Greenhouses for the Northern Climate

Yukon Government

Cold Climate Innovation
YUKON RESEARCH CENTRE • Yukon College

Growing Forward 2
A federal-provincial-territorial initiative

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Introduction

Every greenhouse is different. Even if assembled from the same kit, other factors such as location, orientation, and management make that greenhouse unique. And most home greenhouses are not assembled from a kit. Their construction materials, size and shape vary considerably depending on the desires, skills and budget of the builder. By collecting photos of a wide variety of successful greenhouse options, we hope you will be inspired to recreate those features that make sense to you.

This brochure will focus on solar greenhouses. That is, greenhouses where the heat necessary to grow plants is supplied mostly by the sun rather than other fuel sources. Most of the glazed surfaces face south and any wall that is not glazed is insulated. There may be moveable insulation to cover at least some of the glazing at night to prevent heat loss. These greenhouses include thermal mass to store heat during the day and release it at night and are carefully vented so that the greenhouse keeper is in control of heat collection and storage.

Use the basic principles to design your structure and find helpful details for maximizing production. This website presents these design essentials in a straightforward way.

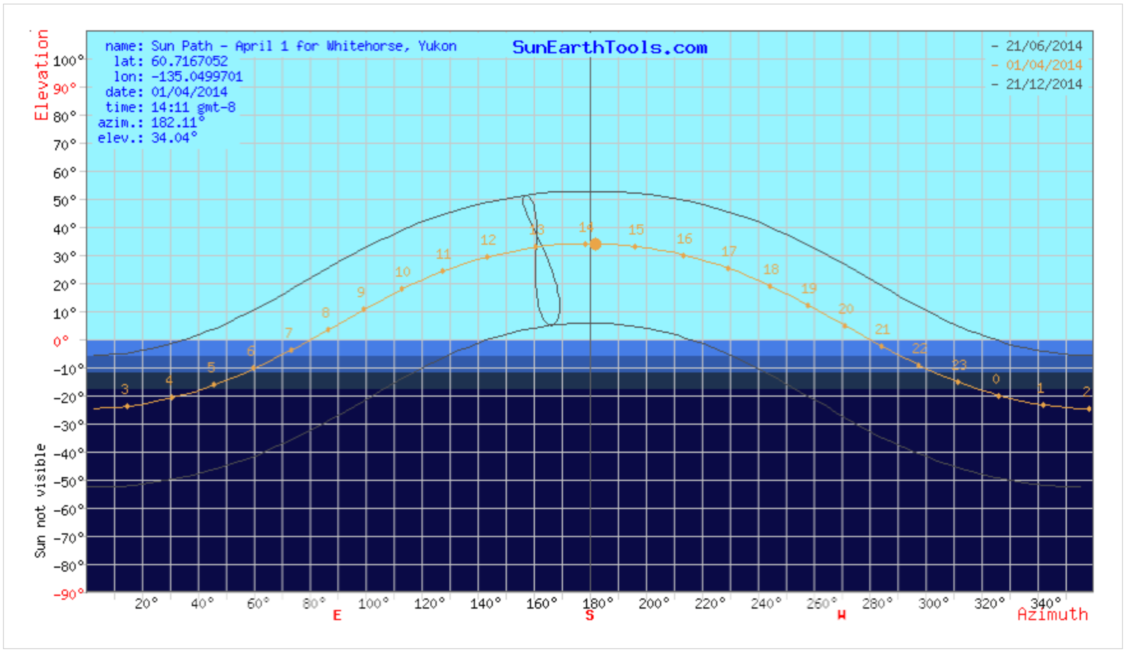
The most important features of a solar greenhouse are that solar greenhouses:

- have glazing oriented to face solar south
- retain solar heat by using heat storing materials such as water or rock
- have insulation in walls and/or roof where there is little or no direct sunlight
- circulate air to stabilize day and night time temperatures
- have an arctic entrance or vestibule to minimize heat loss when entering or leaving

Site Location

Your choice of location will depend on many factors, but a most important consideration is whether objects such as buildings, trees or bushes, or even mountains will interfere with sunlight entering the glazing. In the north, this is especially important in the early spring when that incoming radiation is what will warm the soil in your greenhouse. Later in the summer, the midday sun is more directly overhead so less likely to be shaded by nearby objects. By paying attention to the path the sun takes early and late in the season, greenhouses can be sited to take best advantage of the available light for growing while minimizing overheating. The website, sunearthtools.com, can be used to calculate the path the sun will follow for any day and any latitude/longitude. The image below is for Whitehorse for April 1st.

Stand in your potential greenhouse location and use a clinometer (also called an inclinometer) to plot on grid paper the objects that block your view of the horizon. Instructions to make your own clinometer can be found here. Compare that map with the sun path plots for your site to decide whether there will be enough sunlight shining onto the glazing of your greenhouse.



Orientation

In the north, you will want to face the side of the greenhouse with the most glazing to true solar south. (If it is not possible due to other factors, facing the building slightly to the east of solar south to catch some morning sun is okay too.)

But how do you locate solar south? You can find solar south by placing a peg directly in the shadow of a second peg at solar noon on a sunny day. To do this, the first step is to determine solar noon. This is the time of day when the sun is highest in the sky and is different than 12:00 noon on the clock. To make commerce between communities more convenient, each time zone spans quite a wide area, especially in the north. As well, the change to daylight savings time from early March to early November shifts solar noon another hour later.

Solar noon occurs exactly half way between sunrise and sunset so you can determine the precise time of solar noon by calculating the exact midpoint between sunrise and sunset. A website such as timeanddate.com/ can be used to find a table of times for sunrise and sunset for your location.

For example, on April 1st in Whitehorse, the sun rises at 7:24 am and sets at 8:46 pm which converts to 20:46 on the 24 hour clock. Subtract to get 13 hours and 22 minutes of daylight. (20:46 – 7:24 = 13:22) Half of that is 6 hours and 41 minutes. We now add 6 hours and 41 minutes to our sunrise time of 7:24 and get 14:04 or about 4 minutes after 2 pm.

Optimal angle for maximum exposure

Although there are benefits to building the glazing wall angled to catch the most sun during the coldest part of the growing season, an angled wall does result in construction complications. You will need to decide for yourself whether the benefits outweigh the costs.

If you do choose to angle the south facing glazing wall, the optimum angle should allow the sun to enter the greenhouse at a right angle on the coldest day. This angle can be calculated by adding 15° to your latitude. For Whitehorse, that means the optimal angle for greenhouse glazing is ± 75°.

The cooperative extension service from the University of Alaska recommends vertical glazing over sloped since sloped glazing costs more and is more difficult to install. It has a greater tendency to leak and it is easier to break. They also believe that in winter, sloped glazing actually gets less solar gain because it needs to be cleared of snow and that reflection from the snow is reduced. It is also much easier to insulate a vertical wall of glazing. It is also easier to shade a vertical glazing wall in summer to minimize overheating.

Design/Construction

The good news is that almost any structure that is built to look like a solar greenhouse will work. The most important features are to have the main glazing wall facing south to maximize southern exposure, to insulate walls or roof areas that are not glazed, to have at least some heat storage capacity and a way to move air around inside (and probably out of) the greenhouse.

Our goal as gardeners is to provide optimum growing conditions for plants while minimizing the effort required to maintain those conditions. Optimal conditions for an actively growing plant are air temperatures of 20-25°C, 60-80% relative humidity, 800-1500 ppm CO_2 level, 20-100 W/m2 photosynthetically active radiation (PAR), and an adequate supply of water and nutrients for the plant.

A general consensus among solar greenhouse builders is that the length (east-to-west) should be twice as long as the width. There is a trade off in cost of insulation compared to heating costs. As the price of fuel continues to increase, it makes sense to put in as much insulation as you can afford. If you hope to operate a solar greenhouse without supplemental heating, the recommendations for greenhouses in Zone 1 are for R-40 in the walls and roof, R-15 to below the frost and heat storage of 4 gallons of water or 0.5 cubic feet of rocks per square foot of floor. You can get away with less insulation if you plan to add supplemental heat.

Containers of water or block walls should be painted dark blue or red to maximize heat absorption while still reflecting some useful growing light to plants. The interior north wall and ceiling should be painted white to maximize reflection within the greenhouse. Flat white is better than glossy so that the reflected light is diffused.

For the same reason, translucent glazing like polycarbonate or woven poly is often a better choice for glazing material than glass. Glass is useful where people might want to see in or out, but glass has some drawbacks. It is heavy and prone to breakage. Glass allows so much concentrated light through that it can cause hotspots. Polycarbonate glazing has come a long way in the last few years. It will last a long time, has good transmissivity and provides better insulation values than glass.


Government of Yukon

Construction

For people without a construction background, designing and building a greenhouse from scratch can be pretty intimidating. But don't be tempted by the quick and easy kits available to assemble. Although this option seems like a quick way to provide for protected growing space, soaring daytime temperatures means more attention is needed from the grower for additional watering and providing adequate ventilation. These kits have no insulation so cold night time temperatures on the shoulder seasons make supplemental heating a necessity. As the cost of heating fuel continues to rise, it makes sense to minimize the requirements for supplemental heating with good design.

The simplest and least expensive option to growing your own fresh greens is to use some of the already heated spaces within your own home or workplace. South facing windows can have PVC tube planters hung where it is easy to grow and harvest a few leaves for lunch time sandwiches.

Adding protection to outdoor garden space can be as simple as clear poly laid directly on the ground to warm the soil prior to seeding and then covering with garden fabric such as Agribon. This type of floating row cover can protect from insect damage as well as below freezing temperatures. Weight the fabric edges with soil or rocks to prevent the wind from uncovering the plants.

Slightly more effort and you can create a protected growing space under a cold frame outdoors. An old sliding door supported by a square of straw bales is simple and surprisingly effective. A few pieces of flexible PVC pipe or willow branches can be used to make hoops to support poly or row cover cloth to extend the season by at least a couple of weeks on either end. That's a full extra month of growing with minimal investment.

