ECONOMICS OF GREENHOUSE PRODUCTION IN ALASKA
-
USING THE GREENHOUSE AT CHENA HOT SPRING RESORT AS A MODEL

Markus Mager, University of Alaska Fairbanks; USA

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1 Introduction

This paper provides an economic analysis of the greenhouse installed at Chena Hot Springs Resort (CHSR) under optimal growing conditions. The economic model developed here can be used and modified for other potential production greenhouse projects throughout the State of Alaska. There are many opportunities to use waste heat and excess power generated during off-peak hours and months in rural communities in Alaska to establish local greenhouse production facilities. Table 1 summarizes the results of the economic analysis. Under optimal circumstances, the 60ft x 72ft greenhouse has a plant capacity of 13,858 plants. It could produce 148,107 heads of lettuce per year. Total costs of the optimized current pilot project for greenhouse lettuce production are $297,567 which leads to a breakeven price of $2.01 per head of lettuce. The paper additionally examines alternative cost of heat scenarios.

Total Costs	Plant Capacity	Heads of Lettuce per Year	Breakeven Price to cover Total Costs
$297,567	13,858	148,107	$2.01

Table 1: Economic Analysis – Results

2 Chena Hot Springs Resort

Chena Hot Springs Resort is located approximately 60 miles northeast of Fairbanks. The resort is accessible by road; however it is located 33 miles from the nearest transmission grid so it can be considered a semi-remote site. The goal of CHSR is to become a self-sustained community in terms of electricity, heat, transportation and food. The resort’s buildings are heated with geothermal water. Electricity is generated by a 400kW geothermal power plant. The plant replaced a 400 kW diesel generator and reduced the cost of power onsite from 30¢/kW to approximately 6¢/kW (YOUROWNPOWER 07). The geothermal power plant produces all the electricity used at the resort. As a result of this beneficial use of the hot water, power and heating cost were reduced for the entire resort.

2.1 Greenhouses at Chena Hot Springs Resort

Chena installed a small test greenhouse in 2004, which has operated year-round and is heated entirely with water from the geothermal resource. The resort was able to maintain greenhouse temperatures of 78°F while outside temperatures dropped to a low as -56°F, which is typical for Interior Alaskan winters. The 134°F temperature differential recorded was the largest temperature difference for any controlled environment production facility in the U.S.

In 2006, CHSR constructed a new 4,320ft^2 hydroponic production greenhouse and in 2007 a 1,680ft^2 add on to provide the resort's restaurant with a greater variety of fresh produce on a year-round basis. Heat for the 6,000 ft^2 greenhouse is supplied through 155°F geothermal water pumped from a shallow well as part of an extensive district heating system. Electricity is provided by the geothermal power plant. The reduction in electricity cost combined with geothermal heating made the greenhouse expansion possible.

The greenhouse has been expanded from a collaborative three year project with the University of Alaska Fairbanks to assess the feasibility of local onsite food production at remote and semi-remote sites in Alaska. It is the only year-round production greenhouse facility in Interior Alaska.

The greenhouse was built using a Poly-Tex, Inc. (Castle Rock, Minnesota) structure 60ft x 72ft in size. The crop production takes place hydroponically, using a nutrient film technique, where the water is constantly flowing through the hydroponic system and the rock wool, allowing the plants to absorb nutrients and water through the roots. The greenhouse environment is computer controlled with temperature and humidity adjusted automatically. The water is monitored for pH and nutrient concentration to provide the lettuce plants with optimal amounts. The 60ft x 28ft add on is used as a nursery to start seedlings, and as an air mixing zone in the winter to pre-warm the cold outside air before it enters the main greenhouse.

The greenhouse is divided into two sections with lettuce (Figure 1) and tomatoes (Figure 2). Production is sufficient to meet the demand of the resort's kitchen year-round.

