PLANNING SOLAR HEATING FOR POULTRY— A LINEAR PROGRAMMING APPROACH

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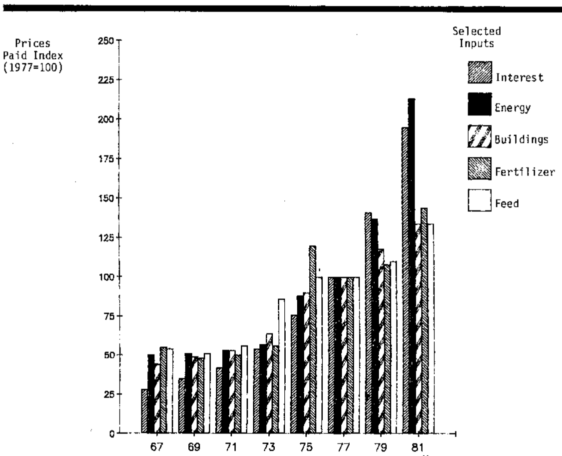
INTRODUCTION

During recent years we have begun to expect increases in prices that farmers pay for inputs. Rising costs of production have adversely affected the profits of many farming operations. The greatest relative change in prices has been in interest rates, but since 1972, and particularly since 1978, energy costs have exhibited a steep climb, as shown in Figure 1 (USDA, p. 427). Energy inputs such as LP gas, which is used heavily by the poultry industry, have shown particularly larger increases. The LP gas price paid by farmers nationwide rose from 38.9 cents per gallon in 1977 to 69.7 cents per gallon in 1981, a 79 percent increase (USDA, p. 422).

These energy cost increases have placed great burdens on many individuals and businesses. Farmers who have depended heavily upon fossil fuels have been especially hard hit. Broiler producers, for example, use significant amounts of natural gas, fuel oil, and propane in heating their facilities. The level of energy resources used in the poultry industry was discussed in detail by Rogers, Benson, and Van Dyne.



Source: USDA

Figure 1. Index of Prices Paid for Selected Agricultural Inputs, 1967–1981

The increased cost of these fuels has forced poultry producers to closely examine the economic efficiency of their operations (Koon, Flood, and Brewer). Some researchers have predicted that there will be significant changes in production practices in the poultry industry and that production will shift more to the Southern region (Debertin and Pagoulatos, p. 54). This shift toward a milder climate should reduce the amount of supplemental heat needed and would also make it possible to more effectively use alternatives such as solar energy.

Solar power has been proposed as an alternative energy source for many years. Price increases of traditional sources of energy during the 1970s have resulted in additional emphasis on its utilization. Even with the improved technology that exists today in the manufacture of solar energy equipment, however, the initial investment cost remains relatively high. It has been emphasized that the high initial investment in a solar heating system is one of the major barriers to its widespread adoption and use (Bezdek; Cain and Van Dyne; Trotter, Heid and McElroy; Yarosh and Beatty). This high cost emphasizes the importance of installing the proper size unit so that maximum benefit is received per dollar spent. According to Reece, "Economically, most of the cost of solar energy is for the equipment to capture and store it; the 'fuel' itself is free of charge" (p. 815).

Research results given in this paper came from a project designed to evaluate the economic potential for a solar heating system in broiler houses.[1] Emphasis is given to how linear programming can be used to assist in selection of the proper size solar heating system for a given broiler house so that the initial investment cost for the heating unit can be minimized. The methodology followed in this example would also be appropriate for determining the minimum-size solar heating system for other applications.

PROBLEM SPECIFICATION

Several factors must be considered when attempting to determine the optimal size solar heating system for

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[1] Data for this study were derived from measurements taken at the Alabama Agricultural Experiment Station Solar Research Unit, Auburn, Alabama.

a broiler house. Basic considerations focus on the demand for and supply of heat. From the demand side, heating needs vary throughout the year. The level of demand is dependent upon outside temperature, age and number of birds in the house, humidity, and heat loss and ventilation rates for the house.

