9 Steps to Designing an Energy-Efficient, High-Yield, AQUAPONICS GREENHOUSE V1.0

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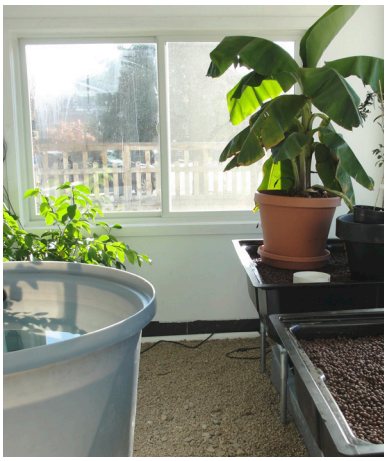


ABOUT CERES

At Ceres, we design and build greenhouses that save energy, water and money. Ceres Greenhouse Solutions started with the idea of applying energy-efficient building design to greenhouses (notoriously inefficient structures). The result is a 'greener greenhouse' -- one that operates independently, with less fossil fuel energy and less hassle. In addition, our greenhouses can be built for any wind / snow load, making them incredibly durable and long-lasting. Because they are energy-efficient, durable and customizable, we've found our greenhouses to be a natural fit with aquaponics growers. This has led us to continue to refine and develop our design for aquaponics, and, as of now, share what we've learned along the way.

ABOUT THIS GUIDE

This guide is intended to provide a framework for you to design an abundant, profoundly-productive, cost-effective aquaponics operation. And, to help you avoid some of the pitfalls along the way. Since our specialty is energy-efficient greenhouses, we spend a lot of time discussing what greenhouse growers don't often think about before they begin: saving energy. While we are located in the Rocky Mountains, the tips below can be applied to greenhouses in any climate, particularly those with harsh winters. Of course, they will need to be tailored: Growers in Florida will not need as much insulation as growers in Maine, for example. We've also aimed to provide advice for operations of all sizes, from residential to commercial. Thus, this guide is intended to provide general overview for planning your aquaponics greenhouse, which you will have to flesh out for your own application. We are always available if you need assistance.

JOIN THE CONVERSATION:

Help us, and your fellow aquaponic growers, get better by letting us know what you think. Was this document helpful? What else would you like to know? What didn't pertain to you? Email us your feedback at info@ceresgs.com

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1 Sketch out your floor plan

Questions to ask: How do I want to grow? How much space do I need?

Start by establishing what you want from your aquaponics greenhouse -- how much space you need and what type of system is best for you. If starting from scratch with a new greenhouse, you can design around your aquaponics system and create an initial floor plan from there. Decide how many beds and fish tanks you will need room for. Keep in mind to make space for potting / work tables, a sitting / teaching area, a hammock... Greenhouses can be for more than just plants! Some greenhouses (like CERES Aquaponics models) already have pre-existing designs and plans for aquaponics systems. If buying a kit greenhouse or working with an existing greenhouse, then you'll have to plan your system around that. When designing your floor plan,

DO

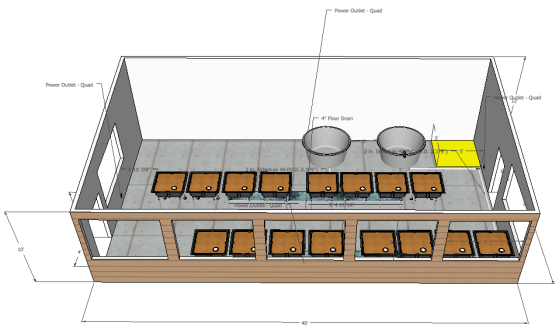
place beds where there will be direct light, like in front of South facing windows.

Use the corners. Most fish tanks are round tanks which makes them inherently awkward in a square greenhouse. You can use oval fish tanks. To best maximize space, think about putting the fish tanks in the corners.

DON'T

place fish tanks fully in direct light if possible. The tanks accumulate too much heat for fish. While it's always possible to heat the fish tanks if needed, it's much more difficult to cool them. You especially want to keep the surface out of direct light if possible – sunlight can cause algae growths on warm water. If light does hit the tank, you may want to consider putting a covering over the top. For this reason, in solar greenhouse designs (those with an insulated North wall and light predominantly coming in from glazing on the South) tanks on the North wall, such as the NW or NE corner, is generally a good location.