Traditionally, market growers would dig a 3 foot deep pit and then add in a foot of fresh horse or chicken manure covered by a foot of topsoil. The heat from the composting manure would warm the soil for early germination of the seeds and then provide nutrients for the growing plants through the rest of the season. The pit could be covered by an old piece of glass or hoops with poly or row cover.

Appearance

Solar greenhouse

The ideal shape for a northern solar greenhouse has the glazing at a steep angle or vertical. The goal is to have light enter the glazing close to 90° when light levels are at their minimum. Depending on the length of growing season you are hoping for, the ideal glazing angle will be between 75° and 80° for latitudes above the 60th parallel. This far north, it is even reasonable to keep the south wall vertical which simplifies construction and will prevent snow from accumulating.

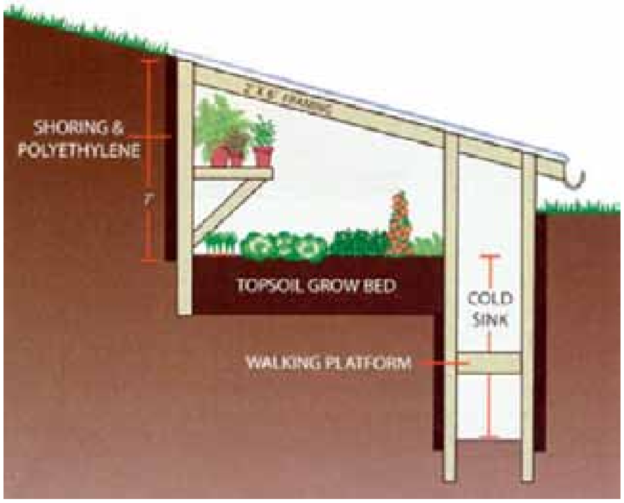
Since a shed roof is easier to build and seal than a gable roof, many excellent designs use a shed roof. A long overhang on the front can help with summertime shading to prevent overheating. The angle of the shed roof can range from 55° to 65°.

Rather than installing glazing all the way to the ground on the south side, building an insulated wall 3 to 4 feet high below the glazing allows for building growing beds inside and prevents snow from piling up on the outside of the glazing.

The best glazing option is either multi-walled polycarbonate or single walled polycarbonate. Other options include woven poly, air inflated double walled poly, glass or even a single layer of poly. Although poly (or polyethylene) is one of the most commonly used greenhouse glazing materials because of its low initial cost, since it needs replacing so often and provides minimal insulative value, it is one of the poorest choices for covering your greenhouse.

Install as much insulation as you can afford. With the high cost of heating fuel, the time it takes to pay back the cost of insulation through lower fuel bills is very short.

For a more detailed look at building a solar greenhouse, the online book "Solar Greenhouses" is available for free download.



Pit greenhouse

The above ground part of pit greenhouses vary as much as standard above ground greenhouses, but what all pit greenhouses have in common is that the growing area is dug down at least 4 feet into the earth. The constant temperature present at that depth help moderate temperature fluctuations in the greenhouse and minimizes heating costs. A trench down the centre of the pit provides a frost trap to keep the air at plant growing levels warmer and many include a vestibule entrance to minimize heat loss when entering or leaving.

A large collection of photos and descriptions of a number of pit greenhouses or pit cold frames are shown on this website. This site follows the whole process of building a pit greenhouse right from digging the hole to harvesting vegetables in Nebraska in November. And a commercial grower discusses the pros and cons of growing in a pit greenhouse. In summary, Doug highly recommends a pit greenhouse for personal use.

Retrofit

The greenhouse design currently in common use all across North America where the roof and walls are all glazed was originally designed for use in the lower part of Europe. There, winter temperatures are fairly mild and since it is generally overcast and rainy for most of the winter, the entirely glazed walls and roof were needed to get enough light into the house for plant growth.

In Canada, and especially in the north, conserving heat is much more important than maximizing light since we have much colder temperatures and clearer skies. From late February to early November, we receive enough solar radiation to make growing plants quite a reasonable proposition as long as we design the greenhouse to minimize heat loss and maximize heat storage.

If you already own a fully glazed greenhouse, you will have experienced the need for supplemental heat at night and the high venting requirements during the day. There are things you can do to make things better. Whatever shape your current greenhouse is, there are things you can do to make it more efficient.

Step 1 – Add insulation

At a minimum, insulation should be added to the north wall. Even better, insulate the north wall and the north roof. Sheets of rigid Styrofoam can be inserted between the supports. If the walls are curved, you can use the rolls of reflective insulation meant to improve performance of radiant heating with concrete floors.

Step 2 – Add heat storage capacity

Fill barrels, cans, or bottles with water and stack them under the beds or against the north wall. Paint all surfaces that the sun will hit blue or dark red to maximize absorption. Rocks can also be used to store heat. Rocks are more unwieldy to install because they are more dense, but store almost as much heat as the same volume of water. And, with rocks, you don't have to worry about emptying containers to prevent freezing if the greenhouse won't be used in winter.

Step 3 – Circulate the air

Add a perforated pipe along the peak of the greenhouse and a small fan to draw the warmest air down and through the heat storage you've created. At night, keep the fan running to return that warmed air to the greenhouse. It is reasonably simple to install an old computer fan in the pipe to keep the air flowing

Step 4 – Add moveable insulation over the remaining glazing at night

To minimize heat loss in cold weather or at night, an insulated tarp or reflective poly bubble wrap can be rolled down at night to trap the heat from the day and minimize the need for supplemental heat in the greenhouse at night.

Wall Design

Ideally, the north wall and any area which is below the growing level should be made of solid walls with insulation. These can be built of dimensional lumber such as 2x4s, with earth bags, or out of concrete. Choose a material which is resistant to rotting in humid conditions.

Building with conventional dimensional lumber is familiar to many of us and is readily available at the local building supply store. Insulation, doors and windows are all designed to fit so the design challenges are minimal. These ready-made materials will cost more though so you may be interested in looking at some of the alternatives.

Tire walls, earth walls, straw bale walls, cob or post and beam made from locally sourced logs all require more labour from the builder, but if you are doing it yourself, can save quite bit of money. When building an earth bag wall, barbed wire is used between the layers to hold the layers together. Good instructions on two options for an earthbag greenhouse are available on this site.

Insulation

Unless very carefully sealed with poly vapour barrier and acoustical sealant, fibre glass insulation is not a good choice for greenhouse insulation because of the extremely humid conditions. Insulations which also act as a vapour barrier or which are completely unaffected by moisture such as Styrofoam or urethane (spray foam) would be better choices. Although the initial cost of these insulations are higher, some savings will be realized by eliminating the need for a separate vapour barrier and they will last much longer.

A layer of row cover fabric (spun bonded polypropylene) over the plants within a greenhouse will provide frost protection of 4 to 8 degrees depending on thickness. The thinnest fabrics allow in the most light through and can often be left in place for the entire season. Heavier fabrics can be used when there is severe danger of frosts. These row cover fabrics also reduce moisture loss and can decrease the time needed for germination.

The north wall, north roof, and part of the east and west faces of the greenhouse should be insulated. Moveable insulation will dramatically improve the efficiency of the greenhouse. Moveable insulation could consist of insulated tarps which are rolled down over the glazed faces on cold night or sheets of solid insulation or air or argon filled pillows that are fitted into the glazing recesses on the inside.

Kat and Ross Elliot built the first bubble insulated greenhouse in Canada. Yukon resident, Andy Lera, visited in 2006 and produced a report showing the payback on the added cost of the insulation in terms of reduced fuel use.

In 2006 and 2007, researchers at St Francois Xavier tested the effectiveness of translucent insulation coverings which would stay in place day and night through the winter. To prevent mechanical failure, these coverings had no moving parts. Three different insulation systems were tested. Poly-nylon tubes filled with argon, commercially available rolls of plastic bubble pack and a third option was two layers of poly inflated with air.

Glazing

Certainly costs can be reduced by using old (free) window glass that you already have around. These pieces would be best used in locations where having a view might be important to you. For overhead installations though, there are many better options than glass. Glass is extremely heavy and so requires substantial support if used overhead. Glass is also prone to breakage.

Polyethylene film (poly) is commonly used as glazing because of its extremely low cost and ready availability. The lifespan of poly is very short though—only about 3 years for building poly and about 5 years for special UV resistant greenhouse poly. If you consider the cost of replacement poly, this option may be more expensive than it first appears. Using a double layer and inflating the space between them with a fan can increase the insulation capacity and will also allow the poly to better withstand wind damage since inflating provides tension to prevent flapping in the wind.

Woven poly provides little in terms of insulation value, but holds up very well as greenhouse glazing. Companies such as Northern Greenhouse Sales in Altona, Manitoba can also provide additional materials to ensure proper installation to maximize the lifespan. This type of woven poly will last for 10 years or more when in constant exposure to the sun. If it is removed and reinstalled for each growing season, it will last even longer.

Polycarbonate panels surprisingly let in more light than glass and have better insulative properties as well. Although one of the more expensive options, polycarbonate is very tough and is an almost permanent glazing solution. Polycarbonate comes in flat sheets and does not bend around a curve so needs to be installed on flat faces of a greenhouse. Polycarbonate sheets can be installed by gluing with epoxy, sealing with silicone, or fastening in place with straps and screws. It is available in several thicknesses. More layers will provide more insulation, but reduced transmissivity. The best recommendation is to use a thin walled clear polycarbonate in combination with a removable shutter to provide added insulation at night or on cloudy days.

This permaculture design site provides a chart listing the R-values for various types of glazing.

Bed Design

Using beds in your greenhouse will make it easier to prevent compaction in the growing areas. Between crops, top dress the beds with an inch of two of compost and work it into the top 6 inches of the soil.

The depth of soil needed in your garden beds will depend on the type of plant you intend to grow. Plants such as salad greens, broccoli, and cabbage are shallow rooted and need a soil depth of only 12 to 18 inches. Deeper rooted plants need closer to 2 ft of soil to do well. These are plants such as eggplant, cucumber, squash or beans. Others such as tomatoes, watermelon or pumpkin are happiest with almost 3 feet of soil. As well as considering the type of plants you intend to grow, you'll also need to consider the weight and cost of that much soil. A list of plants and the depth of soil they require can be found here.

