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# GREENHOUSE ENERGY CONSERVATION: ANALYSIS OF ALTERNATIVE GLASS SYSTEMS

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## ABSTRACT

The economic viability of nine representative energy conservation options for Pennsylvania greenhouse operators is examined. The analysis is done using an Internal Rate of Return procedure for four major fuels under three price escalator assumptions. The minimum energy savings per square foot per year is also calculated for each option. Wide variation is found in the economic feasibility of these options with the ones with the lowest installation costs generally providing the greatest IRR and the lowest required minimum savings per year. The results clearly indicate the need to evaluate carefully the economic viability of such investments beforehand.

## INTRODUCTION

The rapid rise in the cost of energy and money plus a sluggish economy have combined to place a severe strain on the profitability of much of northeastern agriculture. This strain has been particularly acute for greenhouse operators who face a major energy expenditure for space heating each year. While intensive research efforts have been devoted to determining ways for these operators to conserve energy, little analysis has been directed at evaluating the economic feasibility of these conservation efforts. For such projects to be worthwhile it is vital that they provide a cost savings as well as an energy savings to the firm.

This paper is designed to help overcome this shortfall and has the following two objectives: (1) to determine the economic return on nine representative energy conservation alternatives for greenhouses; and (2) to determine the minimum energy savings needed under each alternative to make it economically worthwhile to pursue.

## REVIEW OF LITERATURE

There have been only a small number of published studies that have examined these issues in the northeast. Dunn locked at the overall regional impact of rising energy prices on the competitiveness of the region's agriculture and found it offered little advantage to producers. Though some advantage in transportation was found with respect to western producers, the relatively higher cost of production here more than offsets it. This work is important because it points out the need to look beyond the impact of a change in a single input in the production process when evaluating profitability or comparative advantage. Dhillon and Rossi took a firm level approach and examined the economic feasibility of using solar energy as a means of reducing energy operating costs for growers of greenhouse tomatoes in New Jersey. Their budgetary data indicated that while some relief was possible with their approach, the typical operator was still better off to continue using fuel oil when the installation costs of the retrofit for solar were included. Beierlein and Campbell took a similar tack when they examined the economic feasibility of reducing energy expenditures for a chain of convenience stores by reducing the delivery frequency of fluid milk. They found sizeable energy savings were possible but the cost of additional milk cooler space required to accomodate these adjustments outweighed the energy savings. Thus, it is apparent that investments in energy conservation equipment and processes should be done with great caution to ensure the economic soundness of each undertaking.

## PROCEDURE

Nine energy conservation alternatives were selected for analysis after discussion with greenhouse industry sources (Table 1). It was felt that they represented a broad sampling of the potential energy savings and installation cost options that would confront the average Pennsylvania greenhouse operator seeking to lower his space heating expense. All comparisons were done on a per square foot basis using the midpoint of the energy savings expected.[1] The installation cost estimates were obtained from industry sources. The determination of the energy savings under each option came from experimental data from one-acre ridge and furrow greenhouses in central Pennsylvania that were currently using a 20-inch float glass system. The fuel price data represent actual prices paid in 1982 (Table 2). The analysis focused on the four energy sources most widely used by greenhouses in the region and included number 2 fuel oil, natural gas, coal, and wood. Annual fuel price escalators of zero, 10, and 20 percent were applied to the current prices.

Six additional assumptions were developed after consultation with industry officials and were felt best to represent the typical situation. First, the operator's marginal tax rate was assumed to be 33 percent. Second, the entire investment was assumed to be eligible for an investment tax credit of 10 percent and for an energy tax credit of 15 percent which is applied in the first year.[2] Third, all costs and revenues except installation and space heating were assumed to be unchanged by these alterations.

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[1] The midpoint of energy savings expected is used in all cases except for options #8 and #9 where the upper figure is used. This is done in the case of option #8 because the range of energy savings is narrow. The upper limit for option #9 is used to put it in the most favorable light possible, given its very high installation cost.