Above: Think about multiple uses of a greenhouse, whether relaxing, harvesting, or teaching.



Right: Example of a well-designed aquaponics greenhouse with beds along the South wall, and fish tanks and sump tanks along the North wall.

Left: Beds along a South wall will be more productive; tanks along an insulated North wall will keep water temps more stable. Note how the North East wall (where the water heater and electrical equipment are located) is a standard insulated wall in this 23' x 40' greenhouse. Water heaters need to stay warm; they don't need light!

The roof is also partially insulated to keep direct light off the fish tanks.

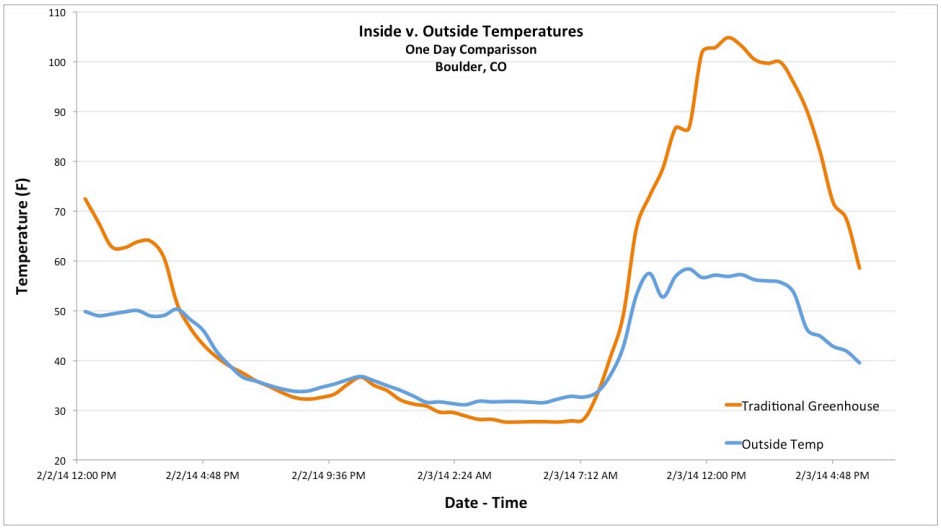
2 Design a smart, durable greenhouse

Questions to ask: What do I want to grow and when? What minimum temperatures do I need? Snow loads and wind loads? Does my site have access to Southern light?

Tip

When it comes to greenhouses, you can't always use standard building materials. Greenhouses are naturally humid environments, and when temperatures drop at night all the water vapor will condense on surfaces inside. Thus, we don't recommend wood siding. Wood anywhere in the greenhouse needs to be stained or painted well. Cedar is often the best for roof beams. We use an interior siding called Magnesium Oxide that is made of a mineral and is water resistant (Ask us for sourcing information). Other materials are plastic, metal or fiberglass sidings.

If you want to save yourself a lot of time and headaches, design an energy-efficient, thermally stable greenhouse. This means a structure that does not fluctuate wildly in temperature as much as regular greenhouse does. For example, take this standard PVC greenhouse located in Boulder CO, and how it performed over the course of a day in November. In one day it froze at night (30 F) and then heated up to over 100 F. Plants, like people, are not going to like these large temperature swings. While you can tame this environment by constantly heating and cooling the greenhouse, you'll save yourself a lot of money and hassle in the long run by starting off with an energy-efficient structure. Thus, follow these basic principles to designing an energy-efficient greenhouse. The fish will thank you.



1. Create an air-tight, insulated, and energy-efficient structure
2. Face glazing where the light comes in (South), and insulate where it doesn't (North and some of the East and West). For most climates with harsh winters this cannot be overstated.
3. Reduce excess heat gain in the summer by using lower transmission glazing on the roof -- like a diffuse or thicker rigid plastic. Sun in the summer and shoulder months is much more intense and will overheat the greenhouse. It comes in at a higher angle (from the roof). Diffuse some of this light with lower transmittance plastics, or by adding shade cloth.
4. Likewise, increase heat gain in the winter by using higher transmittance glazing on the South wall. Winter sun comes in at a low angle, and during this time you want to capture as much of this light and heat as possible.
5. Insulate around the perimeter of the greenhouse. Generally, go 4' down (vertically) or out (horizontally) from the base of the greenhouse to reduce heat loss through the floor.
6. Harness excess solar heat in the greenhouse during the day, and store it using thermal mass (active or passive) for cold evenings -- this evens out the natural temperature swings problematic in greenhouses. To make the most out of thermal mass combine it with a heat exchanger which circulates air through the thermal mass and back into the airspace of the greenhouse. See more info on our Ground to Air Heat Transfer System (GAHT) online.
7. Design proper natural ventilation systems
8. Use materials intended for greenhouse (i.e. humid) environments

Tip: Insulate!

