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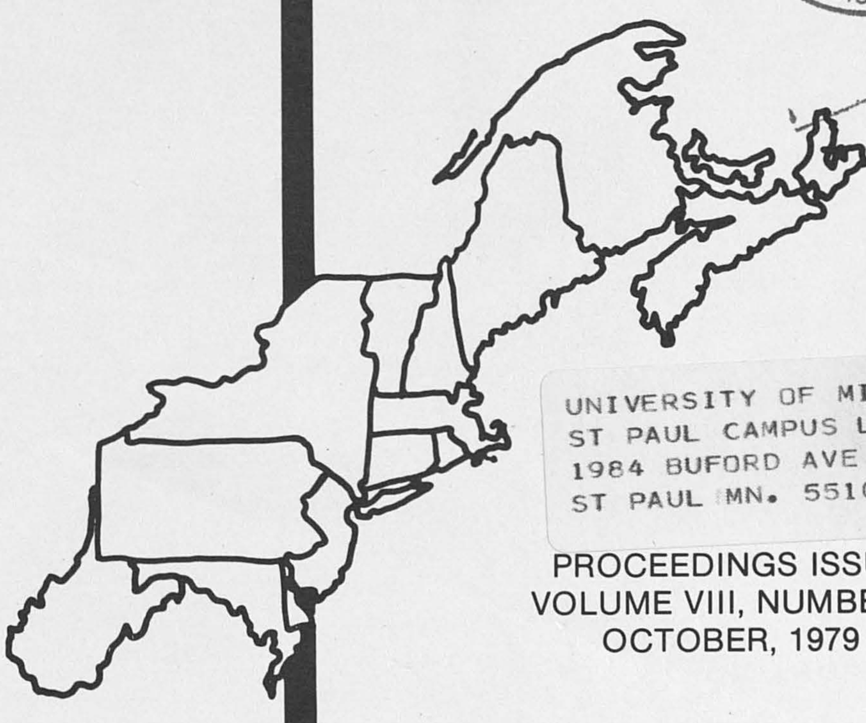

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THE ECONOMIC FEASIBILITY OF SOLAR HOME HEATING SYSTEMS IN NEW ENGLAND

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Since the 1973 oil embargo, substantial interest has focused upon the question of the cost competitiveness of solar space heating and domestic hot water systems for single family residences. As early as 1974, national surveys indicated that homeowners were seriously considering the use of solar systems (National Science Foundation). At the present time, several New England electric companies (Massachusetts Electric, Granite State and Narragansett) are testing commercially available solar domestic hot water heaters in 100 New England homes. Yet, the question of the cost competitiveness of solar systems remains unresolved. For example, a recent study by the Massachusetts Energy Policy Office suggests that solar systems are currently cost competitive with electric resistance heating in the Boston area. The interim findings reported by consultants to the New England Electric Companies conclude that "Solar energy is a victim of unreasonably high expectations...and that several problems must be resolved if solar domestic hot water heaters are to become economically viable." (Little, p. 3). A number of other studies have also arrived at conflicting results (Bezdek, et al; G. Lof and R. Tybout; W.D. Schulze, et al).

The economic feasibility of solar heating systems is reexamined in this paper. The specific objectives are: (1) to evaluate the hypothesis that the diversity of assumptions and data used in economic analysis account for much of the controversy about the feasibility of solar energy; (2) to estimate the extent to which solar feasibility may vary throughout the New England region; and (3) to examine the potential impact of the provisions of the 1978 National Energy Act upon solar energy feasibility.

Solar System Cost Analysis

The simplified design shown in Figure 1 was utilized as the basis for estimating the cost of the solar system. The thermal energy trapped by