Data plotted in Figure 2 illustrate a typical heat demand pattern for brooding poultry throughout the year (Koon). The specific data are for five batches of 15,000 birds each housed in a 12,000-square-foot facility located in Auburn, Alabama. Heating requirements for each flock of birds were derived using procedures outlined by Reece and Lott. Peak demand normally occurs at the beginning of each brooding period. As birds grow larger, reduced temperature requirements and increased body heat help diminish the need for additional heating of the house. Supplemental heat is even required for birds started during the middle of summer.

Several variables must be considered when determining the amount of heat that would be supplied through a solar heating system. Major factors that must be considered are the efficiency of collectors and the storage system, the number of heating degree days,[2] and the probability of sunshine. Procedures are available for estimating the amount of heat that could be generated (Keyes); however, actual experimental data were available for use in this analysis (Koon). Data presented in Figure 3 illustrate the amount of heat (measured in BTUs) provided daily per square foot of collector over the year.

Previous research has indicated that even though a well-designed solar heating system would provide a significant amount of the heat necessary for brooding poultry, it could not satisfy the total needs (Brewer, Flood, and Koon). Variability in the availability of sunshine and extreme heating needs for broilers during winter months would definitely influence the economic feasibility of constructing a solar heating system large enough to supply total year-round heating needs. Therefore, all analyses in this report considered

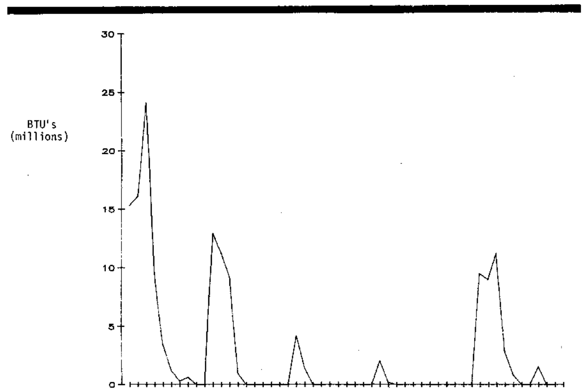

Figure 2. Illustration of Heat Required Throughout Year for Five Batches of 15,000 Broilers in a 12,000 Sq. Ft. House

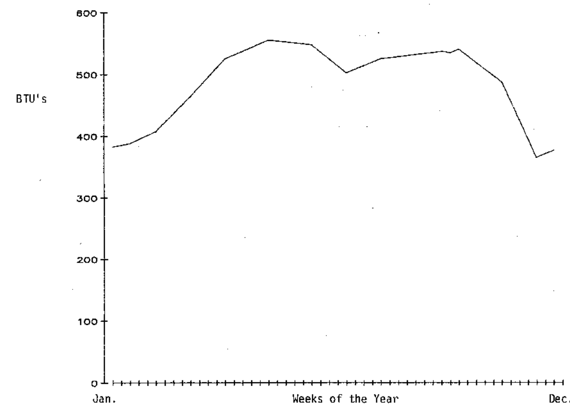

Figure 3. Illustration of Heat Generated per Sq. Ft. of Solar Collection During a Year

the solar heating system as a supplement to an LP gas system.

THE MODEL

After data giving both the demand for heat and the supply available from solar energy were derived, a multiperiod linear programming model was constructed to assist in determining the optimum-size solar heating system for a 12,000-square-foot broiler house. The linear programming matrix given in Table 1 illustrates the basic procedure used to determine the minimum-size solar heating system necessary to provide specified percentages of the total heating needs. Only three periods are illustrated; however, the model used in the analysis had 365 periods to permit a simulation of daily heating requirements.

The first column (activity) represents buying a square foot of solar collector. The number of panels purchased obviously represents the size of the system. If this variable is minimized, the system will be as small as possible, thus minimizing investment cost for the solar heating system. The rows labeled PANELS control the availability of solar panels for each period in the model. Each square foot of panel that is purchased would be available and used for the entire 365-day production process.

The SOLAR COUNT and LP GAS COUNT activities are necessary for controlling the percentage of total heating supplied by the two energy alternatives. Rows SOLAR BTU and LP GAS BTU monitor the number of BTUs of energy from each source. Since the system is not 100 percent efficient, BTU values used represent the levels of heat energy that are actually available. Row BALANCE BTU controls the specified portion of heating needs from solar energy. For the example in Table 1, solar energy would supply 40 percent of total needs. The coefficients in this row may be changed to require the solar heating system to provide other portions of the total heating needs. For example, if the solar heating system was forced to provide 20

[2] Heating degree day is defined as the number of degrees the average daily temperature is below a base point (usually 65° F). A single calendar day may have many heating degree days depending on the outside temperature. For example, if the average temperature for a given day is 45° F, the heating degree days for that day would be 20.

