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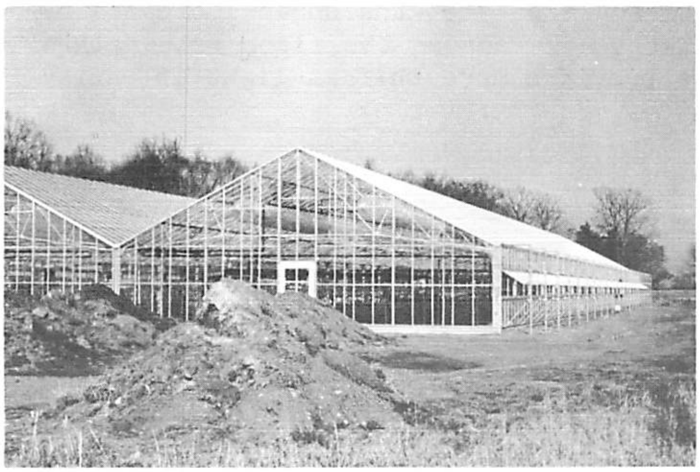

Which Type of Greenhouse Should You Build: Glass or Polyethylene?

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The purpose of this paper is to consider the alternatives of polyethylene or glass as the suitable covering material for a commercial greenhouse. Much of the early discussion and the prices come from the publication by Brumfield et al. (1).

1.1 ECONOMIC ANALYSIS

Construction costs of greenhouse firms of 20,000 ft^2, 100,000 ft^2, and 400,000 ft^2 which will be referred to as small, medium, and large respectively were determined. Price quotations for the basic structure, heating and cooling materials, freight, and labor of erection were received from three manufacturers of glass greenhouses and seven manufacturers of polyethylene greenhouses in January 1980 (Tables 1 and 2). Although prices have increased since that time, the relative prices of glass and polyethylene greenhouses are the only relevant costs in the decision analysis. Since relative prices have remained fairly constant, the resulting decision will not be affected.

The covering on most polyethylene structures has a reasonable life expectancy of two years, perhaps more. The cost of covering the polyethylene structure is not included in the labor of erecting the basic structure, but rather has been broken out as a separate figure so that it may be depreciated over a two-year period. Polyethylene and the labor of covering will have to be purchased nine more times over the depreciable life of the polyethylene greenhouse.

The heating system consists of individually fired unit heaters. The cooling system includes a 4 in. thick CELdek or Kool-Cel pad and fans as well as a convection tube with a pressurizing fan for winter cooling.

Labor is a separate item which includes erecting the basic greenhouse structure and installing the heating and cooling facilities. Wiring, plumbing, grading, paving, and erection of the service building are not included in the labor figure.

Polyethylene greenhouses have sometimes been depreciated over a very short time. Realistically, for determining overhead costs, the cost of the structure should be depreciated over the useful life of the greenhouse. The frames in polyethylene greenhouses are substantial enough to remain functional as long as glass frames. Therefore, a depreciable life of 20 years has been assigned to both.

For this study, the growing area is divided into blocks with the service building in the center. The gutters run north and south so that the shadows created by the ridges, gutters, and north sloping roof will move across the floor rather than remain in one spot during the day (7). This provides more uniform light intensity throughout the greenhouse.

1.2 DECISION ANALYSIS

The decision to build a greenhouse or add to an existing one has already been made. Our problem is to determine the least cost type of greenhouse. Glass and polyethylene greenhouses each have advantages, but all we are considering here are the economic ones. The prices associated with constructing glass and polyethylene covered greenhouses have been detailed in Tables 1 and 2. For illustration purposes we can choose the small size greenhouse (20,000 ft^2).

The only values that are relevant in this kind of analysis are the incremental savings of glass versus polyethylene. These values appear in Table 5. Negative cash savings occur where polyethylene shows a cash savings over glass. Since depreciation is tax deductable, and the annual depreciation for glass greenhouses is greater than for polyethylene greenhouses, glass greenhouses provide a tax advantage. This analysis assumes the business to be in a 46% marginal tax rate bracket. If this is a 20,000 ft^2 addition to a larger existing business, this is probably the correct tax rate. To find the depreciation tax shelter for the first year, subtract the annual depreciation for polyethylene for the first year of $4,500 (Table 1) from the annual depreciation for the glass greenhouse of $5,390 (Table 2) yielding $890 more annual depreciation for glass greenhouses. Multiplying by the 46% marginal tax rate, the glass greenhouse has a tax advantage of $409 per year in years 1 and 2. If this in an initial construction of a new 20,000 ft^2 greenhouse, the business would probably be in the 20% marginal tax rate bracket, reducing the depreciation tax shelter and making glass less of a tax advantage. Subchapter S corporations may be in different marginal tax brackets (6).