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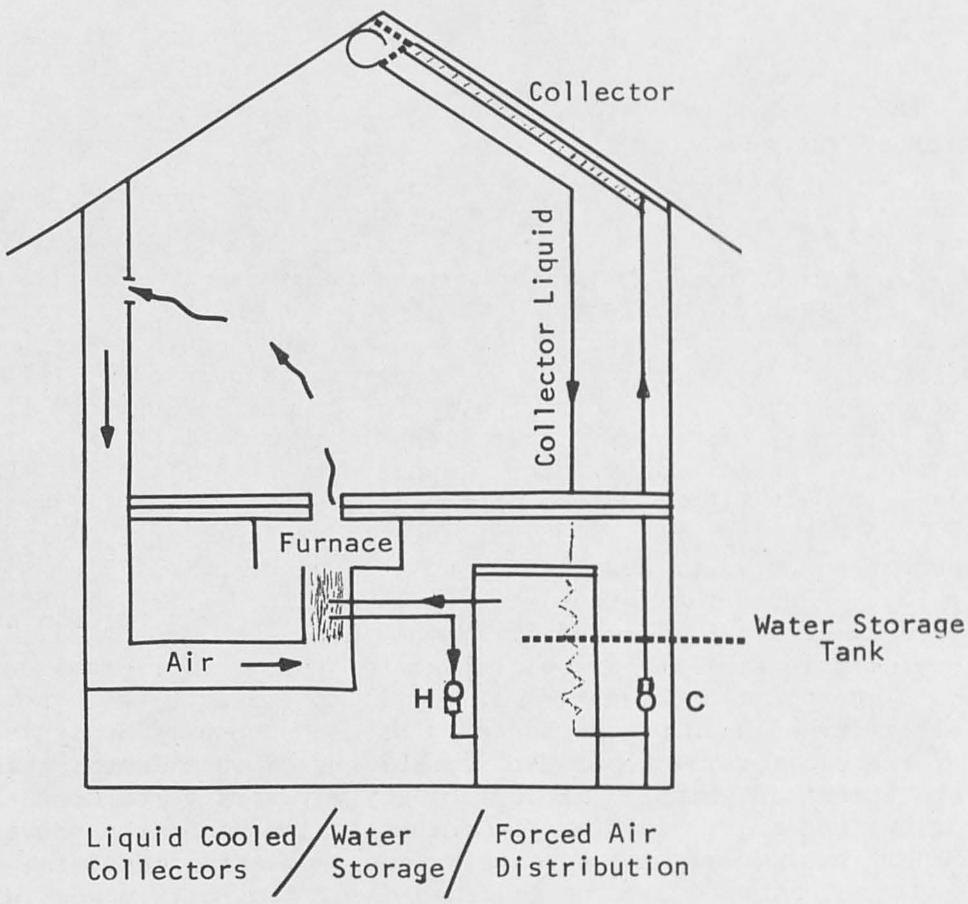
Figure 1. SOLAR HEATING SYSTEM



the collector is transferred to a heat storage unit. By use of blowers and heat exchangers, heat in the storage unit is dispersed throughout the home via a conventional duct system. Hot water can be drawn from the storage unit for domestic purposes. Thus, the system is designed to supply both space heat and domestic hot water. Supplemental heating is provided by a conventional back-up-auxiliary system.

The components for solar heating systems include the solar collectors, the heat storage unit, controls, pipes, fittings, motors, pumps and heat exchangers. The initial cost of a solar system may be expressed as:

$$(1)\quad p_s = p_f + a_c p_v$$

where p_s is the initial solar system cost, p_f the fixed cost of the solar system (piping, controls), a_c the solar collector area and p_v the collector-area-dependent cost of the solar system.[1]

Solar cost estimates vary widely through the economics literature. For the purpose of this analysis, solar contractors were asked to supply cost estimates. The initial fixed cost of the solar components, including average installation cost, was estimated to be $1,000. Collectors were estimated to cost $25 per square foot.

The collector and storage areas needed for the solar system depend upon the supply and demand for heat which are in turn a function of several variables including location, the size of the home, number of occupants, the collector type and performance characteristics, collector tilt, and the thermal (insulation) characteristics of the home. Five geographical locations were considered: Boston, Massachusetts; Amherst, Massachusetts; Portland, Maine; Newport, Rhode Island and Hartford, Connecticut. The amount of heat energy that can be supplied by the solar system in each month in each location was determined by the type of collector, tilt, collector area, and climatic conditions. The demand for space heat for each location was also determined by climatic factors, type of home construction and related variables.

Economic Feasibility

Part of the debate about economic feasibility hinges on the measure of feasibility used. Although the net present value is a preferred investment evaluation technique, most homeowners will also be concerned with the pay-back-period and the number of years before a positive cash flow is realized.[2] Consequently, these three measures of feasibility were used here. In all cases, the economic feasibility of solar energy hinges upon the fact that although a solar system entails a higher initial investment cost (and hence increased mortgage payments), fuel savings will accrue over time.

For the feasibility analysis, a computer program developed for the Department of Housing and Urban Development (HUD) was utilized. Model inputs include location, space heating load of the home, number of occupants, domestic hot water use and temperature, building type and thermal factor, building size, solar collector type, type of auxiliary heating system, fuel prices, fuel price escalation rates, tax rates and interest rates. The computer model was then used to calculate the optimal collector area and to perform the economic feasibility analysis.

