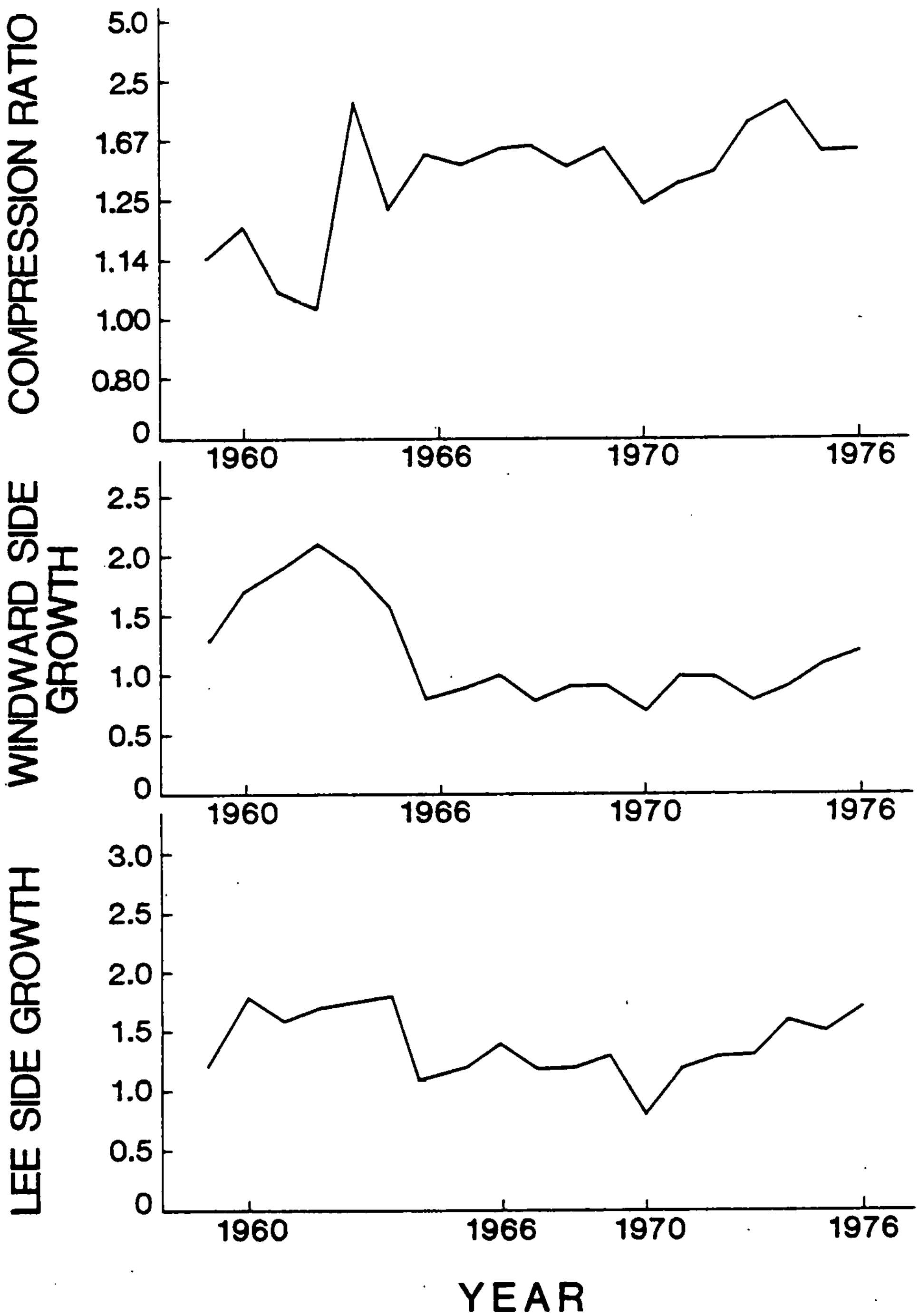

Figure 3. Shows a comparison of windward and leeward growth rate on a coniferous tree. The ratio of the two is called the Compression Ratio and measures the influence of wind on radial growth rate.

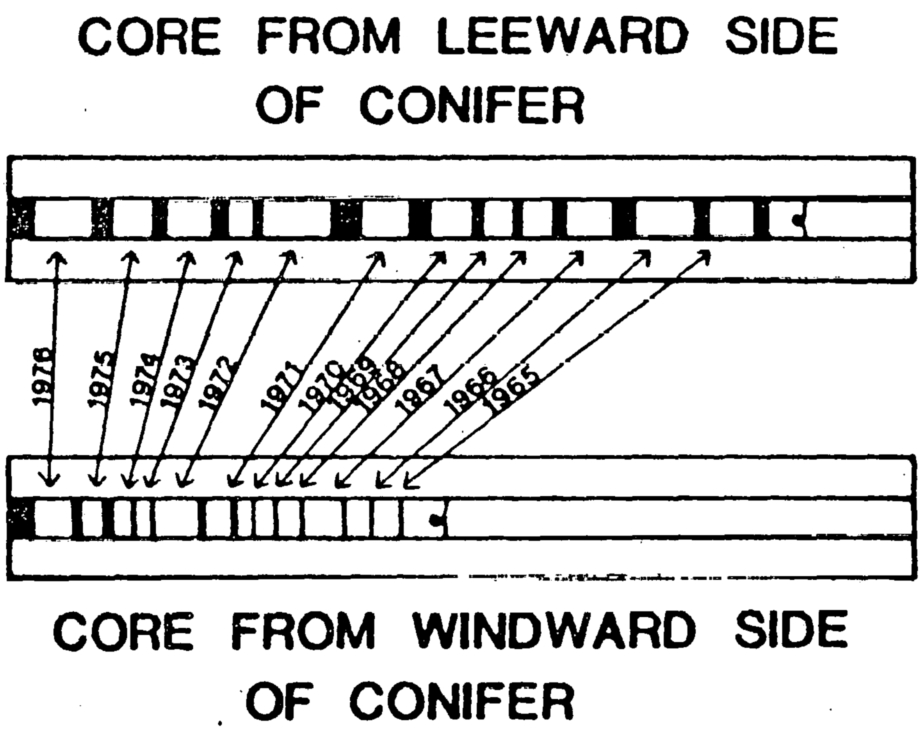

Figure 4. Tree cores are mounted, cross dated and then measured for annual growth increment on the windward and leeward side. Rings on the leeside are wider, and there is a greater proportion of latewood (darkwood). The wider rings are due to compressive stresses on the leeside causing the vertically aligned cells to be shorter and wider.

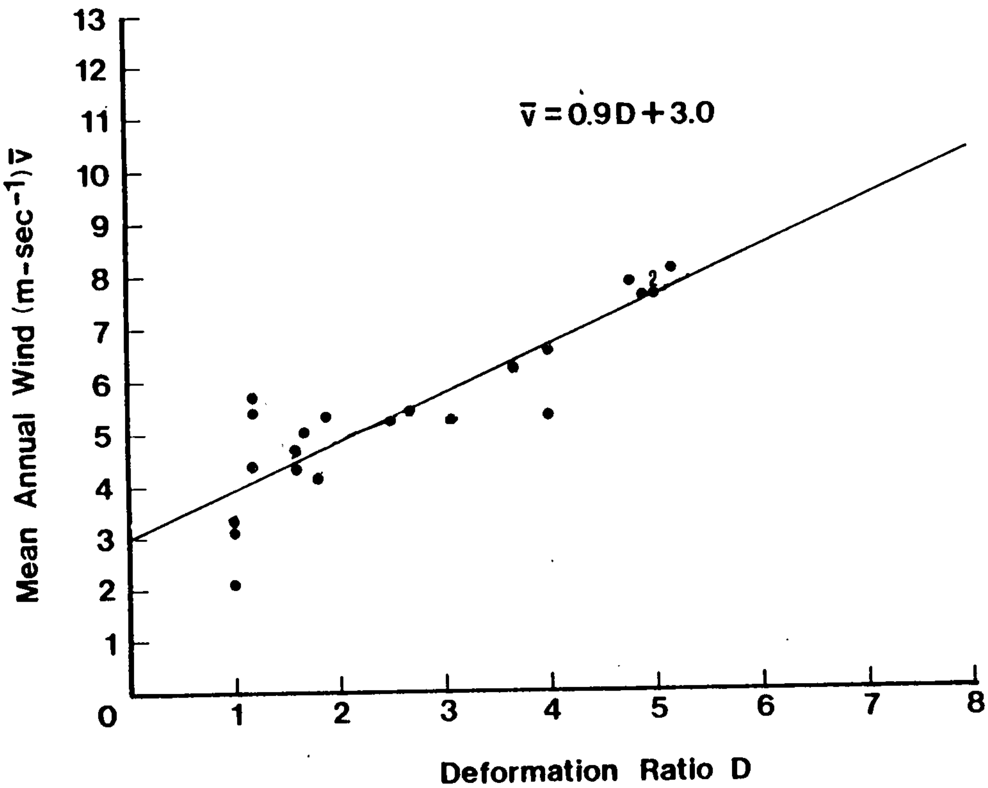

Figure 5. The relationship between the mean annual wind velocity and the Deformation Ratio.

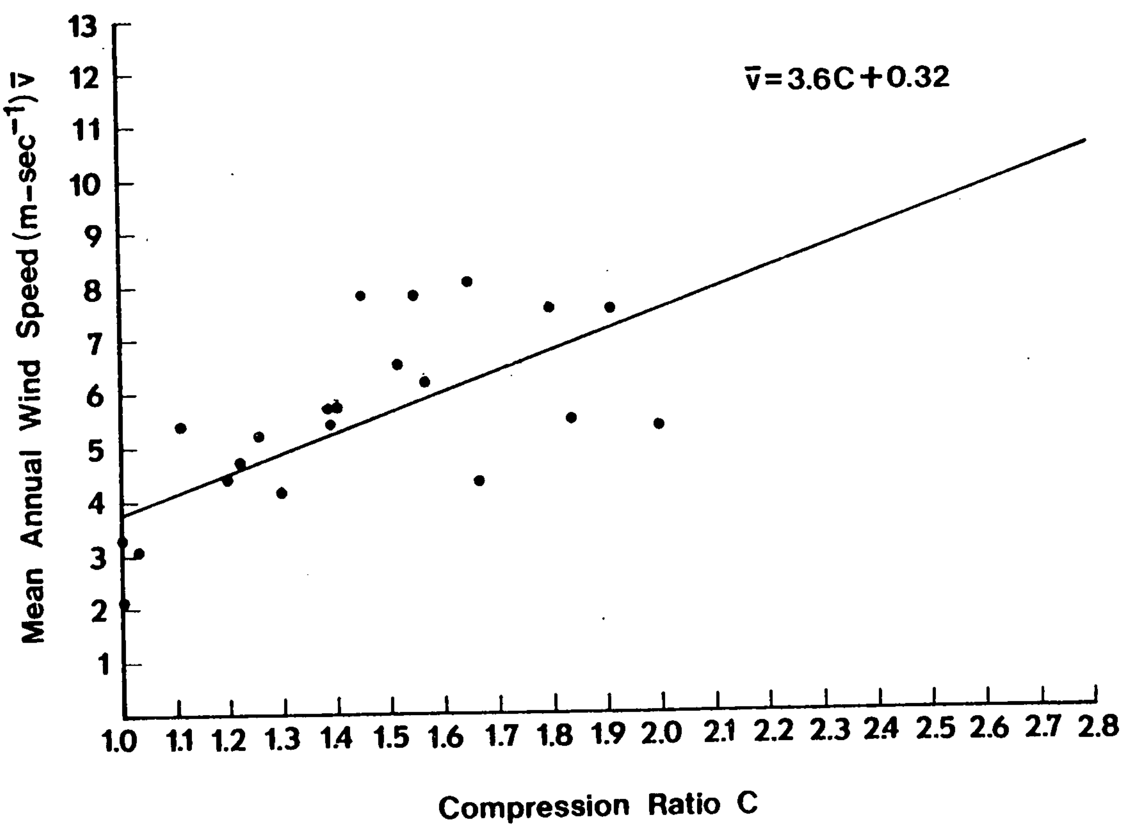

Figure 6. The relationship between the mean annual wind velocity and the Compression Ratio.

SEASONAL WIND FLOW PATTERNS OVER THE PACIFIC NORTHWEST AS RELATED TO WIND POWER POTENTIAL

by

Robert W. Baker and E. Wendell Hewson
Department of Atmospheric Sciences, Oregon State University

ABSTRACT

The seasonal variation in the strength in the wind flow patterns over the Pacific Northwest is investigated to assess the wind power potential in the region. There are basic flow changes from season to season over the Northwest that greatly affect the wind power potential over many areas in the region. However, the diversity in the wind flow on a monthly and seasonal basis over the five-state area diminishes the chance of no output from a simulated network of widely dispersed wind turbine generators and stabilizes the potential network wind energy output on a monthly basis compared to the individual site output.

INTRODUCTION

A unique network of wind measuring stations has been established in the Pacific Northwest for the specific purpose of evaluating the wind power potential of the region. The network was initiated in 1971 by Oregon State University with the sponsorship of the four Oregon People's Utility Districts (PUD) as described by Hewson (1975, 1977). Additional support for the research came in 1975 from the Eugene Water and Electric Board (EWEB) and from the Bonneville Power Administration (BPA). The present network consisting of over 60 wind data stations is now supported by BPA and the Department of Energy, the latter sponsoring a separate study to investigate wind deformed vegetation in relation to wind speed.

The wind data collected from these stations shown in Figure 1 have greatly aided in assessing the wind power potential over the five-state area. This analysis has been described by Hewson and Baker (1978) and indicates there are large wind power resources in the Northwest not only during winter storms but also with blocking high pressure systems over the interior of the Northwest. In the summer the dominant high pressure system over the Pacific results in substantial wind power along the coast and through the Columbia Gorge.

The diverse nature of the wind flow in the region was recently studied with respect to the simulated hourly output of a single 2 MW wind turbine generator (WTG) at each of the five sites noted in Figure 2 for the one year period, December 1976 to November 1977. The monthly and annual energy output for the network and for each of the sites is given in Table 1. Monthly capacity factors (CF)[1] are also listed.

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1 Capacity Factor (CF): A percentage which is the ratio of the estimated (or actual) energy produced to the maximum amount of energy which could have been produced by the WTG if it had been operating at full capacity during the entire time period.

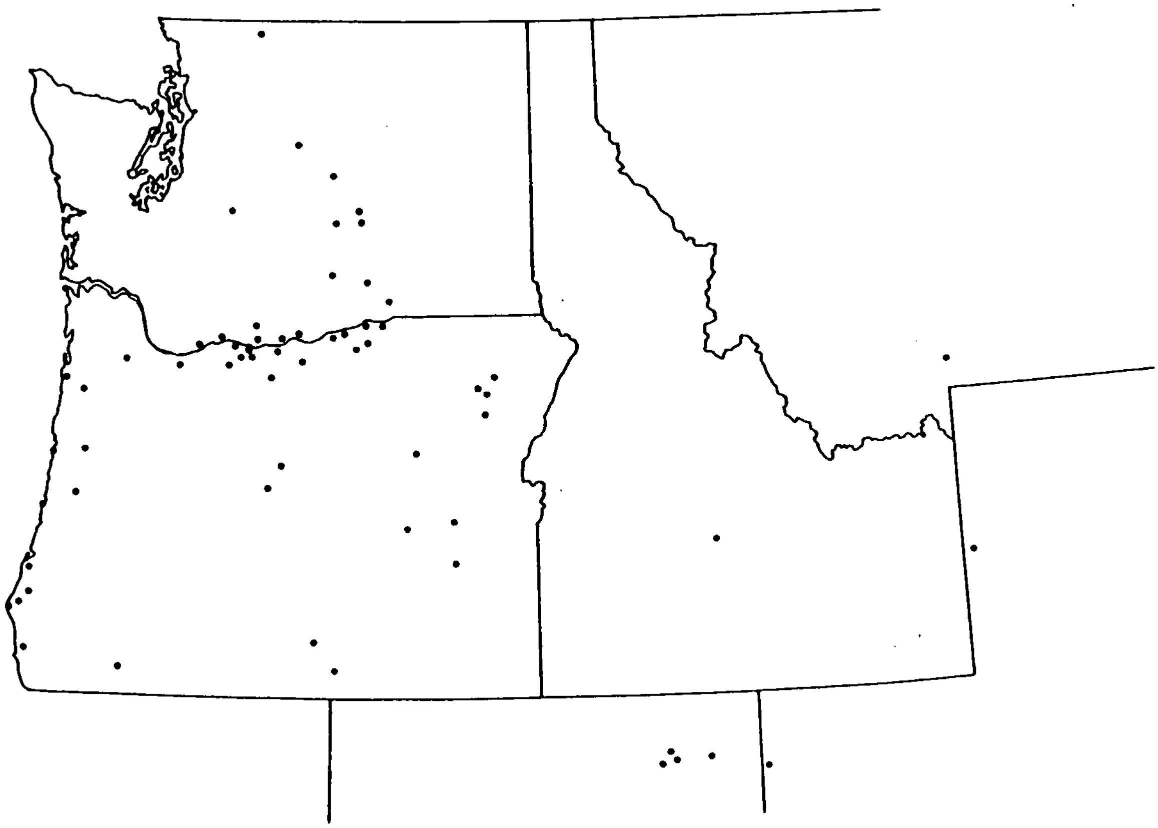

Figure 1. Data Stations

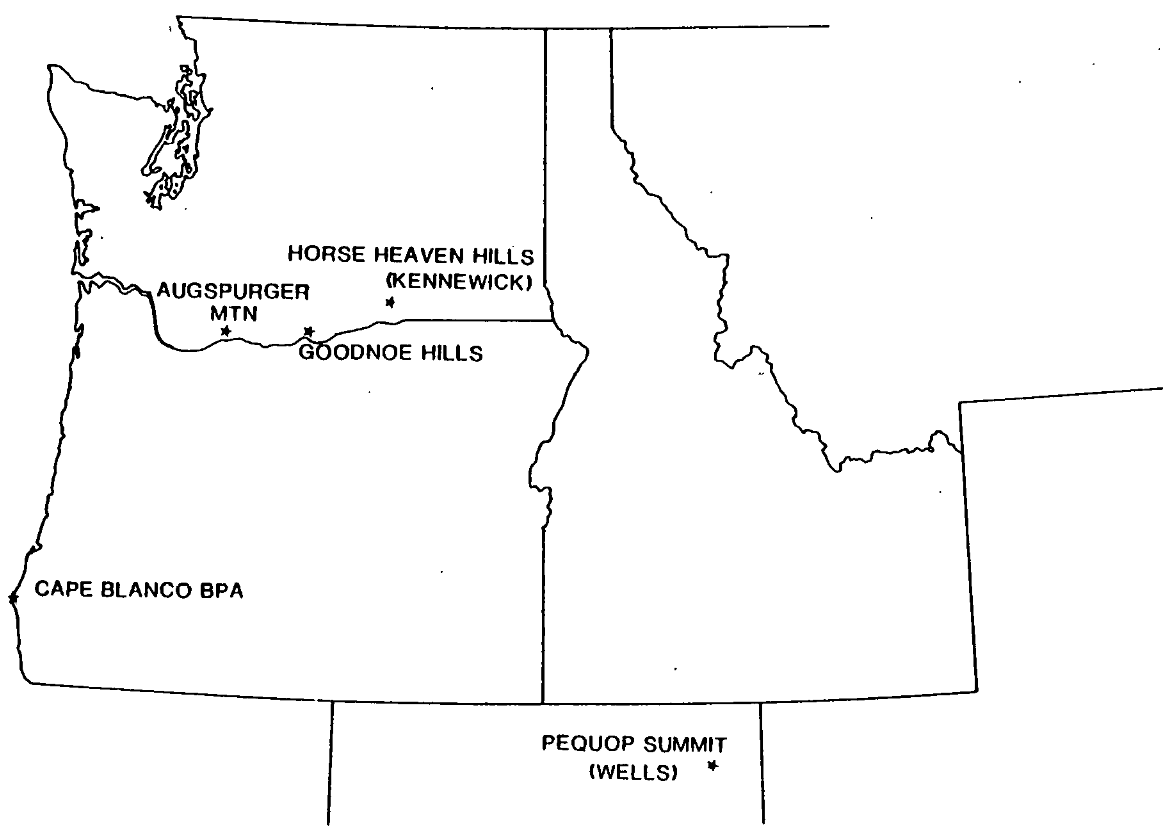

Figure 2. Wind Turbine Generator (WTG) Network.

Table 1. Monthly and annual energy output (MWH) of a network containing a single 2 MW WTG at five widely dispersed sites in the BPA service area for the period 12/76 - 11/77. The energy values have been normalized to represent a full month of output when only partial monthly data were available.

		Dec 76	Jan 77	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Avg	TOTAL MWH
(1.81)* Augspurger	MWH	600.2	469.5[1]	604.1[1]	751.3	625.5	794.3	939.4	1029.[1]	892.4	608.1	690.1	910.0	742.8	8911.9
	CF	.45	.35	.50	.56	.48	.59	.72	.77	.66	.47	.51	.70	.57	
(1.83)* Goodnoe Hills	MWH	396.6[1]	224.1	516.4[1]	986.4	595.7[1]	932.0	586.9	893.4	754.7	579.3	502.3	668.8	636.4	7636.6
	CF	.29	.16	.42	.72	.47	.68	.45	.66	.55	.44	.37	.51	.48	
(1.85)* Kennewick	MWH	421.1	237.9	633.2[1]	753.4	397.3	680.2[1]	308.6[1]	472.5	480.0	606.8	441.1	661.2	491.1	5893.1
	CF	.31	.17	.51	.55	.30	.49	.23	.34	.35	.30	.32	.50	.36	
(1.98)* Cape Blanco BPA	MWH	611.2[1]	538.5	671.0	662.6	757.0	495.0	997.2	966.2[1]	804.2	1118.3	953.7	670.2	770.4	9245.1
	CF	.41	.36	.50	.45	.53	.34	.70	.65	.54	.78	.65	.40	.53	
(1.50)* Wells, Nevada	MWH	422.0	591.1	528.0	655.2	502.4	439.1	405.7	435.9[1]	624.0[1]	276.3[1]	E600.0	E500.0	481.6	5779.7
	CF	.38	.53	.52	.59	.47	.39	.38	.39	.56	.26	E.36	E.46	.44	
NETWORK	TOTAL MWH	2451.1	2061.1	2952.7	3808.9	2877.9	3340.6	3237.8	3797.0	3555.1	2988.8	2987.2**	3410.2**		37468.6
	CF	.37	.31	.49	.57	.45	.50	.50	.57	.53	.45	.44	.53	.48	

* At site rating (ASR).

** The Wells energy output was estimated.

1 Data recovery less than 85%.

METHOD

The hourly mean wind speed data at each of the five sites was applied to the performance curve of the Lockheed design 2 MW WTG. This horizontal axis machine with a 79 m diameter rotor was used for the study since it was representative of the performance of a large megawatt sized WTG. The sea level performance curve based on hub height (54 m) wind speed was modified for each site for the station elevation difference from sea level (air density change) and an anemometer height to hub height wind speed correction factor. The density difference reduced WTG power output by 10% per kilometer of station elevation. Most noticeable effects were seen at the Wells site where a nominal sea level rated 2 MW WTG would have an at-site rating of only 1.5 MW (see footnote 2).

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2 Recent information received too late to include in this paper on the relationship of air density to the WTG performance curve indicates the density correction is a function of the cube root of the ratio of the site air density to sea level air density. Full output of the 2 MW WTG can be achieved by shifting the performance curve upward such that higher wind speeds are needed to achieve full output. Therefore all WTG energy output calculations are very conservative, especially those at Wells.

The WTG performance curve was adjusted for the anemometer height wind by using the simple power law noted in Equation 1. The Cape Blanco, Augspurger Mountain, Goodnoe Hills, and Wells anemometer heights are about 13 m above the ground. The Kennewick anemometer is at the 32 m level. The "power law" expressed in equation 1 where $\alpha = 0.20$ was used to determine equation 2 to obtain a new performance curve based on the anemometer height wind speed.

$$V_A = V_B \left(\frac{Z_A}{Z_B}\right)^{\alpha} \tag{1}$$

$$\frac{V_B}{V_A} = \frac{1}{\left(\frac{Z_A}{Z_B}\right)^{\alpha}} \tag{2}$$

The correction factor (V_B/V_A) is then applied to the cut-in, rated, cut-out, and intermediate wind speeds to obtain the equivalent site data wind speed for given per unit power outputs. From the basic data and corrections the estimated WTG performance at the site is constructed and is shown in the example in Figure 3. A constant value of $\alpha = 0.2$ was assumed for the five sites located in irregular topography and is more conservative than that used by Justus (1976) of $0.23 \pm .03$ in mountainous terrain.

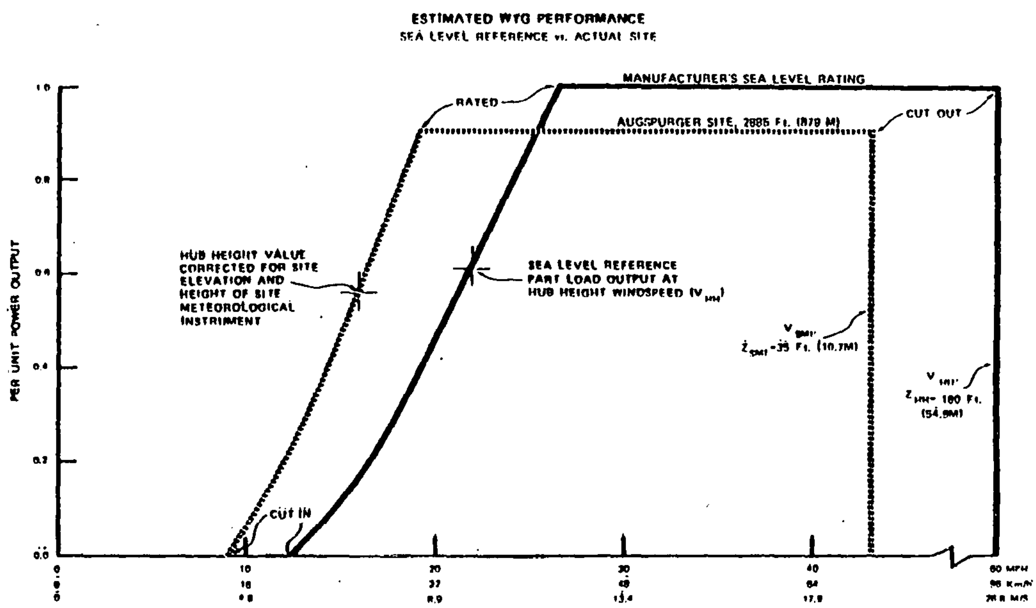

Figure 3. Estimated WTG performance curve from a sea level reference to actual site reference at Augspurger Mountain.

The daily and seasonal fluctuations of the network energy output from this 2 MW WTG array was then investigated with respect to the large scale wind patterns that occurred over this one year period. The results of this investigation follows.

Wind Flow Patterns During the Winter, December 1976 - February 1977

The winter of 1976 will long be remembered as the winter of the 'drought year' when record minimal precipitation was recorded in the Northwest. The large blocking high pressure center that sterred the moisture laiden storms away from the Northwest also produced lighter than normal wind flow throughout the region as noted by Hewson and Baker (1978). Monthly mean wind speeds at several long term National Weather Service data stations in the five-state region were 15 - 40 percent lower than normal in December 1976 and January 1977.

The energy produced by the 2 MW WTG network during December and January was significantly lower than that produced during the rest of the period as noted in Table 1. This is graphically depicted in Figure 4 with reference to the monthly mean capacity factors during the one year period. The general flow circulation over the Northwest was not strong. However, isolated areas of steady brisk winds did occur in the western part of the Columbia Gorge as east winds prevailed, along the southwest Oregon coast where moderate north winds were common, and in northeast Nevada where steady west winds were recorded.

In February this blocking high pressure system broke down and allowed storms to move through the region. All of the stations in Washington and Oregon reported much stronger flow as the energy outputs and the monthly capacity factors increased significantly. The network monthly capacity factor increased from a low of 0.31 in January to a 0.49. In February steady south winds prevailed at Cape Blanco and averaged over 9 m sec^{-1}. The occurrence of westerly flow increased in the Columbia Gorge and averaged over 9 m sec^{-1}. Westerly flow remained strong near Wells in February and averaged about 9 m sec^{-1}.

The advantage of dispersing the WTG units over a large area to take advantage of the diverse wind flow in the region is clearly evident during this winter period. The normal high wind power potential areas at Goodnoe Hills, Kennewick, and to some extent in the Cape Blanco area, experienced much lighter flow while the winds at Augspurger Mountain and near Wells, Nevada remained moderate to strong. The net result was a modest monthly energy output for the network during December and January.

Wind Flow Patterns During the Spring, March - May 1977

Persistent and brisk winds were common at all of the sites during this three-month period. Seven to nine meter per second north and south winds prevailed at Cape Blanco. Strong westerly winds were common in the Columbia Gorge and averaged between 8 - 11 m sec^{-1} from Augspurger Mountain to Kennewick. Persistent west winds average 9 m sec^{-1} in the Wells area. The monthly network capacity factors varied between .45 and .57 during this three-month period.