Table 1. The Greenhouse Covering Options, with the Expected Energy Savings and Installation Costs.

| Option | Covering System | Number of Layers | Expected Percent Seasonal Energy Saving From Current System (Option 0) | Estimated Installation Cost/Sq.Ft. of Ground Area |
|---|---|---|---|---|
| 0 | Current system - old float glass 20" | 1 | -- | $2.50 |
| 1 | Solatex glass 24" with new aluminum bars | 1 | 5-10 | 2.60 |
| 2 | Double layer tedlar panels with new aluminum bars | 2 | 50-60 | 3.00 |
| 3 | Double glass "SunMate" - 34" | 2 | 50-60 | 4.00 |
| 4 | Solatex glass with new Aluminum bars and tedlar panels | 3 | 60-70 | 4.50 |
| 5 | Exolite acrylic with new aluminum bars | 2 | 45-55 | 4.50 |
| 6 | Continue old float glass plus one layer thermal blanket | 2 | 30-40 | 1.40 |
| 7 | Continue old float glass plus two layer thermal blanket | 3 | 50-60 | 1.80 |
| 8 | Solatex glass with new aluminum bars plus two layer thermal blanket (options 1 & 7) | 3 | 55-60 | 4.40 |
| 9 | Double solatex glass with new aluminum bars, HID lighting plus one layer thermal blanket | 3 | 90-100 | 9.70 |

Table 2. Analysis Parameters.

| Energy Source | Estimated Fuel Expense/ Sq. Ft./Year | Average Heating Plant Efficiency | Cost of Energy | Heating Plant Efficiency |
|---|---|---|---|---|
| #2 Fuel Oil | $2.00 | 65% | $1.12/gallon | 161,000 Btu/sq ft/year |
| Natural Gas | $1.00 | 70% | $4.55/MCF | 157,000 Btu/sq ft/year |
| Anthracite Coal | $1.00 | 65% | $100.00/short ton | 162,000 Btu/sq ft/year |
| Wood (sawdust) | $ .50 | 60% | $ 20.00/cu yd | 169,000 Btu/sq ft/year |

Fourth, the salvage value under each option was assumed to be zero at the end of its 10 year useful life. Fifth, the investment was assumed to be eligible for accelerated depreciation under current tax regulations at the following annual percentages of installed cost:[3] 15, 22, 21, 21, and 21 percent. Sixth, a discount rate of 16 percent was assumed to be the minimum acceptable rate of return to greenhouse operators since it was equal to the prevailing interest rates at the time of the study.

Since the incremental cash flows arising from the energy savings accrue over time, while the installation costs must be borne the first year, the appropriate method of analysis is discounted cash flow. To accomplish objective one, an Internal Rate of Return (IRR) procedure was employed. For each given option, the discount rate which equates the after tax present value of the incremental cash outflows with the after tax present value of the incremental cash inflows over ten years was determined. To accomplish objective two, a variation of the Net Present Value (NPV) procedure was applied to determine the minimum before tax energy savings per square foot per year required under each option to make it economically worthwhile (i.e., NPV = 0). A minimum before tax savings per square foot per year figure was sought so as to provide greenhouse operators with a simple means of directly comparing and evaluating each energy conserving option given the six assumptions given above.

## RESULTS

The IRR's calculated for the nine energy conservation options and fuel types showed wide variation (Table 3). However, the rankings of the option under each fuel and price escalator gave uniform results as one would have expected. Options #6 and #7 (continue old glass with one and two layers of thermal blankets added, respectively) consistently gave the highest IRR, while options #9 (double Solatex plus one-layer thermal blanket plus HID Lamps) and #1 (new Solatex Glass plus aluminum bars) consistently gave the lowest return. The high IRR's of these two options reflects the combination of relatively high energy

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[2] Discussion with people knowledgeable in this area indicated this investment would qualify for this tax treatment.

[3] Ibid.