To estimate economic feasibility, a base case analysis using the assumptions listed in Table 1 was first developed. Several of the key assumptions underlying this analysis were then systematically altered to determine the sensitivity of the results to the assumptions specified.

Table 1

Assumptions Used for Base Case Analysis of Solar Energy Feasibility

Item	Assumption
Number of occupants	4
Domestic hot water usage	20 gal./day/person
Domestic hot water temperature	140°F
Building type	New
Building thermal factor	8.42 BTU/degree day/ft.^{2}
Building size	1500 sq. ft.
Number of solar collector covers	2
Solar heat storage capacity	15 BTU/°F/sq. ft. of collector
Backup heating system type	Electric
Electricity price	4.5¢/Kwhr.
Annual rate of real electricity price increase	4%
Purchase price of home excluding solar system	$50,000
Fixed cost of solar system	$1,000
Collector cost per square foot	$25
Market value appreciation rate of home per year	5%
Solar maintenance and repairs*	$25/yr. escalating at 5% per year
Property tax rate	3% of value
Combined Federal/State income tax rate	30%
Percent down payment	25%
Mortgage term	30 years
Interest rate	9%
Discount rate	9%

*Does not include replacement of equipment or materials.

Since the cost effectiveness of solar heating systems is highly dependent upon the assumptions used, the initial assumptions listed in Table 1, warrant discussion. First, a new 1,500 square foot, all-electric structure housing four occupants was assumed. The research by Churn indicates that the current (1979) regional electricity price is 4.5¢ per kilowatt hour. This price is projected to escalate at a real rate of four percent annually (Churn.) HUD estimates that domestic hot water consumption averages 20 gallons per day per person. On the basis of discussion with solar contractors, the fixed cost of the solar system was estimated to be $1,000 and the solar collectors were estimated to cost $25 per square foot installed. The home was assumed to appreciate in value at five percent per year; solar maintenance and repairs were estimated to total $25 per year (escalating at five percent annually) (HUD). Property taxes were set at three percent of the home value. A 30 year mortgage at a nine percent interest rate was assumed. For the calculation of the net present value, a 20 year time horizon and a nine percent discount rate were selected. Engineering assumptions (thermal factor and solar heat storage capacity) were derived from HUD.

The results of the initial feasibility analysis are presented in Table 2.

Table 2

Base Case Solar Feasibility Analysis; Comparison With an All-Electric Home

Location	Collector Area* Sq. Ft.	Years to Positive Cash Flow	Pay Back Years	After Tax Net Present Value $
Amherst, MA	75	14	> 30	- 888
Hartford, CT	125	1	22	- 240
Portland, ME	150	1	20	+ 181
Boston, MA	100	7	29	- 824
Newport, RI	125	1	23	- 293

*Area which maximizes positive or minimizes negative net present value.

As shown in Table 2, the solar system was found not to be cost competitive with electric resistance heating given the assumption specified. Although a small positive net present value was estimated for Portland, the relatively long pay back period indicates that most homeowners would probably not install a solar system of the type examined. In comparison with an oil heated home, solar systems were found to be even less competitive for all locations examined.[3] Systems designed solely to provide domestic hot water were found to have a negative net present value in all locations examined.[4]

These results are, however, sensitive to the assumptions used. Specifically, the cost of solar collectors and the anticipated fuel price escalation rate vary widely within the solar economics literature. Collector cost estimates ranging from $10 to $40 or more per square foot have been reported. Electricity and fuel oil prices have been assumed to escalate from between zero and 10 percent per annum. In fact, the diversity of data used in economic analysis accounts for much of the controversy about the feasibility of solar energy. To demonstrate this, solar collector costs were assumed to range from $15 to $40 per square foot. All other parameter values listed in Table 1 were used. However, the collector area was set at 300 square feet. This was done because the collector area which minimizes a negative net present value would be zero for the high collector cost senarios. The results are presented in Table 3. As shown in Table 3, the economic feasibility of solar home heating systems is quite sensitve to the collector cost value. Of particular importance is the difference in the results obtained between the case where the collector area is optimized (Table 2) and the case when the collector area is set at a predetermined value (row 4 of Table 3).