Table 1. Illustration of Linear Programming Matrix Used for Determining the Minimum Size Solar Heating System to Provide a Specified Percentage of Total Heating Needs for a 12,000 Square Foot Broiler House

	BUY SOLAR PANELS	SOLAR COUNT	LP GAS COUNT	SOLAR ENERGY1	STORE ENERGY1	EXCESS ENERGY1	LP GAS1	SOLAR ENERGY2	STORE ENERGY2	EXCESS ENERGY2	LP GAS2	SOLAR ENERGY3	STORE ENERGY3	EXCESS ENERGY3	LP GAS3	RIGHT HAND SIDES
OBJECTIVE FUNCTIONS	1.															
SOLAR BTU		1.		-388.54		1.		-407.78		1.		-525.68		1.		= 0.
LPGAS BTU			1.				-74,000.				-74,000.				-74,000	= 0.
BALANCE BTU		.6	-.4													= 0.
PANELS1	-1.			1.												= 0.
ENERGY1				388.54	-1.	-1.	74,000.									=2,351,610.
STORE LIMIT1					1.											≤3,000,000.
PANELS2	-1.							1.								= 0.
ENERGY2					1.			407.78	-1.	-1.	74,000.					=501,085.
STORE LIMIT2									1.							≤3,000,000
PANELS3	-1.											1.				= 0.
ENERGY3									1.			525.68	-1.	-1.	74,000	=137,955.
STORE LIMIT3													1.			≤3,000,000.

percent of the total needs, the coefficient would be 0.8 under SOLAR COUNT and 0.2 under LP GAS COUNT.

The SOLAR ENERGY activities indicate the BTUs of usable solar energy that could be collected per square foot of solar panel. STORE ENERGY activities permit excess energy to be "stored" in the system's hot water storage tanks. The capacity and efficiency of the storage tanks permitted a maximum of 3,000,000 BTUs to be stored. This is controlled by the STORE LIMIT row. Stored energy is made available for use in the next period. Excess heat energy, which is stored in the hot water storage tanks, would gradually dissipate over time. A potential problem in this model is that energy could be "stored" past the point where it could supply heat. In application, however, this problem did not arise since energy demands were high during the winter months when energy generation capability was low and very little heat energy went into storage. During the summer when demand was low, enough energy was generated to keep storage capacity constantly at its maximum. Changes in heat generation and utilization in spring and fall were gradual enough that no problems in heat being stored more than a feasible length of time were encountered.

EXCESS ENERGY activities permit consideration of the extreme amounts of excess heat energy that would be available during warm months. After storage tanks were at their limit (controlled by STORE LIMIT rows), any additional heat that is generated could not be used.

LP GAS activities indicate the BTUs of heat energy supplied per gallon of LP gas, thus giving a measure of the total LP gas required. Total energy requirements for broilers on each day were specified as right-hand-side values in the ENERGY rows. Heat availability and utilization were also controlled by these rows.

RESULTS

The linear programming model was used to assist in determining the minimum-size solar heating system required to supply specified percentages of the total annual heating needs for a 12,000-square-foot broiler house. Budgets were developed to illustrate the total investment cost and the annual operating cost for a conventional heated house with an LP gas brooder system with hovers, and for a house using a water-based finned radiator heating system with the water heated by solar energy and LP gas. For the solar house, cost values were estimated with solar energy supplying 60 percent, 40 percent, and 20 percent of the annual heating needs. LP gas provided the remainder of the energy needed for heating the water in the solar house system.

Data presented in Table 2 illustrate the results of the total analysis. The linear programming model indicated that for the solar heating system to provide 60 percent of the average annual needs, a minimum of 1,927 square feet of solar collector would be needed. The total investment required for a house with a solar heating system of that size would be nearly 2.5 times the investment in a conventional heated house. The annual cost per thousand birds (based on five batches of 15,000 each) was also considerably higher for the solar heating system. Annual operating expense for the solar system was $333. This cost was significantly higher than the $170 required for the conventional system.