We can't stress this enough. In most places with harsh winters (continually freezing nights) insulate the greenhouse as you would a normal structure like your house. We use between an R-21 and R-50 insulated walls. See our video at ceresgs.com to see this in action.

Each of these points could be a booklet in itself, so use our other resources online or email us for a copy of our "Beginners Guide to Greenhouse Design" for more information. These provide the basic overview of smart greenhouse design. From there, tailor the greenhouse according to your growing system using the rest of the steps below.

Left: A well-designed energy-efficient greenhouse has glazing (glass or polycarbonate) facing South and uses insulation on the remaining sides.

This greenhouse grows tomatoes and warm weather crops year-round at 9,000 ft elevation in Colorado with little to no extra heating.

3 Decide on flooring

Questions to ask: Do I want to move things around (have things on wheels)? Is it important to clean the floor? How much do I want to spend?

Some options:

Concrete:

This is the most expensive option, but probably the nicest long-term. It creates a level and permanent surface for all your systems, as well as an easy surface to wash down and clean. It will need to have a surface drain, and remember factor in any areas that need to be recessed in the floor, like sump tanks or inset fish tanks (see tips 5 and 6).

Gravel (picture below):

A good middle of the road option. It creates a level surface with good drainage but can be hard to walk on or move things across. If you want to move your beds or tanks and are considering having them on wheels, this is not the way to go.

Pavers or Stone:

Flagstone, or any of the pavers at the local hardware store, is also a great middle of the road option. Looks nice, drains well and creates a level surface.

Dirt:

Not the best, but will do. You are more prone to bug issues, and keep in mind that dirt under the weight of large sump tanks or water tanks will compact over time. Make sure to compact the floor before installing systems so that tanks and beds will stay level. Even with a stone, gravel or dirt floor installing a floor drain is a good addition.

Keep in mind

the location and layout of your pipes when planning your flooring. It's nice to have these buried so you don't trip over or step on and break exposed plastic lines (photo right). Or you can raise your walkways to a level walking surface.

4 Plan for your beds

Questions to ask: How much bed space do I need? Type of system (raft, NFT, media beds, or wicking beds)?

There are lots of different systems out there – either DIY or pre-arranged kits. We're not going to go into recommendations for the systems themselves (see our resources page online to learn more from suppliers or DIYers, or email us if you have a specific question). But here's an important point to keep in mind for beds in a greenhouse:

Know your bed height

and make an insulated knee wall below the top of your beds. There is no need for glazing below the beds. The greenhouse will only loose heat there at night, exposing the bottom of the beds and the root systems to cold air at night, or too much heat gain during the day. You want to keep your beds and root systems at a stable temperature, and the best way to do this is to not put them next to glass or plastic. If building your own greenhouse or buying a custom design, identify the height of your beds (usually hip height or 2-3' above ground) and design the greenhouse with a framed insulated knee wall up to the sill of the beds (see photo bottom left). If you have a kit greenhouse or are working with an existing greenhouse, you can install rigid foam board insulation (aka poly-iso, brand name R-max) along the wall under the beds. Cut it to the size of the area you have beneath the beds and secure it on the wall. Try to layer boards to get as high of an R-value as possible.

Floating raft systems (photo top and bottom right) are often well-suited for greens and plants with lower nutrient requirements whereas media bed systems (bottom left) are best for fruiting plants and plants with higher nutrient requirements. See our resources page at ceresgs.com for more info on which is best for you.

4.1 Grow up

Consider Using Vertical Space

By using the vertical space in the greenhouse, you can add much more production area -- just think: in a 10' x 10' greenhouse (100 sq. ft.), if you plant along the whole 10' high North wall you've added another 100 sq. ft. and doubled (!) your potential growing area. Of course, it's hard to plant an entire wall with planters, but many new products and systems are coming out to make that easier. Here's a few options:

+ Growing towers or columns like the ZipGrow planters from Agrotech (photos top left and center) are popular with aquaponics growers. They can be scaled up for large, commercial systems.