Table 3. Internal Rates of Return Based on Estimated Costs of Materials and Installation, Fuel Source, and Annual Fuel Cost Increase For Nine Greenhouse Covering Options Replacing the Current System.

| | | | | Annual Percentage Change in Fuel Price | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 0% | | | 10% | | | 20% | | |
| Option Number | Description | Installation Cost/Sq. Ft. Ground Area | Expected Percent Energy Saving | Oil | Gas/ Coal | Wood | Oil | Gas/ Coal | Wood | Oil | Gas/ Coal | Wood |
| | | | | -------Internal Rates of Return Percentages------- | | | | | | | | |
| 1 | Solatex Glass + Aluminum Bars | $2.60 | 7.5 | * | * | * | 4.4 | * | * | 10 | 2 | * |
| 2 | Double Tedlar | 3.00 | 55.0 | 34 | 16 | 5 | 42 | 23 | 11 | 50 | 30 | 17 |
| 3 | Double Glass SunMate | 4.00 | 55.0 | 26 | 11 | 1 | 33 | 17 | 6 | 41 | 24 | 12 |
| 4 | Solatex & Tedlar Panel | 4.50 | 65.0 | 27 | 12 | 0 | 35 | 18 | 7 | 42 | 25 | 13 |
| 5 | Exolite | 4.50 | 50.0 | 21 | 7 | * | 28 | 14 | 3 | 35 | 20 | 9 |
| 6 | Old Glass + 1-layer Blanket | 1.40 | 35.0 | 46 | 23 | 9 | 54 | 31 | 16 | 62 | 38 | 22 |
| 7 | Old Glass + 2-layer Blanket | 1.80 | 55.0 | 54 | 29 | 13 | 63 | 36 | 19 | 71 | 44 | 26 |
| 8 | Solatex + 2-layer Blanket | 4.40 | 60.0 | 26 | 11 | 1 | 33 | 17 | 6 | 41 | 24 | 12 |
| 9 | Double Solatex + 1 Layer Blanket + HID Lamps | 9.70 | 100.0 | 19 | 6 | * | 26 | 12 | 3 | 33 | 19 | 8 |

Tax rate = 33%.
Combined Investment and Energy Tax Credits = 25%.
Lifespan of Investment = 10 years.
Salvage value = $0.

*IRR is less than zero.

savings and low installation costs. The low IRR for option #9 is the result of a relatively high installation cost overwhelming a substantial energy savings, while for option #1 it shows a low energy saving outweighing a relatively low installation cost. In each case it clearly indicates the need for careful economic analysis of any conservation investment to determine its relative merit.

Under the most optimistic assumption that energy prices remain unchanged over the next ten years, only fuel oil shows IRR's that consistently (except for option #1) exceed the estimated opportunity cost of 16 percent, while for coal and natural gas there are three, and for wood there are none. The number of options which have IRR's above 16 percent increases under the more likely case where prices are increasing at 10 percent per year. With a 20 percent annual increase in price, only a few of the options give IRR's below this rate. Fuel oil users find more acceptable rates of return under every option primarily because their energy cost per million BTU's is the highest. Under the 10 and 20 percent annual increase scheme a majority of options using natural gas and coal meet the minimum rate of return, while for wood it takes the higher price increase before most of these options become acceptable. Again, these rankings reflect the relative cost per million BTU's of the fuels involved.

IRR's are also computed using the incremental cost and energy savings from replacing the current glass system with more of the same (option #1) versus replacement with a different energy conservation system (i.e., options #2, #3, #4, #5, #8, and #9). Except for wood, the IRR for these marginal dollars is well in excess of the opportunity cost of 16 percent (Table 4). Thus, if funds are available the additional dollars could be efficiently employed in these options.

In order to provide a direct means of comparison under each of the options, the minimum energy savings per square foot per year required to make each option economically viable is determined and compared to the estimated energy savings in the first year, assuming no price increase (Table 5). Again options #6 and #7 show most favorably under each price escalator scheme, while option #9 consistently required the highest savings.

## CONCLUSION

Greenhouse operators who are facing the problem of putting a new glass system on their greenhouse would find many of the energy conservation options examined here to be economically feasible, given the assumption and situations examined. The greatest savings would appear to arise from the options requiring the lowest expenditure rather than from the ones that save the most energy.