To prevent back strain, a growing bed which is close to counter height will be easiest to work in. For lower beds, using a wide edge such as a 2x6 or 2x8 will provide a place to sit while working. A bed 40 inches in height will allow enough room below the bed for the placement of rocks for heat storage as well as at least 18 inches of soil. Since that much soil will weigh quite a bit—especially when wet, it will be necessary to brace the bed internally.

Soil

The soil in your greenhouse should be well drained, fertile and have good water holding capacity. Clay soils hold water well but plant roots need to breathe and soggy clay soils can make that difficult. Adding compost will help break up the clay particles and provide better aeration for the plants. Sandy soils have little water holding capacity but are easy for plant roots to move through. The water holding capacity of sandy soils can be improved by the addition of compost.

The mix you use will vary depending on the materials you have available, but keep in mind the needs of the plants for drainage, fertility and water holding capacity. A good mix for your greenhouse beds could consists of equal parts sandy soil, garden soil and compost. If your garden soil is particularly heavy (high in clay), you may also want to add in up to 20% peat moss, coffee chaff (the hulls left after roasting coffee), vermiculite or perlite.

Solar Gain/Heating

Passive solar heating relies on having your greenhouse designed to maximize the capture of solar energy and then having enough thermal mass to store that energy to be slowly released at night. At night, the vents and shutters used to remove excess heat during the day should be well sealed. This will prevent air leakage and reduce the opportunity for that moving air to take the heat we gained during the day out of the greenhouse.

The main concern that a greenhouse gardener will have with a passive solar greenhouse is to regulate heat absorption during the day. This will require an 'active' cooling system. It's great to get the structure up to temperature and absorbing as much heat as possible, but it's easy to overdo it, so

ventilation must be taken into consideration to keep temperatures at a point where they're friendly to plant growth and survival, while still maximizing energy gain through use of thermal mass.

Heat storage methods

Both water and rock can be used to store heat during the day and release it at night. Something as simple as filling gallon or 4L bottles with water and setting them in among your plants can help soak up some of the incoming heat during the day and release it at night when temperatures in the greenhouse fall. You can maximize the amount of heat absorbed by these bottles of water by adding red food colouring to the water or by painting the outside of the bottles dark red or blue.

Solar collection 'pillow' can be made with black plastic garbage bags. Place one plastic bag inside another and fill (or partially fill) with water. Tie firmly. Place this package inside another double layer of bags and tie again. These solar pillows can be tucked into any unused corner where the sun can shine on it.

Bob Sharp shares some excellent ideas for storing heat using water and a solar collector on the rear wall of the greenhouse or by using the rocks below the bed and a fan to draw heated air from the peak of the greenhouse through the rocks.

Sources of heating to extend the tail-end of seasons

Maximize the heat retention of your heat source by placing cans or tanks of water on or near the stove. One northern greenhouse uses a small pump to direct water warmed in a tank above a wood stove through hydronic heating pipes below the beds. In this way, the heat from a single fire lit in the evening is stored in the soil of the growing beds and provides enough residual heat to keep the greenhouse warm through the night.

Rocket mass heaters (the evolution of the rocket stove) are designed to produce a great deal of heat in a short burn. That heat can be stored in materials such as cob, rocks, water, or garden bed soil which can then slowly release it at night to maintain above freezing temperatures in the greenhouse. There are many sites for people interested in building their own rocket stove. Although this site describes how to build a rocket stove for supplemental home heating, the explanations are very clear with lots of photos. There are also some good links to variations/improvements in the comments section. If you are not interested in building one yourself, you can order a rocket stove ready-made from Zaugs.

Some northern greenhouse operators use the energy of a compost pile to heat their greenhouse. If you decide to do the same, be sure to isolate the air above the compost pile from the greenhouse plants especially when freshening the pile. Fresh compost with a lot of nitrogen will give off ammonia which some plants, like tomatoes, are very sensitive to. It might be better to build the compost pile near the greenhouse and bring the heat energy in through water pipes embedded in the pile or to enclose the compost in a box within the greenhouse so the air in the greenhouse is not affected. The warm box will also serve as a great location for starting seeds or growing microgreens.

The Curious Gardener explores gardening north of 60. In episode #10, Growing and Heating, she tours the greenhouse at Wheaton River Gardens which is heated by compost.

Compost piles produce an enormous amount of heat. This Farm Show magazine article describes a herb grower who heats her small herb growing greenhouse by pumping water through a compost pile outside and then running that warm water below the growing plants inside the greenhouse.

Students at the University of Vermont worked with Compost Power Network to heat a greenhouse for year round growing.

Ventilation

Designing the greenhouse to provide for summer shading will prevent overheating and minimize venting requirements. There are so many factors that will vary from one greenhouse to another that it is difficult to recommend the exact vent size for ideal ventilation. Generally, more smaller vents are better than one large one with the total venting area equal to about 1/6 the area of the south facing glazing. There should be at least one low vent and at least one high vent. Hot air will rise up and exit the upper vent(s) and draw fresh cooler air into the lower vents. Be sure to position vents to prevent cold air from flowing directly across the plants.

Some poly-hoop greenhouses, such as the one in Carmacks, have sides that roll up to provide ventilation in the summer. This leaflet produced by Agriculture Canada focuses on the ventilation requirements for commercial greenhouses.

Besides designing for summer shading, other methods of cooling such as evaporative cooling can also reduce the need for ventilation. Evaporative cooling can be provided by a moist pad with a fan positioned to blow over it, or by spraying a fine mist of water.

All the greenhouse operators I talked to had nothing but praise for automatic vent openers such as these from Lee Valley Tools. Be careful about how they are installed however. They perform better if installed so they lift sections up for venting and the weight of the cover closes the vent when the temperature drops. A large section of an open vent will catch a lot of wind so make smaller vents and position them so they open on the side away from prevailing winds.

Old furnace fans and their accompanying thermostatic controls can be very useful in providing automatic venting in a greenhouse. All that is necessary is to reverse the thermostat so that the fan turns on when the temperature rises and then shuts off when the temperature drops again. This system works best if you also install louvers to allow outside air to enter when the pressure inside the greenhouse drops.

And there is more to venting than just cooling. Adequate ventilation also helps ensure proper levels of humidity, air circulation and carbon dioxide and oxygen exchange. Molds, fungus and mildew thrive in high humidity conditions so keeping air flowing through your greenhouse and particularly at the soil level below the leaf canopy can help reduce these issues.
Good ventilation also ensures there is sufficient carbon dioxide for plant respiration and sufficient oxygen to keep roots healthy.

Innovative methods for passive ventilation

A natural or passive ventilation system is a system that relies on wind and thermal buoyancy for air movement rather than fans. As air is heated it has the natural tendency to rise. This physical property of air is referred to as thermal buoyancy. Gardeners can make use of this property by implementing a series of ridge (roof) and sidewall vents.

As the temperature rises within the greenhouse, the hot air rises and escapes through the ridge vents. This process creates a vacuum that draws cooler air into the greenhouse through the sidewall vents located closer to the ground. Wind can also play an important role in passive ventilation systems. As the wind passes over the ridge vents a similar vacuum effect draws air from the greenhouse out the ridge vents and fresh air into the greenhouse through the sidewall vents. A greenhouse positioned so the prevailing wind blows over the ridge vents will generally be more efficient in terms of natural ventilation.

Greenhouses can be designed with sides that roll up. With the sides down, plants get maximum protection from weather extremes. With the sides up, fresh air can blow through and insects have free access for pollination.

Crops selection for Northern Latitudes

When deciding what type of protected growing space you require, an important question to ask is what crops do you want to grow? You will probably want to focus your attention on those crops that perform well in crowded conditions, that don't need high light levels or those that we are unable to grow outdoors in the north.

In spring, plants that can handle a light frost can be started indoors and transplanted into the greenhouse as soon as the soil starts to warm. Watering with warm water, or covering with floating covers at night can help those plants thrive. Ideal candidates are lettuces which come in an amazing variety of leaf shapes and colours or mesclun mixes. The immature leaves of salad crops are much more cold tolerant than mature ones. You can be clipping salad greens from the greenhouse while there is still snow on the ground.

In the summer, a greenhouse is a great place to grow heat loving plants that can tolerate high humidity. Plants such as tomatoes and cucumbers are favourites for summer greenhouse production. Other crops like beans which are very sensitive to frost might be good candidates for summer space in your greenhouse.

In the fall, some of the hardier crops like leeks, cabbage, kale, or Asian greens can be moved indoors so you can continue to harvest fresh greens even when the outdoor garden is put to bed for the winter. Spinach is an excellent cold weather crop since it performs well even in low light levels.

Carefully harvesting whole leaves without stems rather than entire plants provides greater total yield per square foot of growing bed and better regrowth. In this way, you should get 3 or 4 harvests per plant.

Watering Regime

Ideal watering is 1″ per week. If the greenhouse gets particularly hot or if the water holding capacity of the soil is low, plants may need more watering than that. Be careful not to over water. The roots of plants may rot if the soil is constantly wet so it is better to water thoroughly and infrequently. This will cause the soil in the beds to dry from the top down which will encourage the plants roots to reach deeper into the soil. You'll know it's time to water when you poke your finger down into the soil and it feels dry.

Shallow trays of soil will dry out more quickly than deep beds so will need watering more often. When seeds are first sprouting, they need more constant moisture. One way to keep them from drying out is to lay a thin wet fabric or paper towel over the newly planted seedbed.

Water can also be used to moderate temperature. A fine mist of water will lower air temperatures as it evaporates. But too high humidity can be a challenge for growing plants. Mold, mildew and other fungal growth thrive in a humid environment. Trim leaves from the bottom of large plants to help increase the ability for air to move and ensure there is adequate ventilation.

Water close to the ground or use drip or trickle irrigation to prevent wet leaves and humid conditions which can lead to plant disease. Mulching over permeable water tubes can help the water disperse evenly and prevent evaporation.