+ Wall planters or other small-scale systems like Wooly Pocket, gSky, or Live Wall can be sold as individual units for residential greenhouses. See our blog comparing the various systems.

+ DIY systems -- And then there's all the fun stuff: rain gutters, recycled plastic bottles, tiers and trellises of every shape. Again, see our blog for more ideas and instructions for making your own recycled soda bottle planter (top right) or other suggestions on good planters.

Need help?

We're here to help you plan and design your aquaponics greenhouse the right way, the first time. Whether you need a full design including building plans and instructions, or just an hour of phone consultation, we provide a range of services to help you through the process to create the highest-yield, most energy-efficient greenhouse possible, for both residential and commercial operations. Email our aquaponics expert for more info: Josh@ceresgs.com

5 Plan for sump tanks

The sump tanks need to be a certain height beneath the grow beds. This varies based on how much water is being pumped into the beds. Talk to your supplier to see what the recommended depth of the sump tank is. If the sump tank needs to be buried, keep this in mind when thinking about flooring options. I.e. if using a concrete floor leave a space open for the sump tank before pouring the pad. First identify what height you would like your beds to be at and work from there.

6 Plan for fish tanks

As we noted earlier, try to keep fish tanks out of direct light: it's much easier to heat tanks than to cool them. You'll want to place your fish tanks near electrical outlets, or make sure you can run power to the tank for heaters and air circulation. In addition, you can choose between burying your fish tanks partially underground, or having the tanks above ground. Some considerations...

Underground

tanks have the advantage that you can build a platform over the tank and use it for growing space, or potting / work space. The soil also acts as natural insulation. But, underground tanks come with the obvious disadvantage that the tanks are difficult to clean / empty-- you'll have to rely on a sump pump or shop vac, or design for a deep drain.

Above ground

tanks make it easier to clean the tanks -- necessary every once in a while in every aquaponics operation. You can still build a platform over the tanks (see top right photo) but your height is limited for plants there.

Tip: Insulate your tanks

Insulate around your fish tanks to prevent from getting too cold. Use bubble wrap or flexible insulation (right). You also want to insulate underneath the tank, but remember the weight of the tank can break rigid insulation. Larger aquaponic operations can even have a separated insulated room on the north side of the greenhouse for tanks.

7 Plan for electrical

Questions to ask: How much stuff will I be running? What is going to be the total power draw?

Every aquaponics system is different and thus there is huge variation on electrical requirements. To help you (and / or your electrician) plan for the electric system, calculate the total energy usage or load of the components in your system. Find the wattage of each component. The major energy users to think about:

- Water pumps
- Water heater (size of your heater will depend on the heating requirement. N/A if using a propane heater or other independent system)
- Aeration pumps
- Electric space heaters (the size of your heater in turn depends on your greenhouse, location, required temps etc. See below. N/A if using a propane heater or other independent system).
- Ventilation and circulation fans (primarily your exhaust fan)
- Lights if using them

Once you know the wattage of each component, you can calculate your electrical requirement needed for the greenhouse. Add up the wattage of each component. Then divide the total by your voltage. This will give you the total amps needed for the greenhouse. From there, talk to an electrician about your electrical design. Generally, if using wiring for 20 amps, you can take the total amperage, add a 15% safety factor, and then divide by 18 (again, giving some room so you do not blow the fuses) and round up to the next whole number to determine your number of circuits. Simplified example:

Water heater (2000 W) + 2 Lights (200 W each) = 2400 W total
2400 W / 120 v = 20 amps
20 amps plus 15% = 23 amps
23 amps / 18 amp circuit = 1.3
You'll need 2 circuits. But again, if you're not an electrician, don't try to wire this.

Going Off-Grid

You have the same options with hooking up your aquaponics system as with any new electrical system. You can a) connect to the grid via your home, or nearby structure or b) build an off-grid system with solar PV. Building an off-grid system can be an e-book in itself - stay tuned via our newsletter for this. Generally, your options are creating a grid-tied system (feeding power back into the grid), a stand-alone system or a stand-alone system with battery back-up (recommended if doing a stand alone system). You can ALSO connect the greenhouse to the grid for electrical, and incorporate an off-grid method just for heating, like solar hot water.

