# Hoophouse Decisions and Opportunities

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With all of the enthusiasm they've generated, hoophouses just might be the greatest thing since sliced bread, but their economic benefits depend on what you grow and how you grow it, as well as how much you invest in the structure itself.

For many years the MSU Student Organic Farm (SOF) mantra of the winter harvest has been: *1) the right crops; 2) planted at the right times; 3) for multiple harvests; 4) with the proper protection.* Our findings and experience have been consistent with the farmers who practiced the winter harvest for many years before we started. We also have been successful with extending the season of summer production of tomatoes and other warm season crops. We have worked to demonstrate the opportunities for hoophouse success through the 48 week CSA at the MSU Student Organic Farm, now in the seventh year. We have presented workshops to thousands of participants and now are seeing an increase in construction of hoophouses in Michigan. I have had the opportunity to be involved in construction of at least 20 hoophouses from eight manufacturers with an investment range from the bare minimum to the recent "salad palace" ($20,000+) at the MSU SOF.

Thanks to a partnership with Michigan Food and Farming Systems (MIFFS), the MSU Mott Group for Sustainable Food Systems and the USDA Risk Management Agency Community Partnership Program (2006-2010), Adam Montri, outreach specialist has helped Michigan limited resource farmers construct hoophouses and develop production plans and methods. We have also helped introduce hoophouses as a tool that makes time for urban farms in Flint and Detroit, farmer or job training programs, and community and school gardening programs.

**Some indicators of income potential**

There are many crops suitable for hoophouse production in spring, summer, fall and winter. The planting schedule for the baby leaf salad greens, leafy greens, root crops, and summer fruits is provided later in this handout. We grow them all because our primary market is a 48 week CSA. If you were starting out, how would you choose which crops to grow?

Most farmers start with extending the production season of warm season vegetables like tomato, pepper, eggplant, cucumber, summer squash, green beans and basil. Tomato is assumed to be the most profitable. Tomato yield over a 20 week period (4/15 to 9/15) at SOF averages between 2 and 4 lbs/sq ft of growing area with ~60% growing area. Assuming tomatoes can sell from $2 to $4 per pound (or higher for organic, out of season), the income per sq ft of growing area can range from $4 to $16 per square foot of growing area or $2.40 to $9.60 per square foot total house area. Peppers, eggplants, cucumbers, summer squash are typically less than this. Weed management and pest management are minimal with these crops. Suckering, pruning and trellising with either the Florida weave or single string system require time as does harvesting. (SOF Varieties: Celebrity, Big Beef, grape)

Well managed baby leaf salad green production should average one pound of greens per six square foot (0.167 lb/sqft) averaged across 10 to 12 types of greens. Those greens could sell for anywhere from $4 to $12 per pound which would mean a range of $0.67 to $2.00 per square foot of growing area or $0.40 to $1.20 per sq ft of structure with 60% growing area. That production could take as little as 4 weeks and as many as 12 weeks depending on the time of the year. It is reasonable to get 4 to 6 harvests for fall, winter spring if scheduled with tomatoes for example. Head lettuce can be less harvesting, processing and marketing labor than BLSG and can provide income potential at least as good as BLSG. Other common crops with good income potential include leafy greens and root crops like radishes, turnips and carrots.

Is it possible to compare the profitability of tomatoes over 20 weeks with BLSG over 4 weeks? Yes, if we take into account the crop time using dollars per unit area and unit time or $/sqft*wk. Lets take tomatoes at $9.60 per sqft of tunnel over 20 weeks. The gross income per sqft*wk is 9.60 / 20 or $0.48. For BLSG at $1.20 per sqft of tunnel over 4 weeks, the gross income per sqft*wk is 1.20/4 or $0.30 per square foot week. The tomatoes have greater gross sales, but the labor and other costs would have to be considered before the profitability can be determined. There are several enterprise budgets presented in the publication "Hightunnels Using low-cost technology to increase yields, improve quality, and extend the season". The manual can be downloaded as a PDF file at www.hoophouse.msu.edu .

**Hoophouse Economics Trial**

What we lack in our yield trials at the MSU-SOF is data of the time spent planting and harvesting. However, using the SOF as a measure of labor is not particularly valuable because we are a teaching farm and most operations go significantly slower than would be expected on a strictly production farm. What has been needed is on farm data. A recent summary of the experiences of 12 novice hoophouse growers is now available at www.hoophouse.msu.edu .