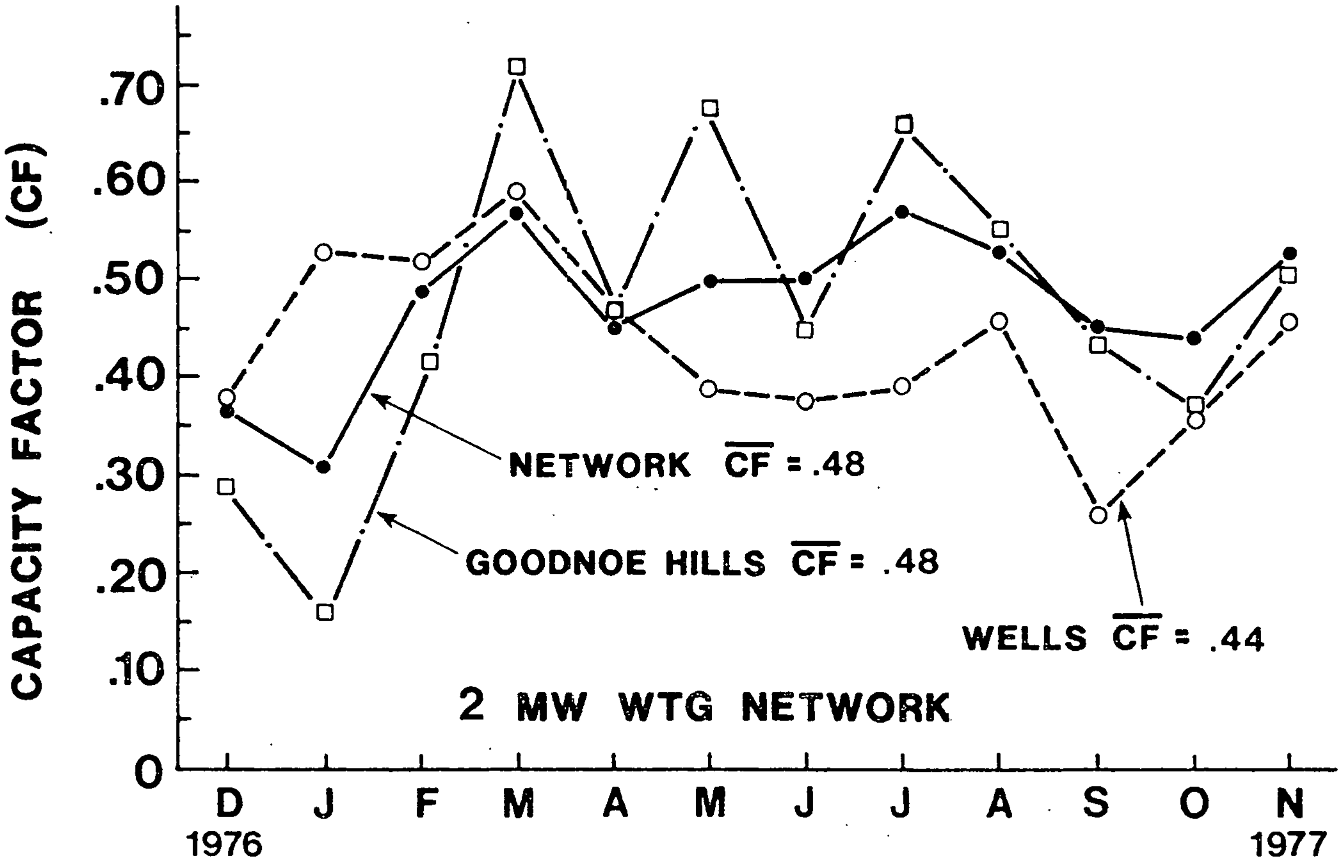

Figure 4. Monthly and annual capacity factor for the 2 MW WTG network, Goodnoe Hills, and Wells for the period December 1976 - November 1977.

Storm passages were quite common during March and April. One such episode generated very high winds over the area. The daily network and station energy output for the period 5 - 11 March 1977 is documented in Table 2. A cold front moved through the Northwest on 6 March and another storm followed on the 8th. The daily energy fluctuations for the network and each site are significant and the network energy production peaked as the storm passed through the interior of the Northwest on 9 March. The network energy production during the six-day period varied with the frontal activity. The maximum energy produced at each of the five sites occurred on 9 March and noticeable energy fluctuations were noted at each location during the other days, especially on the 5th, 6th, 10th, and 11th.

Frequent periods of fair weather prevailed over the Northwest during April and May as a high pressure center was positioned off of the Oregon coast and lower pressure prevailed over the interior. Strong west winds prevailed through the Gorge especially during May.

Table 2. Daily network energy production (MWH) at five selected WTG sites containing 2 MW units for the period 5 - 11 March 1977.

Day	Network Total Energy	Network Capacity Factor	Augspurger	Goodnoe	Kennewick	Cape Blanco	Wells
5	87.73	.41	2.66	32.28	28.85	.46	23.49
6	99.09	.46	19.92	10.21	33.68	30.95	4.32
7	134.62	.63	19.73	28.21	42.43	25.00	19.25
8	160.88	.75	40.10	35.22	39.05	27.35	18.97
9	193.75	.90	41.19	42.25	44.47	32.84	33.00
10	100.89	.47	11.09	32.77	25.56	8.97	22.50
11	60.57	.28	17.73	5.49	18.92	15.65	2.78

Wind Flow Patterns During the Summer, June - August 1977

During the summer of 1977 the large eastern Pacific high pressure center was firmly positioned off the Oregon Coast. Steady and moderate north winds prevailed at Cape Blanco and averaged about 9 m sec^{-1}. Persistent west winds averaged from 9 - 11 m sec^{-1} at Augspurger Mountain and Goodnoe Hills. The steady southwesterly flow at Kennewick averaged over 7 m sec^{-1}. West winds prevailed near Wells and averaged over 7 m sec^{-1} but were not as persistent as those in the Columbia Gorge.

The summer network energy output remained high as most of the stations had capacity factors above 0.50. The lower output at Wells and at Kennewick during June and July was easily compensated for by the high energy outputs at the other three sites.

Wind Flow Patterns During the Fall, September - November 1977

The southwest Oregon Coast experienced strong winds during the fall as steady north and south winds persisted during September and October. South winds averaging over 11 m sec^{-1} prevailed in November as storms frequently passed through the Northwest. West winds were common during September in the Columbia Gorge and were somewhat stronger at Augspurger Mountain and Goodnoe Hills than at Kennewick. Both east and west flow occurred in the Gorge in October. Lighter easterly flow was observed at Goodnoe Hills and Kennewick than at Augspurger which reduced the wind power potential there. The west wind that prevailed in the Wells area in September was rather light and averaged about 6 m sec^{-1}. Wind data was missing from the Wells station in October and November but an estimation of the monthly mean wind speed and monthly energy output was made by extrapolation of wind data from other stations close by. The resulting network energy output and capacity factors during September and October were lower than those during the summer but were still very respectable.

In November storm movements through the region were very common. Strong winds prevailed at all of the sites. Monthly capacity factors ranged from .70 at Augspurger Mountain to an estimated .46 at Wells. The prevailing south winds at Cape Blanco averaged 13 m sec^{-1}, and there were over 100 hours when the mean wind speed exceeded the cutout speed (27 m sec^{-1} at hub height) of the WTG.

Wind Flow Diversity in Relation to WTG Network Reliability

The spatial and temporal fluctuation of wind over the Northwest during the December 1976 - November 1977 period served to minimize the amount of time when the 2 MW WTG network produced no load. This is illustrated in Table 3 which gives the network and individual station no-load frequency of occurrence on a monthly and annual basis. The network no-load time varied from 0 to 6.3 percent on a monthly basis and averaged 2.2 percent for the year. Individual station average no-load times ranged from 0 to 75 percent on a monthly basis and 15 to 43 percent on an annual basis.

The number of hours of no output for the 2 MW WTG network varied from 1 - 16 on 44 separate days during the 12-month period. The longest continuous outage was 13 hours and the average no-load time was 3.3 hours.

If this lack of wind could be construed as a forced outage, the base load capability would not be zero. Distributing the WTG units over a larger area would most likely further reduce the chance of zero network output. This would provide a potential diversity or firm power benefit.

Table 3. Frequency of occurrence (%) of zero power output of the 2 MW WTG network and each individual station for the period Dec 76 - Nov 77. (* indicates < 85% data recovery and M indicates missing data)

	Network	Augspurger	Goodnoe	Kennewick	Cape Blanco	Wells
Dec.	3.5*	26.9	58.6*	53.0	37.4*	40.3
Jan	2.8	23.4*	69.9	75.2	44.5	29.2
Feb	6.3*	0*	34.3*	34.1*	30.5	31.2
Mar	.4	15.4	14.0	22.6	32.3	21.3
Apr	3.3	18.4	37.3*	48.0	30.2	29.2
May	0	14.0	18.0	28.9*	42.4	30.5
Jun	.4	13.5	25.8	46.4*	12.6	34.0
Jul	1.9*	7.2*	15.9	40.3	14.2*	34.4*
Aug	.5*	13.7	22.6	44.8	21.7	19.2*
Sep	5.7	20.7	36.2	45.5	15.6	37.7*
Oct	1.1	20.3	37.6	51.3	21.7	M
Nov	.7	8.5	33.0	28.5	39.1	M
Avg	2.2	15.2	33.6	43.2	28.5	30.7

CONCLUSIONS

It appears that the strength and diversity of the wind flow over the Pacific Northwest are capable of providing a significant amount of energy and a degree of reliability to a network of WTG units dispersed throughout the region. The potential network energy output of the 2 MW WTG array was much more stable on a daily, monthly, seasonal and annual basis than if only one site was utilized to install WTG units. This will probably be true for shorter period fluctuations also. Another advantage of dispersing the WTG units is to minimize the network no output time. The 2 MW WTG network had a 2.2 percent outage time for this one-year period. No output times at individual sites varied from 15 - 43 percent for the year.

The results from this simulated WTG network study indicate that there is sufficient wind in the BPA service area to successfully operate large WTG units in the 2 MW range. Undoubtedly, there are many combinations of sites and different sized machines that could make up an effective WTG network to produce maximum energy and/or reliability on a monthly or annual basis.

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OVERVIEW OF TECHNIQUES FOR ANALYZING THE WIND ENERGY POTENTIAL OVER LARGE AREAS[a]

David S. Renné and Dennis L. Elliott
Pacific Northwest Laboratory
Richland, Washington 99352

1.0 INTRODUCTION

1.1 BACKGROUND AND OBJECTIVE

An analysis of wind energy resources within a large region can provide valuable information to utilities and private individuals who are considering wind energy conversion systems (WECS). The analysis, if done in sufficient spatial detail, can: define feasibility of using wind energy within the region; identify locations in which to do more detailed siting studies; and provide guidelines on the numbers and kinds of machines to be installed. Several national wind energy assessments have recently been completed,[1,2,3] which provide an overview from which WECS planners can make decisions. Because of the size of the area covered, these analyses cannot provide detailed, refined information needed to proceed with implementation and siting studies. Therefore, the U.S. should be divided into large areas, and detailed analyses of wind energy potential in each area should be performed, using all available wind data and applying analytical and observational techniques. This effort is currently underway within the Wind Characteristics Program Element (WCPE), which is managed by the Department of Energy's (DOE) Federal Wind Energy Program (FWEP) by Pacific Northwest Laboratory (PNL).

This study's objective is to produce a refined analysis of wind energy potential over large areas by developing prototype techniques for identifying, screening, and analyzing all available wind data within a given area and for identifying, through observational and analytical methods, regions of high wind energy potential within that area where no data exist. Once developed and tested in a specific region, these prototype techniques will be applied to other large areas of the U.S. This work will ultimately result in a highly refined national wind energy assessment.

1.2 DEVELOPING TECHNIQUES FOR LARGE AREA WIND ENERGY ANALYSES

PNL, with the assistance of Oregon State University, the University of Wyoming, and Marlatt and Associates in Ft. Collins, Colorado have developed prototype techniques for large-area wind energy analyses. The Pacific Northwest, which includes Washington, Oregon, Idaho, Montana, and Wyoming, is a test area for the prototype techniques. The analyses, which these techniques will produce, include: description of spatial variation of total available wind power, and wind power available for representative machine operating

(a) This paper is based on work performed under U.S. Department of Energy Contract No. EY-76-C-06-1830.

characteristics; mean annual and seasonal wind speeds; diurnal, seasonal and interannual variations in wind speed and power; frequency distribution of wind speed and direction, and run duration statistics.

This paper reports on progress in developing prototype techniques focusing on these techniques as used in the Pacific Northwest. These techniques include data analysis procedures as discussed in Section 2.0 and observational and analytical techniques as discussed in Section 3.0. Section 4.0 summarizes the application of these techniques.

2.0 WIND DATA ANALYSIS

2.1 SOURCES OF WIND DATA

Summaries of existing data are the basis for any large-area wind energy analysis. A major source for wind data is the National Climatic Center (NCC) in Asheville, North Carolina, and much of this discussion focuses on that source. Other data sources can provide useful information in a wind energy analysis and may fill in large regions where NCC data are not available; therefore, some of the data sources are also discussed.

2.1.1 National Climatic Center

Several types of wind data are available from the NCC, including data from numerous National Weather Service and Federal Aviation Administration stations throughout the United States, ship measurements from offshore coastal areas, and upper-level winds obtained from rawinsondes launched at a number of National Weather Service Stations. The period of record can vary widely for different stations, and data are available from many stations that no longer exist.

The data appear in various formats. The wind data collected at many of the stations are summarized into frequency distributions of wind speed and direction. These summaries can be used to obtain estimates of total available wind power at each station. A recent publication[4] provides an index for all summarized wind data available from the NCC. In the Pacific Northwest, 157 stations have summarized wind data (see Figure 1). (In earlier, national wind energy assessments (e.g., reference 1), data from approximately half of the stations in the Pacific Northwest for which summaries existed were used.) Figure 1 shows the relative availability of stations with various types of data. (Although the number of fire weather stations exceeds the number of NCC stations, the total number of observations is significantly greater for the NCC data than for the USDA Fire Weather data.)

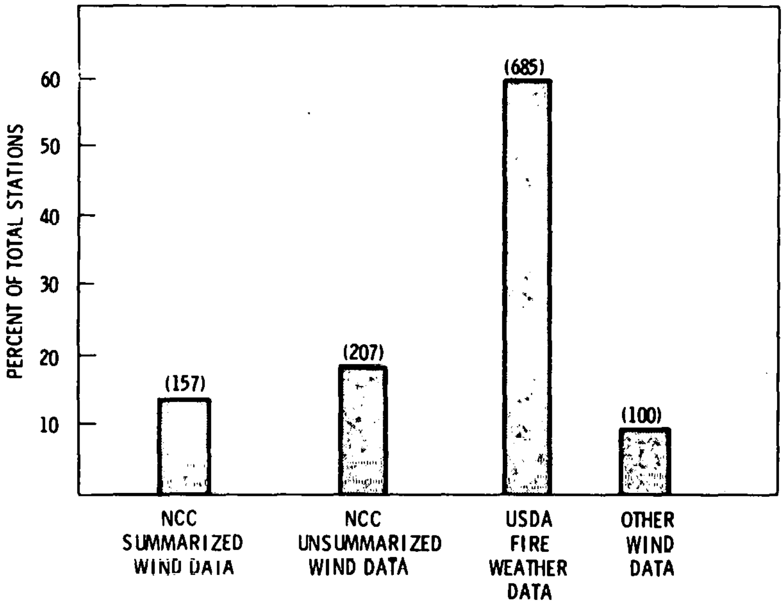

Figure 1. Types of Wind Data and Number of Stations (in parentheses) in the Pacific Northwest.

For many of these stations, hourly observations (or three-hourly after 1964) are digitized on magnetic tape (TD 1440). Since the wind statistics can be computed directly from the hourly or three-hourly data and for a period of record without any changes in anemometer locations, these data are most useful for wind energy analyses.

Many sources of unsummarized wind data are also available from the NCC. Data for these stations are on raw data sheets, and in some cases, monthly and annual mean wind speeds are listed. For the Pacific Northwest, 207 stations with unsummarized wind data are available from the NCC (see Figure 1). Special screening techniques are applied to unsummarized data so that those stations with the most wind power potential can be quickly identified.

2.1.2 USDA Forest Service Data

In many parts of the U.S., fire weather stations collect wind data. Although the data are collected only once daily (typically 3:00 PM local time) and only during the fire seasons (summer and fall), the data cover large regions where no other data exist. Furthermore, the data are often collected along ridge tops or well-exposed locations where the wind energy potential is high. Therefore, fire weather data are quite useful in wind power studies. Statistical methods are being developed that allow the user to estimate the mean seasonal and annual wind speed at a location within certain specified confidence limits.[5]

The U.S. Forest Service has published a user's manual and a computer tape that contain all available fire weather data.[6] From this tape, 685 fire weather stations have been identified in the Pacific Northwest. As compared to the other data (see Figure 1), the locations of fire weather data are numerous; however, the frequency of observations limits their usefulness.

2.1.3 Other Sources for the Northwest

The data sources for wind energy analyses discussed above are not exhaustive. In the Pacific Northwest two other federal agencies besides DOE are involved in wind energy projects. One agency, the Bonneville Power Administration (BPA), has installed a number of anemometers for wind surveys throughout Washington and Oregon. The Bureau of Reclamation has collected wind data in a number of locations in Wyoming.

A number of state, local and private sources of data are available in the Pacific Northwest. These data include that collected by air pollution control agencies, utilities for power plant siting, mining companies, and universities for research projects. Many of these data sources are being tapped for the large-area analysis study underway at PNL. Figure 1 shows over 100 locations with wind data identified; however, not all locations have been identified. Since collecting much of the data is very time consuming and costly, care is being exercised to assure that only data that will significantly contribute to the overall analysis are being collected.

2.1.4 Summary of Data Availability in the Northwest

Figure 1 indicates the total number of data sources for each type of data listed above and the relative contribution of each to the total number of stations. Approximately ten times the number of stations that were used in the same region for earlier national assessments have been found available in a large-area wind energy analysis. This increase is more graphically shown in Figure 2, which shows the locations of Northwest stations used in the national assessment[a], the locations with wind data available from NCC[b], and the locations of fire weather stations[c].

2.2 SCREENING, EVALUATION AND ANALYZING THE DATA

Applying procedures for screening the various types of wind data greatly reduces the cost and time of completing a large-area analysis, while assuring that a detailed and thorough analysis of available data results. Identifying, acquiring, and analyzing all the data sources for a large area can be laborious. However, much of the data can be screened to determine if a location has suitably high wind energy potential. This screening process eliminates much of the data analysis, which can be particularly time consuming for unsummarized data. Therefore, as a part of the techniques for performing large-area analyses, methods have been established that allow much of the wind data to be screened effectively to estimate the wind characteristics.

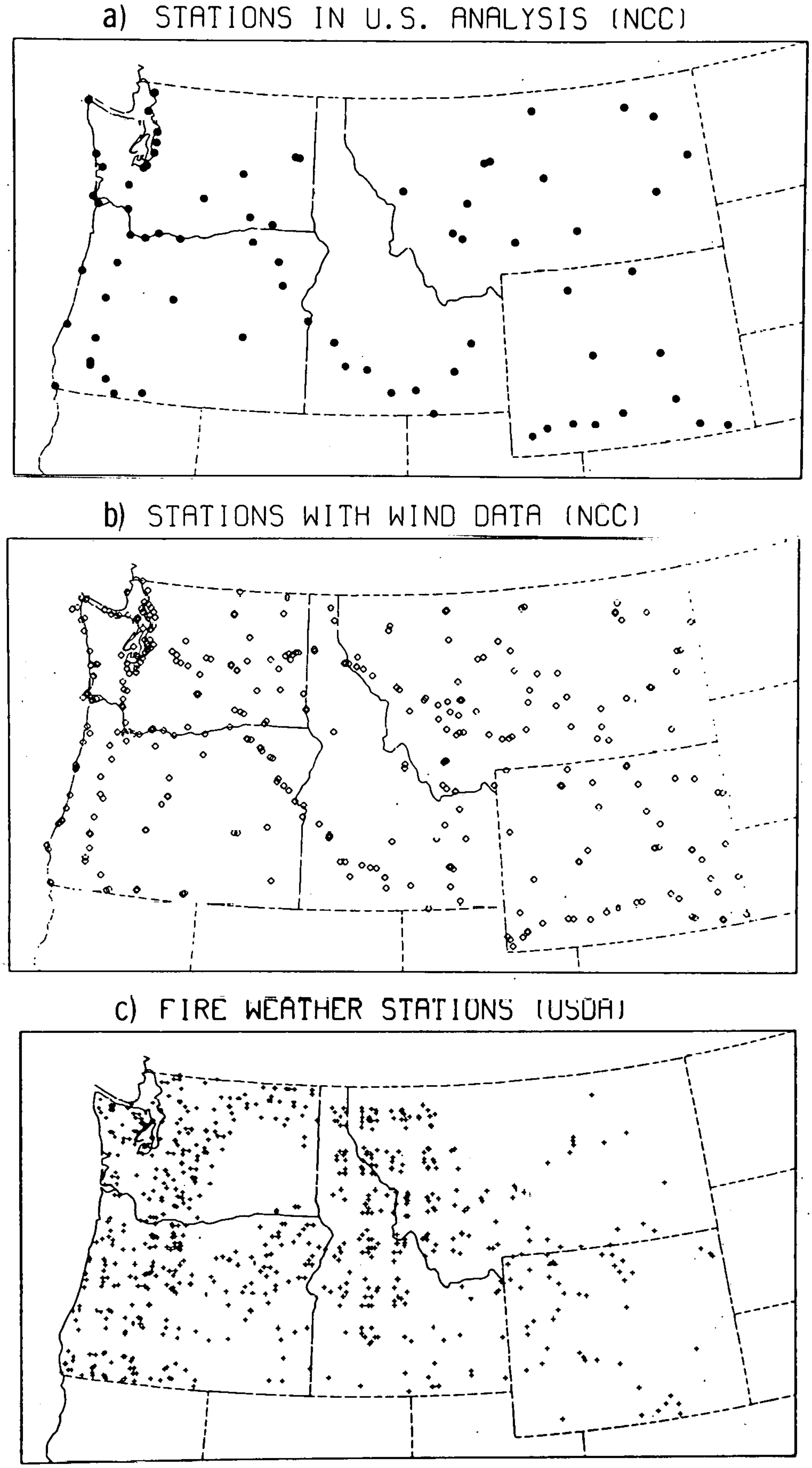

Figure 2. Locations of Wind Data in the Northwest

Methods of analyzing data are important in a large-area wind energy analysis, because the information must be presented in a manner that is useful for utility planners and private individuals who are considering WECS. The information should include an overall description of a region's wind energy potential. These large-area analyses are designed to meet this need by producing a variety of wind statistics. These statistics include: mean wind speed, and average total wind power; seasonal, diurnal and inter-annual variations of wind speed and power; frequency distributions of wind speed and direction; and cumulative frequency distributions of wind power. Several computer programs have been developed for the graphical display of the results.

3.0 OTHER METHODS FOR IDENTIFYING AREAS OF HIGH WIND ENERGY POTENTIAL

Wind measurements provide the basis for any large-area wind energy analysis. However, a number of other techniques have been, or are currently being, developed to identify and provide additional information on regions with high wind energy potential. These methods are particularly valuable in a region where no surface wind data exist. Some of the techniques which have been developed are briefly discussed.

3.1 BIOLOGICAL INDICATORS

Oregon State University has been investigating the use of flagged trees as indicators of high wind energy potential and studying techniques for quantifying wind characteristics from these indicators. Their research, reported separately in "Solar-78," is not discussed in this report. Results indicate that vegetation in windy locations displays certain characteristics that allow an estimate of mean wind speeds. Since these biological indicators are often in regions with little or no wind data, the estimates can fill spatial data gaps in a large-area analysis.

3.2 EOLIAN LANDFORMS AS INDICATORS

The University of Wyoming has been investigating techniques to identify characteristics of eolian land features that can be interpreted as indicators of wind characteristics. They have developed methods for assessing wind energy potential over large regions by interpreting wind characteristics from eolian land features, such as sand dunes, blowouts, and playa lakes.[7] Their methods use remote-sensing imagery to identify and quantify these features. The basic remote-sensing information comes from the LANDSAT satellite, which provides visible and color-infrared photographs of a region every 18 days. Once a region, characterized by these features, has been identified, a high wind energy potential may be assumed to exist during part or all of the year.

The next step attempts to quantify the wind resource by taking field measurements of dune parameters, such as shape, spacing, grain size, and soil characteristics. Gneeral estimates of mean wind speeds during those seasons for which the dunes are active are then obtained.

This technique can be extended to regions where dunes are no longer active because of vegetation growth. As research progresses, some indication of mean wind speed may be possible by measuring dune spacing observed from the remote imagery, thus eliminating field measurements.

Using these techniques, a number of regions in the Pacific Northwest with eolian features have been identified through LANDSAT imagery. These regions are primarily in the arid Columbia basin, southeastern Oregon, and the Snake River valley.

3.3 METEOROLOGICAL AND TOPOGRAPHICAL FEATURES AS INDICATORS

PNL has been investigating combinations of meteorological and topographical features, characteristic of high wind energy areas. Conditions associated with strong winds, such as strong winds aloft, strong pressure or thermal gradients, and enhancement by terrain, have been examined. This investigation is necessary to understand the processes which cause high winds in some areas but not in other areas, even when upper-air winds are light. In areas lacking wind data, regions of potentially high wind energy can be located by identifying similar meteorological and topographical features. For example, persistent strong winds during summer in the Columbia Gorge and Ellensburg Valley of Washington are associated with strong pressure gradients which develop along the Cascade Mountains of Oregon and Washington (see Figure 3a). Because the mountains act as a barrier, separating the cool marine air from the warm dry air in the interior, strong winds occur where the more dense marine air flows through gorges and corridors.

A frequently occurring winter pattern over the Pacific Northwest is shown in Figure 3b. Here strong pressure gradients exist in the vicinity of the Washington Cascades and Rocky Mountains, and strong winds can be expected where the terrain features enhance the pressure gradient flow.

Aside from corridor and valleys where the flow is enhanced, exposed mountain summits and ridges are areas of highest wind energy potential in such terrain. Techniques of applying upper-air data from rawinsonde stations are being tested in order to estimate mountain summit and ridge top wind energy and the results of the estimates compared with available observations.

4.0 SUMMARY

Additional wind data and observational and analytical methods provide a more thorough large-area analysis of wind energy potential. This report described progress in developing procedures for identifying and analyzing various types of data. Observational and analytical methodologies, which aid in estimating wind characteristics in regions lacking sufficient wind data, were also presented. The final wind energy analysis will be based on a synthesis of wind data analyses and observational and analytical methods.

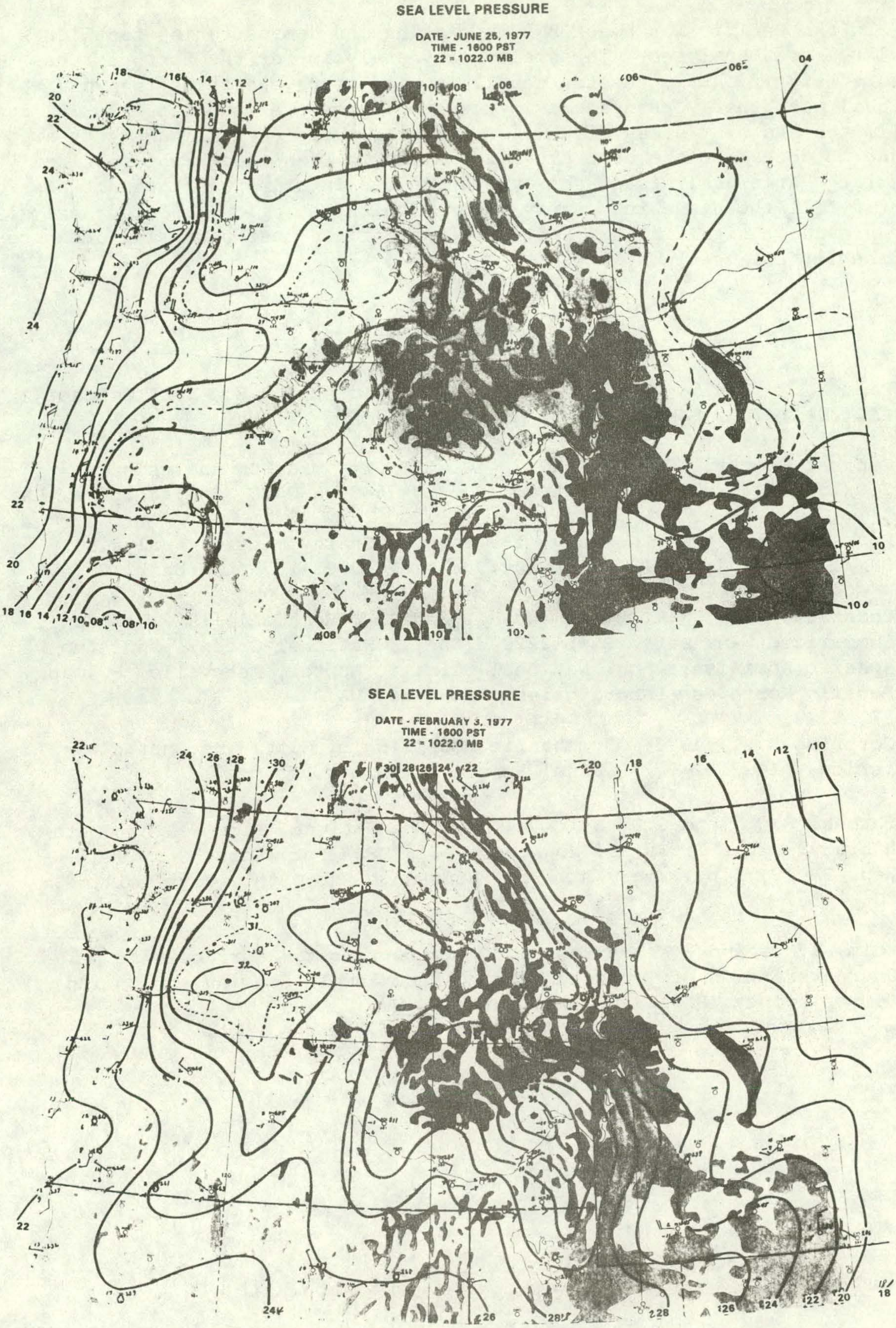

Figure 3. Sea Level Pressure Patterns Over the Northwest for a) a frequent summer condition, and b) a frequent winter condition.