Figure 1: Lettuce Production CHSR

Figure 2: Tomato Production CHSR

3 Economic Analysis Using an Enterprise Budget

A substantial investment in capital and management resources is necessary to grow crops in a greenhouse environment. Profitability can be addressed through an enterprise budget. “Enterprise budgets represent estimates of receipts (income), costs, and profits associated with the production of agricultural products” (AGRALT 94, p.1). Costs are divided into variable and fixed costs. Variable costs are production costs that only occur if the production is started. Fixed costs occur whether or not a production is started. The enterprise budget in this paper is based on a lettuce-only production and shows how an optimal lettuce production system contributes to the profit. The enterprise budget model from SMITH et.al. 07 is used as a basic model and modified based on the construction and operating costs accrued at the CHSR greenhouse facility. The applied model considers an optimized lettuce-only production. It does not analyze the current production layout at the resort. These modifications and adjustments make the model more applicable for rural communities.

3.1 Capital Costs

The 60ft x 72ft greenhouse can be purchased as a kit[1] for $18,355 plus shipping. The kit contains a frame, ventilation system, sheeting, double layered roof and end walls (POLYTEX 07). The twin walls allow for air to be blown between the layers for better insulation than a single layer construction. The floor heating system, water tank and the concrete slab are not included in the kit and get priced separately, as does the electric installation. These additional fixed costs total $17,590. This includes the white floor paint that allows for maximum light reflection. The hydroponic equipment and environment controller cost $30,000.

Costs for buying property, necessary licenses, construction labor and a packaging plant vary throughout different projects. The model in this study does not include costs to purchase property or licenses. An on site warehouse and packaging plant, which would be necessary in an optimal production layout, is estimated at $16,600. Labor and equipment costs to erect the greenhouse structure are estimated at $13,000.

[1] The kit consists of two 30ft x 72ft greenhouses.

A complete list of construction and durable goods costs needed for construction and maintenance of the greenhouse is shown in Table 2. A straight-line depreciation is used. Interests are charged on the average investment, using a rate of 10%. Insurance is assumed to be 1.3% of the original investment.

Construction		Original Cost	Life-Yrs.	Depreciation	Interest*	Ins.**	Annualized
Buying Property	(01)	0	100	0	0	0	0
Licenses	(02)	0	100	0	0	0	0
Greenhouse Frame (60ft x 72ft)	(03)	20,188	20	1,009	1,009	262	2,281
Warehouse & Packing Plant on site	(04)	16,600	10	1,660	830	216	2,706
Controller	(05)	5,500	10	550	275	72	897
Floor (insulation, concrete slab, paint)	(06)	9,035	10	903	452	117	1,473
Floor Heating System	(07)	1,302	10	130	65	17	212
Water Tank	(08)	1,248	7	178	62	16	257
Irrigation/Fertigation (hydroponic structure & equipment)	(09)	24,555	10	2,456	1,228	319	4,003
Electrical Installation	(10)	6,005	10	601	300	78	979
Miscellaneous Supplies	(00)	7,952	5	1,590	398	103	2,091
Labor (Const. & Equip. Install.)	(11)	13,000	10	1,300	650	169	2,119
Total Construction Cost		**$105,386**		**$10,378**	**$5,269**	**$1,370**	**$17,017**
Durables							
Roof & Walls	(12)	799	3	266	40	10	317
Plumbing Hot Water	(13a)	2,835	5	567	142	37	746
Plumbing Fresh Water	(13b)	356	5	71	18	5	94
Plumbing MISC	(13c)	2,130	5	426	106	28	560
Extra Cooling Fans & Environmental Control	(14)	147	5	29	7	2	39
Lights	(15)	16,800	5	3,360	840	218	4,418
Other Durable Goods	(16)	850	5	170	42	11	223
Total Durable Goods		**$23,917**		**$4,890**	**$1,196**	**$311**	**$6,397**
Total Greenhouse Construction & Durables		**$129,303**		**$15,268**	**$6,465**	**$1,681**	**$23,414**
Utility hook-ups (electrical, heat)	(19)	5,000	5	1,000	250	65	1,315
Cost fresh water well & hook up	(20)	4,000	20	200	200	52	452
Total Greenhouse Investment		**$138,303**					
* Interest Rate (%) =	10						
** Ins. Rate (%) =	1.3						

Table 2: Greenhouse Investment Cost for Lettuce Production

3.2 Operation and Maintenance Costs

Lettuce is grown hydroponically and could be made available year-round, with an average time from seed to harvest of 30 days. The production cycle is shorter in the summer and longer in the wintertime and also depends on the variety of lettuce used.