Dr. David Conner and Dr. Mike Hamm received funding from the National Research Initiative (NRI) to evaluate the impact of a hoophouse on the economics of an individual farm and the impact of multiple extended season farms on a farmer's market. Nine structures were funded and built in the fall of 2006 at farms in the Upper Peninsula of Michigan, Western Michigan, and the Ann Arbor area. A similar structure was built at the MSU SOF. Adam Montri was hired half time to guide the teaching builds and provide training and farmer support. During 2007, three additional hoophouses were funded by the Michigan Agriculture Experiment Station and constructed on farms in the Traverse City area with a focus of on-farm marketing.

"The Rimol construction manual for this size and model suggests approximately 100 total person hours for expert level construction. Total person hours for construction across all nine houses averaged 237 hours with a range of 114 to 420 hours. Frame construction ranged from 91 hours to 228 hours, with a mean of 136 hours. Site preparation ranged from zero hours, for a structure built over a field already in production, to 134 hours, with a mean of 47 hours. Polyethylene attachment, which includes both two layers on the roof and a single sheet on each endwall, ranged from 10 to 97 hours, with a mean of 47 person hours. Other labor hours, which include water and electric to the site in some cases, ranged from zero hours to 23 hours, with a mean of six person hours".

The farmers started planting in the spring of 2007 and kept records of the labor hours invested and the sales of product. "Gross sales are defined as total sales while net income is defined as total sales minus total costs. Gross sales by farm ranged from $947 to $7,968, with a mean of $3,801 while net income ranged from $-545 to $5,450, with a mean of $2,248." The target grow sales was ~$15,000 based on the estimate of $5/sq ft of total greenhouse area. "Initial investment per structure is approximated at $10,000. A main focus of this research project is to determine the amount of time required to generate enough net income to pay back the initial structure investment and begin to realize a profit. Based on first year net income across the seven of the nine farms with positive revenue, payback time ranges from 1.8 years to 13.0 years with a mean of 4.4 years."

**What is the minimum structure required?**

A good place to start is what size structure? Any size structure can bring an economic advantage to the farm – from 15' to 30' wide and 48' to 144' long. Early recommendations I read were that a width of greater than 30' might not cool well enough. Excess summer temperatures or lack of air movement has not been a problem in Mid-Michigan. The extra width is generally better for winter

production due to a greater area being covered with less perimeter. Our standard was 30' x 96', but as the price of steel went up, it seemed the entry point around $5,000 to $6,000 may require a smaller initial structure, perhaps 30' x 48' or 72'. We have only built one 34' wide structure compared to more than 20 at 30' wide, but a first impression is to go for the extra 4' if possible. Wider houses are also taller at the peak which facilitates heat rising and moving away through end wall louvers in the summer. We built our first 144' long structure at the SOF in 2008 and it has performed very well. It appears that the larger structure may help keep winter crops warmer.

The structure does not need to be fancy. The primary concerns are maximizing light, shedding snow and minimizing wind and convective air exchange. A single layer of polyethylene over a Quonset shaped roof will grow adequate crops and stand up to most snow storms. But one of the keys is keeping the heavy snow off, both because of the stress on the structure and to allow sunlight in. The gothic or more pointed peak shape is perhaps the first line of defense. Single layer of plastic on the structure with an internal tent will clearly keep crops alive in Zone 5. The single layer also lets in more light, which is good. If it is pulled tight and well attached, it likely will be smooth enough to facilitate snow removal. The second layer of plastic and an inflation fan add significantly to the cost, but can reduce plastic film movement due to wind which reduces useable lifetime and light transmission. Perhaps most importantly, as long as the inflation fan stays powered, the double layer inflated surface also provides a smoother surface for snow to slide off. The extra four or five degrees warmth may also make the difference for crop survival on a very cold winter night. Bottom line – if a single layer can be maintained so that snow does not accumulate on the cover, the second layer likely is not needed.