In the Pacific Northwest PNL is testing and demonstrating techniques for large-area analyses. The preliminary analysis for the Northwest has revealed significantly greater detail in wind energy patterns than did the national wind energy assessments. Over regions where wind data are lacking or limited and over areas of complex terrain, additional measurements are needed to determine the best areas for siting. Even though the results of a large-area analysis of the type described in this report cannot possibly identify all the high wind energy areas within the region, a large analysis does provide a significantly better picture of the most promising areas to examine for siting of WECS.

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REGIONAL WIND ENERGY DEVELOPMENT

Donald Hardy

Solar Energy Research Institute
Golden, Colorado 80401

ABSTRACT

Regional wind energy development is reviewed with emphasis on wind resources and applications in the western United States. The conclusions of existing major studies are noted to indicate the importance of wind energy as a major energy source, its relative place among the other solar technologies and expected social benefits. Problems of wind resource assessment of special importance to the West are described and previous work on wind energy, hydro-electric power, and water resources are summarized. The roles of the Regional Solar Centers and the National Solar Energy Research Institute are discussed and possible areas of interaction in the western region are indicated. Further activities in the development of wind energy technology and its utilization are also described.

1. THE IMPORTANCE OF WIND ENERGY

Several recent studies [1, 4, 5] have taken a new look at all solar technologies and at the relative cost, social benefits, and energy potential at each. Although the detailed projections of these studies differ, each has indicated a very important role for wind energy. A comparative analysis of solar technologies and the potential market impact of each was recently completed by the MITRE Corporation [1]. The societal and ecological benefits of using solar energy instead of relying on coal or nuclear fuels were not included in this study. This analysis was based on computer simulations of solar energy utilization and market impact by region and market sectors up to the year 2020. The broad conclusions of that study were the following: solar energy may eventually displace significant quantities of both fossil and nuclear fuels; significant solar contributions are expected in all regions; federal incentives to promote solar-electric technologies could strongly accelerate their acceptance and use; and most solar systems generally have a rapid net energy payback that should result in a long-term reduction in resource consumption.

Market Penetration

At the present rate of solar development, the projected solar contribution was 0.2 quads by 1985, 6 quads by 2000, and 34 quads of energy displacement per year by 2020. It is of interest to note that nuclear power--after 20 years of development--now contributes less than half of the 6 quads projected for solar after an equal period of development. Wind energy was expected to be the second largest source of solar power by the year 2020 through production of utility electricity in a fuel-saver mode. The projected market response for wind energy by 2020 was more than 6 quads per year of energy displacement.

The four market sectors considered in developing these projections were low temperature heat, process heat, electric utilities, and synthetic fuels. Wind energy was compared with several solar technologies--solar thermal, photovoltaics, biomass, ocean thermal--only for the generation of electric utility power, but dispersed wind energy was not considered. Competing conventional systems included combinations of coal, oil, and nuclear power. Wind energy devices were assumed to have a lower capital cost per kilowatt hour and a capacity factor at least as high as other solar technologies. In addition, wind energy was assumed to be available wherever windy sites occurred, whereas solar-thermal and photovoltaic systems were projected for use only in the Southwest. Wind energy was projected to be cost-competitive in areas with winds averaging about 7 m/s or more. It is estimated [2] that approximately 407,000 square kilometers within the United States have such winds and that approximately 14% of this area is potentially available for development. Deployment of over 100,000 units at high wind sites could displace 6.6 quads of energy per year, but would represent only one-quarter of the maximum potential market. To fulfull this need, a peak annual production of about 6,000 1- to 2-MW capacity units at a capital cost of about $800/kW was projected. These projections are considerably higher than earlier DOE estimates for wind energy [3]. As a result, wind energy dominated the solar technologies in the electric utility sector with an expected installed capacity of from 40 to 60 GW by 2000, and delivered energy ranging from 1.7 to 3.0 x 10^{11} kWh/yr. Differences in projected delivered energy depend on the different federal policies and incentives assumed.

Wind and Solar Energy

The President's Council on Environmental Quality summarized recent technical and economic progress [4] leading to perhaps the most optimistic official evaluation to date of future solar energy applications. That study concluded that with a serious effort to conserve energy, solar technologies might meet one-quarter of our national energy needs by the year 2000. To meet that goal, a wide variety of solar approaches would be required. A total of 20 to 30 quads of displaced fuel per year was estimated by 2000, with wind energy as one of the largest single solar energy sources. It was concluded that the rate at which wind energy can be introduced into the economy will depend heavily on the results of current research programs and on subsequent commercialization efforts. Increased emphasis on smaller scale applications was recommended, under the assumption that smaller systems can be deployed and tested within much shorter times and may, due to manufacturing mass production economies, be the most cost-effective in the long run. An aggressive program to deploy solar technologies in developing countries and thus promote a large enough world market to justify mass production was recommended. Wind energy systems can meet many of the needs of these countries. Relatively small systems can provide energy at dispersed sites without the expense and delay of extensive transmission networks. Simplicity of design can lead to rapid manufacturing of decentralized equipment. While present wind energy equipment cannot compete well with the relatively low electric power rates of 3¢-6¢/kWh in the United States, it is much more competitive abroad. Competitive prices in the developing countries are as high as 45¢/kWh for central power grids, and rural areas may pay as much as $1/kWh for diesel generator electric power.

Social Benefits

A third major review of the federal solar program was recently completed [5] for DOE by SRI International. Many factors, in addition to the number of projected quads of energy delivered in future years, were addressed. The social benefits considered were energy contributions, environmental value, indigenous energy value, conservation of fossil fuels, potential for major technical advances, compatibility with present energy systems, and export market value. The comparative merits of seven major solar technologies were addressed but not evaluated relative to nonsolar options. Each solar technology was ranked in terms of its expected overall benefit to society in future years. In the near term (1985), the three solar technologies of greatest benefit to society are solar heating, biomass, and wind energy. In the intermediate term (2000), the two of the greatest value are solar heating and wind. In the long term (2020), the solar technology of greatest benefit to society was wind energy, which was ranked significantly higher than all competing solar technologies. The results of the ranking process are shown in Table I. In addition, it was also indicated that both wind energy and photovoltaics might produce even greater social benefits under increased research emphasis. These results were meant to provide general guidance to DOE in the formulation of solar energy research, development, and deployment decisions.

Economic Factors

The range of uncertainty in future costs of wind turbines was believed to be smaller than for other solar-electric options. This is because the technology of towers, blades, transmissions and controls are relatively familiar and considerable experience exists in manufacturing of small commercial units. Cost estimates for large wind energy devices can be determined for horizontal- and vertical-axis machines with power ranges of 0.2 MW to 1.5 MW. Most estimates in dollars per kilowatt are based on conceptual designs projected to 100 unit production costs. Present values range from about $500 to $1400 /kW. Current costs for small wind turbines are available for commercial units which range in size from a few to about 50 kW. Costs vary considerably, but a number of units are available at prices of $2000 to $3000 /kW.

The study concluded that horizontal-axis wind turbines may well be economically practical today. The economics of wind energy depend heavily on the mean wind velocity. Although it was concluded that large wind turbines in areas of high mean wind speeds may produce electricity at a cost competitive with electricity from fuel oil today, the most likely candidates for near-term economical generation of electricity included machines of all scales--15 kW, 200 kW, and 1.5 MW. The other important application of wind energy identified was in agricultural water pumping. Small wind turbines have a long and successful history of use for this purpose.

Wind Resource and Limitations

In examining wind utilization, three issues were considered: the wind resource; the wind machines; and integration of the resource, the machine, and the application. In considering the resource, it is useful to note that the sunniest areas of the southwestern United States have a mean insolation of less than 300 W/m^2. Many United States sites have mean wind fluxes of more than 500 W/m^2 (measured in the vertical plane). Some sites, where speeds are enhanced by topography, have very high mean energy fluxes of 1,000 W/m^2 or more. Furthermore, the potential wind resource is enormous. Very large amounts of wind power have been estimated in other studies based upon the mean kinetic energy of the atmosphere. Not all of this energy, however, is available in a practical sense. When a reasonable energy extraction rate and other limiting factors are assumed, a power extraction of about 2.5 TW can be estimated for the United States [6], based on only those areas with the highest wind speeds.

In the evaluation of social benefits, the technical limit of each technology was evaluated rather than a projected market penetration. All technical limits were expressed in quads of energy, fossil fuel equivalent. The largest technical limit, 29 quads, was estimated for wind energy. Although significant technical difficulties were recognized, the technical limit was chosen to represent the maximum contribution expected under favorable circumstances. The maximum potential use of wind energy in the United States is not easy to determine because the wind resource is so large and matching it to suitable applications is so important. Nevertheless, several independent studies [1, 2, 7] have all indicated market saturation limits in the range of 20 to 30 quads for wind energy.

Recommended Program

Because the wind can be used in so many applications, the energy resource is so large, and many applications have near-term economic promise, additional effort to develop this technology was an obvious policy issue. Recommendations for an expanded program [5] included the following: (1) simultaneous development of several different megawatt-scale wind turbines tailored to a wide variety of different sites; (2) accelerated demonstration or experimental programs involving field use of equipment in conjunction with utilities; (3) operational tests of prototype multiunit "wind farms"; (4) continued development of unusual or innovative concepts and designs; (5) additional effort to inventory potential wind sites including the specific requirements of potential users; and (6) providing assistance to industry in equipment design and material selection.

TABLE I
SOLAR TECHNOLOGIES RANKED BY TOTAL BENEFITS[1]

1985		2000		2020	
System	Ranking	System	Ranking	System	Ranking
SHACOB	79	SHACOB	86	Wind	90
Biomass	68	Wind	78	SHACOB	73
Wind	67	Biomass	49	Photovoltaics	65
Photovoltaics	21	Photovoltaics	36	Biomass	48
Thermal Power	12	OTEC	17	OTEC	40
Process Heat	10	Thermal Power	16	Thermal Power	35
OTEC	1	Process Heat	11	Process Heat	21

Each technology could receive a maximum of 100 points, and the ranking gives a relative figure of merit for comparison of one technology with another. In 1985 wind and biomass have an almost equal ranking and are rated well above all technlogies except solar heating. By 2000 wind is only slightly less beneficial than solar heating, and by 2020 it is a clear first choice among all solar technologies. Wind energy conversion devices thus produce high social benefits in all time periods. Important expected benefits include the large potential energy contribution, conservation of oil and gas, and near-term economic competitiveness with alternative energy sources.

[1]As determined in A Comparative Evaluation of Solar Alternatives: Implications for Federal RD&D, Volumes I and II, SRI International, prepared under contract for the Solar Working Group, U.S. Department of Energy, January 1978.

II. WIND ENERGY IN THE WESTERN UNITED STATES

Locations with the highest wind energy densities commonly occur in mountainous or coastal regions. Therefore, many sites in the western United States may be favorable locations for early deployment of wind energy collection systems. Additional areas of high wind energy also exist on the western plains somewhat east of the Rocky Mountains. The siting and wind resource assessment techniques useful over much of the Midwest are not appropriate for the western parts of the nation. Mountainous regions experience complex flow variations, and rugged coastal areas are also affected by the land/sea influence on large-scale weather systems. These complex atmospheric flows require detailed measurement and modeling efforts for optimum siting and energy conversion.

National Resource Assessments

Several studies of the wind energy potential nationwide have been conducted [2, 7, 8, 9]. The conclusions of these studies were similar but not quantitatively identical. In all cases, the greatest uncertainty about the resource existed in the mountainous regions. Available data for these areas are less representative of the true wind energy potential than data for other parts of the nation. The wind power available on mountain peaks and in valley areas depends as much on the shape and alignment of the local terrain and on large-scale regional weather patterns as it does on the height of the mountains. Wind speeds are sometimes greatest on mountain peaks, and in other cases are strongest in gaps between mountains [10]. Only mean wind speed summaries are readily available for many stations, and attempts to estimate the wind energy potential from such records have been shown to underestimate by over 50% the wind energy at some windy sites in the Pacific Northwest [11]. Several areas of possible error or uncertainty in wind power estimates have been noted [9], including atmospheric density variations, year-to-year changes in mean annual wind speed, sheltered or nonrepresentative instrument exposures, vertical extrapolation (which is most difficult in complex terrain), and the interpolation of wind data to intervening locations (which also is difficult in hilly or mountainous areas). Consequently, considerable uncertainty exists with regard to the wind potential in the western region. Nevertheless, reasonable estimates of wind power over exposed areas (e.g., hilltops or open shoreline sites) indicate that large wind power densities are to be expected across the western United States. Energy densities of from 400 to 500 W/m^2 occur in Wyoming, and values of from 300 to 400 W/m^2 are common over the mountainous parts of New Mexico, Colorado, Montana, Idaho, and the coastal areas of California, Washington, and Oregon. The evidence of a high wind energy potential in this region underscores the need for a more refined resource assessment effort in this part of the country. Another interesting feature of wind power in the western United States is that the seasonal maximum occurs in the winter. The wind, therefore, correlates with seasonal heating demands and may also supplement hydroelectric power at the time when minimum water flow is available.

Wind-Hydroelectric Power

Several studies have considered the combination of wind power with hydroelectric power in the West [12, 13]. These studies have included both pumped storage and the substitution of wind energy for water usage in hydroelectric generation. In work conducted for the Corps of Engineers [12], the wind power potential in the Pacific Northwest was studied by evaluating six good wind energy sites in conjunction with the hydroelectric storage and generating capacity of the area. The wind measurement stations used were well exposed in windy areas and generally indicated much more available power than that indicated by nearby National Weather Service stations. Wind data from specific sites were analyzed to determine wind variability and the required amounts of hydroelectric storage for smoothing wind fluctuations. One way to reduce fluctuations in wind-generated power is to combine the power generated at diverse locations. Fluctuations in regional wind-generated power can be further smoothed by storing excess energy in existing hydroelectric reservoirs or at possible future pumped storage sites. By considering the wind data and representative pumped storage sites in the area, it was estimated that a typical storage site could provide about two days of storage for the output of approximately 350 wind turbines with rotor diameters of 40 meters. It was not assumed that the wind generators would be located at these hydroelectric sites, but rather at locations having the largest wind power densities.

Estimated Installed Capacity

Wind data were analyzed for hourly, daily, and monthly variations. A much higher diurnal variation was found in summer than in winter. The six-month period from February through July indicated a much higher power potential than the other months of the year. It was concluded that wind power alone is not reliable on a daily basis, but that it may be used very effectively to supplement hydroelectric power in the Pacific Northwest. If wind electric generation was established at each of the sites studied and suitable energy storage provided, then roughly 176 wind generators of 1.8 MW capacity each could be located at each wind farm. A total of about 900 such wind generators would produce an average of about 3.3×10^9 kWh annually. Energy policy studies for the Northwest concluded that the total installed capacity of wind generators over the next two decades would be limited by the logistics of manufacturing and installing large numbers of wind turbines, available hydroelectric energy storage, and the actual selection of sites. Based on these considerations, it was concluded that 500 to 2,000 MW capacity could be in operation by the year 2000. In order to achieve that objective, it was recommended that a few wind generators be installed in the near future in the Pacific Northwest in order to gain operational experience at prospective sites for wind energy development.

Wind Power and Water Resources

The combination of wind energy with hydroelectric power was considered for other parts of the West by the Bureau of Reclamation. A study of the estimated performance, cost, and marketing aspects of a large wind power system integrated with an existing hydroelectric network was completed [13] for a high wind region in southern Wyoming. This study also concluded that large wind turbine generators could be effectively and economically integrated with the federal hydroelectric system.

In the study, it was assumed that approximately 100 MW of installed capacity would be integrated with the existing hydroelectric system within the Colorado River Storage Project, which would serve as an energy storage system. Generation at hydroelectric facilities would be reduced by an amount equal to the wind turbine generation, thus storing water for later use in power generation or increased agricultural use. The wind site considered was Medicine Bow, Wyoming, where the annual average wind power is approximately 500 W/m^2. The available wind power at Medicine Bow is considerably higher in winter than in summer. This makes the integration of wind power and hydroelectric power easier because spring runoff from snowmelt in the Rocky Mountains provides more water for hydropower in the summer. Wind power is greatest in the winter when the least water is available for power generation. In addition, diurnal wind speeds in the area tend to reach a maximum in midday, corresponding to the period of peak daily power demand. Due to the high wind power potential at this site, a wind turbine designed for 1.5 MW could be provided with a 2 MW generator (at an increased capital cost of approximately 5%) and thus increase annual energy production by approximately 17%.

Integrating wind generators with energy storage permits redistribution of wind energy to meet either base load or daily peaking demands. Wind generators themselves supply energy but contribute little effective base load generating capacity. A hydroelectric facility supplies firm base load generation capacity. If only existing hydroelectric projects are used for back-up power, there is little or no increase in regional generating capacity. However, during periods of wind turbine operation, displaced hydroelectric capacity is available for other uses such as reserve capacity, emergency assistance, and short-term power sales. The several advantages of using hydroelectric storage include the following: a considerable amount of energy can be stored; no new technology is required; existing storage is available for immediate use by wind generator networks; and additional pumped storage could become available in the future. Thus it is probable that existing hydroelectric reservoirs can provide one of the most convenient and economical storage systems presently available for large amounts of wind energy. The combined system taps the energy in the earth's solar-hydrologic cycle (wind, rain, and sea) and has the potential to make wind power more convenient and economically attractive than as a fuel-saver only.

III. SERI AND THE REGIONAL SOLAR CENTERS

As its primary mission, SERI is to function as the DOE lead institution with regard to solar research, development, and demonstration activities nationwide. The Institute has been given the principal responsibility for management and performance of assigned solar research programs. It provides planning support to the Assistant Secretary for Energy Technology in the development of national solar energy policies and research plans and has the major role in international solar technology programs. SERI is also responsible for maintaining a capability in market analysis and in assessing institutional barriers to solar technology on the national and international level. In keeping with these national responsibilities, SERI will assist DOE in coordinating the national solar research, development, and demonstration program and could participate in certain programs carried out for DOE by the Regional Solar Centers and the states.

In carrying out their primary mission, the Regional Solar Centers are responsible, within their respective areas, as the lead DOE institutions for regional commercialization of solar technologies and for energy conservation integral to solar applications. Assignments to carry out these missions are through the Assistant Secretary for Conservation and Solar Applications. In addition, the Regional Solar Centers may undertake solar development projects which complement and support the national DOE program.

The establishment of a network of regional solar centers was based upon a decision by DOE that the most effective way to encourage widespread use of solar energy would be through a regionally diversified effort. Regional programs, to be effective, must be consistent with the requirements of the national solar effort. Both SERI and the regional solar centers are performers, along with many other laboratories, private organizations, and universities, in the national solar program. Within these guidelines, programs at SERI and the regional centers will encompass educational activities and distribution of consumer protection information, technology transfer programs, economic studies, and the identification of appropriate solar incentives. The regional centers have an important role in assisting states in their efforts to implement solar standards and incentives, to provide technical training for solar products, and to develop educational programs. Other additional important activities will certainly be undertaken also. The institutional framework in which wind energy will develop has not yet fully emerged. That framework includes the entire complex of public policy, product distribution and marketing, consumer attitudes, public information, lending practices, and other factors. It is very likely that regional considerations will have a strong influence on the evolution of many elements which constitute that institutional framework.

Regional Differences and Energy Needs

Different climatic conditions in different regions obviously affect the availability of various solar enery forms. Each region also has its own energy requirements and nonsolar energy sources. The relative value of wind energy in meeting local energy needs and in competing with alternative solar or nonsolar sources will be different for each region. This will be very important in influencing the rate at which specific markets for wind energy applications develop in different parts of the country. Thus, the local energy sources, energy demands, and energy economics will influence the commercial development of wind energy and can lead to dramatic regional differences in its rate of utilization. Several areas of analysis and development are most appropriately considered on a regional basis. One is the establishment of economic incentives through the selection of the most effective policies for each part of the nation. Local and regional land use policy can create either barriers or incentives for wind energy utilization, and local building codes must also be considered. Electric utility regulation as it impacts commercial development of wind energy is also important. This issue includes rate structures and regulatory jurisdiction as well as an active involvement of the utilities in the development and promotion of wind energy as a viable technology. Public information and technology transfer need to be oriented to the requirements of local businesses and communities. Assistance at the regional level should be provided to private enterprise in the transfer of wind technology from the research and demonstration stage to commercial products and services. The service industry to distribute, site, and maintain wind energy systems obviously must be built at the local level. A well organized regional involvement will contribute significantly to these objectives.

SERI Wind Program

It is useful at this point to give a brief statement of the SERI program in Wind Energy Utilization. Both the technical and nontechnical aspects of wind energy are treated in the SERI program. There are several primary objectives of the effort. They are: to improve the wind energy resource data base, to determine the economic and environmental requirements for significant market penetration, to identify appropriate governmental policies and incentives that will promote such market penetration, to define the requirements of dispersed wind energy systems in small utility and nonutility applications, and to stimulate the development of innovative wind energy conversion devices. The program is divided into four major tasks which are:

(1) Wind Resource Data Improvement; (2) Market, Social, and Environmental Analysis; (3) Dispersed Applications and Systems Analysis; and (4) Innovative Wind Systems Program Management for DOE. The Wind Resource Data Improvment task involves field measurements, data analysis, and atmospheric modeling activities which address the specific siting and operational requirements of accelerated wind energy utilization. This activity is strongly concerned with meeting the data needs of a rapidly growing wind energy industry. The objective of the Market, Social, and Environmental Analysis task is to develop the information needed to design government incentives and to plan information dissemination efforts that will accelerate utilization of wind energy, especially in nonutility applications or with small utilities. This task will complement ongoing work by selecting several promising applications for detailed market, social, and environmental analyses. The Dispersed Applications and Systems Analysis task addresses near-term applications of wind energy in integrating units with small utilities, matching of equipment in nonelectric usage with industry or agriculture, and performance and cost analyses of electric and nonelectric wind energy conversion devices. The objective of the Innovative Wind Systems Program is to support research that may lead to technological breakthroughs or other improvements which result in more cost-effective wind energy devices for various applications. Management of this program involves issuing solicitations for research proposals and continual review of subcontracted research with respect to the objectives of the DOE national wind program.

Related SERI Activities

Accomplishment of tasks within SERI will be achieved by using the results of both the operational divisions of SERI and results from work contracted to organizations outside SERI in direct support of internal task objectives. A related major activity of SERI is the development of a comprehensive collection of solar energy information. This will provide a unique and valuable resource to the wind energy community. SERI has been assigned responsibility by the Congress for development and operation of a Solar Energy Information Data Bank. It will provide a centralized and comprehensive system to furnish technical and nontechnical information to local agencies, states, and other groups. It will also support a national library and computer system to provide models, data, and library services to researchers across the country. SERI is also active in international wind energy programs with Saudi Arabia, Spain, and the International Energy Agency. In addition, the Institute will also have a major involvement in the support of conceptual research within the academic community.

State, Regional, and National Efforts

What are some specific areas of possible interaction with the western region in wind energy development? The western region has a large wind energy resource. Much of the area is mountainous and requires special siting techniques for optimum use of wind energy. Large-scale hydroelectric facilities are broadly distributed with over half of the national capacity located in the Pacific Coast region. Studies of the integration of wind energy conversion devices with hydroelectric systems for storage and water conservation have been mentioned above. Cooperative programs within the region to evaluate the wind-hydroelectric potential are a possible area of activity. SERI can take an active role in working with other federal departments and agencies in such activities. State programs to test wind turbines under local conditions are another area of possible future interaction. The advantages to the national program would be in developing standarized methods for site documentation and in developing performance information on a variety of turbine designs and sizes in different parts of the country. Wind power could be an attractive alternative for small-scale rural electricity users. Problems encountered in siting or in equipment design to meet an important regional application might be referenced to the SERI research program. Applications of wind energy in water pumping are another area of regional interest. Water is an extremely valuable resource in the West. Demands for irrigation in the West might be met by wind energy in many locations. Nonagricultural water pumping may also use wind energy. These applications include pipelines, aquaducts, municipal water systems, and water treatment facilities. The match between the local wind resource, available wind turbine hardware, and pumping requirements would require study. The wind may also be combined with low-head hydroelectric power throughout the West. Low-head water power is one option in providing energy storage. A first step would be correlating the wind resource in the West with potential low-head water resources and testing available wind and hydroelectric hardware to determine its suitability and economic value in supplying energy. In all these activities the Regional Solar Centers, state, and local governments can be an effective force in resolving regulatory and land use problems.

IV. WHAT IS NEEDED

Additional work in three areas is needed to promote the accelerated use of wind energy. There is a need for greater operational experience with wind turbines and much more performance data for actual machines of different types in various applications and environments. A growing involvement of the private sector and a flexible approach to the design and development of hardware are also important. Additional meteorological data specific to wind energy are needed, as well as further work in developing and testing siting methods. Further comments on these three areas are given below.

Performance Evaluations

In the area of performance data and operational experience, it is important to begin a comparative evaluation of different hardware designs at the same site. Ideally, several sites across the nation with significantly different climatologies would be used in these experiments. Comparative testing of vertical-axis and horizontal-axis wind turbines at the same location is important. Several designs of each major type should be tested together. Such plans should include full instrumentation to measure both the wind environment and equipment stresses and power ouput. Accelerated test procedures could be considered and compared with actual field experience. Public viewing at the test sites can also increase awareness and interest in wind energy.

Intermediate sized machines with rotor diameters of approximately 40 meters and power outputs of from 100 to 500 kW are well suited to comparative testing. The unit cost of such wind turbines is far less than that of the largest units that may ultimately be used for utility power generation. The collection of operational and performance data should proceed in parallel with a research program to solve siting and engineering problems as they occur, and to develop and test operational strategies for either individual machines or "wind farms." This activity would also provide valuable information on equipment reliability and possible environmental or safety problems. To be most effective, the performance data and operational experience must be freely and rapidly exchanged with equipment manufacturers and future wind energy clients in the private sector.

Applications

Wind energy is unique among the solar forms in that it can directly provide mechanical power in the range of from 1 to 1000 kW or more per unit. A wide variety of applications for wind energy exist. It is well suited for remote power at windy sites, for irrigation; for telecommunications power; for water aeration; small industrial applications, and recreational sites; for crop drying and fertilizer production; and in space heating, either directly or by powering a heat pump. Such applications are in addition to large-scale utility power delivery and distributed electric power generation in conjunction with a utility grid. Future equipment designs should be tailored to their application and the wind resource at their intended site. Different physical environments imply different materials problems. The ocean or coastal environment, for example, obviously presents different problems than does a desert site. Ideally the site-specific wind characteristics, wind turbine hardware, intended application, and load all should be included in an engineering design optimization for a given site. This can be approached in practice through the phased development of turbines and relatively minor design refinements to maximize delivered energy.

Hardware Development

A growing involvement of the private sector in wind energy is already becoming apparent. For all the reasons stated above, a flexible approach in equipment design is important in the development of future commercial products. One way to promote this objective is public sponsorship of a large number of designs in parallel at the small, intermediate, and large unit power levels. It is important that the "front end" risk and cost be removed in the early stages of development. As an example, American machines are now designed and built with non-metric unit parts. Standard international (S.I.) manufacturing techniques could be used in building prototype machines in the expectation that a substantial international market for wind energy products will exist. Subsequent industrial conversion to S.I. could thus be avoided in developing these completely new products. Early and significant involvement of the ultimate user, whether it is a utility company, an industrial client, or an agricultural center, is important. An expanded national effort will be required, however, to support several different designs at the 1 to 2 MW size for utility power. The program might also use a large number of intermediate sized machines (approximately 100 kW) in a developmental and testing effort. Machines up to 200 kW in power output can be used both in clusters and as single units. Intermediate sized machines can provide valuable information to manufacturers interested in serving both utility and nonelectric applications. Moreover, the risk of failure is reduced by performing experiments at the smaller sizes, and the lead time required is similarly reduced. Finally, attention will have to be given to building a service industry to distribute, install, and maintain wind turbines.

Meteorological Data

There are presently far less meteorological data collected specifically for wind energy development than there are for other purposes. A strong need exists for an improvement in data collection procedures to support wind energy. Seasonal and diurnal changes in the wind are important, as is the variation of the wind speed with height above ground, especially for the largest machines now planned. A standard approach to data collection and analysis would benefit the industry. This can be supported by a specialized data network for wind energy resource assessment. Many more measurements at remote or presently uninstrumented sites are needed. Modern automated measurement systems can and should be employed. A national data collection network implemented today can provide the long-term data needed ten years from today when large-scale wind energy utilization will occur.

Siting and Resource Utilization

Many approaches to equipment siting exist, but few have been broadly used. Specialized wind resource studies for different regional energy needs are critical. Measurement of many "nonstandard" meteorological parameters will be needed to document the suitability of each site and to provide data to optimally match machines to site applications. Presently available siting methods need to be tested and evaluated by applying them to a wide variety of applications in different geographic settings. Important wind characteristics include the low frequency variability of the average wind on an hourly, monthly, and yearly basis, as well as the sequence and duration of wind calms. Peak gusts and directional shear are important to determine structural requirements. Additional studies on wind turbine wakes are needed as a part of the siting problem to determine optimum machine spacing for local wind characteristics. Much more information is needed to determine vertical wind profiles as a function of atmospheric stability, surface roughness conditions, and surrounding terrain. Improved wind forecasts are important for either utility operations or to predict energy displaced by decentralized wind energy devices. Better forecasting methods are needed to estimate speeds 24 hours or less in advance. A wind speed decrease will require supplemental power generation, and a large speed increase (such as that accompanying a storm) may require protective action.

