ECONOMIC FEASIBILITY OF USING SOLAR ENERGY IN THE PRODUCTION OF GREENHOUSE TOMATOES

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INTRODUCTION

The energy crunch of the mid-seventies has adversely affected the greenhouse tomato industry in the North Central and Northeast regions. Traditionally, these two regions had been the main producers of greenhouse tomatoes in the U.S. where, because of the climatic restrictions, greenhouse tomato production evolved to supply fresh tomatoes during winter and spring months. Since greenhouse producers in the north rely on fossil fuels for heating purposes, their production costs have escalated, thereby tending to price these tomatoes out of the market. In recent years many greenhouse tomato producers in the northern regions have either ceased production or switched into alternative enterprises. For instance, the Census of Agriculture reported 45 growers in Massachusetts in 1974, with covered areas of 535,842 square feet; by 1979, according to extension experts, the number declined to 25 and the area declined to between 150,000 and 200,000 square feet. The number of growers in New Jersey declined from 42 in the 1974 census to only 19 in 1979. Similar declines have occurred in New York and Pennsylvania.

The use of solar energy for heating greenhouses has been suggested as one of the solutions to the problems facing the greenhouse tomato growers. Extensive research by universities and greenhouse equipment manufacturers has resulted in feasible solar greenhouse systems which are currently available for installation. These greenhouses require large capital outlays, however, and it is not known whether tomato growers can use the solar energy profitably or not. The purpose of this paper is to explore the economic feasibility of using currently available solar technology by small scale greenhouse tomato producers in the Northeast.

METHODOLOGY

The economic feasibility of solar energy in the production of greenhouse tomatoes was analyzed by comparing costs of tomatoes raised in solar heated and conventionally heated greenhouses in New Jersey. To estimate the cost of producing greenhouse tomatoes, two model greenhouse operations were developed, one using conventional heating technology and the other using a solar technology. The former was based upon data on actual greenhouse tomato operations in New Jersey collected in 1979. Since there were no solar greenhouses employed in the production of tomatoes in 1979, a comparable model of a solar greenhouse was based on an experimental solar greenhouse constructed at the New Jersey Experiment Station Research Farm.

A budgeting procedure was used to estimate the capital investment and corresponding production costs for each model. Since production of greenhouse tomatoes is most common in the spring, initially production costs for only a spring crop were estimated. However, an alternative scenario was also examined in which a fall utilization of the greenhouse for a double crop was considered.

CONVENTIONALLY HEATED GREENHOUSE MODEL

The typical grower in New Jersey operated a single greenhouse as a part-time activity in the spring season. The greenhouse was covered by plastic and measured 96'x30' in size. The structure was assumed to be purchased as a ready made kit from a manufacturer and assembled by the operator. It was covered with two layers of 6 mil plastic and was heated by hot air from two oil fired furnaces. On the floor six rows of beds were placed lengthwise and lined with 6 mil black plastic. The beds were filled with artificial growing medium consisting of peatmoss, vermiculite and perlite in the ration of 2:2:1. The growing medium was used for three years with small amounts of fresh medium added in the second and third years. Before each use, the medium was sterilized with steam. There were 720 plants grown in the house. While in the early 70's, the seedlings were transplanted in beds in February and tomatoes were harvested from May to early July, more recent attempts to conserve energy have led the majority of growers to delay transplanting by a few weeks and lengthen the harvest through July. The later schedule was assumed for the model operation.

SOLAR HEATED GREENHOUSE MODEL

To affect a maximum conservation of fossil fuel used in heating a greenhouse, scientists at Rutgers University have designed a solar energy system which contains the following key elements: (1) a moveable curtain insulation system, (2) a low cost external solar collector constructed of plastic, (3) a porous concrete capped floor system which serves both as a heat storage and heat exchange system, (4) vertical curtains used as heat exchangers and (5) a styrofoam filled north wall. A 48'x100' double filmed greenhouse had been retrofitted with the above type of solar heating system and used for research on tomatoes and other vegetables. In view of the paucity of information, technical data from this greenhouse was used to estimate the construction and operating costs of a 96'x30' solar heated greenhouse model. The solar heat was captured by water circulating in two 14'x96' plastic solar collectors

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and stored in a gravel filled pool underneath the greenhouse floor. Back up heat was provided through hot water heated by a fossil fuel furnace.

On the basis of research with a solar prototype, a large commercial solar greenhouse which produces bedding plants, and the experimental solar greenhouse, scientists have estimated that a properly installed solar system can supply 50 percent of the heat requirements under climatic conditions existing in New Jersey (Roberts, Simkins, Janes and Mears). Therefore a 50 percent reduction in fuel was assumed for the production of a spring crop of tomatoes.