Andrew McFarlane

Crop Selection and Revenue Generation Potential

When growing crops for sale, the most important consideration is what grows well and what people really want to eat. Although it's great to try out different squash in fancy shapes and brown heirloom tomatoes are truly delicious, the biggest sellers are familiar favourites. Bright orange carrots or tiny red and yellow tomatoes that are so sweet, everyone enjoys eating them like candy. Colourful mixed salad bags with lettuce, baby beet leaves and maybe a bit of arugula are a sure hit at the local farmers' market. Dress them up with a few edible flower petals and you have a truly gourmet product.

Plants grown for baby salad leaves provide for multiple harvests from each plant. This can maximize the revenue potential for the area.

Since space is at such a premium in a greenhouse, these small, fast-growing plants provide very good return during the cooler seasons.

Microgreens pack lots of taste in a tiny package. Everyone who tastes them is excited by the possibility offered by these delicious tidbits. Beyond sprouts, microgreens are harvested when the seed development has progressed to first or second leaves. Because they are snipped right at the stem level, their texture, appearance and flavour are much more like a salad green than a crunchy sprout. Growing microgreens is a way to bring in quick income since the turnaround time from seeding to harvest is only 2 to 3 weeks which is shorter than for any other crop. As well, the spent soil and roots are a great material to add to your compost pile.

Other Design Considerations

Moveable greenhouses

Eliot Coleman, an organic grower from Vermont, gets the equivalent of fourteen months of greenhouse use every 12 months. He accomplishing this by getting his winter harvested crop ready outside of the greenhouse two months ahead of the time it will need protection. He can then leave his warm season crop growing two months longer. When the warm season crop is finished, he slides the greenhouse on rails off the warm season crop and over the winter season crop. The added benefit of this system exposes the soil in the previously covered bed to the cleansing effects of the sun, wind and rain for several months.

The website shows a couple of different ways to accomplish a movable greenhouse. The greenhouse can either move along pipe rails or have wheels installed just in time for the move.

Hugel Culture (Hugelkultur)

A hugel bed or hugelkultur garden uses rotting wood below a mound of soil to provide nutrients and water holding capacity. Some choose to pile the wood on the surface, then add layers of leaves, compost and soil. The mound created provides several microclimates for plants and is sometimes high enough that the gardener doesn't even have to bend over to tend the plants or harvest.

Others start with a trench and lay the layers in the trench starting with branches and even logs.

Lots of ideas for different types of hugel garden beds and one for a hugelkultur bed built in a sun-catching swale.

Kate Fries

Lasagna garden beds

An interesting way to build beds of soil in any location—even a city lawn—are lasagna beds. Start with a layer of animal manure, and then cover the manure with cardboard. Over the cardboard, place a layer straw and then soil. The cardboard, manure and straw will compost during the season providing added heat and nutrients for the growing plants.

Cost-Benefit Analysis

Option A – An indoor plant stand

If you don't have a backyard, you can still grow some of your own fresh greens. This plant stand uses dimensional lumber and off-the-shelf fluorescent fixtures. This is a great option for growing baby salad greens or microgreens. Growing your own microgreens gives you access to fresh living greens all year long with a minimal investment of time, money or even previous experience. They require such a small amount of space that they are an ideal crop to grow inside or in a small protected space on a balcony or deck.

Click here for plans and instructions.

Option B – Solar growing bed

Bob Sharp has designed a solar covered garden bed. A full description can be found here. In this system, the plants grow in a protected environment and the cost is reduced since the structure doesn't have to be large enough to accommodate the gardener as well.

Permanent end hoops and a removable cover create a mini greenhouse to extend the growing season by at least a couple of weeks on either side. Early salad crops and radishes can be replaced by warm loving plants like squash or beans and protected as needed during the season.

Click here for plans and instructions.

Option C – Glazed roof 3-season greenhouse

With features from Lendrum Ross Farm, Lee Mennell and Wheaton River Gardens, the glazed roof 3-season greenhouse design has insulated wall and a roof glazed with Suntuf® Polycarbonate. An insulated tarp can be rolled over the glazing at night or when temperatures drop.

Plans include concrete footings and an 8′ x 24′ washing/preparation area. The footings could be replaced by PWF footing on a gravel pad if soil conditions permit. Mass storage is provided by rocks below the growing beds with air pulled from the ridge and vented back up in the centre of the south bed as well as by a masonry rock wall. If water in barrels is used instead of the masonry rock wall, the water will need to be drained at the end of the growing season.

With the addition of a second door on the other end, the washing/preparation area could be split into two 8'x12' areas—one for washing/preparation, the other keeping small livestock such as rabbits or chickens. This would provide a ready source for animal manure for the compost heater. If animal manures for the compost heater are not available, supplemental heating could be provided by a rocket mass stove, or other source.

Click here for plans and instructions.

Option D – Fully insulated 4-season greenhouse

This greenhouse is designed based on the 4-Season Greenhouse built by the Yukon Research Centre and Yukon College Skills for Employment students. Variations include a foundation (rather than skids) and a vertical wall of glazing as recommended by researchers in Alaska for northern greenhouse design.

To operate effectively through the winter, growing plants would require supplemental lighting to a minimum of 10 hours/day. It is recommended that low wattage LED lights be used for this purpose.

Supplemental heat source such as an electric baseboard heater, a rocket mass stove, or other will be needed to keep temperatures above freezing during the coldest months.

Click here for plans and instructions.

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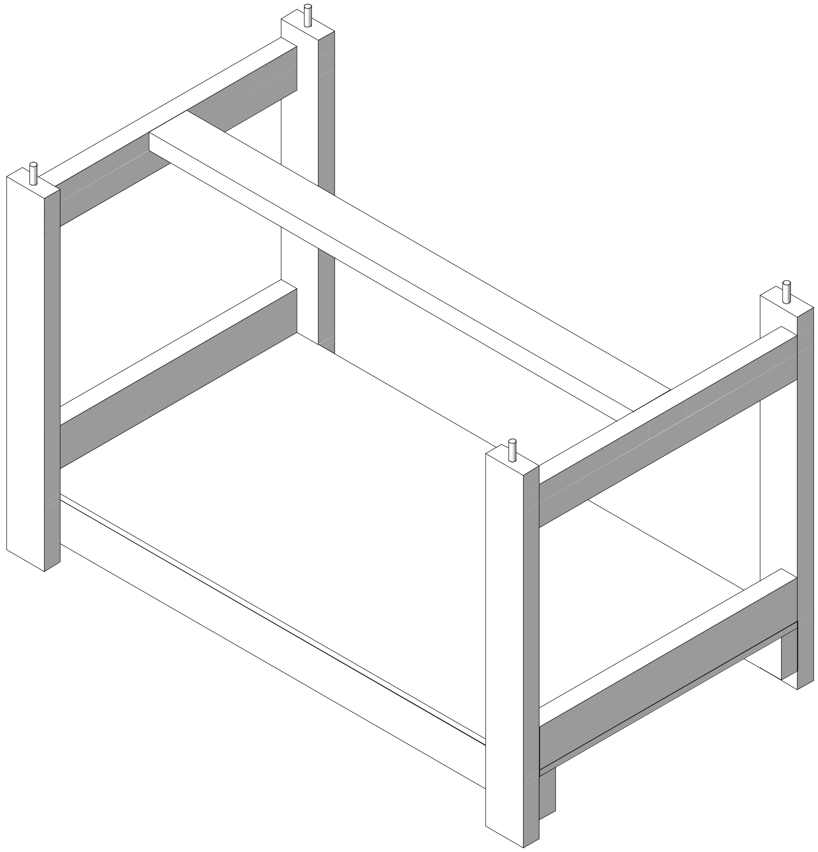
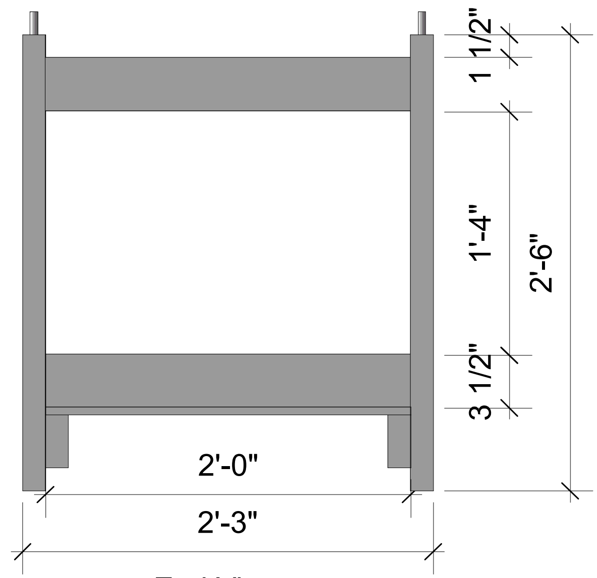




End View

Stacking Plant Stand

Top View

Front View

Materials QUOTE for 2′ x 4′ plant stand
Indoor Growing Stand

This is the materials list for a single stand. Three stands stacked on top of each other will fit in a standard room with 8′ ceilings.

Materials List (One stand):

Material Description & length	Quantity	Purpose
SPF 2″x4″ – 48″	2	Shelf supports
SPF 2″x4″ – 45″	1	Top support
SPF 2″x4″ – 30″	4	Upright posts
SPF 2″x4″ – 24″	4	End support cross pieces
3/8″ plywood – 24″ x 48″	1	Shelf
3/8″ dowel – 1′1/2″	4	Pegs to join multiple units
3/8″ chain – 30″	2	light suspension chains
Hooks	2	Light suspension
Screws	50	
48″ fluorescent or LED fixture	1	Fixture with bulbs – full spectrum preferred

Instructions:

Cut all 2x4 lumber to length. Sand and stain before assembly.

Pre-drill and fasten all joints with screws.

Use scrap pieces of 2x4 as spacers when assembling the ends.

Make two matching ends using two 30″ uprights and one 24″ cross piece for each. Assemble with only the top cross piece installed. The bottom crosspiece will be installed after the plywood shelf is installed.

Lay them flat and use a square to make sure the pieces meet at 90°.

When the ends are assembled, drill top of posts to accommodate dowel.

Drill bottom of posts.

Glue dowel pegs inserted ¾″ into the top of posts.