Improvement of present wind data calls for the review and evaluation of the data requirements necessary for industrial wind energy development. Wind tunnel models, analytical methods to interpolate wind data, numerical computer models, and field measurements all can be expected to contribute in siting and resource assessment studies. Present wind energy data acquisition procedures should be examined and improved methods developed through research and technology transfer activities. Standard methods of data collection and analysis can provide specific wind resource data for future needs.

Problem Areas

Certain problem areas need to be recognized. The economic value of wind energy cannot be simply determined. Wind turbines cannot be readily compared to other devices in terms of dollars per kilowatt of rated capacity. Present methods of indicating machine size are not ideal. For wind turbines, the rotor diameter required for annual energy delivered at a particular site is the primary factor of interest. Therefore, both rotor size and site resource characteristics should be used in comparing wind energy with alternative energy options.

The value of wind energy needs to be judged by the value of the energy it replaces. Energy costs in utility applications are not the same as in other applications. Utility power costs also vary greatly from one part of the nation to another and even more dramatically in other parts of the world. Present estimates indicate that wind energy can soon be economically competitive in many electric and nonelectric applications. Therefore, the achievement of predetermined cost goals is probably less important in the near term than the development, siting, testing, and evaluation of many different turbine designs.

Finally, we should consider what products need to be developed first. Although machines will surely be located in low wind speed areas, the known high wind speed regions within the United States offer a very large energy potential and substantial product market. Indeed, the resource in high wind speed areas alone greatly exceeds all projected saturation levels for wind utilization. Products tailored to the best resource areas thus can be expected to have the greatest opportunity to succeed both technically and economically in the next decade.

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WOOD ENERGY IN THE NORTHWEST

THE ACTIVITIES OF RICHLAND OPERATIONS OFFICE DEPARTMENT OF ENERGY IN THE USE OF FOREST RESIDUES FOR ENERGY

by

Richard L Durham
Special Projects Officer
U. S. Department of Energy
Richland Operations Office
Richland, Washington

The Department of Energy, has an organization in Washington, D.C. that is responsible for the study and demonstration of the use of agriculture and forest products for fuels. This organization is the Fuels from Biomass Systems Branch of the Division of Solar Energy. The Biomass Branch has recently published a six-volume report entitled, "Silvicultural Biomass Farms". The study is summarized in Volume I. The subtitles of the remaining five volumes are:

- Vol. II - The Biomass Potential of Short Rotation Farms
- Vol. III - Land Suitability and Availability
- Vol. IV - Site -- Specific Production Studies and Cost Analyses
- Vol. V - Conversion Processes and Costs
- Vol. VI - Forest and Mill Residues as Potential Sources of Biomass

This study was done by the MITRE Corporation and Georgia-Pacific Corporation, under contract with the Biomass Branch. (The report is available from the National Technical Information Service, U. S. Department of Commerce, Springfield, Virginia 22161.)

The major conclusions of the study are summarized below:

Potential Biomass Sources:

- Major potential sources of wood/bark biomass for conversion to useful energy products include underutilized standing forests, logging residues, mill residues, precommercial thinnings from commercial forests, and silvicultural biomass farms. Biomass farms represent a substantial long-term potential for contributing to the nation's energy supply. Other sources represent both near-term and long-term potential in varying degrees. Underutilized standing forests, in particular, warrant consideration for near-term use.

- The concept of energy farming requires immediate research attention if it is to be developed to a commercial status within a reasonable time frame. This study has concentrated on an analysis of this concept.

- A silvicultural energy farm would involve the intensive management of a densely planted energy crop under short rotations, utilizing selected coppicing species. Major technical problems are in the areas of biomass harvesting and storage, and in increasing biomass productivity.

- The two major factors which will influence the commerciability of biomass farming are biomass productivity and the availability of suitable land.

Biomass Species:

- Tree species which currently appear attractive as energy crop candidates include *Populus* spp. hybrid poplars, *Eucalyptus* spp., *Alnus* spp., sycamore, and tulip poplar. It is fully expected that other species would emerge as promising candidates if exploratory research efforts were increased.

Biomass Productivity:

- Biomass productivity under close-spaced, short-rotation conditions is estimated to range from 6 to 13 dry ton equivalents (DTE) per acre-year with current technology, depending upon species and site selection. It is anticipated that these yields could be essentially doubled within 25 years by a concerted research effort on species selection and improvement, and energy crop management.

Land Availability/Energy Yield:

- If 10 percent of the arable land currently used for private forest, pasture, range, and hayland were to be used for biomass production, up to 4.5 quads[1] of energy could be produced annually at current yield levels, and 8.3 quads at anticipated future yield levels. The production of one quad of energy would require the use of 5.9 million acres at a productivity level of 10 DTE per acre-year.

- In terms of potential availability of suitable land, the Southeast, Delta States, and Lake States regions of the country are most likely locations for biomass farms.

Biomass Farming Costs:

- Biomass production costs would vary considerably depending upon the site and species chosen. Production costs at six selected sites ranged from \$1.21 to \$1.96 per 10^6 Btu at current productivity levels. The use of prime agricultural land for biomass production would result in costs ranging from \$2.00 to \$2.47 per 10^6 Btu. At future productivity levels, production costs at preferred sites would be approximately \$1.00 per 10^6 Btu. The most suitable areas for biomass production in terms of production costs are the Southeast and the Delta States regions.

- The major cost items in biomass farming are associated with crop management. Costs of fertilization and supplemental irrigation may comprise up to 40 percent of the total production costs. Capital costs comprise only 10 percent of total costs. Harvesting could be a major cost item if conventional forestry harvesting methods are used. The use of a conceptualized self-propelled biomass harvester was entertained in this analysis.

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[1]One Quad is equal to 10^{15} Btu.

- Biomass production costs are highly sensitive to biomass productivity and, hence, to factors such as site location and rotation length which influence productivity levels.

Energy Budget:

- The quantity of energy produced in the form of wood biomass by the process of energy farming is estimated to be 10 to 15 times the amount of energy consumed, depending upon the level of productivity achieved.

Forestry Residues:

- Total mill residues generated annually are estimated to be 86 million dry tons (1970). The total may increase to as high as 143 million dry tons by 2020. Approximately 17 million dry tons of wood and 7 million dry tons of bark residues are currently unused. Prices paid for mill residue currently range from $1.00 per dry ton for bark ($.06 per 10^6 Btu) in the south, to $40.00 per dry ton for chipped residues ($2.35 per 10^6 Btu) in Maine and on the West Coast.

- Total above-ground forest residues generated annually are estimated to be 83 million dry tons (1970), and may increase to as high as 195 million dry tons by 2020. Essentially all forest residues are currently unused. Costs of collecting, reducing, and transporting forest residues are estimated to range from $23 per dry ton in the south ($1.35 per 10^6 Btu) to between $44 and $61 per dry ton in the Pacific Northwest ($2.59 to $3.59 per 10^6 Btu).

- The economic feasibility of expanding the capacity of the forest industry to use mill and forest residue, as an energy feedstock is highly dependent upon local conditions, largely in regard to competition for available supplies.

Wood-Derived Energy Products:

- Major energy products which could be economically derived from wood biomass at sometime in the future include electricity, ammonia, methanol, ethanol, and possibly medium-Btu fuel gas, depending in part upon developments in biomass gasification technology.

- The price of generated electricity at a 220 MW capacity wood-fired power plant ranges from 24 mills to 42 mills per kilowatt-hour, at feedstock prices of $1.00 to $2.50 per 10^6 Btu. Such wood-fired plants will probably never compete with large (1000 MWe capacity) coal-fired or nuclear plants. Retrofitting small oil- or gas-fired power plants to burn wood is competitive with new coal-fired plants of similar capacity or with retrofitting to burn coal. The major opportunity for biomass in electric generation is in small plant retrofit, or co-firing with coal in large plants to reduce sulfur oxide emission control costs.

- Production of ammonia from wood biomass is estimated to be marginally competitive today, and very favorably competitive within the next decade.

- Methanol production from wood could become competitive within the next decade, although the demand for methanol will be satisfied by existing plant capacity well into the future unless changes in policy require the use of methanol in gasoline blends.

- Ethanol fermentation from wood hydrolysis products could become competitive within 10 to 15 years. The future demand picture, however, is similar to that for methanol.

- Production of medium-Btu fuel gas from wood pyrolysis could become competitive within the next 12 to 20 years, providing that a suitable market is developed for this product. Future markets would depend upon establishment of systems similar to the town-gas systems of the past.

- The production of substitute natural gas from wood pyrolysis products is not expected to become competitive until the price of natural gas feedstock approximates \$4.00 per 10^6 Btu.

- Charcoal and fuel oil produced from wood are also potential energy products which may become locally competitive in situations where full economic credit can be taken for process by-products. The potential for charcoal resides in the opportunity to develop technology for co-firing with oil and/or coal to reduce emission control requirements.

The study states that forest residues represent a potentially large source of biomass for energy production. The term "forest residues" has been interpreted to include logging residues, intermediate cuttings, understory removal, and annual mortality. Annual mortality refers to trees killed by natural agents such as mountain pine beetles. The study, in Volume VI, concluded that trees killed by annual mortality are generally widely dispersed making it likely that their collection would be noneconomic in most instances.

At the Richland Operations Office of the Department of Energy, we believe that we have an exception in our region to the dispersion of mortality-killed trees.

At the present time, there exists in the Umatilla and Wallowa-Whitman National forests of Northeastern Oregon and Southeastern Washington, an estimated 836 million cubic feet of dead or dying trees, which have been killed by the outbreak of mountain pine beetle. The tonnage represented by this resource is approximately 15,400,000 or 35 tons per acre. These estimates do not include forest residues generated by ongoing chipping or logging in this area. The primary host tree for the beetle infestation is the lodgepole pine. The bark of this species of pine has a heating value of 8,900 Btu's per pound of oven-dry bark.

The U. S. Forest Service is currently spending an estimated \$15,000,000 annually in Oregon and Washington to treat unmerchantable forest residues to meet fire and silvicultural requirements.

If means could be found to utilize the dead timber and forest residues for energy production, then cost savings from hazard reduction and protection perhaps could subsidize removal of the material to local sites where it could be used for energy production. One possible use within the region may be co-generation of electricity. Another possible use would be to convert the dead timber and forest residues to wood pellets, which could be used as a direct fuel source. Gasification of the dead timber and forest residues is another possible solution.

The Richland Operations Office of the Department of Energy, in cooperation with the Pacific Northwest Region of the U. S. Forest Service, has contracted with the Forest Research Laboratory of Oregon State University to prepare a working plan outlining research required to identify methods of utilizing the dead timber and forest residues in the Blue Mountain area of the Umatilla and Wallowa-Whitman National Forests. The scope of the study is subdivided into four broad areas:

1. Determination of the type, volume and location of the dead trees and forest residues.

2. Analysis of feasible methods of harvesting, handling and transporting the dead trees and forest residues.

3. Specification of potential methods for utilizing the dead trees and forest residues to produce energy.

4. An analysis of the economic, social, and political consequences of alternate systems for utilizing the dead timber and forest residues.

The Forest Research Laboratory team is headed by Raymond A. Currier, recognized for his work on pelletized wood; and Stanley E. Corder, recognized for his work on wood and bark residues for energy usage.

The results of the study are available from Region VI, U.S. Forest Service, or from the Richland Operations Office, U. S. Department of Energy.

At the Richland Operations Office, a decision will shortly be made to convert certain of the coal-fired boilers on the Hanford Reservation to wood. If this decision is made, Hanford will become the first major large industrial user of wood for fuel in Eastern Washington. Hanford would require about 120,000 tons of wood pellets annually if all the boilers are converted to wood.

Session 26, Wood Energy in the Northwest

"Densification of Wood and Bark for Fuel"

by

Raymond A. Currier, Forest Research Laboratory
Oregon State University, Corvallis, Oregon

A memento I saved from the 1973-1974 Arab embargo on crude oil is a newspaper cartoon drawn by the famous Bill Mauldin. Featured prominently is an old coal-burning steam-powered railroad locomotive. Across the front of the engine parades a list of its attributes such as "all-weather reliability," "fast enough," "passenger-mile cost cheap," etc. The caption on the cartoon is borrowed from William Shakespeare and states simply "What is past is prologue."

As we all know, the crude oil spigot was turned back on before we started to build such machines once again. Personally, I feel there is a cogent message in Mauldin's cartoon for everyone, and especially for those of us who live in the Pacific Northwest or other regions of the country blessed with climatic and soil conditions conducive to the growth of trees.

Our forests are capable of supplying the energy necessary to heat many of our homes and commercial enterprises. They have done so in more than one period of our country's existence. As recently as 1940, according to Stan Corder, a co-worker at the Forest Research Laboratory, wood was used in 20 percent of occupied dwellings in this country for central heating or cooking. Fuelwood now accounts for only 1 percent of our nation's energy use.

In the years immediately preceeding and following World War II, the Pacific Northwest and Inland Empire burned large quantities of densified wood fuel. This was primarily due to the development of Pres-to-log and stoker fuel machines by Wood Briquetts, Inc., of Lewiston, Idaho. Pres-to-log machines took dry woody mill residues and compressed them into the form of logs about 4 inches in diameter by 12-3/4 inches long, each weighing about 8 pounds. The stoker fuel machines were capable of turning the dry woody residues into small densified rods 1-1/8 inches in diameter and about 1 inch long.

Stoker fuel could be fed into home furnaces or industrial boilers with standard mechanical coal stokers. Advertisements of the era stressed that this fuel was clean, had good combustion efficiency and was economical. One only had to fill a fuel bin or hopper once or twice a day; the rest of the operation was automatic. Cheap fuel oil and natural gas pushed stoker fuel into near oblivion in the 1950's. However, the know-how to utilize densified wood fuel is available, and the hardware required easily could be manufactured again. I am willing to go out on a limb and apply Shakespeare's "What is past is prologue" to stoker fuel for heating our homes and businesses once again. I predict we will see a substantial revival of this method of heating in the Pacific Northwest and Inland Empire.

A more recent development of the stoker fuel principle is production of fuel pellets made from wood and bark. These are 1/2-inch or less in diameter, and 1/2 to 3/4-inch in length. Fuel pellets can be made using standard agricultural pelletmills, and could be used interchangeably with stoker fuel.

Another possibility for combusting stoker fuel or fuel pellets would be adaptation of the old gravity-fed sawdust burners (once a popular method to heat homes in the Pacific Northwest) to burn densified fuel instead of sawdust. Since the flow properties of the densified fuel are much better than sawdust, the old problem of sawdust "hanging up" in the feed hopper would be eliminated.

The volumes of wood and bark required as raw material for stoker fuel or fuel pellets are currently available in the Pacific Northwest and most other forested areas of the country. First, there still are substantial amounts of suitable residues available at primary wood processing plants. Secondly, large quantities of potential raw material are not utilized during logging operations. This is called logging slash or residue and represents substantial tonnages. A third source of raw material results from rather large areas of our forests decimated by beetle or other insect attacks.

All these sources lumped together potentially represent billions of BTU's available for home or other heating and steam or power generation. If the quantity proves insufficient, we could embark upon biomass farms stocked with tree species capable of rapid growth, and harvested on short rotations for the entire tree, including roots and leaves. Densification of this biomass not only would provide a convenient, efficient fuel, but would enhance transportation of the fuel since densified stoker fuel or fuel pellets occupy as little as one third the volume of the original uncompressed biomass, and contains relatively little moisture. When compared to coal, densified wood and bark fuels have less pollution potential since wood and bark have negligible sulfur and are low in ash content.

METHODS FOR THE RECOVERY OF NUTRIENTS AND ENERGY FROM SWINE MANURE

L. Boersma, E. Gasper, and B. P. Warkentin
Department of Soil Science
Oregon State University, Corvallis OR, USA

Introduction

Biomass is the product of photosynthesis. The use of biomass is therefore an attractive and practical method for use of solar energy. The materials include wood and wood waste, agricultural commodities and agricultural waste and residue, animal waste, and municipal waste.

The use of biomass as a source of energy or as a source of feedstocks has several advantages. It is infinitely renewable. Storage is not a problem as it is with direct use of solar or wind energy. Technologies for use of biomass are well developed as are techniques for growing it. A further advantage is that waste products can be used.

There are many disadvantages as well. The most formidable obstacle is the cost of materials and energy derived from biomass. Considering only the cost of the raw material, the cost per gallon of ethanol is $0.87 when corn is used and as high as $2.86 when potatoes are used. Many of the conversion processes require substantial amounts of energy. Biomass contains much water per unit weight. It is a distributed source of low density. Not enough material is available in one location for efficient collection and storage. However, with rising costs of traditional energy sources, the depletion of oil and gas reserves, and with the continued development of less expensive methods for processing, disadvantages are gradually overcome.

The interest in biomass use is growing. There are many methods for extracting energy and useful products from biomass. Orderly progress depends on a careful analysis of the many alternatives. This analysis should consider energy and materials flows of the proposed management alternative. Economic implications must also be clarified. These include not only present costs and benefits, but also future costs of energy, manpower and raw materials.

We developed energy and material balances based on the feed energy needs and waste discharge of 100 pigs. It is assumed that the pigs weigh initially 50 kg each and are fed to reach a final weight of 100 kg. The gain in weight is 0.80 kg/pig/day and the ratio of gain/feed is 0.263. The amount of feed consumed is therefore 3.04 kg/pig/day. Each pig discharges 3 liters of fresh manure per day containing 14% (w/w) solids or 0.42 kg. The duration of the feeding period is 50/0.80 = 62.5 days.

Production Factors

Details of feed required, necessary land area, energy requirements, output of pork and amount of manure produced are available in a complete report from the authors. A summary is shown in Table 1.

Methane and Fertilizer

Process Description and Product Yields

The 300 l of fresh manure produced each day by the 100 pigs must be diluted with about 300 l of water to make the suspension easier to pump and to reduce the concentration of total solids in the digester to about 7% (w/w). The volume of dilution water is not sufficient to operate a gutter flushing system. The pigs must therefore be kept on slatted floors with the manure collecting in a pit below. The manure is mixed with water in the pit and then pumped into the anaerobic digester.

Optimum digestion is obtained with retention times of 10 to 17 days. The digester must be large enough to store the volume of manure produced during this period.

The manure discharged by the 100 pigs each day contains 34 kg of volatile solids. The amount depends on composition of feed, bedding material, and age of pigs. Half of the VS are destroyed by the anaerobic digestion process to yield CH_4 and CO_2. The efficiency of conversion depends on temperature, loading rate, and pH. The digestion may be expected to yield from 1 to 1.4 m^3 of biogas per kg of VS removed. Volumes of gas are reported at the standard temperature of 20 C and pressure of 760 mm Hg. The biogas contains usually about 60 percent CH_4 and 40 percent CO_2. The combustible energy of the mixture is about 5,330 kcal/m^3.

The yield of biogas is 20.4 m^3/day, assuming 1.2 m^3 of biogas per kg VS removed per day. The biogas recovers about 6.1% of the total amount of solar energy and cultural energy represented by the corn and soybean meal. However, the recovery is equivalent to 70% of the energy used in farming operations.

The liquid outflow from the digester contains plant nutrients and is a good soil conditioner. All of the nutrients originally present in the manure are present in the digester outflow. The availability of the N to plants has been increased because of the decrease in carbon molecules which escaped as CH_4 and CO_2.

The daily outflow contains 25 kg of dry matter which consists of 12.5 kg of bacterial cells with a crude protein content of 50 percent, 7.2 kg of fiber residue, and 4.1 kg of N including 1.0 kg of organic N in the bacterial cells (Figure 1). The fiber residues were not solubilized by the bacteria in the digester but can be utilized by fungi in the soil. On an annual basis the total outflow from the digester contains 1,435 kg N, 350 kg P, and 490 kg K. When spread on land, each ha of the 15.26 ha of land needed to raise the corn and soybean meal for the swine ration would receive 94 kg N, 23.0 kg P, and 32.0 kg K per year. The energy value of the recovered fertilizer represents 4.4% of the total energy input. The use of processed sludge as a feed supplement for ruminants merits consideration. The yield of crude protein is 2,888 kg/yr.

Use of Biogas

Although it is possible to use the biogas as it comes from the digester, its value will be increased by removal of the carbon dioxide. Removal of the CO_2 from the biogas increases the energy content from 5,330 to 8,800 kcal/m^3.

The heating value of the 20.4 m^3 of biogas is 108,732 kcal/day. A well insulated home with three bedrooms and a heated space of 283 m^3 requires an average of 62,000 kcal/day in Portland, Oregon, during January which has 791 degree days. The same house requires an average of 122,000 kcal/day in Minneapolis, Minnesota, where January has 1562 degree days. If the biogas were used to generate electricity, it could produce 22 kWh/day. The average use per household is about 23 kWh/day for the U.S. and about 43 kWh/day for Oregon.

On farms, the biogas from the digester can be used for cooking, heating of water and buildings, refrigeration, or generation of electricity. Use for farm machinery does not seem to be practical. For example, a 100 hp tractor operating for 1 hr requires 45 m^3 of biogas. The annual yield of 7,140 m^3 would allow the use of the tractor for 158.7 hrs. This yield is promising in relation to the requirements for cultivation of the 12.41 ha of corn and 2.85 ha of soybeans needed to provide the feed for the 100 pigs.

However, a cylindrical fuel tank, 16 m long, with a diameter of 6 m is required to store 450 m^3 of the biogas which would be sufficient to run a 100 hp tractor for 10 hrs. Compressing the gas is therefore necessary. A standard sized fuel tank for a 100 hp tractor has a volume of 0.227 m^3. Storage of the amount of biogas required to fuel the 100 hp tractor for 1 hr, namely 45 m^3, in this volume at standard conditions would require a pressure of 205 atm. If the pressure is reduced to a more manageable 20 atm, the tractor would run for only 6 min.

The digestion process requires energy to heat and mix the contents of the digester, pump influent and effluent, and perhaps compress the gas for storage. The largest amount is needed for heating the digester and its contents. This heating requirement is determined by the outside temperature and the insulation used for the tank. Heating to 37 C and mixing are necessary to provide optimum conditions for the growth of the bacteria in the digester. Mixing is required for only a few minutes each day.

Increasing the Yield of Biogas

The yield of biogas with a maximum energy content is highest at a C/N ratio of about 30. The yield of methane increases as the C/N ratio approaches 30, while the total yield of biogas remains fairly constant. The C/N ratio of the swine manure used here was 9.8 (Figure 1). To obtain a C/N ratio of 30, 4.1 x 30 = 123 kg COD/day should be added to the digester. Since 40.2 kg COD/day is in the manure, an additional 82.8 kg COD/day must be provided by another carbon source. The estimated yield of biogas is then 123/40.2 = 3.06 times greater than without the COD added, or 62.4 m^3/day.

The straw or other material must supply sufficient carbon to yield 62.4 - 20.4 = 42.0 m^3 biogas/day. Assume a mixture of 60% CH_4 and 40% CO_2 in the biogas. Assume further that straw is used which contains 64% (w/w) of cellulose and hemicellulose with a digestibility of 45% and that the yield is 0.44 m^3 CH_4 per kg of cellulose and hemicellulose. The yield of CH_4 per kg of straw is then 1 x 0.64 x 0.45 x 0.44 = 0.127 m^3 CH_4. The total yield increase is 42.0 x 0.60 = 25.2 m^3 CH_4. The total amount of straw to be added is 25.2/0.127 = 200 kg/day or 200 x 365 = 73,000 kg/year. This amount is 67% of the straw left in the fields (Table 1) and can be harvested without detriment to the land.

By adding the straw the energy yield of the digester becomes 121 x 10^6 kcal/year or 12.7% of the total amount of solar energy and cultural energy represented by the corn, soybean meal and straw (Table 2). The biogas energy is equivalent to 223% of the energy used in farming operations.

Pure cellulose is readily digested under anaerobic conditions. However, in its natural state it is chemically bound to hemicellulose and lignin in a complex structure which is largely inaccessible to the extracellular enzymes of the bacteria in the digester. Pretreatment of the waste is therefore necessary.

Problems

Some serious problems must be solved before acceptance of the use of digesters in combination with small livestock operations can be expected. One problem is the integration between the availability of the gas and the energy needs of the farming enterprise. The quantity of available gas may be expected to vary dramatically during the year as well as from year to year. Progressing through the year, the activity on the farm may range from having very few or only young animals present to a fully stocked herd of marketable animals. The quantity and quality of manure available for digestion varies correspondingly. More importantly, it may be advantageous to have no pigs at all during certain years. The fluctuating level of availability poses limitations on the uses which can be made of the gas. These problems are in part mediated by making the use of straw an important part of the process.

The energy needs of many applications vary during the year and so does the availability of the gas. The situation where energy needs and gas availability are equal will be a very fortuitous circumstance which may never occur unless special operating procedures are carefully worked out and strictly adhered to. The use of the gas may be enhanced by converting it to an energy form which can be more easily stored. Better continuity may also be achieved by feeding the digester with materials other than the manure. Much of the straw left on fields present a readily available source of such materials.

An important research need is the development of management systems which are specifically aimed at the full utilization of all resources available to the farmer. We suggest that problems to be investigated include those of finding means to store the gas for later use, transformation of the gas to a form of energy which can be stored and transported, the development of uses for the gas which lead to products that can easily be sold by the farmer, increase of gas production through the addition of cellulosic waste products, and finally improvement in the digestion process itself.

Summary

Tables 1 and 2 show the combustible energy content of the products involved in raising pigs from 50 to 100 kg. The values are for a oneyear period. In Table 2, certain comparisons have been made. Energy values of the products are shown as percent of the total energy input, including the solar energy fixed by the grain and straw and the energy expended in the farming operations.

The nutrients in the manure represent energy that was expended in the mining and processing. Each time these nutrients are returned to the land, the equivalent amount of energy does not have to be expended and is therefore saved. The production of N, P, and K require 17,600, 3,200, and 2,200 kcal/kg respectively. The use of the minerals represents a saving of 25 x 10^6, 1 x 10^6, and 1 x 10^6 kcal/yr.

Interpretation of the data with respect to efficiency of energy use must be done with care. The efficiency of energy use is defined as the energy content of the product divided by the energy expended to produce the product. Difficulties arise when the energy inputs are not clearly defined. For example, the input of 108 units of cultural energy produces 894 units of energy in the form of grain and straw. The energy efficiency of farming is therefore 8.3 or 830%. On the other hand, the energy input of 619 units produces 59 units of pork for an energy efficiency of 0.09 or 9%. Discussions of energy efficiency can easily lead to misunderstanding and certainly to gross misrepresentation of facts.

The most significant conclusion of our analysis is that digestion of the manure can produce substantial amounts of energy. With straw added to the digester, the energy content of the biogas is 86.4% of the energy used on the farm for all farming activities. This is clear indication that the potential exists to develop methods of operation which allow farms to become energy independent.

Methane and Yeast or Microfungi

Process Description

Organic matter dissolved in the liquid phase of the fresh manure may be used as a substrate for the growth of yeast or microfungi to convert the organic matter into cell mass. Harvesting of the cell mass leaves an effluent which still contains nutrients and minerals.

For this discussion we assume that a gutter flushing system is used to remove the manure from the animal quarters. Flushing at the rate of 140 l/h dilutes the 300 l of manure to a volume of 3,660 l/day (Figure 2). Other rates of flushing may be chosen according to local needs. The diluted manure is collected in a sedimentation pit where the solids are separated from the liquids by settling. The solids are pumped into an anaerobic digester. The liquids overflow into a holding tank from which they are pumped to a fermentation vessel.

It is assumed that 3,000 l of diluted manure are supplied to the fermenter each day in a continuous flow. Conventional processes of yeast manufacture require a retention time of 3 to 5 hrs. At a retention time of 5 hrs, the volume of the fermenter must be 625 l (3000 l/h x 5/24). To allow for the expansion of the substrate due to gassing and foaming, the volume of the fermenter should be increased to about 2,000 l. The substrate has a COD of 16 kg/day and contains 2.4 kg N/day. We shall assume that only N in the ammonium form is readily assimilated by the yeast or microfungi.

If all of the COD is attributed to organic carbon that can be assimilated by the organisms, then a theoretical yield of 0.38 g of cells/g of COD is possible. The expected yield is therefore 6.1 kg cell matter/day (16 kg COD/day x 0.38 kg biomass/kg COD). In general, the N content of the yeast ranges from 8 to 10% of the dry matter so that about 0.5 kg N/day are removed, corresponding to a yield of 3.1 kg of crude protein per day (N x 6.25), which is equivalent to 34% of the amount of protein supplied by soybeans and 8.5% of the total protein requirement.

Addition of Carbon Source

The unused ammonium N, namely 2.4 - 0.5 = 1.9 kg/day, can also be converted into yeast or fungal protein by the addition of organic carbon. Assuming that yeast cells contain 8% N by weight, the excess N of 1.9 kg/day could be converted to 23.75 kg of yeast (1.9 kg N/0.08). Additional COD is required to accomplish this. This can be supplied by properly pretreated cellulosic wastes such as straw. Using the yield of 0.38 kg of cells/kg COD, the requirement is 23.7/0.38 = 62.5 kg COD. This could be supplied by 58.6 kg of sugars (62.5 kg COD/1.067 kg O_2 per kg sugar = 58.6 kg sugar).

The sugars may be obtained by the hydrolysis of straw. Assume that the straw contains 64% (w/w) cellulose and hemicellulose and that 50% is converted to sugars. One kg of straw then yields 1.0 x 0.64 x 0.50 = 0.32 kg of sugar. The amount of straw to be hydrolyzed is therefore 184 kg/day. The fermenter receives 16 + 62.5 = 78.5 kg of COD and the yield of yeast cells is 29.8 kg/day with a protein content of 50% by weight (78.5 kg COD x 0.38 kg cells per kg COD). The protein yield of 14.9 kg/day is 164% of that supplied by soybeans and 41% of the total requirement for protein.