Where to start???

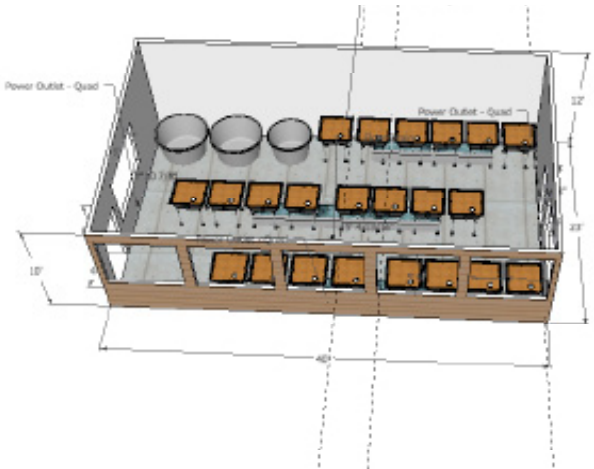
As you can infer from the above points, when planning a greenhouse one thing depends which depends on another which depends on another, ad infinitum. If starting from scratch, here's a good game plan:

1. First you have to know what you want to get out of the greenhouse...what plants and how much. How big does it need to be to produce what you would like?
2. Then go to the structure. How do I create an environment that will make these plants happy? Tomatoes are different than kale. Cold hardy micro-greens have different needs than tropical fruit trees. If going for a large variety, aim to please the plants that need the warmest temps. With greenhouse design there are different general strategies: the "cheap upfront / expensive long-term" route, or the "invest more upfront / reap the energy savings over time" approach. Obviously, we recommend the latter after seeing people loose money on renovating or starting over after using low-quality, energy hogging greenhouses. You should have a general idea of how your greenhouse is going to perform, and how difficult or easy it will be to control. To get a better idea talk to other growers in your area, or talk to us about an energy analysis of the structure.
3. Once you have a rough idea of your air temps inside, go to your aquaponic system. If you anticipate your greenhouse will track air temps and you live in Montana, you will need a sizable water heater. If you are planning a well-insulated greenhouse that utilizes thermal mass, are in a moderate climate, and choose the right fish species, may not need a water heater at all.
4. From here, you can finish out the system: electric requirements, water hook-ups., additional accessories like lights and exhaust fans.