CAPITAL INVESTMENT

Capital investment in the conventional greenhouse model included costs of structure and structural materials, heating and watering equipment, growing medium, land, tools and miscellaneous equipment. Construction costs for the model were based on 1979 prices obtained from greenhouse manufacturers and hardware stores. Total capital investment for the conventional greenhouse model was $14,792.44 (Table 1). The greenhouse structure and structural materials and the heating and watering systems accounted for most of the capital cost. The investment inclusive of growing medium was $5.14 per square foot of greenhouse space.

In addition to investment in the greenhouse structure and the watering equipment of the conventional house, the solar greenhouse model required investment in an overhead movable blanket, a floor storage/heat exchange system, two solar collectors, backup heating system, and vertical curtain heat exchangers. The investment in tools and growing medium was identical to that for the conventional model. The total amount invested in the construction of the solar greenhouse was $30,903.08 (Table 1). Per square foot of the greenhouse space, the investment amounted to $10.73 which is over twice the figure for the conventional heated greenhouse.

PRODUCTION COSTS

Next, the costs of producing a spring crop of tomatoes in the greenhouse models were estimated. Total production costs for each operation were divided into three categories: depreciation and interest, current production expenses, and labor costs. Costs were also calculated under the assumption that a supplementary fall crop was produced in the greenhouse, thereby reducing the overhead costs for the spring crop of tomatoes.

Depreciation and Interest: Straight line depreciation of the capital items used in construction of the model was assumed. Estimates of useful lives were obtained from previous studies and equipment manufacturers. Agricultural engineers were consulted in establishing useful lives of solar equipment which is a rather new technology. Based on the replacement schedules, the annual depreciation was $1,646.92 for the conventionally heated model and $3,052.65 for the solar model. The yearly interest expense was based on

Table 1. Total Investment in Model Greenhouse Operations, 1979

Item	Conventionally Heated Greenhouse	Solar Heated Greenhouse
Land	$ 684.00	$ 1,026.00
Structure	8,020.04	8,020.04
Heating and Watering Equipment	4,028.06	5,616.16
Overhead Movable Blanket Insulation System	N/A	3,875.52
Floor Storage/Heat Exchange System	N/A	4,197.34
Solar Collectors (two)	N/A	5,320.24
Vertical Curtain Heat Exchangers	N/A	787.44
Tools and Equipment	649.50	649.50
Growing Medium	1,410.84	1,410.84
Total Investment	$14,792.44	$30,903.08
Average Investment	$ 7,396.22	$15,451.54
Interest at 10%	739.62	1,545.15

one-half of the initial investment. At an assumed long-term rate of ten percent, the yearly interest expense was $739.62 for the conventionally heated greenhouse and $1,545.15 for the solar model. The total depreciation and interest cost was $2,386.54 and $4,597.80 for the conventional and solar model, respectively.

Current Production Expense: The production expenses were based on a nineteen week growing season for spring tomatoes. In a conventionally heated greenhouse the largest component of current production expenses for a crop of spring tomatoes was fuel, which comprised 40 percent of total expenses. The fuel requirement was estimated at 1,452 gallons and an additional 150 gallons were needed for steaming of the medium. At a price of $0.64 per gallon of No. 2 fuel oil in 1979, the total cost of fuel for the spring season was $1,025.28. For the solar house, the fuel use for backup heat was assumed to be reduced by one half or 726 gallons. The total fuel use, including 150 gallons for steaming of the medium, was 876 gallons, and represented 22 percent of total production expenses. Property tax and insurance costs were relatively higher for the solar greenhouse because of the greater level of investment. Pesticide use was also slightly higher because of the greater humidity in the solar house. Other production expenses were the same. The total current production expenses, including short-term interest calculated at 12 percent annual rate, were $2,569.32 and $2,523.32 for the conventional and solar model, respectively (Table 2).

Labor Cost: The cost of labor used in the production of spring tomatoes was based on a total of 396 manhours of labor used in the conventional greenhouse. The labor requirements were determined from the 1979 survey of growers and a previous study (Dhillon, Griffin and Taylor). At $4.37 per hour, the total cost of labor for the conventional operation was $1,730.52. Solar greenhouse operation was budgeted with an additional two hours of labor for pest management. The total cost for this operation was $1,739.26.

Total Production Cost: The estimated total production cost for a crop of spring tomatoes grown in the conventionally heated model was $6,686.38 (Table 3). Depreciation and interest, current production expenses, and labor cost accounted for 36, 38 and 26 percent, respectively. In the 1979 interviews of tomato producers, an average yield of 13 pounds per plant was reported and assuming 720 plants in the model greenhouse, the total output of spring tomatoes was 9,360 pounds. Thus, the per pound cost of producing spring tomatoes in the conventionally heated model was approximately $0.71.