Anaerobic Digester

Management of the anaerobic digester was discussed in detail above. Yields are lower here because part of the COD is transferred to the fermenter. Yields of 14.3 m^3 biogas/day without the addition of cellulosic waste and 30.4 m^3/day with the addition of cellulosic waste are indicated. We have not discussed uses for the gas here, but suggest that a useful application would be the processing of the single cell protein.

Use of Effluents

Effluent streams from the digester and from the fermenter are available for further use. They can be used separately or in combination. We assume the mixing of the two outflow streams. When spread on land, the 3,660 l/day provide a depth of water of 0.0366 cm per ha per day. Spreading the outflow from 10 days on 1 ha provides 0.37 cm of water and 30 kg N, 8 kg P, and 13 kg K. If all the water were supplied to the 15.26 ha needed to raise the grain, they would receive 0.84 cm of water per year and 68.8 kg N, 18 kg P and 29.8 kg K.

Distribution of water can only be done during the growing season. The storage requirement for 200 days would be 732 m^3, equivalent to a reservoir 3 m deep with a floor area measuring 12.2 x 20 m.

Algae

Dissolved nutrients in the liquid phase of the manure can also be recovered by photoautotrophic organisms such as algae. Details are given in a report available from the authors.

Summary

Tables 1 and 2 show combustible energy content of products involved in raising pigs from 50 to 100 kg. Values shown are for a one-year period with pigs being fed during 350 days. Protein consumption by the pigs and protein recovery from waste products are also shown. Biogas yield is reduced by inclusion of the fermenter. However, as a result, substantial quantities of protein can be produced. The relative advantages can not be judged without a comparison of costs and benefits. These comparisons have not been made. Conclusions depend on the relative costs of energy and protein.

Because difficulties are involved with algae production, not the least of which is the cost of production facilities, we favor the management scheme where straw is used in fermenter as well as digester, and growth of algae is not attempted.

Table 1. Energy values of several products used and produced on a farm where pigs are raised from 50 kg to 100 kg per pig. There are 100 pigs at all times. The through-put is 560 pigs/yr.

		10^6 kcal/yr
SOLAR ENERGY		
Corn (12.41 ha)		
grain (99,295 kg/yr)		447
straw (99,280 kg/yr)		447
roots (62,050 kg/yr)		279
	Total	1173
Soybeans (2.85 ha)		
beans (meal) (7,096 kg/yr)		32
beans (oil) (1,454 kg/yr)		7
straw (9,975 kg/yr)		45
roots (5,700 kg/yr)		26
	Total	110
FARMING OPERATIONS		
cultural energy		108
livestock housing and care		24
feed processing		8
PRODUCTS (DIGESTER ONLY)		
pork (19,600 kg/yr)		59
biogas		
no straw (7,140 m^3/yr)		38
with straw (22,776 m^3/yr)		121
nitrogen (1,435 kg/yr)		25
phosphorus (350 kg/yr)		1
potassium (490 kg/yr)		1
PRODUCTS (DIGESTER AND FERMENTER)		
No straw		
pork (19,600 kg/yr)		59
yeast (2,135 kg/yr)		10
algae (5,906 kg/yr)		35
biogas (5,005 m^3/yr)		27
nitrogen (787 kg/yr)		14
With straw		
pork (19,600 kg/yr)		59
yeast (10,430 kg/yr)		50
algae (2,187 kg/yr)		13
biogas (10,640 m^3/yr)		57
nitrogen (560 kg/yr)		10

Table 2. Energy inputs and outputs for the system of management shown in Figure 1. The numbers shown pertain to a period of one year. Use of digester and fermenter.

Category		No straw Energy	No straw % of total input	No straw Protein	With straw Energy	With straw % of total input	With straw Protein
		10^6 kcal	%	kg	10^6 kcal	%	kg
ENERGY INPUT							
corn grain		447	71.5	9,950	447	42.9	9,950
soy beans		32	6.1	3,185	32	3.7	3,185
straw for digester		--	--		126	12.1	
straw for fermenter		--	--		290	27.9	
farming:							
fuel & electr.	54.2						
fertilizer	32.5						
labor & machinery	21.7						
livestock maint.	24.0						
feed processing	8.0						
	140.4	140	22.4		140	13.4	
		625	100.0	12,775	1,041	100.0	12,775
ENERGY OUTPUT, USEFUL PRODUCTS							
pork		59	9.4		59	5.7	
yeast		10	1.6	1,085	50	4.8	5,439
algae		35	5.6	2,835	13	1.2	1,132
biogas		27	4.3		59	5.5	
N		14	2.2		10	1.0	
sludge		--	--				
		145	23.2	3,920	191	18.3	6,571
OTHER ENERGY SINKS							
heat loss from pigs		260	41.6		260	25.0	
CO_2 and other gases		130	20.8		410	39.4	
other (e.g. fiber residue)		90	14.4		180	17.2	
		480	76.8		852	81.7	

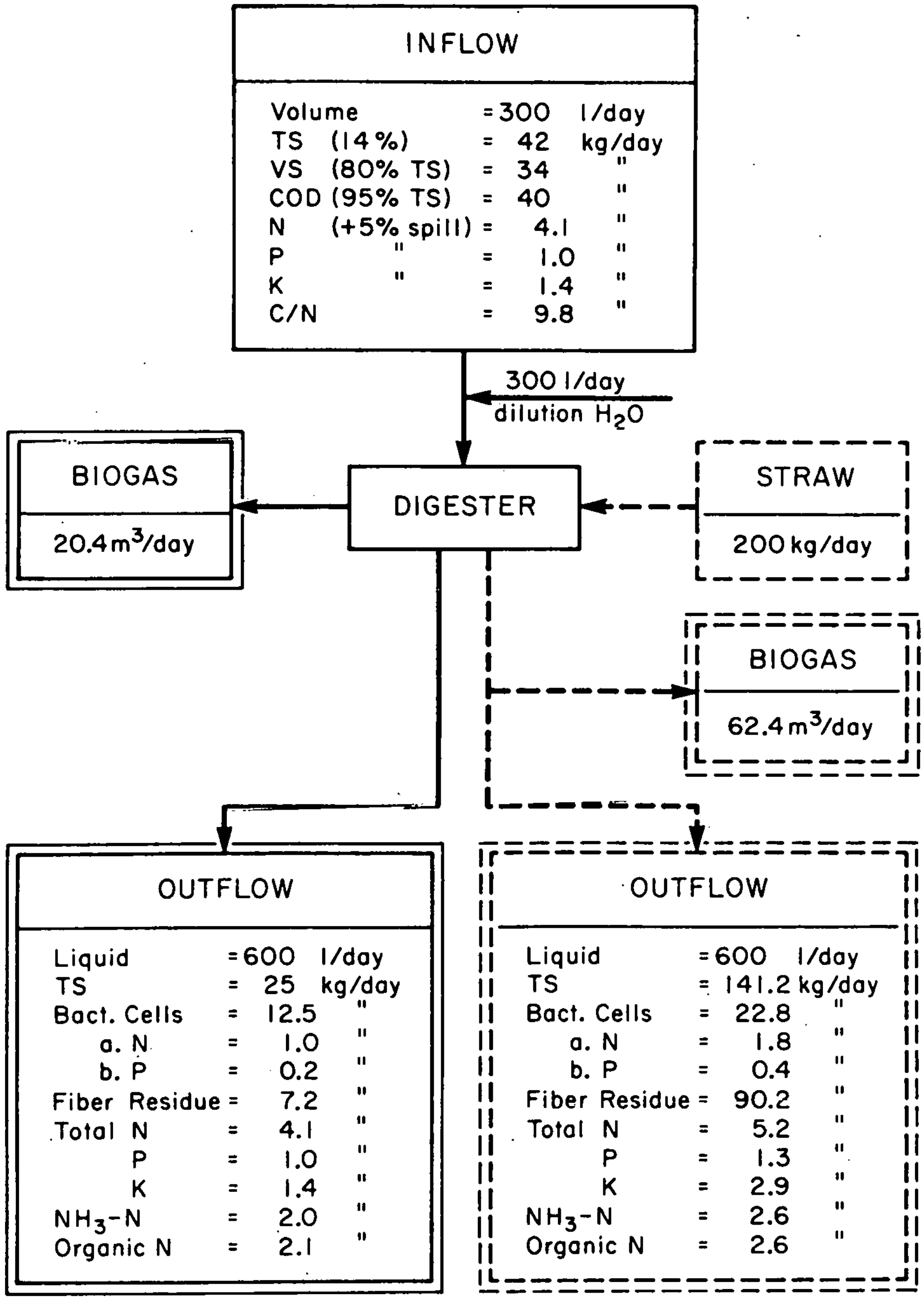


Figure 1. Material balances for the manure discharged by 100 pigs, being fed to gain weight from 50 to 100 kg at the rate of 0.8 kg/day. The manure is routed to a digester for production of biogas. Similar balances are shown for a system of management where straw is added to the digester for increased gas yields.

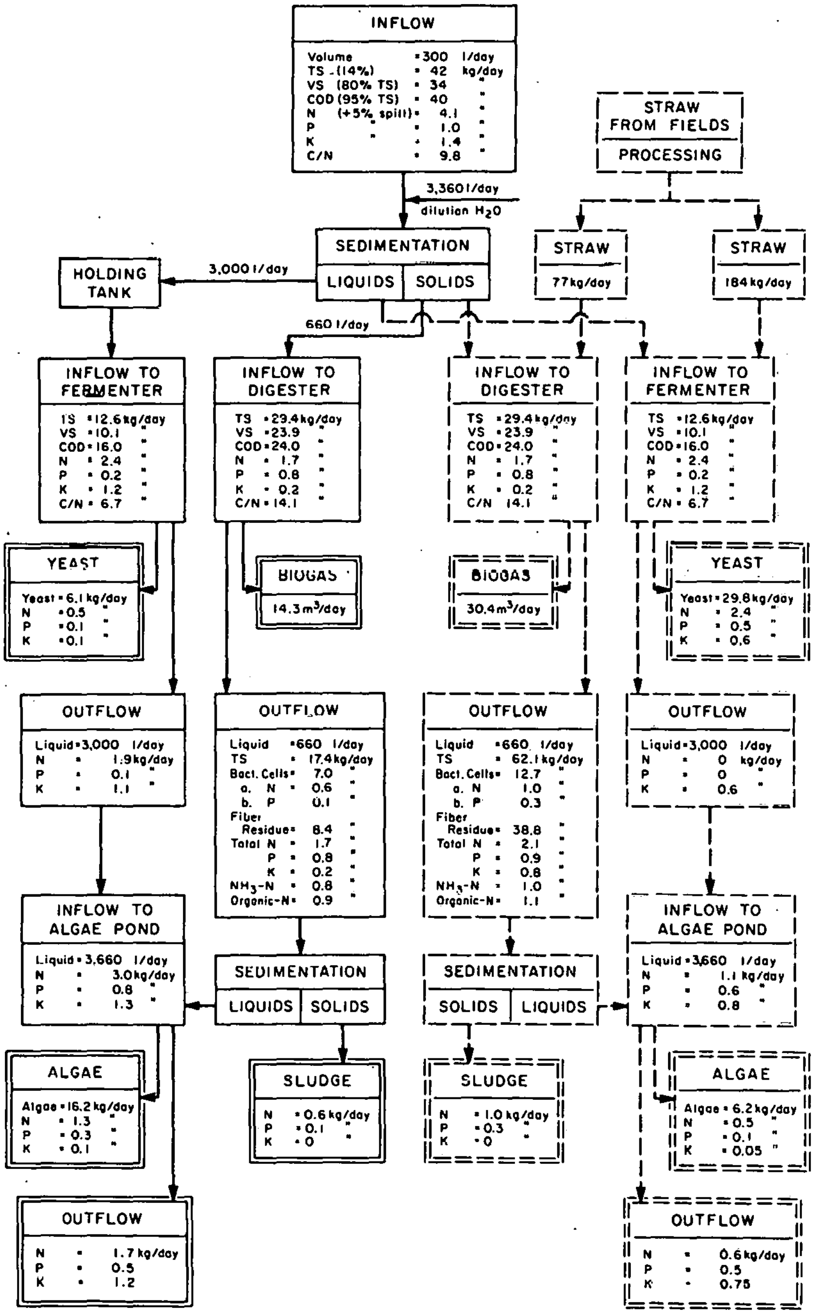


Figure 2. Material balances for the manure discharged by 100 pigs being fed to gain weight from 50 to 100 kg at the rate of 0.8 kg/day. The solids are digested and the liquids are used as a substrate for yeast. Similar balances are shown for a system of management where straw is added to the digester and fermenter.

A METHOD FOR INCREASING METHANE PRODUCTION IN ANAEROBIC DIGESTION SYSTEMS

Richard R. Spencer, Research Engineer,
Battelle-Northwest Laboratories

James A. Coates, Research Engineer,
Battelle-Northwest Laboratories

Battelle-Northwest Laboratories is presently conducting a research program investigating the effect of powdered activated carbon on the anaerobic digestion of municipal sewage sludge. The objective is to develop a technology for anaerobic digesters that will permit an increase in net energy production and a decrease in operating and capital costs at sludge handling facilities. Some of the potential benefits of carbon addition include increased methane production, increased volatile solids destruction, improved sludge dewatering characteristics, and enhanced process stability.

Laboratory experiments are being conducted using 14 bench-scale, single stage, anaerobic digesters. The units are equipped with mixing devices, and temperatures are maintained at 35 ± 1°C. In addition, a mobile anaerobic digestion pilot plant is operating at the Richland, Washington sewage treatment plant. This facility contains three 400 gallon digester vessels. All normal measures of digester performance are monitored, including gas production and composition, volatile solids destruction, volatile acids, soluble COD, pH, and alkalinity.

Studies have been performed establishing the optimum carbon type and dose range for enhancing the digestion process. Experiments have also examined the effect of powdered carbon on digesters operating at various solids residence times. During experiments conducted at a 10 day detention time a two fold increase in methane production was observed with the addition of carbon to stressed digesters. Based on preliminary testing, carbon accounts for about 10-20 percent enhancement in methane production in well-operating systems. Current research efforts are being directed toward determining the mechanism by which carbon aids the digestion process. Subsequent studies will evaluate the effect of carbon on digesters operating at temperatures below the mesophilic range.

The research clearly indicates the effectiveness of powdered activated carbon in enhancing methane production in poorly operating digesters. The impact of carbon on unstressed systems is undergoing continued evaluation in pilot plant experiments. The data generated in the laboratory and pilot plant studies will serve as the basis for planned full-scale demonstration of the carbon addition technique.

ATTENDEES PRESENTATIONS

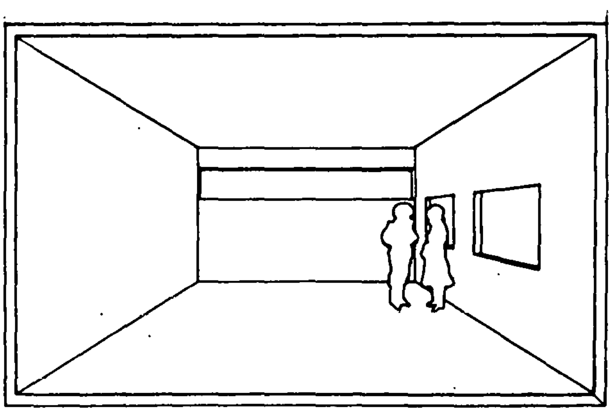
EXAMPLES OF USE OF THE LIGHTING SIMULATION PROGRAM <u>UWLIGHT</u>

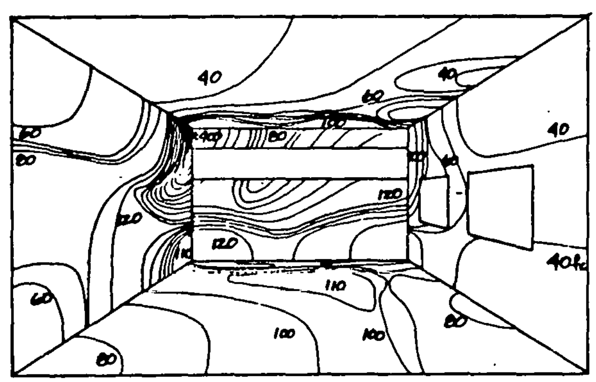
Marietta S. Millet
Department of Architecture
Gould Hall JO-20
University of Washington
Seattle, WA 98105

The role of daylighting in passive solar building design is one that deserves careful study. In commercial and institutional buildings, where large amounts of energy are expended daily to run lighting fixtures, the possibility of using daylight for illumination is apparently attractive and energy-conserving. The trade-offs are delicate, however. The window or skylight that lets daylight in either collects heat or allows heat to escape from the room. It is important to be able to predict the quality and quantity of the daylight for work and for general activities. A computer simulation program, named UWLIGHT, has been developed[1] for the purpose of evaluating these trade-offs in the context of passive solar building design.

There are an infinite variety of sky conditions and room configurations, which make it difficult to predict the effects of daylighting design. Two standard sky conditions, the totally overcast sky and the clear sky, are used to model extreme conditions. UWLIGHT can calculate Daylight Factor and/or footcandles for any number of openings in any wall or the ceiling for a rectangular room. It is intended to be used as a design tool. As such, it is designed to be simple and inexpensive to run. Input required is the physical description of the room and its openings, type of glazing, type of sky, orientation of the room, and type of electric lighting fixtures.

The results of sample room calculations were shown for different sky conditions, different daylighting designs, and supplementary artificial lighting. The one reproduced here shows a room 16' X 28' X 10' with low horizontal windows on the west wall (sill at 3', head at 6') and a high clerestory in the south wall (sill at 6', head at 8'). The curved lines are isolux contours (lines of equal light), drawn to show the light distribution at 2 p.m. on a clear winter day in Seattle (latitude 47.6° N).





1. This work is being done by Marietta Millet, Jim Bedrick, and Guy Spencer as part of an interdisciplinary research team through the Institute of Environmental Studies at the University of Washington, supported by a grant from the Washington State Energy Office. Many thanks to Phil Schmidt for the graphics.

The same room was shown under different sky conditions, clear and overcast, winter and summer. Another daylighting design, with a linear skylight added to this room along the east wall, was also shown. The effects of changing the surface reflectances of the room and using artificial lights to alter light distribution patterns were demonstrated. Indications of the quality of the light can be gleaned from the "steepness" of the isolux contours; from the maximum, average, and minimum illumination levels on the Workplane; and from the ratio of direct incident light to reflected light.

The program has two phases: an initial distribution stage, where the light reaching a "node" from the sky or from an electric lighting fixture is figured; and the interreflection stage, where the light reflected among the interior surfaces of the room is figured. The program can account for external obstructions, such as buildings across the street, and for overhangs and window jambs. Certain louvers and sunscreens can also be modelled.

EVOLUTION OF A HYBRID SOLAR HOUSE
WITH THE AID OF COMPUTER SIMULATION

by

Marc Rappoport
Energy Consultant

It is my observation as a solar home designer, that cost-effective, energy conscious housing can be achieved by using computer simulation that provides the designer with relevant data regarding heating performance from numerous variables that may be part of the design but have not been decided on. These variables help show the designer a direction which will achieve an integrated, esthetically pleasing design.

Use of a computer simulation having a high correlation to real performance can provide the public with the most cost-effective design and result in an optimally sized solar system. Another way of saying it is, that the simulations can point up errors in design and give the designer the experience of seeing hundreds of house simulations without building a house, saving thousands of dollars to the potential buyer. The designer can gain valuable knowledge of effective solar sized systems in his area for various house sizes, without using the rule-of-thumb, and with far more accuracy.

As home design becomes more energy conscious, designers will put more energy knowledge into their designs. Designers could make their mistakes on the computer, not real homes. To do this the programs must have the ability to provide information, in useful format, that the designer can use for making decisions about window area, roof size, south wall size, other windows, and storage capacity. In the development of a design for a residence many factors are considered with some 50 variables and the micro climate to be considered. The questions of view and exposure are additional to the other variables.

The computer simulation can be run varying south window area, vertical collector area, angled collector area, and storage capacity, these can be changing to one another and for all variations of each. The interrelationships of solar gain through the windows can have a large effect on the sizing of the solar collector area, indicating less area may be necessary. Use of the computer program for design development, site optimization, and solar component sizing provides information on heat gain with selected variables that helps give direction in sizing of the total house's elements. This format has these advantages of 'F' chart analysis for design decisions, but lacks at this time the economic component that 'F' chart has. For this reason, it is best to use both programs.

The importance of the passive solar gain is overlooked in 'F' chart and the passive additions in design can make large contributions to house heating. This process helps find the best mix. This area of solar design should have more emphasis than it has received for it can help the development of the solar industry and the home owner. It can help with more efficiently designed systems, and with fewer failures the industry can have more of an impact on the energy problem.

Solar-powered Temporary Airway Lighting System

Craig Mortensen, Electrical Engineer
Bonneville Power Administration

The Bonneville Power Administration has helped develop a solar-powered, self-contained temporary airway lighting system. It will be used to light the tops of transmission towers when regular sources of power are not available during construction or emergencies. The system is designed to meet Federal Aviation Administration requirements for temporarily marking a structure hazardous to aircraft. It is on display at the Solar '78 Northwest Conference.

A 24-volt strobe light activated by a photocell at nightfall flashes about 40 times a minute at an intensity of 1500 peak effective candelas. The light operates on a continuous current of about 1 amp from batteries charged with a 4 amp (peak) current from a solar collector panel measuring 4 by 5 feet. The batteries can be placed at the base of a tower and the panel mounted at different angles on the tower about 30 feet above the ground. The batteries will store about 160 amp-hours (roughly 10 days of power).

BPA has acquired three specially built lights from Flash Technology Corporation of Nashua, New Hampshire, for installation at a Columbia River crossing.

The system is designed to generate sufficient power for such relative low solar radiation areas as Seattle for 9 months of the year. Larger components would be required for the months of November, December and January. BPA construction usually is at a low ebb during these winter months.

BPA is also developing an amp-hour recorder for use with the system. The recorder will monitor current flowing to the light as well as the charging current. Readings shown will include the voltage on the battery every 24 hours. The recorder can be programmed to show readings for briefer intervals.

BPA plans to use solar cells to power remote repeater stations on its communications network. It is investigating the feasibility of using solar cells in cathodic protection systems and for permanent airway lighting units.

TERA One Solar Experience

by

C. D. Stultz, R. S. Carr, P. M. Sööt

TERA One, the solar house and conservation laboratory sponsored by PP&L and other companies is now completing its first year of operation. To date, more than 7 1/2 million experimental data points have been taken, on 78 different parameters including solar radiation, wind speed and direction and numerous system temperatures. Insulation tests are also being conducted to evaluate the relative performance of various types of insulation located in different parts of the household. TERA One is open to the public and between June 1, 1977 and June 1, 1978 over 45,000 people visited the house. Visitors represented 45 States of the U. S. and 28 foreign countries.

The information presented in this paper include reduced data upon which some conclusions have been drawn. As the project continues these data will be supplemented, and additional substantive conclusions will be offered relative to a number of systems which will be studied at TERA One.

Other publications are currently available from PP&L which describe the physical layout and equipment to be found in TERA One.

The daily amounts of sunlight falling on the TERA One collector for the first year varied from a low of less than 30 BTU/Ft^2/day, to a high of 1710 BTU/Ft^2/day, a ratio of almost 60 to 1. The total amount of solar energy incident on the collector surface (185 Ft^2 of active area) for the 12-month period of this report is approximately 63 million BTU. If this energy was converted to useful heat at a conversion efficiency of 50%, it would be equivalent to 9,170 kwh of electricity valued at about $222 at present PP&L rates. Preliminary analysis of the collector and collector-storage cycle indicate that instantaneous collector efficiencies of 77% have been reached with overall efficiencies of incident to stored energy of 37% being achieved. If the solar energy is used to directly heat the house without first going to storage, efficiencies greater than 50% are common.

TERA One utilizes two 1.5 ton water-to-water heat pumps in parallel to complement the main solar collector heating system in the winter and to provide cooling in the summer. During the past heating season, both heat pumps were required on only 12 occasions to heat the 1250 ft^2 house. One was usually sufficient in combination with the solar collector-storage system. At no time during the winter season was the backup electric heating unit needed and it is anticipated that it will be required only under extended cold and cloudy weather conditions.

It has been determined that TERA One and the Portland airport experience essentially the same temperatures. The result is that both locations have about the same number of heating and cooling degree-days when averaged over an extended period of time. This is not true of comparisons made with other local weather stations such as Hillsboro which is miles to the west from TERA One. This points out that even in the Portland area, microclimates are evident and use of weather station data to project heat losses at other locations may not be reliable.

Climate

Solar Radiation (Insolation)

In Portland, Oregon, the 30-year horizontal daily average amount of insolation is 1,300 BTU/ft^2/day as reported by the U. S. Weather Bureau. The daily amount of solar energy available here varies from 370 BTU/ft^2/day in January to 2,050 BTU/ft^2/day in June.

At TERA One, insolation data is being gathered to provide detailed local information on amounts of solar radiation available throughout the year.

Annual variations in the amount of insolation at any one location is caused by the yearly change in orientation of the earth's axis with respect to the sun. The results of this change are days becoming longer and hotter during the summer, with the reverse being true in the winter. This changing condition can be used to optimize a solar collector's inclination such that the amount of insolation is maximized during the times of peak demand. For TERA One, its 70° collection angle maximizes the energy received during the winter months. A horizontal surface would receive its maximum energy during the summer months and, as might be expected, these two surfaces, all other factors being equal, should receive the same amount of energy during mid-September and March. The cross-over point will be slightly different as measured at TERA One and shown in Table 1 because the inclined surface receives a significant amount of reflected radiation from surface bodies (i.e., the deck, ground, trees, buildings, etc.), while the horizontal surface does not.

Table 1

Available Monthly Insolation at TERA One

MEASURED IN BTU/ft^2

		Horizontal-h	70° Angle-a	h/a
1977	Jun.	55,387	40,624	1.36
	Jul.	53,212	40,577	1.31
	Aug.	45,319	39,773	1.14
	Sep.	28,125	29,595	.95
	Oct.	24,120	34,848	.69
	Nov.	10,174	16,585	.61
	Dec.	6,461	12,003	.54

		Horizontal-h	70° Angle-a	h/a
1978	Jan.	6,555	8,602	.76
	Feb.	11,516	15,083	.76
	Mar.	26,358	31,259	.84
	Apr.	29,795	27,387	1.09
	May	42,262	32,565	1.30

It may be of interest to compare the results in Table 1 with available historical data. Since historical solar radiation data has been available for Portland only for a relatively short time, the comparison has to be made with historical data for other cities in Oregon. Astoria and Corvallis have had radiation measured for more than 15 years. Comparing the results from TERA One with those data, the following observations can be made:

1. In January, 1978 the collector received only 60 percent of anticipated solar radiation.

2. During September, 1977, and February, April and May, 1978 the collector received between 70 and 80 percent of long range average solar radiation. A later section of this article notes that September, 1977 was also notably colder than average.

3. August, 1977 was somewhat below average for insolation, even though it had the hottest August day on record for Portland.

4. All other months were within 20 percent of the anticipated insolation amounts.

It is a common notion that regions such as the Willamette Valley which experience many cloudy days are not good regions for solar collectors. This is not necessarily true because of the moderate climate found here. This climate exhibits much cloud cover which reduces the amount of solar radiation received; however, the number of heating degree-days are also reduced. A better indicator than monthly solar insolation data for determining the best locations for solar heating is the ratio of the incident solar radiation to the heating degree-days during the heating season. This ratio has been used by the Federal DOE in suggesting the relative merits of solar heating in various Northwest locations as compared to sites in other parts of the United States.(1) These ratios ranged from a low of 0.60 for Chicago, Illinois to a high of 1.07 for Medford, Oregon. Using the '77-78 data on solar radiation and heating degree-days at TERA One we arrive at a ratio of .84. This shows that for the winter of '77-78 Portland was comparable to Corvallis (.88) with respect to solar heating sites. This is not an unexpected finding since both Portland and Corvallis lie in the Willamette Valley.

Temperature

Table 2 shows the temperature variations at different locations at TERA One. It is interesting to note that the vestibule and greenhouse temperatures are always greater than both the minimum and maximum outside temperatures, which indicates these two spaces could be a source of energy for the structure or are at least a good buffer for the structure during the heating season.

Table 2

TEMPERATURES EXPERIENCED AT TERA ONE

	OUTSIDE AMBIENT		GREENHOUSE		VESTIBULE		INSIDE		ROOF SOIL	FOUNDATION
	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	AVG.	AVG.
Jun.	92	48	126	57	106	56	81	65	76	72
Jul.	94	47	131	54	102	56	80	62	78	72
Aug.	103	49	141	54	107	57	85	63	82	75
Sep.	79	46	135	53	83	54	85	65	68	64
Oct.	71	41	125	52	75	50	86	65	59	58
Nov.	63	24	106	36	70	37	78	66	49	49
Dec.	58	25	99	40	66	37	80	60	48	47
Jan.	53	21	91	36	66	34	83	66	43	44
Feb.	62	33	112	43	71	42	82	59	47	48
Mar.	71	33	121	41	74	43	77	60	50	53
Apr.	76	34	112	41	80	46	71	60	54	55
May	88	37	114	43	93	49	83	62	59	N/A*

*Instrument Malfunction

The TERA One outside ambient temperatures compare closely with those recorded at the Portland Airport by the U. S. Weather Bureau. These values are, on the average, within a few percent of each other. The Airport is 8 miles northeast of TERA One, but on the same side of the West Hills of Portland. On the other side of the West Hills there is apparently a difference in temperatures. A comparison of TERA One temperatures with those reported by the Hillsboro weather station shows that Hillsboro has slightly warmer temperatures in the summer and cooler ones in the winter. Hillsboro is about 14 miles west of TERA One. This indicates that micro-climates may be an important factor to consider for a homeowner or builder trying to anticipate monthly heating losses using data taken some distance from a housing site.