The major advantage of polyethylene versus glass greenhouses other than the lower initial investment is the lower heating cost. Estimates of consumption of fuel oil in number of gallons were obtained and are depicted in Table 3 (8). A 1980 price of 90 cents per gallon was assumed.

To obtain the difference in heating costs in year 1, the difference of 7,663 gallons in fuel oil consumption (Table 3) is mutiplied by the price of $.90 per gal

TABLE 1. Construction prices and depreciation of gutter-connected, double layer polyethylene greenhouses by size of firm.

	Small		Medium		Large	
	$\$/\text{ft}^2$	Total $	$\$/\text{ft}^2$	Total $	$\$/\text{ft}^2$	Total $
Greenhouse						
Basic structure	1.35	27,000	1.25	125,000	1.18	472,000
Heating materials	.34	6,800	.29	29,000	.29	116,000
Cooling materials	.66	13,200	.64	64,000	.63	252,000
Labor	.55	11,000	.45	45,000	.41	164,000
Freight	.09	1,800	.08	8,000	.08	32,000
Sub-total	2.99	59,800	2.71	271,000	2.59	1,036,000
Depr/yr (20 yrs)	.15	2,990	.14	13,550	.13	51,800
Covering						
Polyethylene	.096	1,920	.090	9,000	.055	35,600
Labor	.055	1,100	.055	5,500	.055	22,000
Sub-total	.151	3,020	.145	14,500	.144	57,600
Depr/yr (1st 2 yrs)	.08	1,510	.07	7,000	.07	28,800
Total initial purchase price	3.14	62,820	2.86	285,500	2.73	1,093,600
Total depr/yr (1st 2 yrs)	.23	4,500	.21	21,000	.20	80,600

† From Brumfield et al. (1).

TABLE 2. Construction prices and depreciation of glass greenhouses by size of firm.

	Small		Medium		Large	
	$\$/\text{ft}^2$	Total $	$\$/\text{ft}^2$	Total $	$\$/\text{ft}^2$	Total $
Basic structure	2.77	55,400	2.48	248,000	2.39	956,000
Heating materials	.77	15,400	.70	70,000	.69	276,000
Cooling materials	.56	11,200	.55	55,000	.55	220,000
Labor	1.10	22,000	.97	97,000	.90	360,000
Freight	.19	3,800	.18	18,000	.18	72,000
Total initial purchase price	5.39	107,800	4.88	488,000	4.71	1,884,000
Total depr/yr	.27	5,390	.24	24,400	.24	94,200

† From Brumfield et al. (1).

to yield $6,897. However, the price of fuel oil is expected to rise faster than the

TABLE 3. Annual Fuel Oil Usage[1]

Size	Polyethylene	Glass	Reduction by Using Polyethylene
20,000 ft^2	13,420 gal.	21,083 gal.	7,663 gal.
100,000 ft^2	63,700 gal.	100,155 gal.	36,455 gal.
400,000 ft^2	250,600 gal.	394,000 gal.	143,400 gal.

[1] Assumptions are that the fuel oil is 90% efficient, the heating value is 138,500 BTU/gal., and the surface area is approximately the same for glass and polyethylene.

rate of inflation, and this must be taken into consideration. Based on predictions by an specialist in the field of fuel prices (4) fuel prices are expected to rise 1.9% faster than the general rate of inflation. Inflation will be considered after the cash flows for each year have been calculated. We must inflate the price of fuel by 1.9%, so multiplying $6,897 by 1.019, the additional cost of fuel in a glass greenhouse in year 1 is $7,028. The same procedure is used in all following years. The consupmtion in gallons remains constant, so the dollar cost differential in any year is simply 1.019 times the dollar cost differential in the previous year.

The polyethylene cover must be replaced every other year, thus there is no cost for this in year 1, but recovering is encountered in year 2. The original cost of the polyethylene is $1,920 (Table 1). Because two years have passed since the initial purchase, $1,920 must be inflated by the 1.9% increase in polyethylene cost above the rate of inflation, yielding a cost of $1,993 in year 2. The same procedure is followed in alternating years.