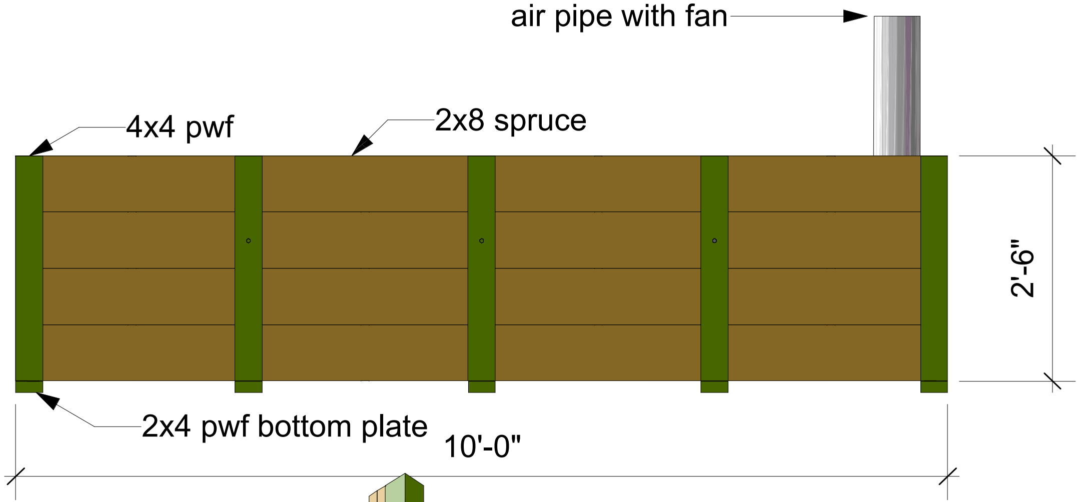
Stand up the sides and attach the 48″ shelf supports.

Centre the 45″ top support between the uprights. Pre-drill and screw together with edge flush with top of support.

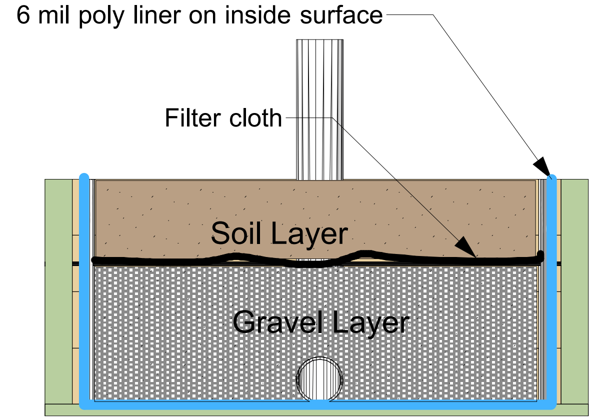
Attach one end of each piece of chain to each end of the top support with a screw.

Position a hook at each end so that the chain can loop through the hangers on the light fixture and then hang from hook.

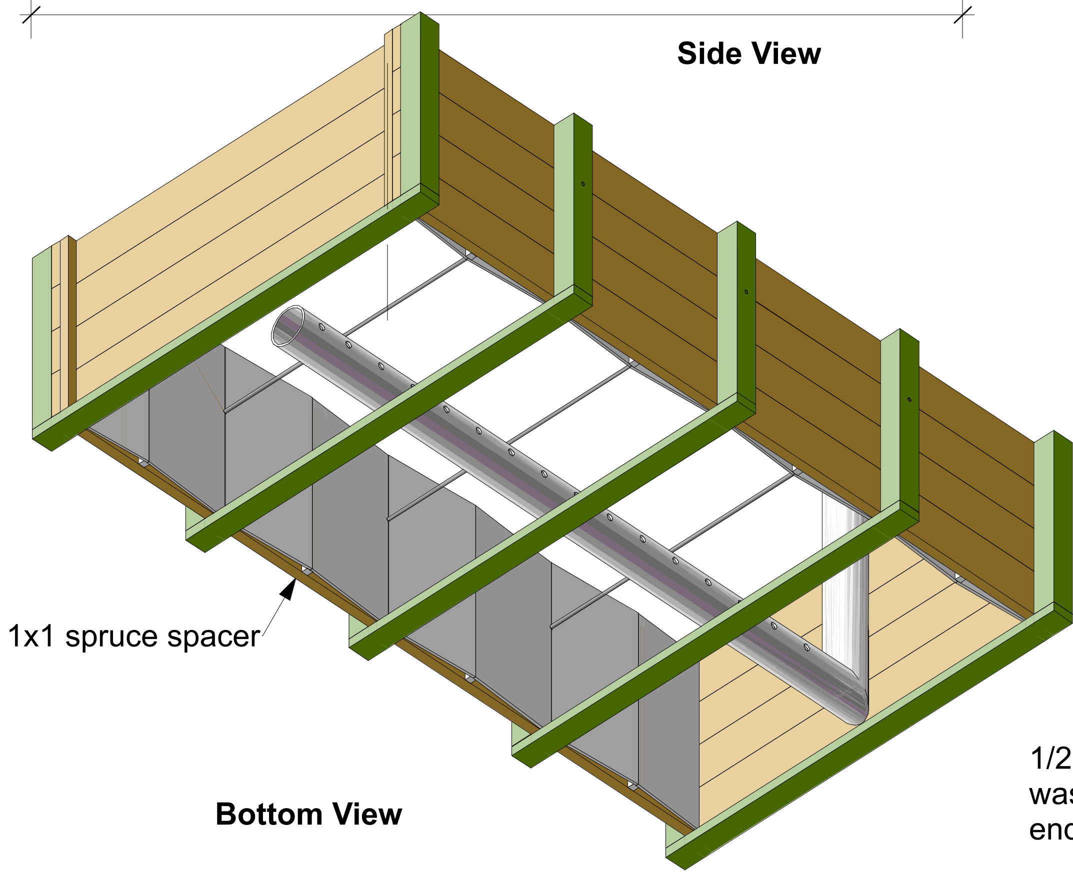
Slide the shelf into place. Install the bottom cross pieces.