Degree-Days

Energy consumption varies almost directly as the difference between outside temperature and 65°F. This difference between 65°F and the average outside temperature for a day provides an index called the Degree-Day to estimate heating requirements.

A heating degree-day results for every degree the average outside temperature is below 65°F for a 24-hour period, and a cooling degree-day results when the average temperature is above 65°F.

Table 3 shows the comparison of degree-days at TERA One with the Portland airport (USWB). There is good correlation of the data between the two locations. A listing of 30-year averages for these months also provides a comparison of 1977 climate with past years. The most notable variation occurred in August when Portland experienced its hottest August day on record. During this same period, there were also several consecutive days with unusually high temperatures. As a result, the cooling degree days were twice the average for that month.

Table 3

DEGREE DAYS IN PORTLAND

	HEATING			COOLING		
	TERA One	USWB		TERA One	USWB	
MONTH	77-78	77-78	30-Yr. Avg.	77-78	77-78	30-Yr. Avg.
1977						
June	61	68	128	55	42	38
July	38	40	48	85	90	114
August	30	19	56	229	233	106
September	132	131	119	6	10	35
October	304	339	347	0	0	0
November	604	644	591	0	0	0
December	716	707	753	0	0	0

MONTH	HEATING TERA One 77-78	HEATING USWB 77-78	HEATING USWB 30-Yr. Avg.	COOLING TERA One 77-78	COOLING USWB 77-78	COOLING USWB 30-Yr. Avg.
1978						
January	766	764	834	0	0	0
February	536	561	622	0	0	0
March	451	485	598	0	0	0
April	398	430	432	0	0	0
May	294	N/A*	264	10	N/A*	7

*Information was not available at the time that this report was published.

The degree-days in Table 3 have been determined by the standard ASHRAE method of averaging the maximum and minimum temperatures for a day (i.e. $\frac{T\ max + T\ min}{2}$) and subtracting this value from 65°F. This method is most commonly used because weather stations report T max and T min for the day and not the true daily average. Since the TERA One data system records temperatures every five minutes, it was possible to determine the true daily average (median value) and use this value to generate a second set of degree-days which could be compared with those using the ASHRAE method. Table 4 lists the degree-days determined by both methods for the months reported in this publication. These data show that there can be large variations on a month-to-month basis, but a good correlation is observed over the entire twelve-month period. This implies that degree-day data may be useful for projecting annual energy use for a structure, but monthly energy usage projections may be notably in error during mild months such as September.

(Note: Comparison of data in Tables 3 and 4 shows an apparent discrepancy in degree-day totals. The difference is that Table 3 uses "adjusted monthly total" data for TERA One. Since the data collection system at TERA One has at times been down due to power failures or maintenance requirements, it is necessary to "adjust" the available data so it becomes representative of a total month. Actual collected monthly data are multiplied by a ratio of total days in the month to days with reported data to produce the adjusted totals. The data shown in Table 4 are unadjusted values. These values were used for expediency and the percent difference reported would be the same whether the data were adjusted or not.)

Table 4
Comparison of Degree-Day Calculation Method

		ASHRAE Method[1]	True Value Method[1]	% Difference[2]
1977	June	13.1	41.4	-216
	July	47.6	30.0	+ 37
	August	199.1	167.4	+ 16
Summer Totals		259.8	238.8	+ 8 summer avg.
	September	124.8	168.0	- 35
	October	266.4	291.2	- 9
	November	484.7	455.4	+ 6
	December	499.1	464.1	+ 7
1978	January	766	775	- 1
	February	536	566	- 6
	March	451	484	- 7
	April	398	459	- 15
	May	294	316	- 7
Winter Totals		3819.6	3978.7	- 4 winter avg.

Insulation and Heat Flow

Three major types of insulation were installed at TERA One: cellulose fiber, fiberglass, and foam. Each insulation under test has a heat flow transducer to monitor the energy flowing in or out of the wall section. The sections of wall were chosen to permit several variations in wall construction and orientation to be tested. This also allows direct comparison of the various types of insulation.

The initial findings of the insulation tests show that uninsulated, below-grade concrete walls experience much higher losses than insulated ones. This is not an unexpected condition since it is well known that basements are cool in the summer time and colder in the winter when compared to the rest of the household. What will be published in later reports is the actual magnitude of this effect for year round conditions. It has also been determined that there are large differences in the net wall heat losses through easterly and southerly facing walls. Low R value insulations in the south wall allow a greater amount of solar

[1] Unadjusted totals (i.e., heating + cooling degree-days) for the month.

[2] (ASHRAE - True Value)/ASHRAE

energy into the interior of the house than very high R value insulations. If one compares the net monthly heat losses for two insulations of different R values in a south wall, the lower R value insulation might show lower total losses for mild months such as September and April. The east facing wall would have little solar effect, showing high R value insulation to be the best even in mild months. This shows the need for accumulating year around data before truly objective conclusions can be drawn concerning the optimum insulation.

Solar Heating System Efficiency

During October and November a number of days with clear sky conditions were used to evaluate, on a preliminary basis, the performance of the solar collection system. The results are shown in Figure 1.

The instantaneous efficiency of the collector compares the insolation available (Ia) and the energy output (Qo) of the collector for a number of 5-minute segments.

The average daily efficiency of the collector then compares the Ia and Qo for a number of daily cycles.

The average daily efficiency of the collector-storage systems compares the Ia and the energy to storage (Qs). This was calculated for several individual days.

This evaluation shows the efficiencies to be quite good, with an instantaneous efficiency of 77 percent, an average efficiency of 58 percent, and an overall efficiency from solar into storage of 37 percent.

It should be qualified that the above values represent the transfer efficiencies between various components in the collection storage system. This does not take into account the fact that a large fraction of the solar energy lost in the transfer process ultimately ends up as heat in the house. In the heating season this energy appears as an indirect solar component whose magnitude can only be inferred because of the complexity of the processes involved. Hence, the quoted efficiencies are slightly less than the actual total solar contribution from the collector to the house.

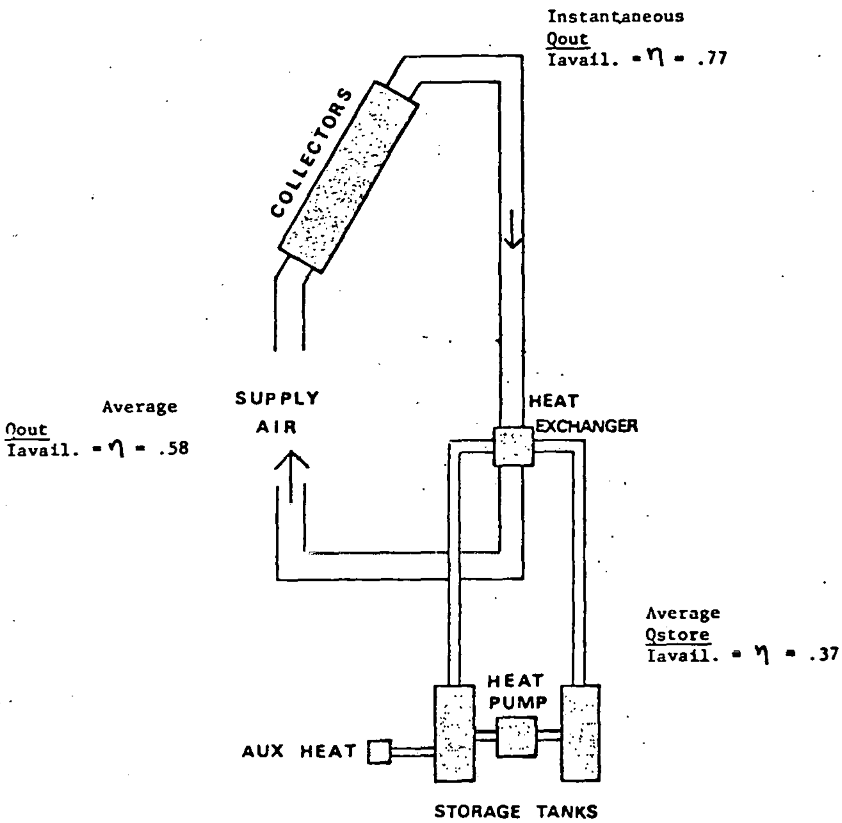


Figure 1. System Efficiency

EVALUATION/PNWSEA/EXHIBITORS/SPEAKERS/ATTENDEES

SOLAR 78 NORTHWEST EVALUATION SUMMARY

by

Linda Reppond
Conference Evaluator

Of the 800 participants in SOLAR 78 NORTHWEST, 165 (approximately 20%) turned in Conference Feedback forms. The data in this summary is based on that sample.

The clear highlight of the conference was the Sunday bruch speaker, David Wright, AIA, who spoke on "Natural Solar Architecture". Fifty respondents named him specifically as "the highlight of SOLAR 78".

The overall evaluation of the conference was rated high, with 79% of the respondents marking either "Great conference, just what I wanted!" or "Good conference, mostly useful information".

Conference details rated highly include registration, length of conference, audio-visual presentations and acoustics. Details rated poorly or as needing improvement include the setting (Sheraton Hotel), meals and room space, and commercial and non-commercial exhibits.

Pre-conference publicity was rated adequate by 79% of the respondents. Areas noted as having inadequate publicity include Vancouver, B.C., Bellingham, Washington, and Southern Oregon.

Sixty-four percent of the respondents noted that the content of the sessions was "about right" while 3% thought it was "too technical" and 33% thought it was "too general".

In response to a question about interest in attending a conference next year in Spokane, 57% said yes, they would attend in Spokane; 32% said no; and an additional 19% said maybe, depending primarily upon scheduling.

Many respondents took time to make suggestions and write extensive comments. All comments and suggestions were recorded to be forwarded to the SOLAR 79 steering committee. A few of the comments include:

1) Move to a college campus;

2) Run two concurrent sessions in each subject area: one for lay people and one for professionals;

3) Add publicity and workshops geared towards educating the general public.

The participant profile was primarily young professionals (78% between ages 20 and 40), with architects and designers most strongly represented (121), followed by educators (64) and engineers (57). Participant interest in solar energy focused on designing and building solar homes for others (61) and building solar systems in participants' own homes (59).

PNWSEA

pacific northwest solar energy association
2332 e. madison, seattle, wa. 98112

What are we?

PNWSEA is a grassroots, technical-professional organization whose primary purpose is to further the development of solar energy with concern for the environmental, social and economic fabric of the region. This is being accomplished through such activities as those listed below. PNWSEA serves to inform the public and institutional and governmental bodies of the Northwest states of Washington, Idaho, and Oregon and seeks to raise the level of public awareness of its purposes. We are affiliating with the American Section of the International Solar Energy Society (ISES-AS).

Who are we?

We are strictly a solar organization and want to attract a wide base of solar advocates regardless of background, employer, political affiliation, or attitudes about other energy sources. We want the best technical expertise, the strongest pro-solar activists, members of solar industries, and educators -- as well as those citizens simply interested in keeping up with solar progress in our region.

What do we do?

Depending upon the strength of our members involvement, and keeping in mind that PNWSEA activities will be centered to a large extent around the activities of local chapters, our goals are as follows:

- provide a means of information exchange among members, primarily through the publication of the PNWSEA newsletter, SUN STROKES, 4-6 times per year;
- serve as a clearinghouse for identifying solar projects, speakers, building sector participants, information sources and directories, etc., in the Northwest;
- provide the general public and the media with an independent source of credible and technically sound solar information for applications in the Northwest;
- facilitate the organization of workshops and educational seminars through local affiliates, drawing upon the materials and technical resources developed through its membership & its clearinghouse activities;
- assist in organizing the annual Northwest solar conference and exhibit;
- develop other activities and directions as initiated by the membership.

PACIFIC NORTHWEST SOLAR ENERGY ASSOCIATION
Membership Application Form

NAME ______________________________ PHONE __________
ADDRESS ______________________ CITY __________ STATE ______ ZIP ______
AFFILIATION ______________________________

PLEASE CHECK THE AREAS OF YOUR GREATEST PERSONAL INTEREST AND CIRCLE THE AREAS ON THE LEFT IN WHICH YOU HAVE EXPERTISE AND/OR WOULD LIKE TO ASSIST IN DEVELOPING MATERIALS FOR PNWSEA USE:

INTEREST AREAS

// annual conference & exhibit
// general information
// system design--passive, active, hybrid
// installation and maintenance
// equipment supplier directory
// research--system performance, economics, area of research: __________
// consumer protection
// financing, appraising, insuring, etc.
// regulatory code, zoning & sun rights
// legislative activity
// educational institutions
// information networking, newsletter
// utility interface
// media relations
// speakers' bureau

SOLAR TECHNOLOGIES

// solar hot water
// solar heating (passive & active)
// solar cooling (passive & active)
// large wind systems
// small wind systems
// biomass
// small head hydro
// solar-thermal
// solar-thermal-electric
// photovoltaics
// wind data collection
// solar radiation data collection
// biomass availability data
// water power data
// energy efficient design
// other: __________

ANNUAL MEMBERSHIP

	ISES-AS MEMBERS	NON-ISES-AS MEMBERS
UNEMPLOYED	$ 5.00	$ 5.00
STUDENTS	5.00	10.00
REGULAR MEMBERSHIP	10.00	15.00
CONTRIBUTING MEMBER	$ 50.00	
SUSTAINING MEMBER	100.00	

If you are a member of ISES-AS, please list the topical divisions of which you are a member: ______________________________

ANY CORRESPONDENCE, INCLUDING PNWSEA APPLICATIONS WITH DUES OR NEWSLETTER CONTRIBUTIONS, SHOULD BE SENT TO:

PACIFIC NORTHWEST SOLAR ENERGY ASSN.
c/o ECOTOPE GROUP
2332 E. MADISON
SEATTLE, WA 98112

SOLAR 78 NORTHWEST

COMMERCIAL EXHIBITORS

Dave Ammons
DSA Solar Heating and Insulating
P.O. Box 352
Gladstone, Oregon 97027

Charles L. Bliege, P.E.
Hitek, Inc.
42673 Ames Creek Dr.
Sweet Home, Oregon 97386

Tom Brownell
Boeing Aerospace Company
P.O. Box 3999
Seattle, Washington 98124

Anton Eder
Energy Alternatives, Inc.
2217 South Main
Moscow, Idaho 83843

Glenn Howk
Jack Howk Plumbing
3442 S.E. Belmont
Portland, Oregon 97214

William R. Miller
Miller & Sun Enterprises
P.O. Box 19151
Portland, Oregon 97219

John Peterson
Peterson Solar Drier
Box 303
Corvallis, Oregon 97330

Marc Rappaport
Earthouse Designs
P.O. Box 10445
Portland, Oregon 97210

Eugene R. Smerchek
Solar Northwest Corp.
P.O. Box 518
Longview, Washington 98631

John Stackpole
Thermal Efficiency
815 Mercer Street
Seattle, Washington 98109

Perry Scott Woodfin
Community Design Center of the NW
4604 Stone Way N.
Seattle, Washington 98103

Devon E. Wardwell, Jr.
Radiant Systems Northwest
Rt. 2 Box 65
Molalla, Oregon 97038

Books: The Catbird Seat Books
Deborah Robboy, proprietress
1231 S.W. Washington
Portland, Oregon 97205
(503) 222-5817

Tapes: Rose City Sound
Wayne Lund
1925 S.E. Morrison St.
Portland, Oregon 97214
(503) 238-6330

SOLAR 78 NORTHWEST

NON-COMMERCIAL EXHIBITORS

Dan Menking
Atomics International Division
Rockwell International
Rocky Flats Plant, Colorado

testing of small (less than 100kw) wind energy conversion systems

Matthew Hummel
Northwest College and University Association for Science (NORCUS)
Richland, Washington

"Guess It" computer terminal with solar energy programs

Craig Mortensen
Bonneville Power Administration
Portland, Oregon

solar cell array used for airway lighting

Dr. David Renné
Pacific Northwest Laboratory
Richland, Washington

graphic exhibit depicting research and coordinating activities in the wind characteristics program of the federal DOE's wind energy program

Bob Lorenzen/Steve Baker
University of Oregon Solar Center
Eugene, Oregon

Northwest solar radiation data-gathering stations

Carl Stultz
Pacific Power & Light Co.
Portland, Oregon

TERA One project

Sam Sadler
Lane County
Office of Appropriate Technology
Eugene, Oregon

low-cost water heater

Bill Overall
The Community Action Team of Columbia County
St. Helens, Oregon

low-cost water heater

NON-COMMERCIAL EXHIBITORS (CONT'D)

Fred Nelson, Associate Editor
Sunset Magazine
Menlo Park, California 94025

photographic exhibit: Western passive solar projects

ILLUSTRATION BOARDS

The Architects Forum: Hybrid Solar Heating

Campfire Girls (Bill Meyers): solar-heated 165,000 gal. pool

Bill Church, AIA: Schwartz residence

Tom Clark, Campbell-Yost-Grube, Architects and Planners

Andrew Laidlaw, AIA: Sparta Solar House

Wm. D. Perry: Low Energy Housing

Portland Community College: Solar Hot Water Workshop

Lauren A. Smith, AIA: Koler's Cabin

Sunlight Holding Company

SPEAKERS AND STEERING COMMITTEE

Ray Anderson
Washington State Energy Office
400 E. Union
Olympia, Washington 98504

Robert Baker
Wind Power Group
Dept. of Atmospheric Sciences
Oregon State University
Corvallis, Oregon 97331

Steven Baker
Solar Center
University of Orėgon
Eugene, Oregon 97403

Doug Balcomb
Solar Energy Group
Mail Stop 571
Los Alamos Scientific Lab
Los Alamos, N.M. 87545

Sara Balcomb
1 First Village Rt. 3
Santa Fe, N.M. 87501

David Baylon
Ecotope Group
2332 E. Madison
Seattle, Washington 98112

Jim Bennet
Sun Life Solar Products
P.O. Box 447
Clackamas, Oregon 97015

Birny Birnbaum
Grant County Comm. Action
604 W. Third
Moses Lake, Washington 98837

Dr. John S. Blakemore
Professor of Applied Physics
Oregon Graduate Center
19600 N.W. Walker Rd.
Beaverton, Oregon 97005

*Douglas R. Boleyn, P.E.
Portland General Electric Co.
121 S.W. Salmon
Portland, Oregon 97204

Emily Boleyn
17610 Springhill Place
Gladstone, Oregon 97027

Xerpha Borunda
FIRL
20 and Race Streets
Philadelphia, PA 19103

*William C. Church, AIA
4004 N.W. Thurman St.
Portland, Oregon 97210

Kye Cochran
AERO
435 Stapleton Bldg.
Billings, Montana 59101

Kay Collins
The Conservation Library
Denver Public Library
1357 Broadway
Denver, Colorado 80203

Elizabeth Coppinger
Ecotope Group
2332 E. Madison
Seattle, Washington 98112

Dr. Raymond Currier
Associate Professor
Dept. of Forest Products
Oregon State University
Corvallis, Oregon 97331

Dr. Melvin Cutler
Proessor of Physics
Oregon State University
Corvallis, Oregon 97331

*Donald J. Davey
Energy Conservation Officer
Bonneville Power Administration
P.O. Box 3621
Portland, Oregon 97208

Bill Day
Anchor Tools and Wood Stoves
618 N.W. Davis
Portland, Oregon 97209

Dick Delauder
Asst. Chief Plumbing Inspector
Building Codes Division
State Dept. of Commerce
Salem, Oregon 97310

*Dr. Jean F. Delord
Professor of Physics
Reed College
Portland, Oregon 97202

David Deppen
P.O. Box 3945
Portland, Oregon 97208

Kirk Drumheller
Battelle - NW Labs
P.O. BOx 999
Richland, Washington 99352

*Richard L. Durham
Special Projects Officer
U.S. Dept. of Energy
P.O. Box 550
Richland, Washington 99352

Henry Eaton, Staff Member
Committee on Science and Tech.
U.S. House of Representatives
2321 Rayburn Bldg.
Washington, D.C. 20515

Anton "Kip" Eder
Energy Alternatives, Inc.
1006 East D Street
Moscow, Idaho 83843

*Conference Steering Committee

Ken Eklund
Ecotope Group
2332 E. Madison
Seattle, Washington 98112

Ted Engelmann
c/o Idaho Office of Energy
State House
Boise, Idaho 83720

Alex Fassbender
Battelle - NW Labs
P.O. Box 999
Richland, Washington 99352

Dr. Ekkehart Gasper
Dept. of Soil Science
Oregon State University
Corvallis, Oregon 97331

Don Gibbs
3701 Sycamore Dr.
Boise, Idaho 83703

*Howard L. Glazer, AIA
The Architects Forum
2068 N.W. Flanders
Portland, Oregon 97210

Mayor Neil Goldschmidt
City of Portland
City Hall
Portland, Oregon 97204

*Jill Goodnight
Research Specialist
Battelle - HARC
400 N.E. 41st
Seattle, Washington 98105

Kirk Hall, Director
Idaho Office of Energy
State House
Boise, Idaho 83720

Dr. Donald Hardy, Senior Scientist, Wind Energy Section
SERI
1536 Cole Blvd.
Golden, Colorado 80407

David P. Hartmann, Project Mgr.
Energy Retrieval-Solar System
Bonneville Power Administration
P.O. Box 3621
Portland, Oregon 97208

Dr. Martin L. Hellickson
Asst. Professor
Dept. of Ag. Engineering
Oregon State University
Corvallis, Oregon 97331

*Marion Hemphill
Energy Advisor
City of Portland
620 S.W. Fifth Rm. 610
Portland, Oregon 97204

Roy Henderson
35160 S.E. Gunderson
Sandy, Oregon 97055

John Hermannsson
Anderson Hall 108
Oregon State University
Corvallis, Oregon 97331

Steven G. Hickok
Field Representative for U.S. Senator Mark O. Hatfield
Pioneer Courthouse
Portland, Oregon 97204

*Suzi Hosch
Coordinator of Emerging Energy Sources - Wash. St. Energy Off.
400 E. Union
Olympia, Washington 98504

Randy Hoskins
Rocket Research Co.
York Center
Redmond, Washington 98052

Jane Howard
Ecotope Group
2332 E. Madison
Seattle, Washington 98112

Lee Johnson
External Affairs Officer
U.S. Dept. of Energy
1992 Fed. Bldg. 915 Second Ave.
Seattle, Washington 98174

*Lee Johnson
RAIN Editor
2270 N.W. Irving
Portland, Oregon 97210

Roy Josi
Space Conditioning Consultant
Portland General Electric Co.
121 S.W. Salmon
Portland, Oregon 97204

Dr. Daniel Kaehn
Physics Department
University of Oregon
Eugene, Oregon 97403

Bill Kingrey
4208 E. 16th
Spokane, Washington 99203

*Al Kiphut
Solar Specialist
Oregon Dept. of Energy
111 Labor & Industries Bldg.
Salem, Oregon 97310

Dr. Glenn Kranzler
Washington State University
Dept. of Ag. Engineering
Pullman, Washington 99164

Andrew Laidlaw, architect
2019 N. 16th
Boise, Idaho 83702

*Mary Lawrence
Conference Coordinator
620 S.W. Fifth, Rm. 610
Portland, Oregon 97204

*James P. Leshuk, P.E.
775 High Street
Woodburn, Oregon 97071

G. Lonn Liffick
U.S. Dept. of Energy
P.O. Box 550
Richland, Washington 99352

*Conference Steering Committee

Mark Lindgren
5211 S.W. Vermont
Portland, Oregon 97219

R. H. Lindsey
Asst. Mgr. for Reg. Activities
U.S. Dept. of Energy
P.O. Box 550
Richland, Washington 99352

David Lohman, Staff Member
Committee on Appropriations
U.S. Senate
1401 Dirksen Bldg.
Washington, D.C. 20510

Bob Lorenzen
Solar Center
University of Oregon
Eugene, Oregon 97403

*Richard A. Lowell, Asst. Vice-Pres. Appraisal Dept., Benj. Franklin Federal Savings & Loan Assn. 1 S.W. Columbia
Portland, Oregon 97258

Bill Mackie
Oregon Dept. of Energy
111 Labor & Industries Bldg.
Salem, Oregon 97310

Marsha Mackie
Yamhill County Energy Office
Courthouse
McMinnville, Oregon 97128

Tim Magee
Ecotope Group
2332 E. Madison
Seattle, Washington 98112

Dr. Keith Masterson
SERI
1536 Cole Blvd.
Golden, Colorado 70407

Tom McCall
c/o KATU-TV
2153 N.E. Sandy Blvd
Portland, Oregon 97232

Gloria McGregor, Director
Community Development
City of Davis
226 "F" Street
Davis, California 95616

Dr. Fred Miller, Director
Oregon Dept. of Energy
111 Labor & Industries Bldg.
Salem, Oregon 97310

Roger L. Moment, Manager
Tech. Dept. Wind Systems Prog.
Atomics International Division
Rocky Flats Plant P.O. Box 464
Golden, Colorado 80407

David R. Mosena
Director of Research
American Society of Planning Officials 131 E. 60th St.
Chicago, Illinois 60637

William Moshofsky, Vice-Pres.
Govt. Affairs & Environment
Georgia-Pacific Corp.
900 S.W. 5th
Portland, Oregon 97204

Laird Parry
Battelle - NW Labs
P.O. Box 999
Richland, Washington 99352

Janis Philbin
4811 7th Avenue
Sacramento, California 95820

Dr. David Renné
Atmos. Physics Sec., Atmos. Science Dept.
Battelle - NW Labs
P.O. Box 999
Richland, Washington 99352

*John S. Reynolds
Professor of Architecture
University of Oregon
Eugene, Oregon 97304

George Reynoldson
Space-Time, Inc.
13654 N.E. 16th
Bellevue, Washington 98005

Jack Robertson
Acting Regional Rep., Reg. X
U.S. Dept. of Energy
915 Second Ave.
Seattle, Washington 98174

Ed Rossiter
Mgr. Business Development
Acurex Aerotherm
485 Clyde Ave.
Mountain View, CA 94042

Chris Salsbury
N. 4609 Post
Spokane, Washington 99205

Charles Schachle
Wind Power Products Co., Inc.
KPFF Consulting Engineers
700 Lloyd Bldg.
Seattle, Washington 98101

M. Peter Scofield
Mgr. of Solar Programs
Idaho NEL
P.O. Box 1625-TSA
Idaho Falls, Idaho 83401

Tom Scott
TWI/Solar Systems
P.O. Box 2522
154 Lawrence St.
Eugene, Oregon 97448

Jim Sencenbaugh
Sencenbaugh Wind Electric
P.O. Box 11174
Palo Alto, California 94304

*Conference Steering Committee

Ken Smith
Office of Appropriate Tech.
1530 10th St.
Sacramento, California 95814

Peter Smith, Staff Member
Comm. on Energy and Natural Resources
U.S. Senate
3106 Dirksen Bldg.
Washington, D.C. 20510

Robert Sparkes
Dubin-Bloome Associates
P.O. Box 383
West Hartford, Connecticut 06107

R. R. Spencer, Research Eng.
Battelle - NW Labs
P.O. Box 999
Richland, Washington 99352

Governor Robert Straub
State Capitol
Salem, Oregon 97310

William Thomas
American Bar Foundation
1155 E. 60th
Chicago, Illinois 60637

Jim Thompson
Conservation Specialist
Oregon Dept. of Energy
111 Labor & Industries Bldg.
Salem, Oregon 97310

John Wade, Meteorologist
Wind Power Group
Dept. of Atmospheric Science
Oregon State University
Corvallis, Oregon 97331

Ed Warchol
Bonneville Power Administration
Thermal Engineering Section
P.O. Box 3621
Portland, Oregon 97208

Ellwood Werry
Battelle - NW Labs
P.O. Box 999
Richland, Washington 99352

Dr. Eric Willis, Deputy Asst. Secretary, Energy Technology
U.S. Dept. of Energy
20 Massachusetts Ave. N.W.
Washington, D.C. 20545

David Winitzky, architect
1210 Villard St.
Eugene, Oregon 97403

David Wright, AIA
P.O. Box 49
Sea Ranch, California 95497

Lynn Youngbar
8143 S.W. 41st
Portland, Oregon 97219

Please Note: The following pages list all persons who registered for SOLAR 78 NORTHWEST. Some substitutions were made, however, and a few people were not able to attend.