A word of caution is in order. Though these results show energy conservation to be generally

Table 4. Internal Rates of Return Based on Incremental Cost and Energy Savings of Retrofitting with Options 2,3,4,5,8,9 vs. Retrofitting with Option 1.

| | | | | Annual Percentage Change in Fuel Price | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 0% | | | 10% | | | 20% | | |
| Option** | Estimated Installation Cost/ Sq. Ft. | Incremental Cost/Sq. Ft. Relative to Option 1 | Incremental Energy Savings vs. Replacement with Option 1 | Oil | Gas/ Coal | Wood | Oil | Gas/ Coal | Wood | Oil | Gas/ Coal | Wood |
| | | | | -------Internal Rates of Return Percentages------- | | | | | | | | |
| 2 | $3.00 | $ .40 | 47.5% | 148 | 79 | 44 | 156 | 88 | 52 | 166 | 97 | 60 |
| 3 | 4.00 | 1.40 | 47.5 | 56 | 29 | 14 | 64 | 37 | 20 | 73 | 45 | 27 |
| 4 | 4.50 | 1.90 | 57.5 | 52 | 27 | 12 | 60 | 34 | 18 | 68 | 42 | 25 |
| 5 | 4.50 | 1.90 | 42.5 | 39 | 19 | 6 | 47 | 26 | 13 | 55 | 34 | 19 |
| 8 | 4.40 | 1.80 | 52.5 | 50 | 26 | 11 | 58 | 33 | 17 | 66 | 41 | 24 |
| 9 | 9.70 | 7.10 | 92.5 | 24 | 10 | * | 31 | 16 | 5 | 39 | 23 | 11 |

Tax rate = 33%.
Combined Investment and Energy Tax Credits = 25%.
Lifespan of Investment = 10 years.
Salvage Value = $0.

*IRR is less than zero.

**It is assumed here that the old glass will be replaced. Thus, options six and seven are no longer possible.

Table 5. Minimum Energy Savings per Square Foot In First Year Required to Make Each Conversion Economically Feasible.

| Option | Estimated Installation Cost/Sq. Ft. | Estimated Energy Savings Per Square Foot First Year | | | Minimum Energy Saving/Sq. Ft. in the First Year to Make Economically Feasible | | |
|---|---|---|---|---|---|---|---|
| | | Oil | Gas/Coal | Wood | 0% | 10% | 20% |
| | | ---------cents/sq. ft.---------- | | | ---------cents/sq. ft.---------- | | |
| 1 | $2.60 | 15.0 | 7.5 | 3.8 | 43.2 | 18.5 | 11.5 |
| 2 | 3.00 | 110.0 | 55.0 | 27.5 | 49.9 | 21.3 | 13.3 |
| 3 | 4.00 | 110.0 | 55.0 | 27.5 | 66.5 | 28.4 | 17.7 |
| 4 | 4.50 | 130.0 | 65.0 | 32.5 | 74.8 | 31.9 | 19.9 |
| 5 | 4.50 | 100.0 | 50.0 | 25.0 | 74.8 | 31.9 | 19.9 |
| 6 | 1.40 | 70.0 | 35.0 | 17.5 | 23.3 | 9.9 | 6.2 |
| 7 | 1.80 | 110.0 | 55.0 | 27.5 | 29.9 | 12.8 | 8.0 |
| 8 | 4.40 | 120.0 | 60.0 | 30.0 | 73.1 | 31.2 | 19.5 |
| 9 | 9.70 | 200.0 | 100.0 | 50.0 | 161.2 | 69.9 | 42.9 |

Discount Rate = 16 Percent.
Marginal Tax Rate = 33%.
Energy and Investment Tax Credit = 25%.
Lifespan of Investment = 10 Years.
Salvage Value = $0.

economically feasible, they should not be generalized without care since they are dependent upon the assumptions made. For example, the economic viability of these results rests in large measure on the tax savings provided. However, a firm gets to utilize them only if the business has profits to which they can be applied. The conservation investments analyzed here can improve the profit picture of a greenhouse but are usually not sufficient on their own to make a business profitable. This change requires selection of a crop that can be grown profitably in this region.

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