The total cost of producing a crop of spring tomatoes in the solar greenhouse was $8,860.38. Assuming, again, a total output of 9,360 pounds, the cost per pound for producing spring tomatoes was $0.95.

Total Production Cost with Fall Use of the Greenhouse: It is reasonable to assume that in addition to a spring crop, a fall crop of tomatoes or flowers may be grown in the greenhouses. This would result in the reduction of overhead costs for the spring crop. Specifically, depreciation, interest expense, property tax and insurance costs would be reduced by one half due to the extended use of the greenhouse. Assuming no effect on other current production expenses and labor costs, the total cost of producing the spring crop of tomatoes under this arrangement would be $5,331.42 for the conventionally heated house and $6,203.03 for the solar house. The respective per pound costs would be $0.57 and $0.66 (Table 3).

COMPARISON OF COSTS

Under New Jersey conditions, the per pound cost of producing a single crop of spring tomatoes in a solar heated plastic greenhouse was 34 percent greater than the cost for an oil heated greenhouse ($0.95 versus $0.71). Use of solar energy reduced the fuel cost by about 5 cents per pound but increased the investment related costs by about 29 cents. Even if the greenhouse was also utilized for a supplementary fall crop, the per pound cost with solar energy was still 16 percent greater than the cost with oil heat. Thus, with the prevailing solar technology and fuel prices, use of solar heat was not competitive with the conventional oil heat.[1]

SENSITIVITY ANALYSIS

Though yield had no effect on the relative difference between the per pound costs, the absolute difference increased at lower yields and decreased at higher yields (Table 4). Even at the high yield of 16 pounds per plant the cost of solar tomatoes was 19 cents greater than the cost of conventionally produced tomatoes. With the use of the greenhouse in the fall, the difference in costs narrowed to eight cents.

An increase in the fuel price would increase both costs, but the impact would be relatively greater on the cost of conventionally produced tomatoes. However, the results showed that even at a relatively high fuel price of $1.20 per gallon, substantial differences between the two production costs persist (Table 4).

Other important factors affecting the differential in per pound costs were the interest rate and the extent of fuel savings. An increase in the interest rate would again increase both costs but would impact more heavily on the solar costs because of the greater investment in the solar operation.

With the assumption of 75 percent fuel savings, solar energy was still not competitive with conventional heat. According to agricultural engineers, under ideal conditions this may be the maximum extent of fuel saving accomplished with a solar system. Under this assumption, per pound costs were $0.92 with one crop production and

[1] The break-even price of fuel oil which would equalize the cost of solar production with that of conventional production was estimated to be $3.46 per gallon when no fall crop was produced and $1.77 per gallon when the greenhouse was utilized in the fall.

Table 2. Estimated Current Production Expenses for Spring Tomatoes, Model Operation, 1979.

Item	Conventionally Heated Greenhouse	Solar Heated Greenhouse
Fuel - Number 2 Oil[a]	$ 1,025.28	$ 560.64
Electricity	357.96	357.96
Rent for Boiler	110.00	110.00
Medium Addition[b]	46.98	46.98
Clips	156.00	156.00
Twine	26.00	26.00
Seed	80.00	80.00
Pots	30.00	30.00
Local Property Tax	245.09	556.33
Insurance	60.00	120.00
Fertilizer:[c]		
for Mixing with Medium	86.60	86.60
for Feeding Plants	74.98	74.98
Insecticides, Fungicides	125.00	175.00
Sub total	$2,423.89	$2,380.49
Short-term Interest @12% for 6 months	145.43	142.83
Total	$2,569.32	$2,523.32

[a] Conventionally heated house required 1,602 gallons of fuel and solar heated house required 876 gallons of fuel with 50% energy obtained from the sun.

[b] Five percent of the initial mix was assumed to be added annually to compensate for decomposition of medium.

[c] Based on Growing Greenhouse Tomatoes in Trough Culture Using a Peat-Vermiculite Medium, G.A. Taylor and R.L. Flannery, Cooperative Extension Service, Rutgers University, Vegetable Crops Offset Series No. 33, 1975.

Table 3. Total Cost of Producing Spring Tomatoes With and Without Fall Use of the Greenhouse Model Operations, 1979.

	Conventionally Heated		Solar Heated	
	Without Fall Use of Greenhouse	With Fall use of Greenhouse	Without Fall Use of Greenhouse	With Fall Use of Greenhouse
Depreciation and Interest	$ 2,386.54	$1,193.27	$ 4,597.80	$ 2,298.90
Current Production Expenses	2,569.32	2,407.63	2,523.32	2,164.87
Cost of Labor	1,730.52	1,730.52	1,739.26	1,739.26
Total Cost	$6,686.38	$5,331.42	$ 8,860.38	$ 6,203.03
Cost per pound[a]	$ 0.71	$ 0.57	$ 0.95	$ 0.66

[a] Based on a crop of 720 plants with a yield of 13 pounds each.