Mary Lawrence

AABCO Heating & Cooling Service Inc
252 47th Ave. S.E.
Salem, Oregon 97301

Charlotte Abernathy
751 Briercliff Lane
Lake Oswego, Oregon 97034

Mrs. Frank Abrams
122 E. 4th St.
Moscow, Idaho 83843

Frank Abrams
122 E. 4th St.
Moscow, Idaho 83843

Cassandra Adams
1227 Federal Ave. E.
Seattle, Washington 98102

David S. Adams
118 High Meadows Dr.
Richland, Washington 99352

Nancy N. Adams
118 High Meadows Dr.
Richland, Washington 99352

Stan Adams, 22-480
Tektronix, Inc.
Box 500
Beaverton, Oregon 97077

Jim Addcox
Sims Electric, Inc.
721 S.E. Oak Ave.
Roseburg, Oregon 97470

Jose R. Aguilar
Bonneville Power Administration
P.O. Box 3621
Portland, Oregon 97208

Mohamad Ahramian
19765 S.W. 65th #2
Tualatin, Oregon 97062

Jerry Aldeman
Box 603
Sherwood, Oregon 97140

Dodee Alexander
5100 W. Clearwater #K-6
Kennewick, Washington 99336

L. Connie Allen
36877 Parsons Creek Rd.
Springfield, Oregon 97477

Bob Anderson
32 S. Ewing
Helena, MT 59601

Dr. Charles R. Anderson
Solargistics
P.O. Box 766
Friday Harbor, Washington 98250

Deanna Anderson
P.O. Box 766
Friday Harbor, Washington 98250

Eric Anderson
1016 N.E. 10th
Hillsboro, Oregon 97123

H. C. William Anderson
P.O. Box 88074
Seattle, Washington 98188

Wendy Anderson
4245 S.W. 99th Ave.
Beaverton, Oregon 97005

William E. Anderson
1865 N.E. 129th
Portland, Oregon 97230

Virginia Andrick
P.O. box 547
Corvallis, Oregon 97330

Moulton Andrus
1421 S.W. 12th
Portland, Oregon 97201

Larry Arnold
4490 S.W. 186th Ave.
Aloha, Oregon 97005

Mari Arnold
4490 S.W. 186th Ave.
Aloha, Oregon 97005

Roland G. Arper
P.O. Box 37
Silverdale, Washington 98383

Michael J. Arrington
2533 S.E. 34th
Portland, Oregon 97202

Dale Aspevig
6807 S.E. Morrison
Portland, Oregon 97215

Michael Atherton
460 S.W. Madison C.
#79 Wellsher Bldg.
Corvallis, Oregon 97330

Tom Ayres
P.O. Box 140
Cannon Beach, Oregon 97110

Wm. A. Bagwell
1145 Liberty St. N.E.
Salem, Oregon 97301

Scott Bailey
Solar Systems N.W.
6309 Reid Drive N.W.
Gig Harbor, Washington 98335

David C. Bakke
12707 S.E. Madison
Portland, Oregon 97233

Buzz Barban
1909 28th W.
Seattle, Washington 98199

Linda Barnes
2532 S.W. 87th
Portland, Oregon 97225

Rebecca Barnes
2019 N. 16th
Boise, Idaho 83702

Steve Barney
3407 N.W. Harrison
Corvallis, Oregon 97330

Jeffrey Barr
1909 Fourth St. N.E.
Salem, Oregon 97303

W. E. Bartsch
R.R. 1 Mansell Rd.
Ganges, Canada B.C. V05-1E0

Scott Baumhofer
7900 S.W. Broadmoor Terr.
Portland, Oregon 97225

Douglas G. Beaman
Center for Solar Energy App.
San Jose State University
San Jose, California 95192

Dr. C. R. Beaton
Economics Department
Willamette University
Salem, Oregon 97301

Wayne Belmont
230 E. Second, St.
City Hall
McMinnville, Oregon 97128

Jeffrey A. Benner
123 N.W. Second
Portland, Oregon 97209

Richard Bennett
Rt. 3 Box 294
Sherwood, Oregon 97140

D. E. Benoit
Energy Plus, Inc.
P.O. Box 40160
Portland, Oregon 97240

Bill Berg
P.O. Box 54
Gearhart, Oregon 97138

Michael J. Berger
4432 N.E. Wistaria Dr.
Portland, Oregon 97213

Michael Bierman
1430 N.E. 22nd Ave.
Portland, Oregon 97232

Patrick Binns
765 So. Grant
Denver, Colorado 80209

Lewis C. Birdsall
6815 S.E. 36th Ave.
Portland, Oregon 97202

Frank Bicehel
Rt. 1 Box 337-A
Prosser, Washington 99350

Duane G. Bischoff
90205 Greenwood Dr.
Leaburg, Oregon 97401

Rusty Blake
P.O. Box 124
Elmira, Oregon 97437

David C. Blocksom
Portco Corporation
4200 Columbia Way
Vancouver, Washington 98661

Prof. J. R. Bodoia
10504 Durland Ave. N.E.
Seattle, Washington 98125

Robert F. Boehm
Mechanical & Indus. Engrg. Dept.
University of Utah
Salt Lake City, Utah 84112

Bill Boese
61794 Ward Rd.
Bend, Oregon 97701

Kay S. Bogart
950 N.W. Oakdell Pl.
Corvallis, Orégon 97330

Robert Boileau
7915 S.W. Canyon Lane
Portland, Oregon 97225

Linda Bolduan
1700 S. Skyland Dr.
Lake Oswego, Oregon 97034

Bruce Bolme
Corps of Engineers, Ptld. Dist.
P.O. Box 2946
Portland, Oregon 97208

Steve J. Bolton
P.O. Box 681
Salem, Oregon 97308

Carole Boone
Wash. State Energy Office
400 E. Union
Olympia, Washington 98504

Andy Bortz
460 S.W. Madison
#79 Wellsher Bldg.
Corvallis, Oregon 97330

Belinda Boulter
219 - 12th Ave. E.
Seattle, Washington 98102

Don Bowman
3175 Black Hills Dr.
Boise, Idaho 83705

Beth Bown
2922 S.W. 2nd
Portland, Oregon 97201

Samuel A. Boyce
11537 S.W. Riverwood Rd.
Portland, Oregon 97219

Gordon S. Bozeman
Design Etcetera
3511 S.E. Milwaukie,Ave.
Portland, Oregon 97202

Greg W. Branch
Branch Development Co.
307 Great N.W. Bldg.
Bremerton, Washington 98310

C. E. Brandt
P.O. Box 125
Yacolt, Washington 98675

Mrs. C. E. Brandt
P.O. Box 125
Yacolt, Washington 98675

Jeanette A. Brandt
13380 Monmouth Hwy.
Monmouth, Oregon 97361

W. B. Branin
2937 N.E. 59th
Portland, Oregon 97213

Terry Bratvold
P.O. Box 1869
Seattle, Washington 98111

C. H. Branham
Puget Power Bldg.
Bellevue, Washington 98005

Robert Brevik
431 Ewauna St.
Klamath Falls, Oregon 97601

George A. Brink
2332 E. Madison
Seattle, Washington 98112

Janet Brislawn
3242A. French Loop Rd. N.W.
Olympia, Washington 98502

Mike Brislawn
3242A French Loop Rd. N.W.
Olympia, Washington 98502

Dorothy F. Brown
Milam Hall 161
Oregon State University
Corvallis, Oregon 97331

Evan C. Brown
747 16th East
Seattle, Washington 98112

John E. Brown
2260 Division N.W., 17-B
Olympia, Washington 98502

M. J. Brown
17604 N.W. 41st Ave.
Ridgefield, Washington 98642

William C. Brown
P.O. Box 8881
Portland, Oregon 97208

Ralph Bruinsslot
P.O. Box 130
Occidental, California 95465

Roger Bryerton
956 E. 16th Ave.
Vancouver, B.C. Canada V5T-2V9

Tom Bryson
111 Labor & Industries Bldg.
Salem, Oregon 97310

Charles R. Burger
Dept. of Architecture
Washington State University
Pullman, Washington 99164

Dennis Burmeister
Box 682
Chewelah, Washington 99109

Colleen Callison
3955 S.W. 91st
Portland, Oregon 97225

David Cameron
3427 N.W. Franklin Ct.
Portland, Oregon 97210

W. Leigh Campbell, M.D.
Oregon City Eye Clinic
421 High St.
Oregon City, Oregon 97045

Parker Cann
101 Senate Office Bldg.
Olympia, Washington 98504

Bob Cantrell
2021 N.E. 144th
Portland, Oregon 97230

Lawrence-Pat Cantwell
P.O. Box 5263
Vancouver, Washington 98663

Jim Capp
822 Harmony Ln.
Ashland, Oregon 97520

Wayne P. Card, A.I.A.
620 S.W. Fifth Ave.
Portland, Oregon 97204

Dunbar Carpenter
Dunbar Orchards
801 N. Foothills Rd.
Medford, Oregon 97501

Terry L. Carruthers
1622 Justice C.
Salem, Oregon 97301

Charles J. Cauchy
3943 Biscay Rd. N.W.
Olympia, Washington 98502

Leonard Chaffey
13560 S.W. Fielding Rd.
Lake Oswego, Oregon 97034

Bill Chaloner
5822 Noon Rd.
Bellingham, Washington 98225

Childress & Childress - Ullma
Architects
767 Willamette St., Suite 201
Eugene, Oregon 97401

Mr. Philip Christian
Seattle City Light
1015 Third Avenue
Seattle, Washington 98104

Barbara Church
4004 N.W. Thurman
Portland, Oregon 97210

Norm Clark, A.I.A.
6730 S.W. Parkwest Ln.
Portland, Oregon 97225

Ron L. Clark
P.O. Box 707
North Plains, Oregon 97133

Steve Clay
Richard Gessford & Associates
19 N.W. 5th
Portland, Oregon 97209

Gale Clemenson
3933 S.W. Kelly
Portland, Oregon 97201

Max Clement
2609 Joeger St.
Bellingham, Washington 99225

Steve Clinehens
Northwest Appropriate Tech. Inst.
P.O. Box 1211
Friday Harbor, Washington 98250

Jack D. Cluck
P.O. Box 394
Vashon, Washington 98070

Jeff Collum
1148 N. 96th
Seattle, Washington 98103

Ed Colombi
Rt. 1 Box 42B
Amity, Oregon 97101

Community Design Center of t
4604 Stone Way N. N.
Seattle, Washington 98103

Dr. Dale R. Comstock, Dean of
the Graduate School & Research
Central Washington University
Ellensburg, Washington 98926

Louise Condren
c/o Dreamers Lodge Motel
144 N. Canyon Blvd.
John Day, Oregon 97845

Dale R. Conner
2214 Donovan Dr.
Eugene, Oregon 97401

Philip Conti
3832 S.W. Patton Rd.
Portland, Oregon 97221

Garry M. Cook
Box 8521 Elkhorn Dr.
Lyons, Oregon 97358

David C. Cooper
Umb#1 10701 S.E. Hwy. 212
Clackamas, Oregon 97015

Ken Cooper
Solar Application & Research
1751 Nanaimo St.
Vancouver, B.C. Canada
V5N-5C1

Kent L. Cootes
Boeing Energy Technology
Applications Division
Mail Stop 9C-01, P.O. Box 24346
Seattle, Washington 98124

Michael Wm. Corke
7240 Holmes Isld. Rd.
Olympia, Washington 98503

Steve Corker
1107½ S. Grand Blvd
Spokane, Washington 99202

Karen M. Corkum
0230 S.W. Gaines #26
Portland, Oregon 97201

Carol Costello
Washington State Energy Office
400 E. Union
Olympia, Washington 98502

Sandra Coursen
3416 23rd Ave. W.
Seattle, Washington 98199

Hal M. Coverdale
Rt. 3 Box 292P
Sequim, Washington 98382

Joan Coverdale
Rt. 3 Box 292P
Sequim, Washington 98382

Ann L. Cowan
Hanford Science Center
Box 800
Richland, Washington 99352

Harold Lou Crowell
2548 S.E. 36th
Portland, Oregon 97202

Steve M. Cruzen
1305 S.E. 14th
Portland, Oregon 97214

Jack C. Cummings
2224 Benton
Richland, Washington 99352

Tom Cunningham
Energy Office
Yamhill County Courthouse
McMinnville, Oregon 97128

Sandra Currier
3710 S.E. Concord
Milwaukie, Oregon 97222

Clifford Curry
189 Liberty N.E., Box 266
Salem, Oregon 97301

Harland Curtis
156 5th St.
Ashland, Oregon 97520

Kelly Cushing
1031 Prospect Ave.
Grants Pass, Oregon 97526

G. M. Davidge
P.O. Box 662
Camp Sherman, Oregon 97730

Norma Davidson
2603 78th Ave. N.E.
Bellevue, Washington 98004

Peter Davis
8118 S.W. 36th
Portland, Oregon 97219

Jon Decherd
2316 N.W. Quimby
Portland, Oregon 97210

John DeJager
6210 Lakeview Blvd.
Lake Oswego, Oregon 97034

Gary Decker
143 S. 5th E.
Missoula, MT 59801

Steve Denner
Washington Energy Extension Ser.
312 Smith Tower
Seattle, Washington 98104

Mike Dennis
8775 S.W. Becker Dr.
Portland, Oregon 97223

Pauline Sargent Deppen
1123 S.E. 23rd
Portland, Oregon 97214

A. P. DiBenedetto, FAIA
2665 S.W. 73rd
Portland, Oregon 97208

Shirley Dickinson
2241 81st Ave. S.E.
Mercer Island, Washington
98040

Dorothy Dixon
1705 N.W. 32nd
Portland, Oregon 97210

James E. Doherty
3946 S.E. 28th Pl.
Portland, Oregon 97202

Steve Dransfeldt
6800 Park Way
Gladstone, Oregon 97027

Kirk Drumheller
2336 Camas
Richland, Washington 99352

Donna DuBeth
The Daily News
Longview, Washington 98632

Mary Lynn Durfur
7580 S.W. Fulton Park Blvd.
Portland, Oregon 97219

David Dumas
2735 S.E. 37th
Portland, Oregon 97202

Dundas
2376 D Walker Valley
Mt. Vernon, Washington 98273

Joe Dunham
P.O. Box 4525
Portland, Oregon 97208

Dr. David A. Dunnette
Rt. 1 Box 408D
Forest Grove, Oregon 97116

James E. Durbin
2275 Friendly St.
Eugene, Oregon 97405

John D. Durbin
5950 Griffin Cr. Rd.
Medford, Oregon 97501

Tim Durbin
2611 "G" St.
Springfield, Oregon 97477

Mrs. Shirley S. Durham
West 121 Orchard Way
Richland, Washington 99352

R. B. Dwyre
Williams Electric Co.
4248 S.E. Belmont
Portland, Oregon 97215

Andrew Eby
Box 268
Redmond, Oregon 97756

Kathleen Eby
Box 268
Redmond, Oregon 97756

Al Edelman
2316 N.W. Quimby St.
Portland, Oregon 97210

David Edrington
Threshold, A Group of Architects
1210 Villard St.
Eugene, Oregon 97403

Ralph C. Edwards
2635 S.E. Division St., #3
Portland, Oregon 97202

Terry Egnor, ERLC
The Bush School
405 36th Ave. E.
Seattle, Washington 98112

Michael Eisenberg
Rt. 5 Box 404B
Bellingham, Washington 98225

Rano Ellertson
Energy House
1343 Edgewater St. N.W.
Salem, Oregon 97304

Dennis Elliott
Battelle - NW Labs
Richland, Washington 99352

John L. Ellis
Rt. 1 Box 1082
Rainier, Washington 98576

James R. Emerson
1125 N.E. Morton St.,
Portland, Oregon 97211

Parker C. Emerson
17935 Cardinal Drive
Lake Oswego, Oregon 97034

Ernie Endlich
12345 30th N.E.
Seattle, Washington 98125

Candice English
12320 N.W. Barnes Rd. Apt. M-7
Portland, Oregon 97229

Jeanne Erdahl
6327 150th Pl. S.W.
Edmonds, Washington 98020

Melvin A. Erland, jr
2801 N.W. Nela
Portland, Oregon 97210

Roy Ettinger, A.I.A.
6227 Wayzata Ct.,
Lake Oswego, Oregon 97034

Walter L. Faulkner
2965 S.E. River Rd.
Hillsboro, Oregon 97123

Wayne Fawbush
5000 O'Leary Rd.
Hood River, Oregon 97031

Robert Feibleman
4206 S.W. Idaho Terr.
Portland, Oregon 97221

Virginia Guest Ferriday
122 S.W. Marconi Ave.
Portland, Oregon 97201

Dennis Finck
16615 S. Wachtman Rd.
Oregon City, Oregon 97045

Renda Finck
16615 S. Wachtman Rd.
Oregon City, Oregon 97045

Walter L. Finlay
Rt. 3 Box 100
Port Townsend, Washington
98368

Fisher, Wallin & Long
Architects - Planners
220 The Water Tower
5331 S.W. Macadam
Portland, Oregon 97201

David A. Fisk
3225 N.E. 15th Ave.
Portland, Oregon 97212

David B. Fleming
Rt. 2 Box 54A
Portland, Oregon 97231

Bob Foelkl
Rt. 1 Box 86
Brookings, Oregon 97415

Dwayne L. Foley
123 N.W. Flanders St.
Portland, Oregon 97209

David Fong
Dept. of Physics
University of Oregon
Eugene, Oregon 97403

Pat Ford
Box 844
Boise, Idaho 83701

Toni Franchey
2330 Augusta St.
Eugene, Oregon 97403

Richard H. Francis
Box 588
Chiloquin, Oregon 97624

Rollin R. Francisco
19526 Old Burn Rd.
Arlington, Washington 98223

Kitrick R. Frederic
Star Rt. 1 Box 13
Grand Ronde, Oregon 97347

Armel H. Freed
2408 N.E. 146th Dr.
Portland, Oregon 97230

Fred Fritz, jr.
1905 N.W. 29th Ave., Apt. 220
Portland, Oregon 97210

Edie Fronske
33787 White Oak Dr.
Corvallis, Oregon 97330

Sam Fugua
12150 S.W. 9th St.
Beaverton, Oregon 97005

Nels D. Gabbert
Star Rt. Box 1670
Forest Grove, Oregon 97116

Rene' E. Gamache
P.O. Box 583
Toppenish, Washington 98948

Michael A. Gates
3017 N.E. 105th
Seattle, Washington 98125

Mike Gavin
P.O. Box 782
Klamath Falls, Oregon 97601

Don Gerber
809 N.E. Skidmore
Portland, Oregon 97232

Paul Gerhardt
4240 S.W. Altadena Ave.
Portland, Oregon 97201

Nancy Gerhardt
4240 S.W. Altadena Ave.
Portland, Oregon 97201

James Gipson
Rt. 1 Beacon Light Rd.
Boise, Idaho 83702

David Goerz
14818 249th Ave. S.E.
Monroe, Washington 98272

Scott Gossler
4319 S. 7th
Tacoma, Washington 98405

Betty Graves
257 Dearborn N.
Salem, Oregon 97303

Ernest D. Graves
257 Dearborn N.
Salem, Oregon 97303

Gary L. Gray
425 Laguna
Klamath Falls, Oregon 97601

Steven D. Gray
18531 Wax Wing
Lake Oswego, Oregon 97034

Jeffrey Greene, A.I.A.
The Burr Associates
P.O. Box 99885 Lakewood Center
Tacoma, Washington 98499

Marjorie R. Greene
Battelle - HARC
4000 N.E. 41st St.
Seattle, Washington 98105

William T. Greene
2705 N.E. 42nd
Portland, Oregon 97213

Stephen Greenleaf
1790 Riverview St.
Eugene, Oregon 97403

Bob Grieson
P.O. Box 545
Gresham, Oregon 97030

Gary W. Grimes
50 Compton Lane
Richland, Washington 99352

David H. Griswold
6656 S.W. Miles Court
Portland, Oregon 97223

Daniel Grudin
1851 Jadwin Ave.
Richland, Washington 99352

Allan Gubrud
Lane Community College
4000 E. 30th Ave.
Eugene, Oregon 97405

Robert O. Guddat
Bonneville Power Administration
P.O. Box 3621
Portland, Oregon 97208

Peter A. Guyer
606 14th St. N.E.
Salem, Oregon 97301

Todd Hagen
1241 Marine Dr.
Bellingham, Washington 98225

John W. Haide
4145 S.W. Primrose St.
Portland, Oreogn 97219

Alan Haley
665 Shoreline Lane
Shelton, Washington 98584

Collin C. Hall
T & H Systems
329 Myrtle
Oregon City, Oregon 97045

Samuel F. Hall, A.I.A.
1590 Federal Bldg.
1220 S.W. 3rd
Portland, Oregon 97204

Bryce Holonen
Mid Willamette Valley Council of Governments 220 High St. N.E., 400 Senator Bldg.
Salem, Oregon 97301

Thomas W. Hamann
2041 S.W. 58th
Portland, Oregon 97221

Tom Hampson
Blue Mountain Sheet Metal, Inc.
Rt. 1 Box 743
Pendleton, Oregon 97801

H. L. Hampton
P.O. Box 999
Richland, Washington 99352

O. Floyd Hand
12585 S.E. 26th Ave.
Milwaukie, Oregon 97222

Robert H. Hango
9736 S.E. 46th
Milwaukie, Oregon 97222

Sam K. Hanna
P.O. Box 8161
Portland, Oregon 97207

Yoneko Hara
2546 N.W. 53rd Dr.
Portland, Oregon 97210

Jim Hare
1270 River Rd.
Eugene, Oregon 97404

John A. Hare
Biology Dept.
Linfield College
McMinnville, Oregon 97128

Carol Stevenson Harlow
Seattle City Light
1015 Third Ave.
Seattle, Washington 98004

Terry Haroldsen
1908 Rd. 35,
Pasco, Washington 99301

Margie Harris
Oregon Dept. of Energy
Rm. 111 Labor & Industries Bldg
Salem, Oregon 97304

Otis Haselton
11700 S.W. Terra Linda
Beaverton, Oregon 97005

Robert C. Hatton
310 S.W. 4th
Portland, Oregon 97204

C. W. Havicson
Rt. 5 Box 5100
Pasco, Washington 99301

Kent Haworth
627 Oak St.
Brownsville, Oregon 97327

Polly Hays
344 17th Ave. E.
Seattle, Washington 98112

Michael S. Healy
8011 N. Fessenden
Portland, Oregon 97203

Donald R. Heil
N.E. 505 Morton
Pullman, Washington 99163

Dennis D. Hellesvig
460 E. 2nd
Eugene, Oregon 97401

Arthur C. Herstrom
Dept. of Public Utilities,
Light Division
P.O. Box 11007
Tacoma, Washington 98411

Tom Hewes
460 S.W. Madison C.
#79 Wellsher Bldg.
Corvallis, Oregon 97330

Peter D. Hiatt
1933 Federal Ave. E.
Seattle, Washington 98102

Linda W. Hickok
59 S.W. Tanglewood Dr.,
Lake Oswego, Oregon 97034

Greg Higgins
P.O. Box 777
Soap Lake, Washington 98851

Arthur Hilbrands
40730 S.E. Latigo Ln.
Sandy, Oregon 97055

Bob Hill
P.O. Box 268
North Bend, Oregon 97459

Walter H. Hill
303A Ag. Phase II,
Washington State University
Pullman, Washington 99163

Karin H. Hillhouse
Solar Energy Research Instit
1536 Cole Blvd.
Golden, Colorado 80401

Frank Hillman
105 Bayon Dr.
McMinnville, Oregon 97128

John Hogan
1685 E. 24th
Eugene, Oregon 97403

Wm. J. Hohnstein
P.O. Box 3141
Portland, Oregon 97208

Gene Hoit
1688 N.W. Rolling Hill Dr.
Beaverton, Oregon 97005

Bob Holder
Rt. 1 Box 61
Newberg, Oregon 97132

Mark D. Hood
Rt. 1 Box 498
Philomath, Oregon 97370

Alton Hooten
Box 3141
Portland, Oregon 97208

Rose-Ellen Hope
962 Colverleaf Lp.
Springfield, Oregon 97477

James W. Hopkins
3847 N.E. 155th Place
Seattle, Washington 98155

David Horner
P.O. Box 550
Camas, Washington 98607

Mark W. Hoskins
624 No. 64th
Springfield, Oregon 97477

Glenn M. House
Rt. 1 Box 258
Mulino, Oregon 97042

Eric Hovee
620 S.W. 5th Ave., Rm. 610
Portland, Oregon 97204

Graham Hubenthal
2367 C. Stanwood Rd.
Stanwood, Washington 98292

Rich Huggins
Eastern Oregon Community
Development Council
P.O. Box 1006
LaGrande, Oregon 97850

William A. Hughes
Rt. 1 Box 55
Hillsboro, Oregon 97123

David R. Hummel
285 N.W. 86th Ave.
Portland, Oregon 97229

Matthew Hummel
129 W. Entiat
Richland, Washington 99352

Greg Hutchins
3814 S.E. 26th
Portland, Oregon 97202

M. A. Hutchins
4115 S.W. Nehalem Ct.
Portland, Oregon 97201

Bill Imhof
2735 S.E. Main
Portland, Oregon 97214

Ellsworth P. Ingraham
P.O. Box 3066
Portland, Oregon 97208

Cary Jackson
211 City Hall
Portland, Oregon 97208

Annabeth Jamieson
4840 S.W. Lamout Way
Lake Oswego, Oregon 97034

Mrs. Albert Jansen
1525 Fern
Walla Walla, Washington 99362

Brent Jauch
2038 N.E. Alberta
Portland, Oregon 97211

Wayne D. Jearls
P.O. Box 169
Lowell, Oregon 97452

Brian Jelgerhuis
2520 Seminary Hill Rd.
Centralia, Washington 98531

Steven C. Johannesen
3540 34th Ave. N.E.
Salem, Oregon 97303

Architects Johnson, Erlewine
& Associates
1410 Eleventh St.
Bellingham, Washington 98225

Dale Johnson - Eng. Dept.
City of Salem
555 Liberty S.E.
Salem, Oregon 97301

Genevieve Johnson
3180 W. 14th Ave.
Eugene, Oregon 97402

Marcia Johnson
Kristia Associates
213 S.W. Ash
Portland, Oregon 97204

Betty Jones
P.O. Box 8315
Portland, Oregon 97207

Elizabeth E. Jones
4115 S.W. Nehalem Ct.
Portland, Oregon 97201

Cecil R. Jordan
1635 N.W. 138th
Portland, Oregon 97229

Igo Jurgens
425 S.E. 70th Ave.
Portland, Oregon 97215

Joan Kane
P.O. Box 2407
Pasco, Washington 99302

Bill C. Kanrich
282 N.W. 16th St.
Ontario, Oregon 97914

Kelly Karmel
1417 S.W. 10th #411
Portland, Oregon 97201

Charles Kassler
775 W. 13th St., #4
Eugene, Oregon 97402

Vera Katz
2068 N.W. Johnson St.
Portland, Oregon 97209

Ray Keim
216 S.W. Madison
Corvallis, Oregon 97330

Raymond H. Kelly
Box 335
Bandon, Oregon 97411

James R. Kelly
United Nuclear Ind.
P.O. Box 490, 1101-N
Richland, Washington 99352

Pat Kerschner
N.W. Neighborhood Project
635 N.W. 21st
Portland, Oregon 97209

Felix Kersting
Castle Plumbing Co.
P.O. Box 66175
Portland, Oregon 97266

Kirk Ketter
hewlett, jamison, atkinson & luey, architects
3223 S.W. Front Ave.
Portland, Oregon 97201

Niel C. Kierulff
Bonneville Power Administration
P.O. Box 3621
Portland, Oregon 97208

Fred J. King
10580 N.W. Walters Ln
Portland, Oregon 97229

Sally King
Battelle
4000 N.E. 41st St.,
Seattle, Washington 98105

William N. King
Oregon Inst. of Technology
Klamath Falls, Oregon 97601

Mary Ann Kirsling
5100 W. Clearwater Ave., #K-6
Kennewick, Washington 99336

Rep. Clayton Klein
P.O. Box 1339
Medford, Oregon 97501

Rick L. Klettke
8405 N.E. Eugene
Portland, Oregon 97220

Ron Kloster
1227 Federal Ave. E.
Seattle, Washington 98102

Donn D. Knokey
2685 Oak Street #6
Eugene, Oregon 97405

Robert Knudson
3921 148th S.E.
Bellevue, Washington 98006

Jan J. Kofranek, A.I.A.
2150 N. 107th., Suite 310
Seattle, Washington 98133

Ken Kongslie
2990 Dearing Dr. N.W.
Salem, Oregon 97304

Jan Konigsberg
Montana Energy Division
DNRC Capitol Station
Helena, MT 59601

Larry L. Kraft
13775 S.W. 6th., Apt. I
Beaverton, Oregon 97005

Charles Kroeger
405 N. Denver
Albany, Oregon 97321

Mel Kroker
30 N.W. 23rd Pl.
Portland, Oregon 97210

Charles Kruch
22885 Abilene Ct.
Bend, Oregon 97701

Steve Kujawa-Soft Tech Homes
90472 Sheffler Rd.
Elmira, Oregon 97401

Tom B. Kuntzman
614 E. 15th., Apt. B
Eugene, Oregon 97401

Michael J. Kyle
9912 S.W. Tigard St.
Tigard, Oregon 97223

Lawrence A. LaDage
P.O. Box 2981
Portland, Oregon 97208

Augusta Laidlaw
2019 N. 16th
Boise, Idaho 83702

Richard E. Lakeman, AIA, ASPO
430 S.W. Morrison
Portland, Oregon 97204

Hugh LaMaster
525 S.W. 6th
Corvallis, Oregon 97330

Bob Lane
The Seattle Times
P.O. Box 70
Seattle, Washington 98111

Joseph R. Lash
14090 S.W. Rochester Dr.
Beaverton, Oregon 97005

Terry R. Lash
c/o Natural Resources Defense Council
2345 Yale Street
Palo Alto, California 94306

Dennet Latham
1928 S.W. Laurel Apt. 1
Portland, Oregon 97201

George F. Lastomirsky
Box 199
Gearhart, Oregon 97138

Tom LaVelle
2565 Onyx
Eugene, Oregon 97403

Angie LaVigne
8025 30th Ave. N.E.
Seattle, Washington 98115

Paul LaViolette
2238 N.E. 13th Ave. #30
Portland, Oregon 97212

Bill Lawler
3615 S.E. Stott Ave.
Troutdale, Oregon 97060

David Lawrence
205 S. 2nd
Hillsboro, Oregon 97123

Jerry Lawrence, AIA
The Burr Associates
P.O. Box 99885 Lakewood Center
Tacoma, Washington 98499

Austin Leach
11740 S.W. Breyman Rd.
Portland, Oregon 97219

Marc Ledbetter
2041 N.W. Everett
Portland, Oregon 97209

Harry A. Lee
Bldg 271-T 200-W Area
Rockwell Hanford Operation
Richland, Washington 99352

Kurt Leipzig
5149 S.W. 26th Dr.
Portland, Oregon 97201

Reis L. Leming
Energyloc Inc.
1166 N.E. 31st
Portland, Oregon 97232

Thomas E. Lenchek
7715 Atchinson Dr. S.E.
Olypmia, Washington 98503

Thomas Leslie
1631 S.E. 60th
Portland, Oregon 97215

Thelma Lester
7508 S.E. 29th Ave.
Portland, Oregon 97202

Bernard L. Lewis
Regional Eng., U.S. Fish & Wildlife Service
500 N.E. Multnomah St.
Portland, Oregon 97232