Bench space in greenhouses is a valuable resource. A structural bench space optimization according to the properties of the greenhouse and the grown crop is essential for a successful operation. The model presented here differs from the current set up at CHSR and approaches an optimal bench setting. Figure 3 shows a possible optimal setup arrangement for lettuce production in the Poly-Tex greenhouse.

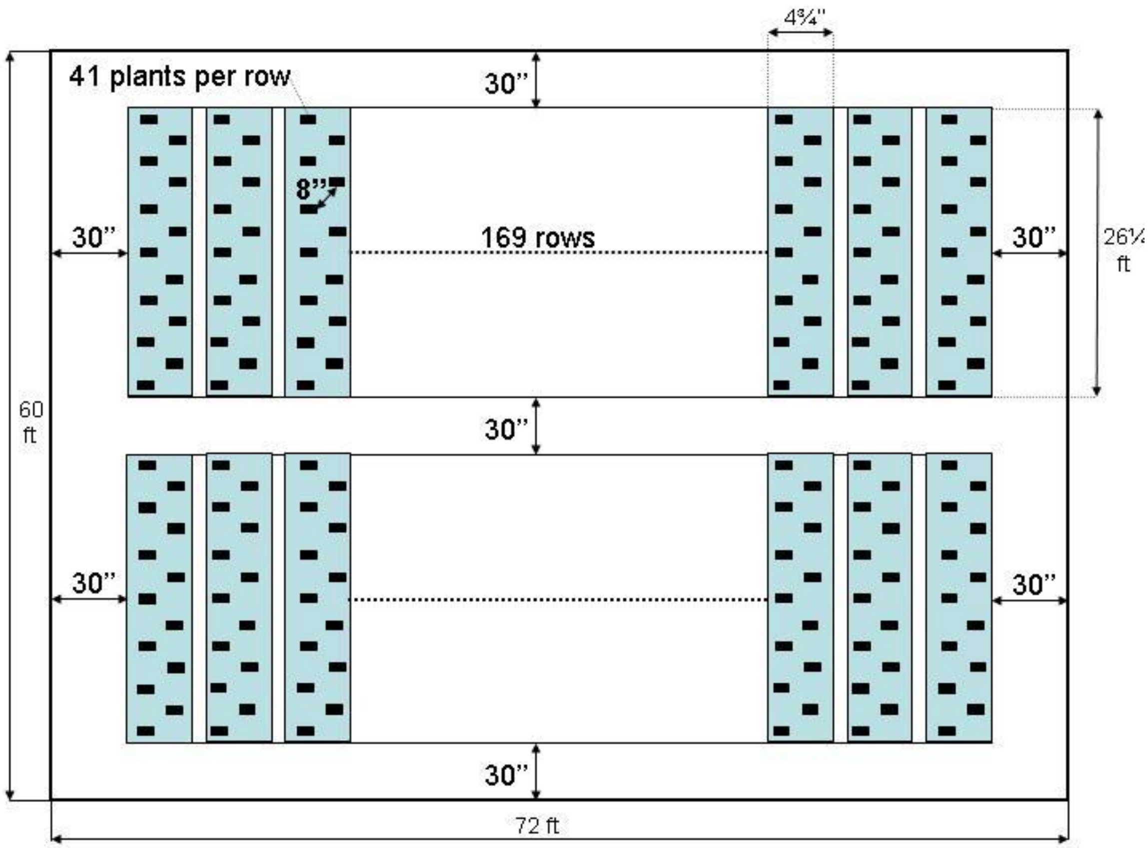

Figure 3: An Optimal Setup for Hydroponic Lettuce Production

Using hydroponics, the lettuce seeds are started in rock wool sheets. In the model each sheet can hold 50 seeds. A sheet of 50 2" x 2" x 2" cubes costs $8.00. Therefore the total costs for the rock wool sheets are $25,000 per year, assuming 400 to 450 seeds are started per day. The price of the seed varies with the type of lettuce grown in the greenhouse and is estimated on the upper end of the price range at $110 for 50,000 seeds (JOHNNY 07). The plants stay in the sheet system for the first 7 days of growing (Figure 4). After 7 days they are moved into the hydroponic growing system in the greenhouse. There the plants are spaced 8 inches apart and complete their growth.

Figure 4: Rock Wool Sheet with Lettuce Seedlings

The enterprise budget with its assumptions is presented in Table 3. The greenhouse would need to be staffed with a minimum of two full-time, salaried employees. One would be the Greenhouse Production Manager; the second would be the Marketing Manager. There would be some overlap in their responsibilities. Salaries are expected to be approximately $40,000 per year, or approximately $125,000 total labor cost. Total annual labor, accessories, and material input (nutrients, beneficial insects, seeds, and rock wool) cost approximately $172,000.

The heating needs of the greenhouse are highest in October through March and are expected to average approximately 500,000BTU/h. This is equivalent to about 75 gallons of fuel oil per day. The model assumes that the “waste heat” from the geothermal resource is sold to the greenhouse operation at a stable, long-term rate which compares favorably to fuel oil. This is mutually beneficial as long-term economic projections can be made for the installation without being effected by fluctuations in fuel oil.[2] Heating costs represent an expense of $23,650 to the greenhouse facility if the heat is purchased for the equivalent of $1.50 per gallon of heating oil. In comparison, the average cost of heating fuel in Interior Alaska in 2006 was $3.73 (DCED 07, p. 3).