Table 4. Sensitivity of Per Pound Production Costs of Spring Tomatoes With or Without Fall Use of Greenhouse, Model Operation

	Yield Per Plant					
	10 Pounds		13 Pounds		16 Pounds	
Price of Fuel Per Gallon	Conventional	Solar	Conventional	Solar	Conventional	Solar
	----------Dollars----------					
Without Fall Use						
$0.64	0.93	1.23	0.71	0.95	0.58	0.77
1.00	1.01	1.28	0.78	0.98	0.63	0.80
1.20	1.06	1.30	0.82	1.00	0.66	0.81
With Fall Use						
$0.64	0.74	0.86	0.57	0.66	0.46	0.54
1.00	0.83	0.91	0.63	0.70	0.52	0.57
1.20	0.87	0.94	0.67	0.72	0.55	0.59

$0.64 with the production of a fall crop, well above conventional costs in both instances.

EFFECT OF TAX CREDITS

The above comparison of costs needs to be refined for the tax credits applicable to the greenhouses. Since costs have been based on the construction of new greenhouses, investment in both types of facilities would be eligible for the regular investment credit. In addition, part of the energy related equipment in the solar greenhouse would be eligible for an additonal energy investment tax credit. Therefore, production costs of spring tomatoes were adjusted for the applicable tax credits to allow a more realistic comparison of the solar and oil heated operations.

Regular investment credit would apply to items which have a life of at least three years.[2] Items with seven or more years of life would qualify for the full ten percent credit while items with lives of over three years but less than five years would qualify for 1/3 of the full rate, and items with lives of over five years but less than seven years would be eligible for 2/3 of the full rate (Internal Revenue Service). The additional investment credit for the eligible energy equipment would also apply according to the above schedules except that the full credit for the solar collectors is permitted at 15 percent of the investment. The total regular investment credit for the conventionally heated house was $1,158.15. For the solar heated greenhouse the regular investment tax credit was $1,941.33 and the additional energy related investment tax credit amounted to $913.46.

Adjusting the production costs to account for these credits reduced the per pound costs of spring tomatoes in the conventional model two cents to $0.69 for the single crop production and one cent to $0.56 with the fall utilization. For the solar house, tax credits reduced the per pound costs six cents to $0.89 without fall use and two cents to $0.64 with fall use of the house. Thus, even though the solar operation had a bigger tax credit and experienced a greater reduction in costs, the overall magnitude of the savings was too small to bridge the gap substantially between the solar and conventional costs. After considering the tax credit, the solar costs of spring tomatoes still exceeded the conventional costs by 29 percent without fall utilization of the greenhouse and by 14 percent with the fall utilization

[2] Information was obtained through IRS Publication 572 and consultations with Barbara Bessel of the IRS. The authors disavow any responsibility stemming from the misinterpretation of the tax laws. It should be noted that tax laws are subject to change, hence actual benefits may vary from year to year and with different circumstances of operations.

SUMMARY AND CONCLUSIONS

Recent increases in energy costs have stimulated the interest of greenhouse tomato growers in solar energy. The estimates from an engineering model show that construction of a solar greenhouse would involve a large investment of capital. Construction costs of a typical 96'x30' plastic greenhouse fitted with the Rutgers solar heating system were estimated to be $30,903 or $10.73 per square foot of floor space. This was 109 percent greater than the comparable investment in a conventional oil heated plastic greenhouse.

Based on engineering estimates, a properly constructed solar greenhouse used in the production of spring tomatoes may conservatively capture 50 percent of its energy requirements from the sun, thereby reducing the fuel costs by 50 percent. These savings would, however, be more than offset by the higher investment related costs of the solar greenhouse. As a result spring tomatoes produced with solar heat would cost 34 percent more than the tomatoes produced with the conventional heat. Utilization of the greenhouse for a fall double crop would spread the overhead costs and thereby reduce the solar per pound costs to a greater degree than the conventional per pound costs. Still, per pound costs with solar heat would exceed that of the oil heat by 16 percent.

The investment tax credits available to the new greenhouse operators would benefit the solar greenhouse operation to a greater extent than the conventionally heated operation but the overall reduction in costs would be small. Even after the tax credits were included, per pound costs of spring tomatoes produced in the solar house exceeded the costs with oil heat by 29 percent when one crop was produced in the greenhouse and by 14 percent when two crops were produced.

Thus, with prevailing technology and fuel prices, use of solar heat in the production of spring greenhouse tomatoes does not appear to be a viable alternative to oil heat. Only drastic increases in oil prices and low interest rates would favor the use of solar energy. However, at the moment, both of these developments seem unlikely.

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