Table 3
Sensitivity of Solar System Feasibility to Collector Cost Assumption: Comparison With All Electric Home*

Solar System Cost Per Square Foot	After-Tax Net Present Value $				
	Hartford	Portland	Amherst	Boston	Newport
$10	3163	4045	1849	1879	3039
15	1635	2517	322	321	1511
20	108	989	-1206	-1206	-16
25	-1420	-538	-2733	-2734	-1544
30	-2947	-2066	-4261	-4266	-3071
35	-4475	-3593	-5788	-5789	-4599
40	-6002	-5121	-7316	-7316	-6127

*For 300 square feet collector area.

To determine the sensitivity of the results to the electricity price escalation rate, solar collectors were assumed to cost $25 per square foot; all of the other base case assumptions (Table 1) were used; and electricity prices were assumed to escalate from between 0 and 10 percent per year. The results reported in Table 4 indicate that solar feasibility is very sensitive to the anticipated fuel price escalation rate.

Table 4

Sensitivity of Solar System Feasibility to Electricity Price Escalation Rate: Comparison with an All Electric Home*

Electricity Price Escalation Rate Per Annum (%)	After-Tax Net Present Value $				
	Hartford	Portland	Amherst	Boston	Newport
0	-3315	-2655	-4300	-4300	-3409
1	-2912	-2204	-3966	-3966	-3011
2	-2465	-1705	-3597	-3597	-2572
3	-1969	-1152	-3188	-3188	-2083
4	-1420	-538	-2733	-2733	-1544
5	-809	144	-2229	-2229	-943
6	-129	903	-1667	-1667	-275
7	-627	1747	-1042	-1042	469
8	1471	2689	-345	-345	1299
9	2411	3739	432	432	2224
10	3461	4912	1300	1300	3257

*For 300 square feet collector area.

To evaluate the effect of a combination of assumptions, collectors were assumed to cost $15 per square foot and electrictiy prices were assumed to escalate at six percent per annum. In this case, the optimum collector area was calculated for each location as is shown in Table 5.

Due to the high initial cost of solar systems and the uncertainty about collector costs and fuel price escalation rates, the feasibility of solar heating systems appears to be uncertain from a financial viewpoint.

This siutation arises in part because incentives which were instrumental in the development of fossil fuels have historically been lacking in solar energy development. Many economists point out that the special tax provisions granted oil and gas producers have resulted in the delay in the development of renewable energy resources such as solar (Chapman). Several policies designed to stimulate the use of solar systems have, however, recently been enacted. Specifically, the National Energy Act of 1978 provides for an income tax credit for the installation of solar home heating systems. In addition, state incentive programs, such as property tax exemptions have recently been implemented. To evaluate the potential

Table 5

Solar Feasibility Analysis: Comparison With an All-Electric Home, Low Collector Cost - High Fuel Price Escalation Rate

Location	Collector Area* Sq. Ft.	Years to Positive Cash Flow	Pay Back Years	After Tax Net Present Value $
Amherst, MA	275	1	15	1445
Hartford, CT	375	1	13	3075
Portland, ME	425	1	12	4287
Boston, MA	250	1	15	1468
Newport, RI	350	1	13	2872

*Area for which net present value is a maximum.

effect of these programs the feasibility analysis was revised to include an income tax credit (22 percent of the cost of the solar system) and a 100 percent property tax exemption for the solar system components.

Given the assumptions in Table 1, the results (Table 6) indicate that with these subsidies, solar home heating may be marginally competitive with electric resistance heating systems (on a net present value basis) in all locations examined. However, the relatively long pay back periods indicate that solar systems may not be widely adopted. The net present value of a system designed solely to provide domestic hot water ranged from $233 (Amherst) to $667 (Portland, Maine).

A stronger program to facilitate the transition from nonrenewable to renewable energy resources such as solar may be needed. In fact, the current Federal tax subsidy program may be economically inefficient. The benefit/cost ratios in Table 7 were defined as the net present value of solar savings per dollar of subsidy. Regional variations in the subsidy program may clearly be preferred on the basis of economic efficiency.