The smallest solar heating system, which provided only 20 percent of the average annual heating needs, was still more expensive than the conventional system. Annual operating costs are fairly close, however, and give some indication of the future economic potential for solar heating.

Continued increases in the price of LP gas and improvements in the efficiency and cost reductions for solar equipment (made possible through improved technology and mass production) could move the economic advantage to favor a solar-supplemented heating system. If all costs were held constant except for the price of LP gas, the gas price would have to in-

Table 2. Estimated Investment and Annual Operating Costs for 12,000 Square Foot Broiler House with Conventional LP Gas Heat and with Solar Heating Systems Supplying Specified Percentages of Total Heat Requirements for Five batches of 15,000 Birds Each

Item and description	Conventional LP gas heat	Percentage Solar Heat 60[1]	40[2]	20[3]
	---------- -Dollars	----------	----------	----------
Investment				
Building	22,944	22,944	22,944	22,944
Equipment				
Heating (LP GAS)	1,598	---	---	---
Solar Collector	---	40,640	21,195	5,652
Storage and Distribution	---	9,365[4]	9,365[4]	6,210[4]
Auxilary Hot Water	---	680	680	680
Feeding, Watering, Insulation, Equip	13,992	13,992	13,992	13,992
Total	38,534	87,621	68,176	49,478
Annual Expenses				
Insurance[5]	385	876	682	495
Taxes[6]	166	159	159	159
Electricity	266	392	392	392
LP Gas[7]	1,538	628	941	1,251
Maintenance[8]	1,927	4,381	3,409	2,474
Misc.[9]	771	1,752	1,364	990
Interest[10]	4,624	10,514	8,184	5,937
Depreciation[11]	3,096	6,275	4,979	3,732
Total	12,773	24,977	20,110	15,466
Annual cost/1,000 birds	170	333	268	206

[1] Requires 1,927 square feet of collector.
[2] Requires 1,005 square feet of collector.
[3] Requires 268 square feet of collector.
[4] Storage for the 40 percent and 60 percent systems was about three million BTUs. Storage for the 20 percent system was about two million BTUs.
[5] One percent of total value.
[6] Assessed value of buildings and basic equipment times 0.43. Additional value added by solar equipment is exempt from property tax.
[7] Figured at a rate of 0.77 per gallon.
[8] Five percent of total purchase price.
[9] Two percent of total purchase price for incidental miscellaneous expenses.
[10] First year interest with 12 percent loan. Building is financed over 20 years, basic equipment for 8 years, and solar equipment for 15 years.
[11] Straight line depreciation with building life at 20 years, basic equipment at 8 years, and solar equipment at 15 years.

crease to $10.25 per gallon for a water-based solar heating system that provides 40 percent of the heating needs to be economically feasible. Likewise, if the cost of installing the solar heating system was reduced to about 10 percent of its current level, with all other costs constant, the alternative would be viable. With advancements in mass production technology or the use of homemade collectors, these low cost levels might be realized.

Other factors might also help to enhance the economic potential of using solar heating. For example, larger storage tanks could increase the overall production efficiency of the system. Also, additional insulation in the house would cut down on heating requirements and reduce the size of the solar heating system needed. Another alternative, related to poultry production procedures, would be to use partial house, multistage brooding. With this practice, birds of different age groups would be kept in separate sections of the house, resulting in level heating demands over the year and in more efficient use of the total heating system. None of these alternatives were evaluated in this research effort.

SUMMARY

Continued increases in the costs of fossil fuels have forced the consideration of alternatives such as solar energy. High investment costs required for solar equipment have, however, slowed the adoption of this process. The linear programming model presented in this paper provides a mechanism for establishing the minimum-size system needed for given heat demand and supply situations. Construction of the smallest necessary units would help in reducing initial investment costs. The linear programming procedure may be adapted to determine the minimum-size solar heating system for any application as long as the necesary demand and supply data are available.

The poultry example given in this paper illustrates the use of this linear programming procedure and confirms the current economic disadvantage of solar heating for that particular application. Future cost changes and improvements in solar technology could significantly change this economic situation and make solar-supplemented heating a viable alternative in the future.

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