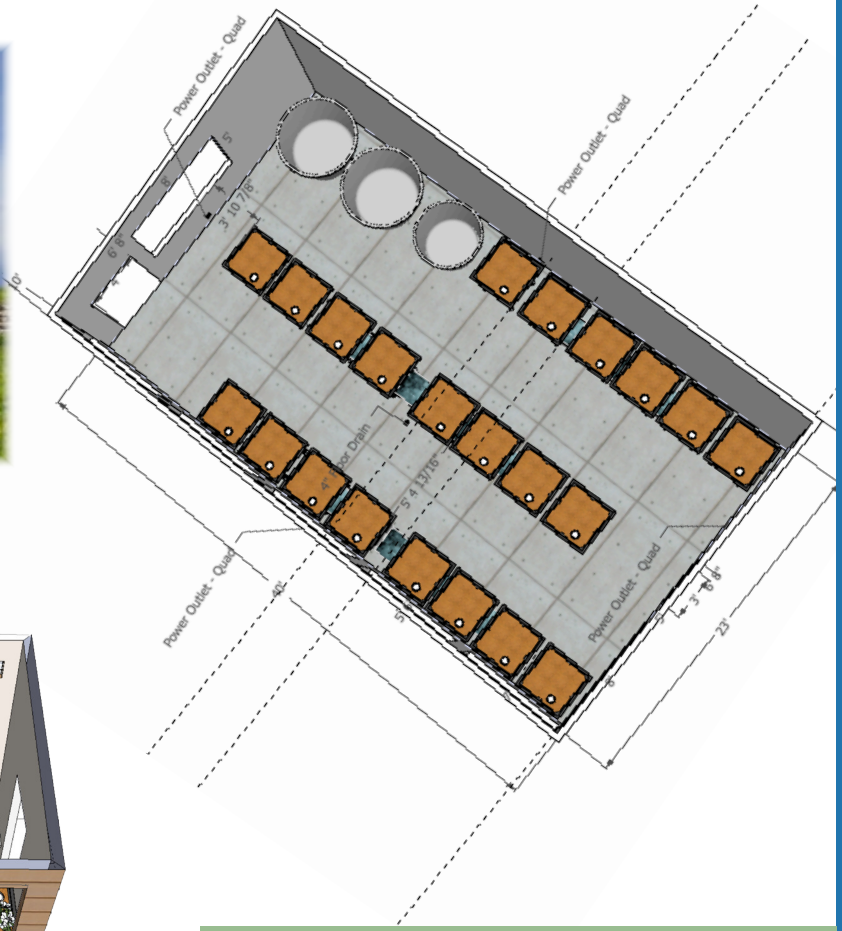
8 Some Design Ideas

Here are a few example floor plans for residential and small-scale commercial or community greenhouses, using Ceres solar greenhouse designs. Each has been optimized for the climate and the system, to maximize space and to create an incredibly productive, energy-efficient greenhouse. These will vary by location and your aquaponics system, but can give you some ideas for your own design / layout.

Right and next page: A 920 sq ft greenhouse has (22) 3' x 3' beds, and (3) 130 gallon fish tanks.

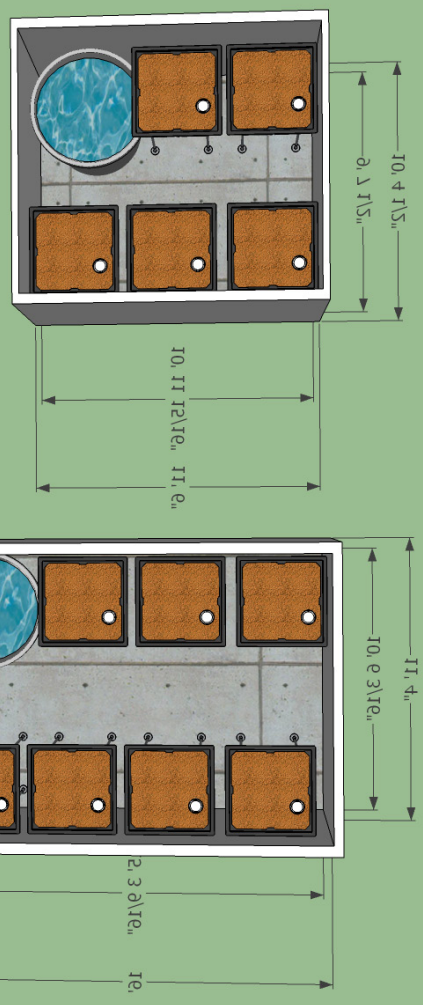


how to design an aquaponics greenhouse



Above: A 10 x 12 greenhouse with (5) 3' x 3' grow beds, (1) 180 gal fish tank and (2) 130 gal sump tanks (sold as the 5 bed Easy Reach Aquabundance System from The Aquaponics Source)

Above: A 12 x 16 greenhouse with (7) 3' x 3' grow beds, (1) 180 gal fish tank and (2) 130 gal sump tanks (sold as the 7 bed Easy Reach Aquabundance System from The Aquaponics Source)



9 Thoughts on planting

1. In the winter, light will come through the windows at a low angle from the South. Therefore, put shorter plants along the South side of the greenhouse so they do not shade the plants in the back. Likewise, put taller things – vines, tomatoes, trees – along the North wall. Many plants prefer the 'morning light' – the light coming from the East – for growing compared to the Western afternoon light, which often overheats greenhouses and wilts plants. Thus, if debating which side to put your fish tank on, a well-insulated North West corner is generally the best.

2. Watch the windows / glazed walls: the they will get much colder than other spots in the greenhouse. Plants on or near the windows / polycarbonate / plastic walls will get much colder than those planted a few inches inside the air space. Plant hardy crops around the edges or plant things a few inches away from the windows if need be.

The plants along the South side of this standard glass greenhouse may be getting a little high, but because there is so much glass (on all sides) there should be enough light for the plants on the North side. It does "leak like a sieve" though, says Aquaponic Source co-owner Sylvia Bernstein. Photo courtesy of the Aquaponic Source.

Join the conversation.

Don't forget to let us know what you think.

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