[2] The same argument is used for electricity costs.

Electricity is another significant operating expense, particularly during the months of October through March. The model assumes the greenhouse will require 62kW of electric power, primarily for lighting, 16 hours per day. The greenhouse is laid out with 48x 1,000 Watt lights installed for an optimal production area of 4,300ft^2. The total electricity costs are approximately $30,200 per year assuming a price of 10¢/kWh. This electric rate would be a wholesale value, and significantly less than the 10 to 14¢/kWh rate that the operation would pay if purchasing power directly from GVEA, the utility company in and around Fairbanks (GVEA 07).

Marketing and bags to seal the lettuce for sale would be an additional expense of $0.25 per head, or $37,000 per year. Assuming a local market for the lettuce, the model does not include transportation costs.

Dimensions	60ft x 72ft						
Revenue	Lettuces per Year*			Price$/Lettuce		**Total$**	
	148,107			3.00		**444,322**	
Costs			Unit	Quantity	Price	Value	**Total$**
Pre-harvest & harvest							
	Material Inputs	(21)	$			45,243	
	Accessories	(22)	$			1,978	
	Labor (2 people full time)	(23)	hours	4160	30	124,800	
	Heat	(24)	$			23,625	
	Electricity	(25)	$			30,188	
	Int. on Op. Capital**	(26)	$	225,834	0.05	11,292	
	Total Pre-harvest Variable Cost						**237,126**
Packing & Marketing	Custom Packing & Marketing	(30)	heads	148,107	0.25	37,027	
	Total Packaging & Marketing Cost						**37,027**
Total Variable Cost							**274,153**
Fixed Cost							
	Depreciation & Intrest	(31)	$	1	21,733	21,733	
	Ins.	(32)	$	1	1,681	1,681	
	Total Fixed						**23,414**
Total Cost							**297,567**
Returns Above Cash Cost							**170,169**
Returns Above Total Costs							**146,755**
Breakeaven Price to cover cash costs							**$1.85**
Breakeaven Price to cover total costs							**$2.01**

* production losses 5%

** Interst on operating expences charged at 10% for 6 months

Table 3: Greenhouse Lettuce Enterprise Budget

3.3 Revenue and Total Profit

The model assumes a conservative 32 day growing period. Assuming all available space was committed to the lettuce production operation, 148,100 plants per year could be harvested and sold locally, making long distance transportation unnecessary. This number already takes a 5% production loss into account.