Kenneth Lielz
4103 Storm Ave.
Yakima, Washington 98908

Peter Lilienthal
1619 S.E. Reedway
Portland, Oregon 97202

Louis L. Lino, Director
Solar Terrestrial Laboratory
10254 S.W. Lancaster Rd.
Portland, Oregon 97219

Jane M. Lindsey
2533 Harris
Richland, Washington 99352

James Litton
8335 S.E. 17th Ave.
Portland, Oregon 97202

Wayne E. Livingston
2980 N.E. Division St., Sp. #17
Gresham, Oregon 97030

Walter Lofstrom, jr.
1611 N.W. 7th St.
Vancouver, Washington 98665

Pat Logie
Seattle City Light
1015 Third Avenue
Seattle, Washington 98104

Jeff Lopatynski
418 Douglass
Richland, Washington 99352

Howard M. Loucks
1422 N.E. 36th
Portland, Oregon 97232

Perry Lovelace
2203 N.W. 63rd
Seattle, Washington 98107

Jay LuBoff
University of Washington FS-15
Center Social Man. Tech.
Seattle, Washington 98195

J. Min Luey
hewlett, jamison, atkinson
& luey, architects
3223 S.W. Front Ave.
Portland, Oregon 97201

J. James Macica
Mid Willamette Valley Council
of Governments 400 Senator
Bldg. 220 High St. N.E.
Salem, Oregon 97304

David P. MacKenzie
P.O. Box 2082
Vancouver, Washington 98661

Michael Maes
Energy Sciences Corp.
Penthouse, Seattle Tower
Seattle, Washington 98101

Frank T. Magiera
2935 N.E. Everett
Portland, Oregon 97232

John T. Malcolm
Idaho Office of Energy
Statehouse
Boise, Idaho 83720

Richard C. March
Energy Enterprises
1730 10th Pl. N.E.
East Wenatchee, Washington
98801

Henry S. Markus
P.O. Box 339
Pendleton, Oregon 97801

Rep. Tom Marsh
12060 S.W. Butner Rd.
Portland, Oregon 97225

Tom Marsh
hewlett, jamison, atkinson &
luey, architects
3223 S.W. Front Ave.
Portland, Oregon 97201

Mary G. Marshall
306 Saint St.
Richland, Washington 99352

Charles A. Marshall
5909 West A. St.
West Linn, Oregon 97068

Robert P. Marshall
P.O. Box 999
Battelle - NW Labs
Richland, Washington 99352

Gary Mart
P.O. Box 33
Corvallis, Oregon 97330

H. Daniel Marten
3481 Irving
Astoria, Oregon 97103

Dennis H. Martin
467 Ramp Rd.
Roseburg, Oregon 97470

Austin Marts
715 So. Capitol #405
Boise, Idaho 83706

Mathews Heating Oil, Inc.
8966 Gravelly Lake Dr. S.W.
Tacoma, Washington 98499

Mr. S. P. Mather
Division of Regional Assessme:
Dept. of Energy MS E-201
Washington, D.C. 20545

Walter E. Matson
Dept. of Ag. Engineering
Oregon State University
Corvallis, Oregon 97331

Carolyn Maxted
P.O. Box 59
Gearhart, Oregon 97138

Ron Maxted
P.O. Box 59
Gearhart, Oregon 97138

Donald F. Mazziotti
620 S.W. Fifth Rm. 610
Portland, Oregon 97204

R. P. Mazzucchi
3112 W. Opal St.
Pasco, Washington 99301

Bruce McAllister
Energy Centre
1230 Government St.
Victoria, B.C. Canada V8W-1Y3

Brian D. McCarl
1804 S.E. Pine
Portland, Oregon 97214

Barry W. McClain
9603 Roosevelt N.E.
Seattle, Washington 98115

G. M. McCormack
McCormack Consulting Engineers
P.O. Box 5072
Eugene, Oregon 97405

Shannon McCormick
Washington Energy Extension Service
312 Smith Tower
Seattle, Washington 98104

Brad McCuaig
1220 E. 23rd
Eugene, Oregon 97403

Charles W. McDaniel
Rt. 1 Box 63C
Mosier, Oregon 97040

David K. McDaniels
Physics Dept.
University of Oregon
Eugene, Oregon 97403

Reg McDonald
8405 S.E. Morrison
Portland, Oregon 97216

Claudia McDuffie
Oregon Dept. of Education
942 Lancaster Dr. N.E.
Salem, Oregon 97310

Gilbert McGee
1608 E. 39th
Spokane, Washington 99203

Keith McKenzie
19014 11th Ave. N.E.
Arlington, Washington 98223

Phyllis McKenzie
19014 11th Ave. N.E.
Arlington, Washington 98223

Clarence C. McNeir
94024 Horton Rd.
Horton, Oregon 97448

Rick McNicholas
1006 Wynoochee W.
Montesano, Washington 98563

John Meadows
Threshold, a Group of Architect
1210 Villard
Eugene, Oregon 97403

George R. Mead
Eastern Oregon Community Dev. Council
P.O. Box 1006
LaGrande, Oregon 97850

Lee Meier
4516 S.E. 33rd Pl.
Portland, Oregon 97202

John Mepham 22-480
Tektronix, Inc.
P.O. Box 500
Beaverton, Oregon 97077

O. J. Merrill
850 E. 20th Ave.
Eugene, Oregon 97405

Thomas W. Merrill, architect
312 S.W. 6th Avenue
Albany, Oregon 97321

Arthur D. Merriman, jr.
Future Oregon Homes, Inc.
P.O. Box 10483
Eugene, Oregon 97440

Loren Meyer
P.O. Box 825
Bellevue, Washington 98009

Rick Meyers
1938 S.E. Elliott
Portland, Oregon 97214

K. R. Michel
P.O. Drawer 9
Lake Oswego, Oregon 97034

Thomas R. Miles, jr.
7106 S.E. 36th
Portland, Oregon 97202

Mike Miller
P.O. Box 16
Netarts, Oregon 97143

Roger C. Miller
5260 S.E. 67th
Portland, Oregon 97206

Tom Miller
401 E. 10th Ave., Suite "E"
Eugene, Oregon 97401

Marietta S. Millet
1227 Federal Ave. E.
Seattle, Washington 98102

Matt Miovac
Castle Plumbing Co.
P.O. Box 66175
Portland, Oregon 97266

Elijuh Mirochnik
3722 S.W. Condor Ave.
Portland, Oregon 97201

Hussain Mirza
4233 S.E. 34th
Portland, Oregon 97202

Stephen Monaco
General Delivery
Sisters, Oregon 97759

Craig Monaghan
510 N.W. Third
Portland, Oregon 97209

Daniel G. Montague
Willamette University
Salem, Oregon 97301

Mike Morgan
P.O. Box 488
Cannon Beach, Oregon 97110

Rick Morgan
4220 Oakman St. S.
Salem, Oregon 97302

M. H. Morgenstern
Battelle - NW Labs
P.O. Box 999
Richland, Washington 99352

Thor Mork
6111 Walconda Rd.
Walport, Oregon 97394

Kevin L. Morrill
3275 S.W. 178th
Aloha, Oregon 97005

Robert Morris
669 Duane
Astoria, Oregon 97103

Michael E. Morse
4426 41st S.W.
Seattle, Washington 98116

Craig Mortensen
2182 N.W. Hoyt #3
Portland, Oregon 97210

Edd Moss
6733 S.E. 36th
Portland, Oregon 97202

Zarl Moaveni
19765 S.W. 65th #2
Tualatin, Oregon 97062

Dan Mulkey
Box 1111
Albany, Oregon 97321

Mrs. Dan Mulkey
Box 1111
Albany, Oregon 97321

Richard Murph
121 S.W. Salmon
Portland, Oregon 97204

Patrick Murray
5807 S.W. Nebraska St.
Portland, Oregon 97221

Jason Naiman
2600 S.E. Belmont
Portland, Oregon 97210

Donald Nash
2111 Front St. N.E., 101-D
Salem, Oregon 97303

Gregg Neilson
808 Reed Ave.
Idaho Falls, Idaho 83401

Fred Nelson
Sunset Magazine
Menlo Park, California 94025

John A. Nelson
2541 S.W. Taylors Ferry Rd.
Portland, Oregon 97219

Larry Nelson
2160 S.W. Kings Ct.
Portland, Oregon 97205

Will Newman II
1915 N.E. Couch
Portland, Oregon 97232

Roy E Newton
P.O. Box 1045
North Bend, Oregon 97459

Harry Newton & Associates
10700 S.W. Beaverton Hwy., Suite 11
Beaverton, Oregon 97005

Richard A. Nichols
Design Etcetera
3511 S.E. Milwaukie Ave.
Portland, Oregon 97202

Wesley L. Nicholson
406 Shoreline Ct.
Richland, Washington 99352

Mrs. Wesley Nicholson
406 Shoreline Ct.
Richland, Washington 99352

Jean Nickerson
14120 S.W. Barlow Ct.
Beaverton, Oregon 97005

Quin Nickerson
14120 S.W. Barlow Ct.
Beaverton, Oregon 97005

Judith Noall
2494 E. 2100 S.
Salt Lake City, Utah 84109

Eunice Noell
123 N.W. 2nd Ave.
Portland, Oregon 97209

Robert Allen Nolan
12750 Hwy 234
Medford, Oregon 97501

Sally Norton
2315 E. Ward St.
Seattle, Washington 98112

Barbara-Jo Novitski
2692 University
University of Oregon
Dept. of Architecture
Eugene, Oregon 97403

Joni Nystrom
185-No. 11th St.
St. Helens, Oregon 97051

Greg Oberlin
2502 Jeppesen Acres Rd.
Eugene, Oregon 97401

Carol Oberton
Ecotope Group
2332 E. Madison
Seattle, Washington 98112

Glen Odell
Seton, Johnson & Odell, Inc.
317 S.W. Alder
Portland, Oregon 97204

Robert Odland
Solar Energy Research Institute
1536 Cole Blvd
Golden, Colorado 80401

Mike Oedell
Rt. 2 Box 65
Molalla, Oregon 97038

Vincent Oredson
640 Pracht St.
Ashland, Oregon 97520

Carl Ohgren
Box 812
Reed College
Portland, Oregon 97202

Terry Oliver
P.O. Box 5000
Vancouver, Washington 98663

Steven Olson
14025 S.E. Callahan Rd.
Happy Valley, Oregon 97236

Brad O'Neill
P.O. Box 825
Bellevue, Washington 98009

Oregon Solar Institute
3921 S.W. Kanan Dr.
Portland, Oregon 97221

Owen D. Osborne
Office of Energy Research & Development
Oregon State University
Corvallis, Oregon 97331

Billy W. Overall
351 Col. Blvd.
St. Helens, Oregon 97051

John D. Owen
P.O. Box 11122
Portland, Oregon 97211

Gary L. Owens
1440 N.E. 53rd
Portland, Oregon 97213

Catherine Palm
3875 S.W. Lake Grove Ave. #22
Lake Oswego, Oregon 97034

Kathy Pape
531 W. 13th St.
Port Angeles, Washington
98362

William L. Parish, architect
2892 N.W. Upshur St.
Portland, Oregon 97210

Richard C. Parker
4090 W. State St.
Boise, Idaho 83703

William Parretta
The Burr Associates
P.O. Box 99885, Lakewood Center
Tacoma, Washington 98499

Douglas Parmeter - architect
Rt. 2 Box 183D
Sheridan, Oregon 97378

H. Patton
Cold Spring Farm
Underwood, Washington 98651

Gerald R. Paulson
4849 Canada Way
Burnaby, B.C., Canada
VG5-1L6

Philip M. Paulsrude
1621 Elliott
Olympia, Washington 98502

Artemio Paz, jr.
220 N. 5th St.
Sprinfield, Oregon 97477

James R. Pease
7625 S.W. View Point Terrace
Portland, Oregon 97219

George A. Perrault
121 S.W. Salmon
Portland, Oregon 97204

Rebecca Pete
Box 17181
Portland, Oregon 97217

David Philbrick
Oregon Dept. of Energy
Rm. 111 Labor & Industries Bldg
Salem, Oregon 97310

Jim Pierce
Odyssey Engineering
2508 Dumas Dr.
Springfield, Oregon 97477

Doreen Pierson
2204 W. 14th
The Dalles, Oregon 97058

Jim Pierson
2204 W. 14th
The Dalles, Oregon 97058

Dr. Hayden W. Pitman
Dept. of Chemistry
Linfield College
McMinnville, Oregon 97128

Albert D. Poe, AIA
c/o Architecture Department
Washington State University
Pullman, Washington 99164

J. W. Pope
2406 S.W. Nye Ave.
Tecset Company
Pendleton, Oregon 97801

Dave Porter
837 N.E. Tillamook
Portland, Oregon 97212

Robert Pratt
7805 Poplar View Way
Yakima, Washington 98908

K. P. Pressnall
1793 N. Pine
Canby, Oregon 97013

Mrs. K. P. Pressnall
1793 N. Pine
Canby, Oregon 97013

Tom Princen
521 Pleasant Ave.
Oregon City, Oregon 97045

Melonie Pullon
Rt. 3 Box 798
Estacada, Oregon 97023

Don Pyle
1131 S.E. 23rd
Portland, Oregon 97214

Radiant Systems Northwest
Rt. 2 Box 65
Molalla, Oregon 97038

Jim Raisch
2232 N.E. 8th Ave.
Portland, Oregon 97212

James Ralph
1615 S.E. Skylark
Bend, Oregon 97701

Gordan Rands
Box 844
Boise, Idaho 83701

Pamela Rands
207 E. Ave. H.
Jerome, Idaho 83338

Shanna Reed
OMSI Energy Center
4015 S.W. Canyon Rd.
Portland, Oregon 97221

Linda Reppond
820 N.E. 28th #2
Portland, Oregon 97232

Ron Rich
685 Larry Ave. N.
Salem, Oregon 97303

Sandy Richards
19103 N.E. Hassalo St.
Portland, Oregon 97230

Bruce Richey
1110 N.E. Freemont
Roseburg, Oregon 97470

Jim Richmond
1020 Lewisburg Rd.
Corvallis, Oregon 97330

Peter F. Ringsrud
277 S. Ward Ave.
E. Wenatchee, Washington
98801

Paul Rising, AIA
The Burr Associates
P.O. Box 99885 Lakewood Center
Tacoma, Washington 98499

Ralph E. Robbins
5764 S.W. Kimball Ct.
Lake Oswego, Oregon 97034

Nelson E. Roberts
616 S.E. 38th
Portland, Oregon 97214

Jerry Robichaud
3555 S.E. Clinton
Portland, Oregon 97202

William Robinson
1087 Dearborn Ave., N.E.
Salem, Oregon 97303

Adair Rogers
2087 Harts Lane
Conshohochen, PA
19428

Dennis Rogers
P.O. Box 769
Madras, Oregon 97741

Vincent L. Romeo
P.O. Box 1237
Corcoran, California 93212

Dr. Henry F. Romer
1501 S. Capitol Way
Olympia, Washington 98501

R. G. Rosholt
409 N.E. 156th
Portland, Oregon 97230

Bob Rowe
108 N. Wenatchee Ave.
Wenatchee, Washington 98801

Donella Russell
620 S.W. Fifth Ave., Rm. 610
Portland, Oregon 97204

Pat Russell
P.O. Box 5000
Vancouver, Washington 98663

Penny Russell
Star Rt. 1 Box 13
Grand Ronde, Oregon 97347

Samuel Sadler
1991 Columbia
Eugene, Oregon 97403

Paul Sansone'
Star Rt. Box 1038
Gales Creek, Oregon 97116

Leslie W. Sargent
1924 S. 254th Pl.
Kent, Washington 98031

Brian C. Saunders
Rt. 2 Box 190-A
Arlington, Washington 98223

Ralph Schlichtig
11212 3rd Ave. S.
Seattle, Washington 98168

Frank B. Schmitz
1626 N.E. 9th Avenue
Portland, Oregon 97232

Robert H. Schneider
1000 Union/202
Seattle, Washington 98101

Peter Kipp Schoonmaker
Box 337
Terrebone, Oregon 97760

Cornelius Schnell
610 38th S.E.
Seattle, Washington 98122

Robert K. Schroeder
0324 S.W. Abernethy
Portland, Oregon 97201

Mark S. Schuette
c/o Mexico Solar Energy Assoc.
Box 2004
Santa Fe, New Mexico 87501

Charlie Schultz
1308 31st
Anacortes, Washington 98221

Joyce Schwenke
Rt. 3 Box 285
Walla Walla, Washington 99362

Quent Schwenke
Rt. 3 Box 285
Walla Walla, Washington 99362

Debbie Seifert
OMSI Energy Center
4015 S.W. Canyon Rd.
Portland, Oregon 97221

Larry A. Selivanow
2144 N.E. 21st
Portland, Oregon 97212

Gerald Sevenson
920 S.W. 13th Ave.
Portland, Oregon 97205

Ellen Sharon
Lane County Housing and Energy
Program
170 E. 11th Ave.
Eugene, Oregon 97401

Brian Shafer
141 Knoop Lane
Eugene, Oregon 97404

John C. Shaw
8001 Engelwood Crest Dr.
Yakima, Washington 98908

Betsy Shay
389 W. 4th St.
Prineville, Oregon 97754

Gwen S. Shearer
Rt. 2 Box 150
Estacada, Oregon 97023

Neil B. Sheets
P.O. Box 604
Cornelius, Oregon 97113

Barry Shell
1319 Stanley St.
Victoria, B.C. V9A-6V5
Canada

Theodore C. Sheimo
2605 E. Lynn St.
Seattle, Washington 98122

Mimi Sheridan
1015 3rd Ave. Rm. 922
Seattle, Washington 98104

Nic Shur, AIA
1017 S.W. Morrison St. Suite 5C8
Portland, Oregon 97205

Dan Simpson
Energy Centre
1230 Government St.
Victoria, B.C. Canada V8W-1Y3

Marcia Sims
1297 S.E. Hawthorne
Roseburg, Oregon 97470

Allan Sindelar
22787 White Oak Dr.
Corvallis, Oregon 97330

Randall P. Skoog
c/o Ecotope Group
2332 E. Madison
Seattle, Washington 98112

Bard Slaymaker
Rt. 11 Box 266
Olympia, Washington 98502

Dr. W. G. N. Slinn
Air Resources Center
Oregon State University
Corvallis, Oregon 97331

Rodger Small
Rt. 2 Box 135
Pullman, Washington 99163

Byron Smith
1530 Spruce St.
Lake Oswego, Oregon 97034

Douglas R. Smith
12820 S.W. 107th Ct.
Tigard, Oregon 97223

Malcolm G. Smith, jr.
Peterson Assoicated Engineers
620 S.W. 5th Ave.
Portland, Oregon 97204

Michael A. Smolak
P.O. Box 474
Lake Oswego, Oregon 97034

Chris Snell
2524 Nixon
Eugene, Oregon 97403

Chuck Snider
5739 A. S.E. 136th
Portland, Oregon 97236

Ken Snider
7907 S.E. Roslyn
Milwaukie, Oregon 97222

Marvin Snow
P.O. Box 672
North Plains, Oregon 97133

Ron Soberg
hewlett, jamison, atkinson &
luey, architects
3223 S.W. Front Ave.
Portland, Oregon 97201

Harold V. Soballe
3415 Forest Ave.
Medford, Oregon 97501

Peet M. Soot
Pacific Power & Light Co.
920 S.W. 6th Ave. 808EB
Portland, Oregon 97204

Michael Sprague
Salem Community Food Store
1635 Fairgrounds Rd. N.E.
Salem, Oregon 97303

John B. Stackpole
P.O. Box 1869
Seattle, Washington 98111

James R. Staffey
Energy Sciences Corp.
Penthouse, Seattle Tower
Seattle, Washington 98101

Jonathan Stafford, architect
437 E. 11th Ave.
Eugene, Oregon 97401

Larry Stanley
11740 S.E. Orient Dr.
Boring, Oregon 97009

George Starr
909 N.E. 114th Ave.
Portland, Oregon 97220

John Steadman
P.O. Box 11
Tualatin, Oregon 97062

Dorene Steggell
1736½ Moss St.
Eugene, Oregon 97403

Robert A. Steigerwald
3440 N.E. Lombard Ct.
Portland, Oregon 97211

John T. Stephens
4608 64th S.E.
Salem, Oregon 97301

Douglas M. Still
P.O. Box 188
Cottage Grove, Oregon 97424

Stephen Still
401 E. 10th Ave. Suite "E"
Eugene, Oregon 97401

Scott Stemper
c/o Rainbow Valley Design &
1970 Garfield St. Const.
Eugene, Oregon 97405

Thomas A. Stinchfield
52 E. 23rd
Eugene, Oregon 97405

Gary Stige
11985 S.W. Lanewood
Portland, Oregon 97225

C. D. Stoner
1215 S.E. Linn
Portland, Oregon 97202

Davis Straub
2332 E. Madison
Seattle, Washington 98112

George Stricker
523 North C
Tacoma, Washington 98403

David K. Strong
Box 2680
Lewis & Clark College
Portland, Oregon 97219

G. E. Stuart
P.O. Box 14038
Portland, Oregon 97214

Carl D. Stultz
920 S.W. 6th
Portland, Oregon 97204

Bob Sullivan
P.O. Box 2244
Olympia, Washington 98501

Than Sutan
915 2nd AVe.
DOE-Office of Public Affairs
Seattle, Washington 98174

Richard E. Suther
3415 23rd Ave. W.
Seattle, Washington 98199

Wm. M. Svensson
P.O. Box 185
Port Townsend, Washington 98368

Phil Swaim
318 E. 8th
The Dalles, Oregon 97058

Roger R. Swets
455 Division
Eugene, Oregon 97401

David L. Swett
5901 E. 6th Ave., #203
Anchorage, Alaska 99504

Dennis Swanson
100 Sprout Rd
Richland, Washington 99352

Mark Talbrook
Amity Foundation
2760 Riverview
Eugene, Oregon 97403

Charles L. Taylor, Director
Bureau of Electronic Services
1130 S.W. 17th
Portland, Oregon 97205

Richard Teasley
8101 E. "L" St.
Tacoma, Washington 98404

Gary L. Teters
329 Myrtle
Oregon City, Oregon 97045

Isaac Tevet, architect
Morris, Redden & Associates
1310 Coburg. Rd.
Eugene, Oregon 97401

George Thiessen
5825 S.E. Oetken Rd.
Milwaukie, Oregon 97222

Frank J. Thomas
1456 Cloverfield Blvd.
Santa Monica, California 9040[illegible]

Carol Thomas
1456 Cloverfield Blvd.
Santa Monica, California 90404

Howard Thompson
90472 Sheffler Rd.
Elmira, Oregon 97437

Robert Thornfeldt
1171½ S.W. 2nd Ave.
Ontario, Oregon 97914

John D. Thorpe, M.D.
1015 N.W. 22nd Avenue
Portland, Oregon 97210

Joseph Tompkin
1324 Jordan Drive S.
Salem, Oregon 97302

Warn V. Toms
7302 Huckleberry St. N.W.
Olympia, Washington 98502

Dwight Trahin
16201 S.E. 4th
Vancouver, Washington 98664

Pam Trexler
3973 N. Montana, #4
Portland, Oregon 97227

Kris Tribys
Rt. 1 Box 49B
Amity, Oregon 97101

Dr. George Tsongas
Dept. of Engr. & Appl. Sci.
Portland State University
Portland, Oregon 97207

Jess Tufts
3550 S.E. 26th
Portland, Oregon 97202

Ron Tuininga
Issaquah Glass Inc.
1380 N.W. Mall
Issaquah, Washington 98027

Elaine Ulmer
2815 Spring Blvd.
Eugene, Oregon 97403

Jim Upton
2411 Lindley Way
Klamath Falls, Oregon 97601

Glenda Fravel Utsey
2160 Agate St.
Eugene, Oregon 97403

Michael Utsey
2160 Agate St.
Eugene, Oregon 97403

David W. Vannatta
Portland General Electric Co.
121 S.W. Salmon St.
Portland, Oregon 97204

Bob Vian
989 Claggett N.E.
Salem, Oregon 97303

Frank E. Vignola
Physics Dept.
University of Oregon
Eugene, Oregon 97403

Grant W. Vincent
2344 S.E. 52nd AVe.
Portland, Oregon 97215

Roger L. Von Gohren
703 Barclift Ln. S.E.
Tumwater, Washington 98501

John E. Votipka
1834 N.E. 38th
Portland, Oregon 97212

John Wabel
303 N.E. 56h
Seattle, Washington 98105

Ray Wagner
Rt. 3 Box 238
Sherwood, Oregon 97140

Joan M. Wahl
1031 N.W. Prospect
Grants Pass, Oregon 97526

David Waldron
2727 N.E. Siskiyou
Portland, Oregon 97212

John Wales
2105 Roland Way
Eugene, Oregon 97401

Doug Walker
6880 S.W. 68th Ave.
Portland, Oregon 97223

Hubert E. Walker
900 S.W. 5th Ave.
Portland, Oregon 97204

Dr. Stel N. Walker
145 Vista Ave.
Pasadena, California 91107

James K. Walsh
856 Isbister St.
Victoria, B.C. Canada V9A-605

Fred Walter
Scientific Components Co.
35985 Row River Rd.
Cottage Grove, Oregon 97424

Fliegle Walters
Rt. 1 Box 869
Beaverton, Oregon 97005

Devon E. Wardwell, jr
Rt. 2 Box 65
Molalla, Oregon 97038

Deborah Warner
1724 Lakeside
Coeur D'Alene, Idaho 83814

Don Webb
P.O. Box 37 Fulford Harbour
Salt Spring Island
British Columbia, Canada
V0S-1C0

Paul Webber
3180 W. 14th Ave.
Eugene, Oregon 97402

Adela Weinstein
129 Dorffel Dr. E.
Seattle, Washington 98112

Patricia R. Weis
1536 Cole Blvd
Golden, Colorado 80401

Kneeland M. Welch
112 View Ridge Circle
Wenatchee, Washington 98801

Valerie Lederer Welch
General Delivery
Tualatin, Oregon 97602

William F. Welch
General Delivery
Tualatin, Oregon 97602

David G. Welsh
0324 S.W. Abernethy
Portland, Oregon 97201

Dean E. Werth
P.O. Box 772
Rainier, Oregon 97048

Jack Westland
P.O. Box 908
Monterey, California 93940

Cynthia Weston
OMSI Energy Center
4015 S.W. Canyon
Portland, Oregon 97221

Joseph M. Weinstein
129 Dorffel Dr. E.
Seattle, Washington 98112

Lloyd S. Whannell
Rt. 1 Box 1400
Lopez, Washington 98261

Tom White
2626 S.E. Pine
Portland, Oregon 97214

Arthur E. Whitson
1412 Elizabeth Pl.
Bainbridge Island, Washington 98110

Maureen Wicks
Rt. 1 Cascade Orchards
Leavenworth, Washington 98826

Senator Al Williams
4801 Fremont North
Seattle, Washington 98103

Bob Williams
307 Jefferson St.
Oregon City, Oregon 97045

Kenna F. Williams
1827 Clayter Rd. N.E.
Salem, Oregon 97303

Roger Williams Contracting
Star Route South
Box 164
South Beach, Oregon 97366

W. G. Wilmot, jr., AIA
Architectural Consultant
Oregon Dept. of Education
942 Lancaster Dr. N.E.
Salem, Oregon 97310

Robert E. Wilson
Dept. of Mechanical Engineering
Oregon State University
Corvallis, Oregon 97331

Stewart M. Wilson, jr.
216 Garden Valley Shopping Ctr.
Roseburg, Oregon 97470

Sharon Wilson
216 Garden Valley Shopping Ctr.
Roseburg, Oregon 97470

William K. Wilson, AIA
815 S.W. Chestnut St.
Portland, Oregon 97219

Andrew Wolf
509B Santa Roza
Yakima, Washington 98901

Kent Wong
hewlett, jamison, atkinson, &
luey, architects
3223 S.W. Front Ave.
Portland, Oregon 97201

Lynn Woodworth
Bonneville Power Administration
P.O. Box 3621
Portland, Oregon 97208

James P. Wright
Earthcraft Construction
12715 S.E. Flavel
Portland, Oregon 97236

Dave R. Wyatt
N. 5226 Discoll Blvd
Spokane, Washington 99208

Susan P. Wyatt
N. 5226 Discoll Blvd
Spokane, Washington 99208

George W. Wyss
7617 S.W. 24th
Portland, Oregon 97219

Joel Yamauchi
3415 S.E. Kelly
Portland, Oregon 97202

Clayton Young
2366 Eastlake Ave. E.
Seattle, Washington 98102

Dennis N. Young, AIA
P.O. Box 2128
Spokane, Washington 99210

Gary Young
1205 N.W. 25th
Portland, Oregon 97210

Byron L. Youtz
6113 Buckthorn Ct. N.W.
Olympia, Washington 98502

Dr. Elliot Jacob Zais
7915 N.W. Siskin Dr.
Corvallis, Oregon 97330

Linda Ziegenfuss
1908 Rd. 35
Pasco, Washington 99301

Richard Zimmerman
7450 S.W. Ridgemont
Portland, Oregon 97225

Robert Zimmerman
7450 S.W. Ridgemont
Portland, Oregon 97225

Attendees out of order:

Mike Aronson
Clackamas Community College
19600 S. Molalla Ave.
Oregon City, Oregon 97045

Ted Allen ('Cosmo')
2515 N.W. Mulkey
Corvallis, Oregon 97330

Jean Dalby
620 S.W. 5th Ave., Rm. 610
Portland, Oregon 97204

Ken Ellison
The Benjamin Franklin
1 S.W. Columbia
Portland, Oregon 97258

THE CITY OF

PORTLAND

OREGON