POLICY IMPLICATIONS AND CONCLUSIONS

The results indicate that the diversity of data and assumptions used may account for much of the debate about the feasibility of solar energy. The sensitivity of the results to several assumptions was examined, and the relative importance of each evaluated. The cost-competiveness of solar energy was shown to vary rather widely throughout New England and it was demonstrated that the tax provisions in the 1978 Energy Act may stimulate solar utilization. However, the solar systems examined appear

Table 6

Solar Feasibility Analysis With Solar Subsidies:
Comparison With An All-Electric Home

Location	Collector Area* Sq. Ft.	Years to Positive Cash Flow	Pay Back Years	After Tax Net Present Value $	Electrical Energy Saved (mm BTU)** Per Year
Amherst, MA	275	1	19	1535	37
Hartford, CT	375	1	17	2928	54
Portland, ME	425	1	16	3963	64
Boston, MA	250	1	18	1554	36
Newport, RI	350	1	17	2754	51
Comparison With Oil Heated Home					
Amherst, MA	150	4	23	$247	
Hartford, CT	200	1	20	$824	
Portland, ME	225	1	19	$1182	
Boston, MA	150	3	22	$337	
Newport, RI	200	1	21	$806	

*Area for which net present value is a maximum.

**Accounts for system efficiency factor.

to be only marginally feasible in comparison with the most costly alternative - electric resistance heating.

The current Federal tax incentive system is probably not sufficient to significantly stimulate the utilization of solar energy if fuel oil is available at the prices specified (Table 6).

Table 7

Benefit-Cost Analysis of Federal Solar Tax Subsidy Program: All-Electric Home Comparison*

Location	Solar System Cost	B/C
Amherst	$ 7,875	.89
Hartford, CT	10,375	1.28
Portland, Me	11,625	1.55
Boston, MA	7,250	.97
Newport, RI	9,750	1.28

*Calculated from Table 6

Despite the potential for cost competitiveness with electric resistance heating, solar systems are not expected to capture a major share of the energy market in the near future. Market adoption will be limited by several factors. First, the industrial base for solar systems is inadequately developed. A report by General Electric indicates that the necessary industrial base may not be established until the mid 1980's. Second, since the housing capital stock is renewed at a very slow rate, the major energy savings from the use of solar systems will depend upon as yet unproven retrofit applications. That is, although solar energy may be cost-competitive for new homes, they are likely to be less so for older homes. As a result, the potential impact of solar home heating systems may be only a small percentage of the total energy demand by 1990.

Further research is obviously required. Little is known about the economic feasibility of passive solar home heating systems, active airflow systems, retrofit applications, or economies of scale in solar component manufacture. Moreover, as with all relatively new technologies, experience gained may result in more efficient production in the future. Although "learning" theories have been traditionally applied to production line processes, they may also apply to less standardized processes such as solar energy systems. Research to estimate the benefits and costs of "learning by doing" may therefore prove fruitful.

FOOTNOTES

[1]The cost of the auxiliary heating system was included in the purchase price of the home.

[2]The pay-back-period is defined as the number of years necessary for the cumulative value of fuel savings to equal the remaining unpaid principal due to the solar system. A positive cash flow is received in the year in which the energy savings of the solar systems become greater than the extra expenses due to the system.

Most purchasing decisions by homeowners are not made solely on a life cycle cost basis. The decision to purchase an energy system will likely be a function of several factors. Homeowners with similar decision criteria may act differently depending upon the perspective concerning the risk, reliability, cost and performance of alternative heating systems. This implies that a solar heating system may not be purchased even though it may be life cycle cost competitive.

[3]The fuel oil price was assumed to be 55¢/gallon escalating at a real rate of four percent per year.

[4]On the basis of conversations with solar contractors, the fixed cost and area-dependent costs of a domestic hot water system were estimated to be $500 and $30/sq. ft., respectively.

REFERENCES

Bezdek, R.H., et al. "Economic Feasibility of Solar Water and Space Heating." Science. 203. (March 1979):1214-1220.

Chapman, Duane. Taxation, Energy Use and Employment. Washington: U.S. Congress, Joint Economic Committee, Subcommittee on Energy. March 15, 1978.

Churn, W.S., et al. Regional Econometric Model for Forecasting Electricity Demand for Sector and State. Springfield: National Technical Information Service. October 1978.

General Electric. Solar Heating and Cooling of Buildings. Washington: Government Printing Office. 1974.

Lof, G. and R.A. Tybout. "Cost of Home Heating with Solar Energy." Sol. Energy. Vol. 14, Number 253, (1973).

Massachusetts Energy Policy Office. "The Use of Solar Energy for Space Heating and Hot Water." Boston: Energy Policy Office. 1976.

National Science Foundation. Project Independence. Washington: Government Printing Office. 1974.

Schulze, W.D., et al. Solar Home Heating. Joint Economic Committee, U.S. Congress. 1977.

U.S. Department of Housing and Urban Development, Division of Energy. HUD Residential Solar Economic Performance Model. Washington: Housing and Urban Development. June, 1977.