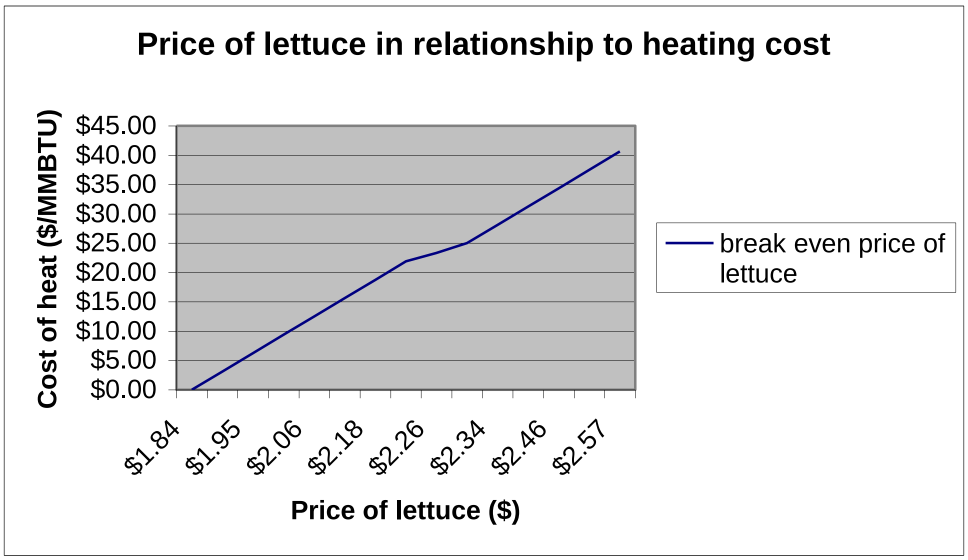

Figure 5: Price of Lettuce in Relationship to Heating Cost

Figure 5 shows the relationship between cost of heat and the price of lettuce. The model assumes a price of $1.50 per gallon of heating oil. At this level the heating cost is $9.38 per MMBTU. The break even price to cover the total cost of production is $2.01.

Lettuce production breaks even at $1.84 if heat is considered free. If the current price of heating oil were charged towards the greenhouse operation, the break even price would be $2.26. In general, a $0.50 price increase per gallon of heating fuel relates to a $0.05 price increase per head of lettuce with all other variables staying constant.

If each head of lettuce were sold for $2 wholesale, the net loss for the facility would be $1,352. At a price of $3 per head, the potential income for the optimal greenhouse would be $146,755. It can be expected that the optimal greenhouse production would be able to sell the lettuce for a premium because the lettuce is harvested and sold with its roots. This allows the lettuce to have a longer shelf life and stay fresh longer. Higher lettuce wholesale prices can also be assumed in remote areas with limited access compared with Fairbanks or Anchorage.

4 Applications and Outlook

The greenhouse technology demonstrated at CHSR could be exported to high cost rural communities in Alaska taking advantage of local renewable resources. Any kind of waste heat can be utilized to provide heat for a greenhouse facility. The knowledge acquired from CHSR's greenhouse could be used to assess the feasibility of rural greenhouse operation combined with biomass power plants, coal power plants, diesel generators or other heat sources. The heating required for a greenhouse can be seen as a productive use for the waste heat rejected from the power cycle and as an increase in thermal efficiency of the power plant. Heating costs for the greenhouse are additional revenue for the power plant facility. The goal for other projects would be to achieve a combined heat and power (CHP) cycle with higher efficiency compared to power plant alone solutions in order to operate a greenhouse facility economically year-round in Alaska. The optimized greenhouse, if applied, would be the only commercial lettuce operation of this type in Alaska. For this reason, a new project would not compete with existing growers.