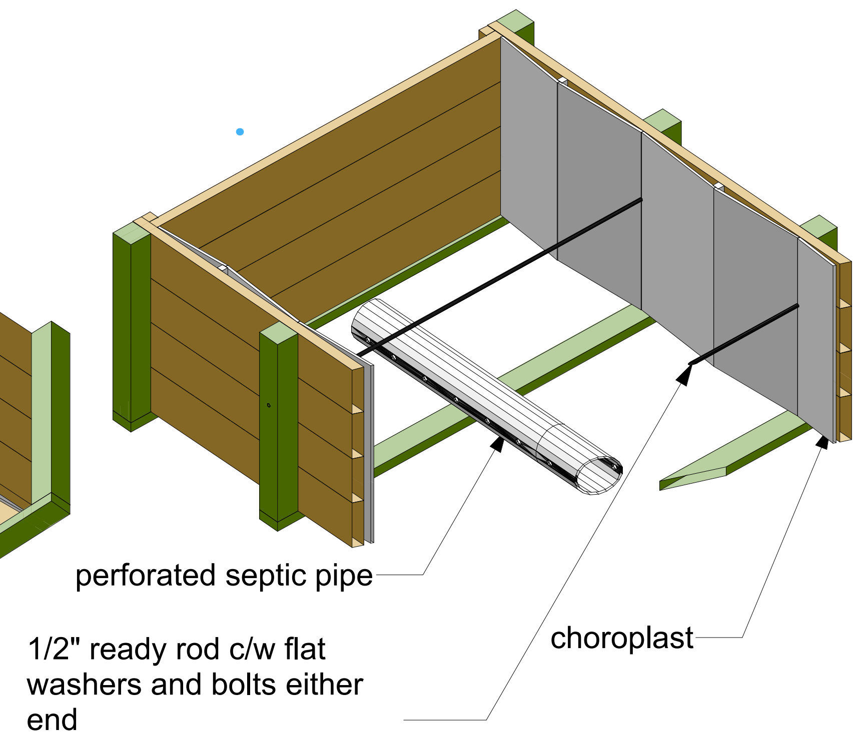
Side View



Section through planter box

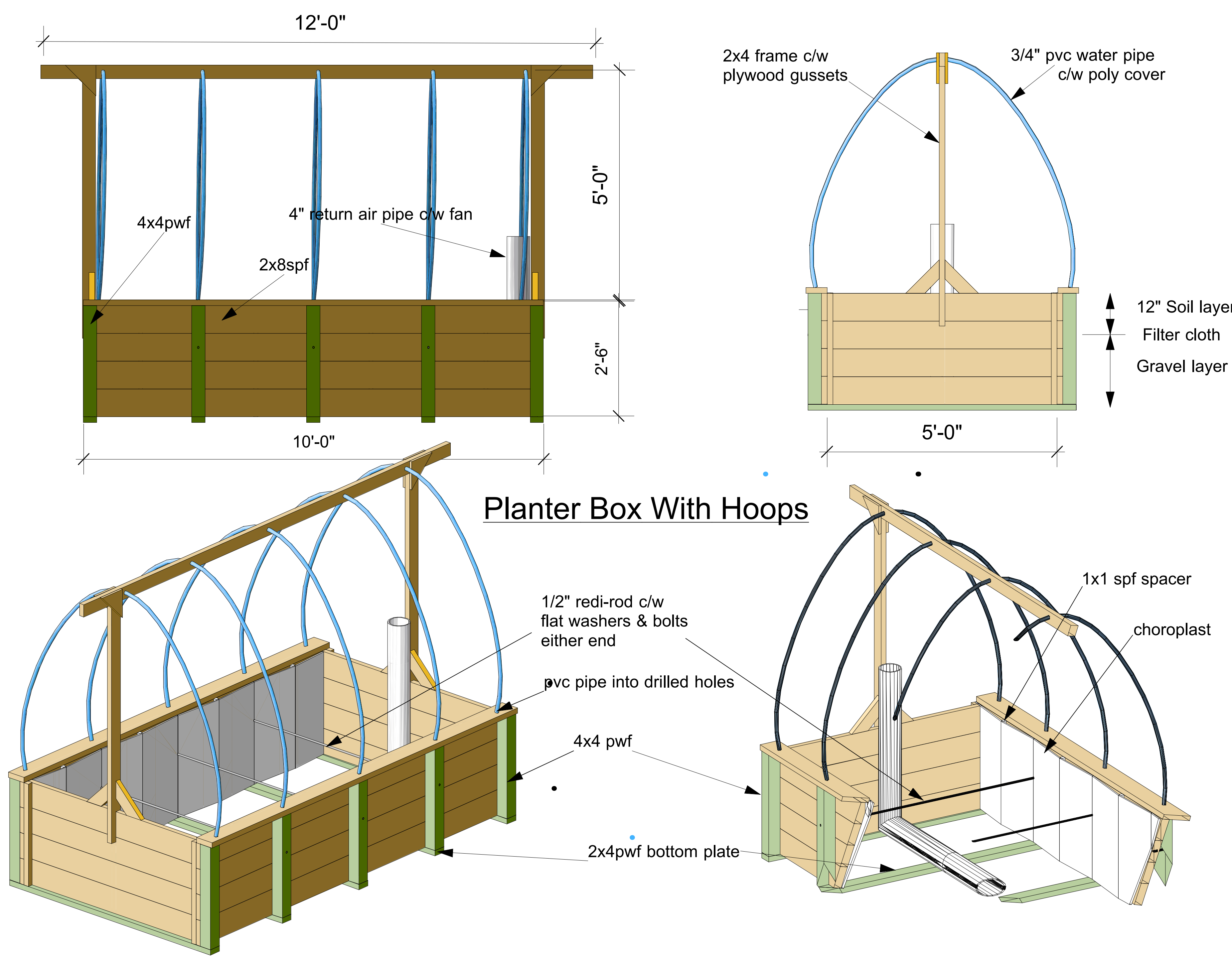


Bottom View



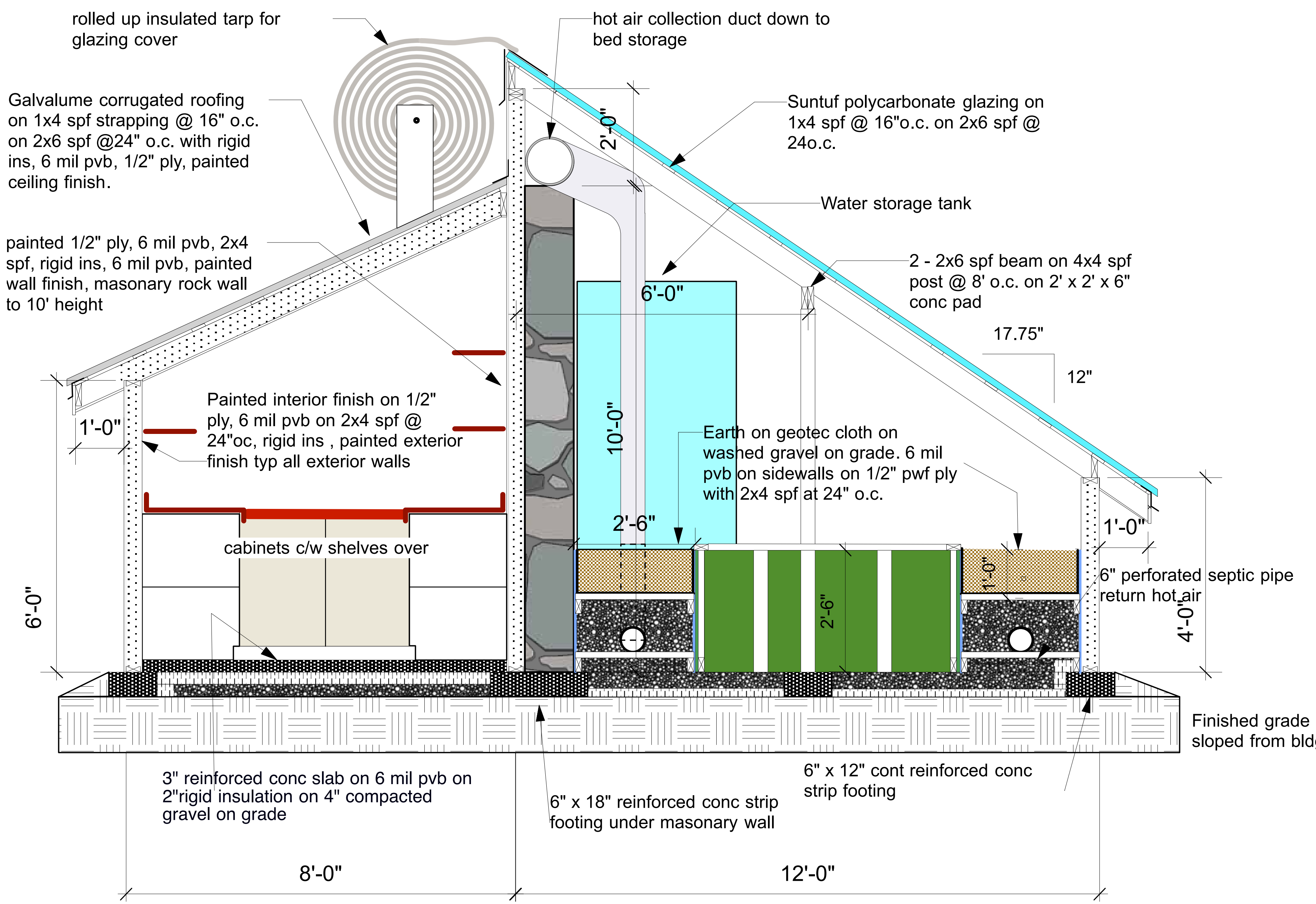
Section View

Planter Box With Hoops

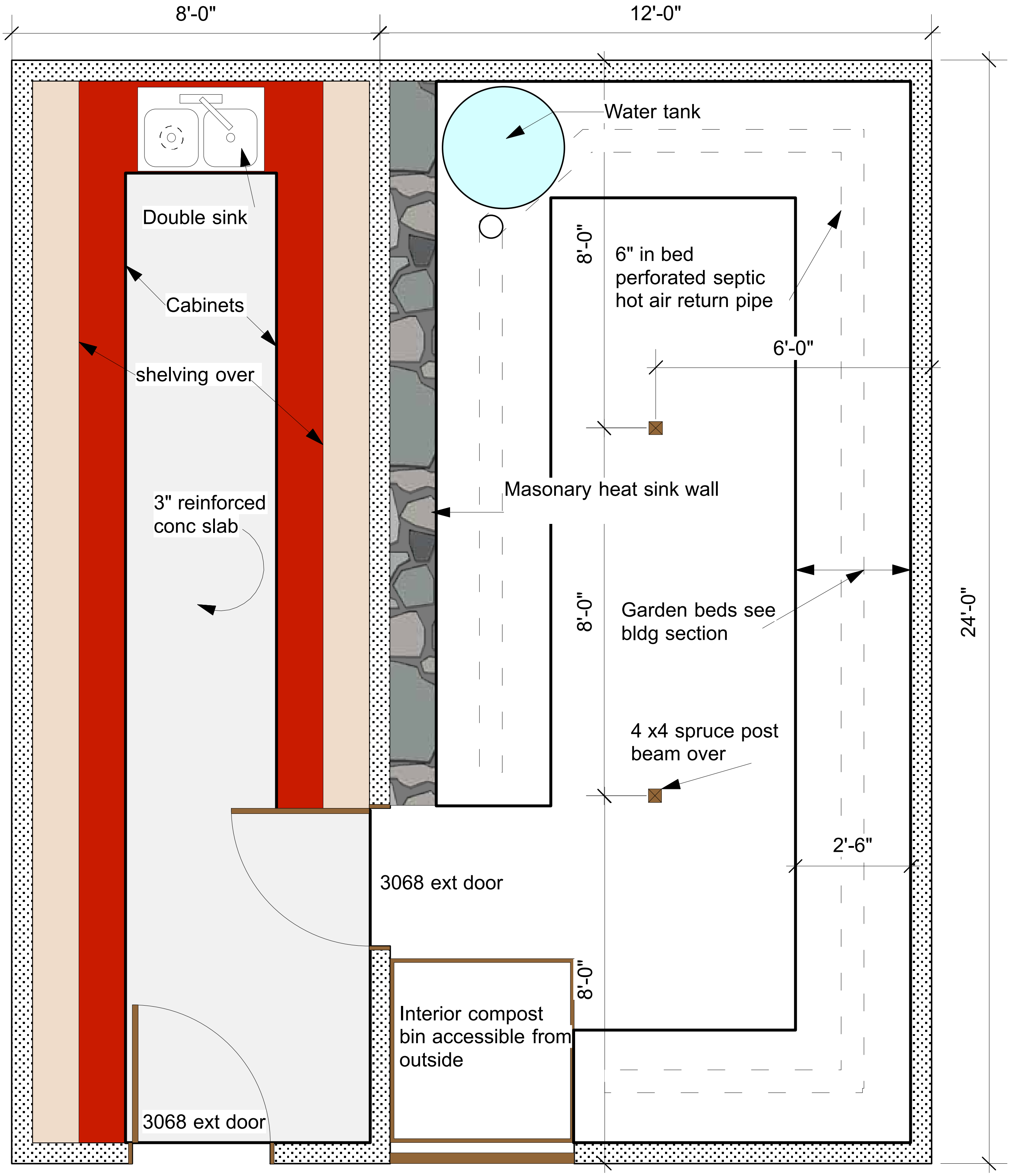


Materials QUOTE for 4′ x 10′ Garden Box
Covered Growing Bed

Material Description	Intended use	$/ unit	# units	Total $
Bed Frame				
PWF 4″x4″ x 10′	Side posts		5	
PWF 2″x4″ x 6′	Bottom support		5	
SPF 1″x1″ x 2′-6″	Spacers		8	
SPF 2″x8″ x 10′	Side wall		8	
SPF 2″x8″ x 10′	End wall		4	
SPF 2″x2″ x 2′-6″	End nailers		4	
SPF 2″x6″ x 10′	Top plates		2	
Heat Storage				
Perforated septic pipe – 4″ od	Air flow below the cobble		10′	
Solid septic pipe – 4″ od	Air flow from surface		6′	
Septic pipe 90° elbow – 4″ od			1	
Bed Support and Lining				
Geotech filter cloth – 5′ x 10′	Layer between cobble and soil		50 sq ft	
6 mil poly – 2′-6″ x 30′	Inside walls of box		75 sq ft	
Choroplast – 2′-6″ x 20′	Air flow up sides of box		50 sq ft	
½″ Redi-rod – 6′ pieces			3	
½″ Flat washers			6	
½″ Lock nuts			6	
Bed Cover				
Woven poly greenhouse fabric	12′ x 17′		204 sq ft	
¾″ pvc pipe – 6′ long			10	
½″ plywood	Gussets		2 sq ft	
SPF 2″x4″ x 10′	Cover support		1	
SPF 2″x4″ x 12′	Cover support		1	
SPF 2″x4″ x 8′	Diagonal braces		1	
Nails				
Screws for PVC pipe				
Glue for PVC pipe				
Staples for poly and chloroplast				
Exterior paint/stain			1 gal	
Cobble (fist sized)			2.7 cu yd	
Soil (mix of sand, compost, soil)			2 cu yd	