Every time the polyethylene house is recovered, labor cost is also involved. The initial labor of covering was estimated to be $1,100 (Table 1).

Based on the past history of wages (2) and consultation with an specialist in the field of wage policy (5), it is assumed for purposes of this study that wages for hourly personnel will increase with the inflation rate, therefore the $1,100 labor cost will be encountered every other year.

Maintenance costs were obtained from four greenhouse managers and show that glass maintenance averages 21.6 seconds of labor time per ft^2 more annually, than does polyethylene. For 20,000 ft^2, the small glass greenhouse requires 120 hours more maintenance labor than does the polyethylene greenhouse. At a 1980 wage rate of $3.10 per hour, this results in an additional cost of $372 per year for the glass greenhouse.

Adding all of the cost differences between glass and polyethylene for year 1, the net loss of a glass greenhouse is $6,971 (Table 5). The cost differences have been tabulated for years 1 through 20. These numbere cannot be simply added because of the time value of money. The net present value appoach will be used to express all cash flows in terms of dollars in year 0.

The net present value (NPV) discounting procedure can be thought of as the reciprocal of compounding present values to reflect future dollars:

$FV = PV\ (1 + k)$ where

FV = future value of today's dollars

PV = present value of today's dollars

k = interest rate or discount rate

t = year

The future value of money invested today is the present value plus the interest earned on the investment. The present value of cash to be received in the future must be discounted by the rate that could be earned on the money if it were received today:

$$PV = \frac{FV}{(1+k)^t}$$

To determine the present value of cash flows to be received in the future in this analysis, we must determine the discount rate, k. There exists uncertainty or risk with the prices of fuel, labor, and materials for recovering should the polyethylene be chosen. The discount rate is adjusted to compensate for risk. As the risk increases, the discount rate increases and the present value of any given stream of expected cashflows is reduced. The effect is to make the project less attractive as the risk increases because of the lower present value. Consider the net present value concept for a project. The procedure is as follows:

$$NPV = -C + \sum_{t=1}^{N} \frac{C_p - C_g}{(1+k)^t}$$

where

N = number of time periods

C = the initial outlay for the project

$C_p - C_g$ = the incremental difference in the cost of polyethylene and glass greenhouses in time period t

k = risk adjusted discount rate for project A.

t = time period or year

We can see as we adjust the discount rate for more risk the cashflow will be decreased and the net present value will be smaller.

The discount rate to be used in this analysis of real money flows is the real rate of interest (time value of money, without inflation, which can be assumed to be 3%), plus a premium that lending institutions would expect for ventures of this kind. We will assume a risk premium of 4%, therby making our discount rate 7%. This is a predicted long run average for the economy.

We can apply the net present value formula to the greenhouse decision as detailed in the last line of Table 5. Each of the cash flows will be discounted by one plus the discount rate raised to the power of the year represented. The cash flows received further in the future have less value today. The values are all negative, reflecting the higher cost of owning glass versus polyethylene greenhouses.

We must subtract the difference in the cost of the initial investment. Due to the unique nature of greenhouses which are considered as single purpose units, they can be eligible for the investment tax credit normally reserved for machines (3). Since the depreciable life is longer than seven years, this will amount to 10% of the initial cost. After allowing for the investment tax credit, $40,180 is the cash savings for the initial outlay for the polyethylene greenhouse (Table 4). Summing the cost of the initial investment ($40,180 from Table 4) and all the cash flows ($69,232 from Table 5) we can see a very significant result. All cashflows are shown as cash savings if polyethylene is chosen over glass. Using the net present value formula and our discount rate of 7%, the net present value of choosing polyethylene over glass is $109,412.

Using sensitivity analysis, we can determine how sensitive our estimate of fuel is in the decision. Let us assume that there is no difference in the heating cost for the two types of coverings (i.e. the cash savings is zero for a choice of one over the other). This perhaps could be achieved by switching to an alternate source of heating. Subtracting the fuel savings from the total yearly savings and using the NPV formula with a 7% discount rate, we obtain $24,174 savings if polyethylene is used. It appears that this decision is sensitive to the random variable, fuel

TABLE 4. Initial outlay for 20,000 ft^2 polyethylene of glass greenhouse.