This study considered the economics of a greenhouse installation only. Waste heat could also be captured and used in a number of other beneficial ways. Other uses for the heat could include:

- wood palletizing facility (industrial drying)
- absorption refrigeration
- space heating for buildings

Future studies could also analyze the cash flows in and out of the enterprise for a fixed interval of time. Another focus could be to specify the heating and lighting requirements for winter operation. Construction costs for the heating and lighting system could be allocated seasonally to determine if it is economically beneficial to have a year-round greenhouse in Interior Alaska, or whether operating for three seasons with no production during the mid-winter months would be more economical.

Future studies could also improve the model in terms of bench space. For example, in order to make maximum use of available space, the planting system described above can theoretically be optimized as follows:

Day 1 - Day 7:	The seedlings stay in the rock wool sheets.
Day 7 - Day 15:	The plants are moved into the hydroponic trays and would be spaced 1 inch apart.
Day 15 - Day 30:	The plants are moved a second time into trays with 8 inch separation between holes.

A higher production would be possible with this 3-phase growing cycle, but it would also result in higher labor cost. An analysis of the economical feasibility would be necessary and could be part of future studies.

Besides a supply of fresh lettuce to the local community, the modeled greenhouse with its assumptions would generate a positive return and create two skilled full time jobs. When considering a project in a rural area, these aspects can be very important. From a research perspective, the University of Fairbanks and rural Alaskan communities will also benefit from a greenhouse project. The greenhouse could benefit local K-12 education systems by including the facility in school curricula and involving students of FFA chapters[3].

[3] formerly known as Future Farmers of America

5 Conclusion

The model developed here can be used as a starting point for an economic analysis of a year-round greenhouse production considered in Alaska.

An enterprise budget is used to analyze the existing greenhouse at CHSR with optimized crop-growing parameters. The modeled 6,000ft^2 Poly-Tex greenhouse could produce approximately 148,100 heads of lettuce per year assuming a (conservative) average growing period of 32 days. Total greenhouse investment costs are expected to be \$138,300. Variable costs are estimated to be \$274,200 and fixed cost an additional \$23,400 in the applied enterprise budget. The breakeven price for lettuce sales to cover the total cost is \$2.01 per head. Selling the produce for \$3.00 per head the yearly revenue potential is \$146,755.

Sources

AGRALT 94	Agricultural Alternatives; Enterprise Budget Analysis; College of Agricultural Sciences, Cooperative Extension, Pennsylvania State University, 1994.
DCED 07	Department of Commerce, Community, and Economic Development, Division of Community Advocacy; Current Community Conditions: Fuel Prices across Alaska, Fall-Winter 2006 Update, 2007.
GVEA 07	GVEA, Golden Valley Electric Association; http://www.gvea.com/billing/rates.php, accessed: 08-05-2007.
JOHNNY 07	Johnny's Selected Seeds; http://www.johnnyseeds.com/, accessed: 08-20-2007.
POLYTEX 07	Poly-Tex, Inc.; Pricing, XA-300 — 60' twin span; http://www.poly-tex.com/, accessed: 07-09-2007.
SMITH et al. 07	Smith, J. / Hewitt, T. / Hochmuth, R. / Hochmuth, G., A Profitability and Cash Flow Analysis of Typical Greenhouse Production in North Florida Using Tomato as an Example; Cooperative Extension Service University of Florida; http://nfrec-sv.ifas.ufl.edu/Reports%20PDF/GHCashFlowAnalysis.pdf, accessed: 07-10-2007.
YOUROWNPOWER 07	Yourownpower – Chena Hot Springs Resort renewable energy and sustainable development website; http://www.yourownpower.com/, accessed: 07-07-2007.