rolled up insulated tarp for glazing cover
Galvalume corrugated roofing on 1x4 spf strapping @ 16" o.c. on 2x6 spf @24" o.c. with rigid ins, 6 mil pvb, 1/2" ply, painted ceiling finish.
painted 1/2" ply, 6 mil pvb, 2x4 spf, rigid ins, 6 mil pvb, painted wall finish, masonary rock wall to 10' height
hot air collection duct down to bed storage
Suntuf polycarbonate glazing on 1x4 spf @ 16"o.c. on 2x6 spf @ 24o.c.
Water storage tank
2 - 2x6 spf beam on 4x4 spf post @ 8' o.c. on 2' x 2' x 6" conc pad
17.75"
12"
2'-0"
6'-0"
10'-0"
1'-0"
Painted interior finish on 1/2" ply, 6 mil pvb on 2x4 spf @ 24"oc, rigid ins , painted exterior finish typ all exterior walls
cabinets c/w shelves over
Earth on geotec cloth on washed gravel on grade. 6 mil pvb on sidewalls on 1/2" pwf ply with 2x4 spf at 24" o.c.
2'-6"
2'-6"
1'-0"
1'-0"
6" perforated septic pipe return hot air
4'-0"
6'-0"
Finished grade sloped from bld
3" reinforced conc slab on 6 mil pvb on 2"rigid insulation on 4" compacted gravel on grade
6" x 18" reinforced conc strip footing under masonary wall
6" x 12" cont reinforced conc strip footing
8'-0"
12'-0"

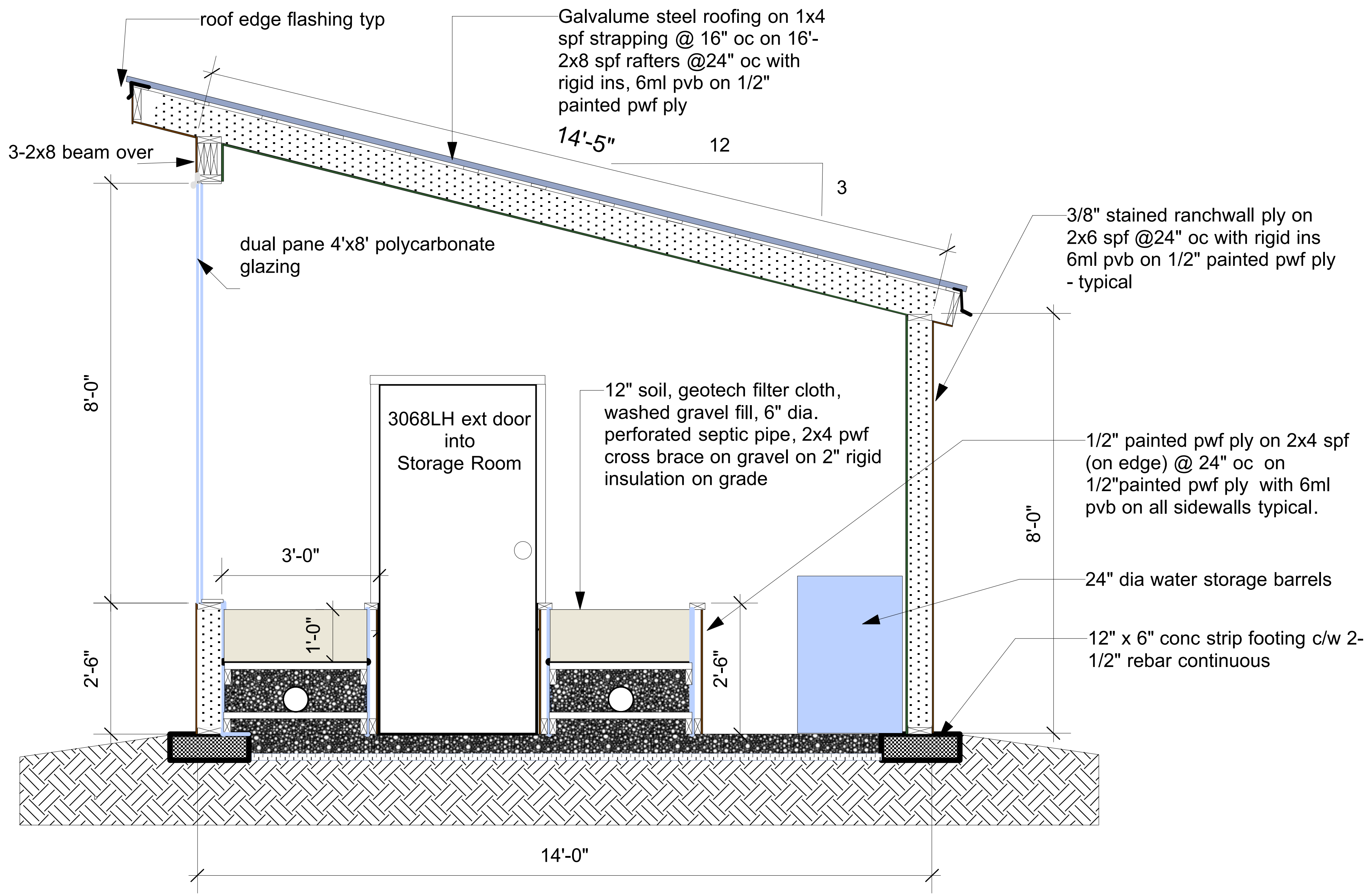


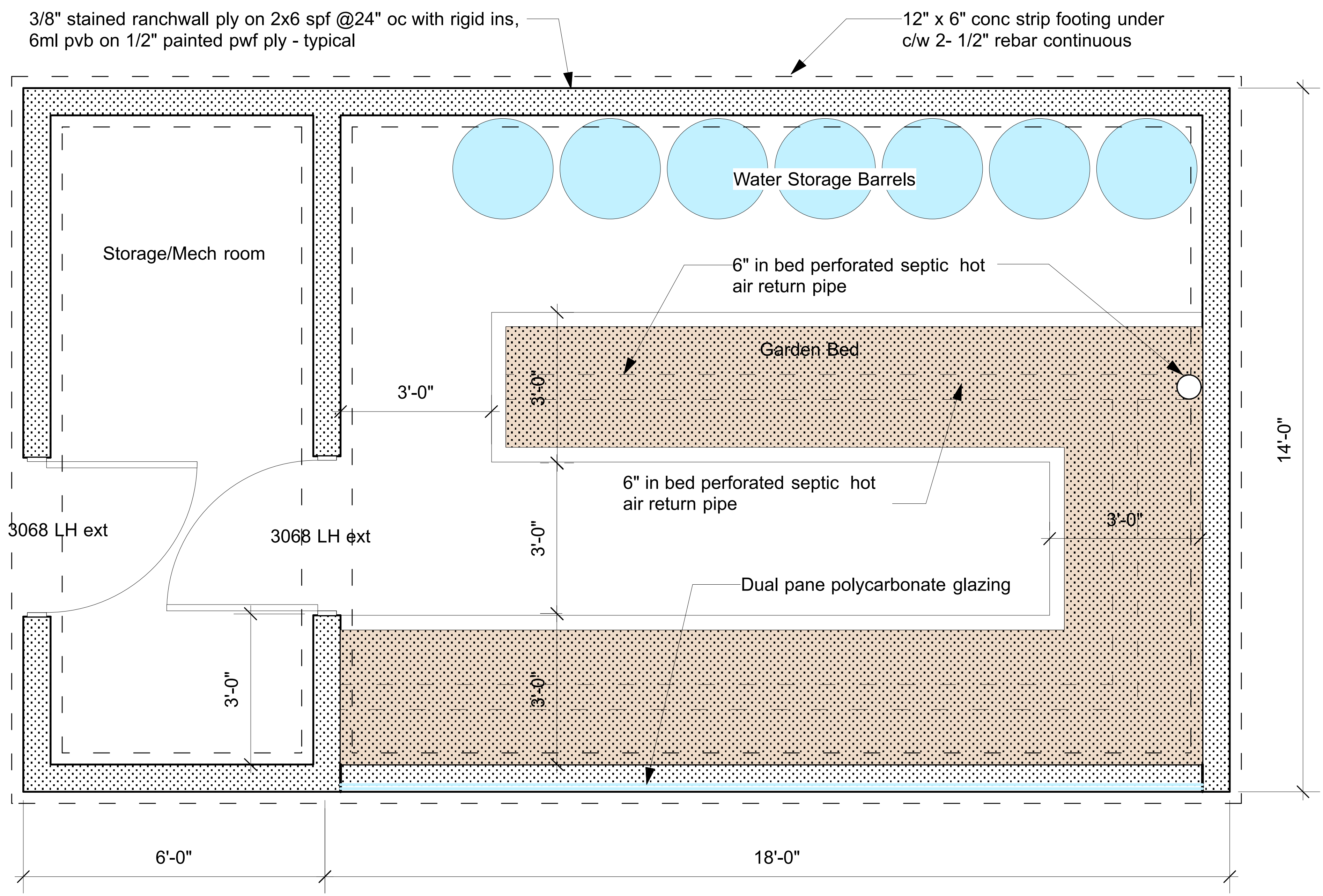
8'-0"
12'-0"
Water tank
Double sink
6" in bed
perforated septic
hot air return pipe
Cabinets
6'-0"
shelving over
8'-0"
Masonary heat sink wall
3" reinforced
conc slab
Garden beds see
bldg section
8'-0"
24'-0"
4 x4 spruce post
beam over
2'-6"
3068 ext door
8'-0"
Interior compost
bin accessible from
outside
3068 ext door