Item	Polyethylene	Glass	Difference
Materials, labor, and freight	$59,800	$107,800	48,000
Price of polyethylene and labor	3,020	0	(3,020)
Investment tax credit	(-5,980)	(-10,780)	(4,800)
Net Outlay	$56,840	$ 97,020	$ 40,180

price, but that there would have to be a savings in order to make glass preferable. At equivalent fuel expenditures, polyethylene is still preferred to glass, due to the large savings in the initial outlay.

There may be more risk involved in greenhouses firms than with similar businesses due to such factors as high opportunity cost of capital, lack of insurance, weather risks, etc. We can take the point of view of a risk averse manager by applying a 20% discount rate to our calculations as opposed to a 7% rate. This results in a savings of $70,244 for polyethylene as compared to glass. The savings is smaller than with the 7% discount rate, but the decision is the same.

Why, then do some growers still build glass greenhouses? We would have to ascertain a utility function for each grower to be able to determine this. There evidently are advantages to glass that are not easy to measure in monetary terms.

If a grower is very risk averse, he may be willing to bear the added expense for a permanent structure and not have to face the risk of losing an entire crop during a severe windstorm. Some growers still have the belief that the difference in light intensities cause crops to be of higher quality under glass, although studies have not been conducted to test this point. Some growers have greenhouses already constructed of glass and are building expansions to conform to the existing structure. Finally, glass greenhouses are considered to be a symbol of success in the horticulture industry and, as such, are a status symbol for the more affluent growers. These reasons may give some insight into why glass is still considered even though polyethylene is economically more feasible.

Only one size of greenhouse has been considered in this study, but we would expect to find the same situation for the medium and large scale greenhouses, perhaps even to a greater degree as economies of scale are brought to bear. Construction of glass appears to be declining as the economy forces growers to become more cost conscious.

TABLE 5. Partial annual differences in cashflows of glass versus polyethylene.

year	discount rate @ 7%	depr. tax shelter	fuel oil	poly covering	labor cost to cover	maint. cost	savings with glass	net present value
1[1]	1.07	409	(7028)	0	0	(372)	(6971)	(6515)
2	1.14	409	(7162)	1993[2]	1100	(372)	(4032)	(3522)
3	1.23	393[3]	(7298)	0	0	(372)	(7277)	(5940)
4	1.31	393	(7437)	2069	1100	(372)	(4247)	(3240)
5	1.40	375	(7578)	0	0	(372)	(7579)	(5404)
6	1.50	375	(7722)	2148	1100	(372)	(4471)	(2979)
7	1.61	357	(7815)	0	0	(372)	(7830)	(4876)
8	1.72	357	(7908)	2230	1100	(372)	(4593)	(2673)
9	1.84	338	(8059)	0	0	(372)	(8093)	(4402)
10	1.97	338	(8212)	2315	1100	(372)	(4831)	(2456)
11	2.10	319	(8368)	0	0	(372)	(8421)	(4001)
12	2.25	319	(8527)	2404	1100	(372)	(5096)	(2254)
13	2.41	298	(8689)	0	0	(372)	(8763)	(3636)
14	2.58	298	(8858)	2496	1100	(372)	(5332)	(2068)
15	2.76	277	(9022)	0	0	(372)	(9117)	(3304)
16	2.95	277	(9193)	2591	1100	(372)	(5597)	(1896)
17	3.16	255	(9368)	0	0	(372)	(9485)	(3003)
18	3.38	255	(9546)	2690	1100	(372)	(5873)	(1738)
19	3.62	232	(9727)	0	0	(372)	(9867)	(2728)
20	3.87	232	(9912)	0	0	(372)	(10052)	(2598)
Total								(69232)

[1] Calculations for year 1:

Depr. tax shelter

$5390 depr-glass
-4500 depr-poly

890
x.46 tax rate

$ 409

Fuel oil

7663 gal.
x$.90/gal.

6897
x1.019 difference between 7% inflation & 8.9% annual fuel price increase

(7028)

Maintenance costs

20000 ft^2
21.6 sec/ft^2

432000 sec.
120 hrs.
x$3.10/hr.

(372)

[2] Polyethylene cost to recover in year 2 = $1920 \times 1.019^2 = 1993$

[3] Depreciation tax shelter in year 3 =
$5390 depr-glass
-4536 depr-poly

854
x.46 tax rate

$ 393

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