| **Considering the Range of Options and Costs for Hoophouse Construction** | | | | | | |
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| Size | Low cost - thinner or smaller diameter steel or make your own out of wood | | | | | |
| 30'x96' | High cost - best steel available and best, mechanized (electric) options | | | | | |
| | Average - Current recommendation | | | | | |
| Feature | Low | High | Average | Low | High | Average |
| Site preparation -grading, water lines, electric, drainage, gravel | $200 | $1,000 | $500 | $0.07 | $0.35 | $0.17 |
| Frame - rafter thickness, diameter, spacing; purlins; cross bracing | $4,000 | $8,000 | $6,000 | $1.39 | $2.78 | $2.08 |
| Hip and base boards - pine vs treated vs aluminum and steel | $300 | $1,000 | $600 | $0.10 | $0.35 | $0.21 |
| End walls -none vs pine vs treated vs steel; door options | $300 | $1,000 | $600 | $0.10 | $0.35 | $0.21 |
| Roll up sides:make your own vs purchased vs thermostat / electric | $300 | $600 | $400 | $0.10 | $0.21 | $0.14 |
| Plastic film: single vs double inflated; IR and condensation | $400 | $1,000 | $800 | $0.14 | $0.35 | $0.28 |
| Ventilation louvers - wooden vs electric louvers | $300 | $700 | $500 | $0.10 | $0.24 | $0.17 |
| Ridge Vent (not recommended) | $500 | $1,000 | $750 | $0.17 | $0.35 | $0.26 |
| Delivery: miles and number of houses | $400 | $1,000 | $500 | $0.14 | $0.35 | $0.17 |
| | | | | | | |
| Total | $6,700 | $15,300 | $10,650 | $2.33 | $5.31 | $3.70 |

While some might say roll up sides are essential for summer cooling, others have claimed profitable production without them by using large doors on the ends. It seems like the logic is that the roll ups may decrease winter warmth. It only takes a little more effort to make a seal for the rollups and to get them to inflate once they are no longer needed for winter ventilation. I would agree that they are not essential, but I see no reason not to add them if I was building a house. Using a solid aluminum strip like a wire lock channel to attach the plastic to the roll up bar is more expensive than clips (~$100 vs $10-$20) but a good investment from my perspective and experience.

As the cost of the structures has gone up, we have begun to suggest smaller sizes than the 30'x96' structure. After building some smaller structures, we realized that not only is the cost lower, but the effort needed to build one is also significantly less for a smaller structure.

Are there limiting factors that need to be identified for increasing hoophouse use for season extension on farm? Is the limiting factor a) confidence that the economic return is there? or b) resources to purchase the structure? or c) the time to consider additional tasks on the farm? or d) all of the above or e) none of the above?

Like any investment for farm tools or equipment, there needs to be a clear benefit for improving quality of life and increasing profitability of the farm. If a tractor is a tool that makes it possible to farm more space, the hoophouse is a tool that makes it possible to farm more time by extending the time available for growing and harvesting.

**What about moveable structures?**

The concept of moveable structures to maintain soil quality and increase productivity of the structure has been part of the goal of hightunnels for two decades. Moveable structures have not been used that often due to lack of commercially available models. That has changed in the past few years with the availability of moveable models from Four Season Tools (www.fourseasontools.com ) and Rimol Greenhouses (www.rimol.com ). The additional cost of the structure is justified by the additional use of the structure. For the sake of a simplified example, a stationary 30' x 96' Noreaster by Rimol with steel endwalls and rollups can cost about $12,000. A comparable mobile structure might be $16,000. The difference in cost can be justified by using the stationary structure for 12 months of the year but the mobile structure the equivalent of 16 months of the year by starting crops under cover and finishing them outside or starting them outside and finishing them under cover.

**Crop Selection, Scheduling and Rotation**

Perhaps the most important decisions related to high tunnel success is the crop selection and scheduling. Most crops will grow well in ahigh tunnel, but onl a limitednumber can provide the return to make the high tunnel profitable. Example crop schedules and rotations are provided in the following tables based on experience at the MSU Student Organic Farm. These schedules were developed for a Community Supported Agriculture program and a campus farm stand and reflect the preferences of the CSA members. For organic production the high tunnel must be treated line a field and managed with a diverse crop rotation. Even though tomatoes can be more profitable, other crops need to be in rotation.