Materials QUOTE for 20′ x 24′ with Suntuf roof
3-Season Greenhouse

Material Description	Intended use	$/ unit	# units	Total $
32′ x 36′ filled and level	Site prep			
Forms				
PWF 2″x6″ x 12′	Formwork for footings		18	
SPF 2″x2″ x 2′	Stakes		62	
½″ or 12 mm rebar	Concrete reinforcing		247′	
Tie wire	Spool		1	
Wall Framing				
PWF 2″x4″ x 12′	Bottom plates		10	
SPF 2″x4″ x 12′	Wall studs		26	
SPF 2″x4″ x 10′	Walls		10	
SPF 2″x4″ x 8′	Walls		6	
SPF 2″x4″ x 12′	Top plates		12	
Support Beam				
SPF 2″x6″ x 16′			2	
SPF 2″x6″ x 8′			2	
SPF 4″x4″ x 8′	Posts		2	
Roof Framing				
SPF 2″x6″ x 16′	Rafters		18	
SPF 2″x6″ x 10′	End plates		18	
SPF 2″x6″ x 12′	Ladders		5	
SPF 1″x4″ x 10′	Strapping		42	
SPF 1″′x4″ x 12′	Strapping		11	
Roof				
Suntuf Polycarbonate glazing	With fasteners		26′x16′	
Galvalume metal roofing	With fasteners		26′ x 10′	
Insulation				
Rigid insulation for 2x4 walls			848 sq ft	
Rigid insulation for 2x6 ceiling			216 sq ft	
Rigid insulation under floor			391 sq ft	
Masonry Wall	Rock and mortar		6 cu yd	
Siding, pnl cedar chalet	Exterior wall sheathing		21	
SPF GIS 3/8″ plywood	Interior walls and ceiling		45	
6 mil poly	Vapour barrier		1584 sq ft	
3068 LH exterior door with window	Outside door		1	
3068 RH exterior door with window	Greenhouse – workroom		1	
Insulated tarp	To cover glazing		26′ x 20′	
Roll up mechanism	As built			
Washed gravel	Floor base		4.7 cu yd	
Beds				
Perforated septic pipe – 6″ od	Conduct warm air below beds		50′	
6″ od 90° septic pipe elbow			4	
6″ od end caps			2	
6″ od T connector			1	
6″ od solid septic pipe			12′	

PWF 2″x4″ x 10′	In bed supports		7	
PWF 2″x4″ x 10′	Bottom plate		5	
SPF 2″x4″ x 10′	Top plate		5	
SPF 2″x4″ x 2′-6″	Uprights		30	
6 mil poly	Lining on bed walls		262 sq ft	
PWF ½″ plywood	Lining bed walls		9	
SPF G1S 3/8″ plywood	Outside of bed walls		4	
Geotech filter cloth	Between cobble and soil		51′ x 3′	
Cobble (fist sized rock)	Heat storage below beds		7 cu yd	
Soil (garden soil, compost, sand)	Soil for growing beds		5 cu yd	
Compost Bin heater				
PWF ¾″ plywood			2	
Plastic liner with access to outside	As built			
Cabinets				
36″ high base cabinets			38′	
36″ high corner caminets			2	
Shelving				
1′ deep shelving and brackets			114′	
Workroom concrete slab	With rebar reinforcing		167 sq ft	
Add 10% tool replacement and repair				
Add 5% non-reusable	Screws, nails, glue, etc			
Exterior paint (1 gal cans)			2	
Interior stain (1 gal cans)	White		4	
Paintable silicone caulking	Interior			
Mono Caulking	Exterior			
½″ anchor bolts	c/w masonry drill bit		28	
Roof flashing	Custom bend		104′	
Double sink and plumbing	Workroom – contractor			
200 gal water storage tank	With Plumbing connections			
Electrical (by certified electrician)	**Could include:**			
4′ light fixtures in workroom			2	
Electrical panel	For grid and gen set			
Wall sockets	Workroom & greenhouse			
Exterior door light				
Ceiling outlets @ 4′ oc over beds	For potential grow lights			
Grow lights	On timer (LED or fluorescent)			
2000 – 4000 Watt	Electric heater			
Ceiling light fixture in greenhouse	Switchable			
Return air fan	On rheostat			


roof edge flashing typ
Galvalume steel roofing on 1x4 spf strapping @ 16" oc on 16'-2x8 spf rafters @24" oc with rigid ins, 6ml pvb on 1/2" painted pwf ply
14'-5"
12
3
3-2x8 beam over
dual pane 4'x8' polycarbonate glazing
3/8" stained ranchwall ply on 2x6 spf @24" oc with rigid ins 6ml pvb on 1/2" painted pwf ply - typical
8'-0"
3068LH ext door into Storage Room
12" soil, geotech filter cloth, washed gravel fill, 6" dia. perforated septic pipe, 2x4 pwf cross brace on gravel on 2" rigid insulation on grade
1/2" painted pwf ply on 2x4 spf (on edge) @ 24" oc on 1/2"painted pwf ply with 6ml pvb on all sidewalls typical.
3'-0"
1'-0"
2'-6"
2'-6"
8'-0"
24" dia water storage barrels
12" x 6" conc strip footing c/w 2-1/2" rebar continuous
14'-0"



Fully Insulated 4-Season Greenhouse Plans: 2/4

Materials QUOTE for 14′ x 24′ with South Glazing
4-Season Greenhouse

Add 10% of budget for tool replacement/repair. Add 5% for non-reusables – screws, nails, bits, blades

Material Description	Intended use	$/ unit	# units	Total $
Forms				
PWF 2″x6″ x 12′	Skids (total of 162′)		14	
SPF 2″x2 x 2′ ″	Stakes		60	
Footings				
Concrete	1.6 cubic yards or 1.23 m^3		1.6	
Rebar – ½″ or 12 mm	Concrete reinforcing (190′)		190′	
Tie wire	1 spool		1	
Wall Framing				
Sill gasket – 6″ wide	Total 87′		87′	
PWF 2″x6″ x 12′	Bottom plate		8	
SPF 2″x6″ x 12′	Top plate		8	
SPF 2″x6″ x 10′	Studs		29	
SPF 2″x6″ x 12′	Studs		20	
SPF 2″x6″ x 8′	Studs & beam support		17	
SPF 2″x8″ x 8′	Beam		4	
SPF 2″x8″ x 10′	Beam		4	
Roof Framing				
SPF 2″x8″ x 16′	rafters		14	
SPF 2″x8″ x 12′	End plates		4	
SPF 2″x8″ x 12′	Ladders		2	
SPF 1″x4″ x 12′	Roof strapping		24	
Roofing				
Galvalume metal roofing	16′ 6″ long x 26′ coverage		429 sq ft	
Interior Sheathing				
SPF GIS 3/8″ plywood	Walls and ceiling		40	
Exterior Sheathing				
Siding, pnl cedar chalet	Outside wall finish & soffits		21	
Insulation & Vapour Barrier				
6 mil polyethelyne	Vapour barrier (square feet)		1160 sq ft	
R20 rigid foam insulation	Wall insulation (square feet)		812 sq ft	
R28 rigid foam insulation	Ceiling insulation (square feet)		348 sq ft	
R12 rigid foam insulation	Floor insulation (square feet)		215 sq ft	
Dual pane polycarbonate 4′x8′ sheets	South wall glazing		4	
3068 LH exterior prehung door	With window		2	
Washed gravel	Floor (cubic yards)		2.6 cu yd	
24″ diameter plastic barrels	Water storage barrels		8	
Planter Box Frame				
PWF 2″x4″ x 12′	Support on ground and mid		25	
PWF ½″ plywood	Inside lining		10	
SPF 3/8″ plywood	Outside of boxes		6	
PWF 2″x4″ x 12′	Frame – bottom plates		4	
SPF 2″x4″ x 12′	Frame – top plates		4	
SPF 2″x4″ x 12′	Frame - studs		6	
Inside Planter Boxes				

Cobble sized rock	Heat storage below beds		6 cu yd	
Soil mix: 1 sand: 1 compost: 1 soil	Soil for growing beds		4 cu yd	
6 mil poly vapour barrier	To protect bed walls		195 sq ft	
Geotech filter cloth	Between cobble and soil		108 sq ft	
6" Return Air				
Perforated septic field pipe – 6" od	Air channel into cobble		37.5'	
End caps – 6" od			2	
90° elbows – 6" od			3	
T connectors – 6" od			1	
Solid plumbing pipe – 6" od	Riser to ceiling		12'	
Exterior paint – gallon cans			2	
Interior stain – gallon cans	White		4	
Caulking – paintable silicone	Interior			
Caulking – mono brand	Exterior			
Spray foam insulation	Door and window frames			
Anchor bolts	Drilled in		22	
Roof flashing	Custom bends		52'	
Door and window flashing	Common		21'	
Hurricane straps			28	
PL400 glue				
Mounting hardware for polycarbonate				
Electrical	**Done by Contractor- surface mounting conduit**			
Switched light fixture	outside			
Switched Light fixture	Mechanical room			
Electrical space heater	2000 to 4000 watts with thermostat			
2 outlets	Mechanical room			
1 ceiling mounted outlet every 4' of garden bed				
Auto-timers for grow lights				
Switched light fixture	Greenhouse room			
4' grow lights				
Interior panel	Suitable for grid/gen set backup			
Return air fan	With rheostat			