**Additional Sources of Information**

For a ~13 page article covering basics of hoophouse construction and use go to www.msuorganicfarm.org under the resources tab and click on organic farming principles and practices. First try clicking the link below. http://www.msuorganicfarm.org/practices.htm

For a 75 page PDF of Hightunnels - Using low-cost technology to increase yields, improve quality, and extend the season go to http://www.uvm.edu/sustainableagriculture/hightunnels.html

**Passive Solar Greenhouses for Local Food and Farming**
**Frequently Asked Questions about Design and Construction**
John Biernbaum, Michigan State University

1. **Sun** – *What is the best orientation for the PSGH, EW or NS?* To maximize winter light in northern climates (40N latitude or higher) a single PSGH structure is placed with the ridge running east and west so the sun comes in the side. There are other factors to consider when deciding on orientation including blowing and drifting snow, wind direction for summer cooling either through end wall doors or side wall roll-ups, and the space available. The best orientation needs to consider all of these factors. With westerly winds, snow may drift against the side of a NS structure and an unbalanced snow load, ie more on one side of the house than the other is undesirable. An EW orientation might allow a west wind to blow snow away from structures.
2. **Shadows** – *How much distance is needed between houses?* For PSGH oriented EW the shadow in December at 40-45N latitude will be approximately twice the height of the structure. With that in mind, a minimum distance between 20' wide, 10-11' tall houses would be 20' and for 30' wide houses, 13-15' tall would be 30'. Space between the houses is also important for snow removal. The area between the houses can be used for outdoor production in the summer.
3. **Site Elevation and Water Absorption** – *Where will the rain water go?* A 30' x 96' PSGH will displace 1800 gallons of water with a 1" rainfall. Snow melt will also result in water that needs a place to drain other then into the PSGH. On sandy soils drainage may not be an issue but on heavier soils either a natural slope away from the structure or buried drainage lines around the structure need to be provided. An elevated site may also improve air flow in the summer and cold air drainage in the winter.
4. **Soil Preparation** – *What is the best way to prepare the soil?* It is important to prepare the soil in advance of construction and to add organic matter either from green manures or compost. Prepare an area larger than the structure footprint so ground cover around the structure will not grow into the structure.
5. **Soil Moisture** – *Is irrigation necessary in the winter?* Yes, irrigation is needed year round and is best provided by a frost free hydrant either in or very near the PSGH. Irrigation is also critical in the summer for plants to take advantage of the warmer temperatures in the PSGH. Drip irrigation is highly recommended for the summer. On heavy soils, subirrigation may also be possible.
6. **Stationary or mobile -** *What are the advantages of a mobile PSGH?* A mobile PSGH can provide more production over a longer period of time (14+ vs 12 months) by allowing winter crops to be started outdoors while warm season crops are protected during the late summer and early fall. A mobile greenhouse also allows the soil to be exposed to rainfall for a part of the year and cover crops to be grown outside. Purchasing a commercial structure suitable for or designed for moving has been a limitation but a new design with rollers is expected on the market soon.
7. **Shape** – *Is there a preferred greenhouse roof shape?* The rounded or quonset roof shape was most common for early polyethylene covered greenhouses. In the past five to 10 years the gothic or more peaked design has become more common due to better shedding of snow, increased light transmission in the winter and decreased light transmission in the summer. The peak also allows heat to move up away from the crop.
8. **Size** – *What width and length options are available?* Widths run from narrow at 14' to 16' to medium at 20' to 26' or wide at 30' to 34'. Additional width is considered an advantage for winter harvesting while it may be a disadvantage in high temperature climates. Added width adds height and the need for larger sheets of plastic film. Lengths are possible in multiples of 4' depending on rafter spacing; commonly offered lengths are 48', 72', 96' or 144' which is influenced by the common lengths of plastic film which are 100' or 150'.
9. **Side wall ventilation**- *Are roll up sides a good investment?* For PSGHs greater than 48' in length, roll up or drop down sides are an economical way to provide summer ventilation. Variations in design influence effectiveness and cost. Homemade rollups can be low cost but need to be done so the poly stays attach and the bar moves horizontal. Automation is possible when there is not someone present through the day to make adjustments. The guide ropes to hold the bar under windy conditions is essential and must be maintained.
10. **Sliders or hinges** – *What options are available for doors?* Doors purchased from and shipped by greenhouse manufactures can cost significantly more than locally available or even recycled doors. Sliding barn doors

that move left to right on track vs in or out on a hinge can be much easier when moving crops or equipment. Large endwall doors can provide significant passive ventilation.

11. **Shutters** – *What is the advantage of manual or motorized louvers or shutters in the endwall peaks?* Butterfly or center pivot vents can be made on sight to provide a large endwall vent opening that is manually managed or managed with a temperature sensitive wax piston. A set of thermostatically regulated louvered shutters at the end of the PSGH can handle the required ventilation six or seven months of the year in our zone five climate for about $500 to $600 if electricity is available.
12. **Short vs tall** – *Is there an advantage to taller sides?* Taller ground posts or side walls cost more but provide the advantage of allowing pathways to be along the typically colder and wetter outside walls. The extra height provides for large roll up sides, moves the summer heat up away from the crop and creates a more pleasurable working environment. In some settings the extra height may be an aesthetic problem and it also increases the size of the polyethylene film required for covering.
13. **Steel (aluminum) or wood** – *What are the options for baseboards, hipboards, and ends?* Wooden hipboards, baseboards and endwalls clearly work although they may need to be replaced with the second changing of polyethylene after 8 to 10 years. Steel baseboards and aluminum hipboards together with metal endwalls leads to a more permanent and maintenance free structure, but at a cost.
14. **Strength** – *What are the options for diameter, thickness (gauge) and shape of steel?* Galvanized steel used for greenhouse construction can vary in diameter and thickness. In general, for a 30' structure, 1.9" or greater diameter steel of either 13 gauge (thicker and preferred) or 14 gauge steel is most common. For 22' or less, 1.66" diameter steel of 14 gauge is most common. Round rafters are most common but the use of oval or square steel can provide greater strength or allow rafter spacing to increase from 4' to 5' which may help offset cost and reduce the number required.
15. **Single vs double** – *Is one layer of plastic enough or are two layers inflated necessary?* One layer is clearly enough (with an internal layer) to keep the PSGH soil from freezing and to protect crops even in cold years in zone 5. The second layer inflated will provide ~4F more protection and may help insure a smooth surface that will facilitate snow sliding off the roof.
16. **Snow** – *What strategies are used to deal with heavy snow?* A greenhouse rated to National Greenhouse Manufactures Association (www.NGMA.com ) guidelines of 15 lbs per square foot of snow load will handle an average snowfall with no heat in the structure. The keys are a peaked structure, tight or inflated plastic, room for the snow to move away from the sides, and an even build up of snow on both sides. Stability due to snow weight on the top of the greenhouse is influenced by the number of and strength of purlins and the strength of the end wall since snow weight will tend to collapse the center of the greenhouse and pull the endwalls down and in from the top.
17. **Sash (wood) or wire lock** – *What options are there for attaching plastic?* 1"x2" wooden sash can be attached to wooden hip boards and used to attach polyethylene for about $0.25 per foot. Aluminum wire lock base and wire insert typically costs more than $1 per linear foot. Since about 300' are needed for a 30x96, the total cost of about $300 vs $75-100 is good investment of the higher cost and strongly recommended to protect the $500 or $1000 dollars worth of plastic.
18. **Space** – *What are the options for size and arrangement of the growing beds?* The beds can be oriented either the length of the greenhouse or across the width of the greenhouse. Beds oriented north and south will get more uniform sunlight on both sides of the bed/crops. The amount of space used for beds needs to be aleast 60% of the floor area and can be as high as 80-85% with wide beds.
19. **Support** – *What are the options for supporting the interior cover?* The interior cover is important when outside temperatures drop below 20-25F. The cover can be frost fabric like Remay or Agribon or it can be polyethylene if venting on hot days is used. The covers have been supported by sections of No. 9 wire formed into wickets that straddle the growing beds, flexible irrigation or water pipe bowed over the beds, or electrical metal tubing (EMT) or conduit to make a frame. High tensile wire attached to greenhouse endwalls or posts can also be used if combined with the appropriate tightening and tensioning devices.
20. **Support- Knowledge** - *Where do I go for more help or ideas?* For more information check out the website www.hightunnels.org and consider joining the hightunnel list serve.