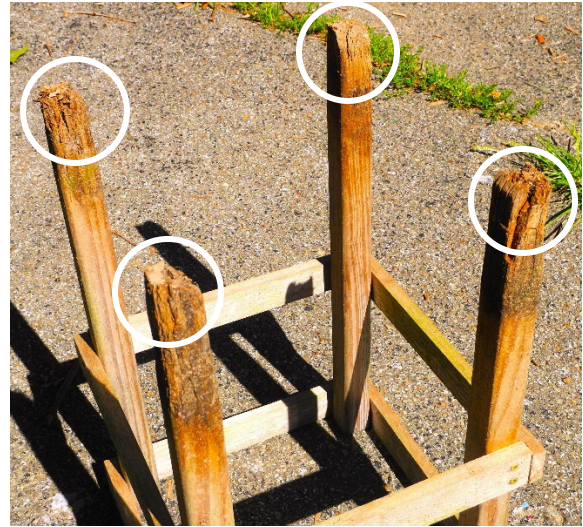


A-01 Building Useful Things with PVC

These are winter projects for the homestead. After the final harvest is in, the gardens have been put to sleep, and your memories are fresh, get busy with projects before next spring. Once that starts rocking and rolling, there won't be any time to get these done. That's why winter on a homestead is busy time.

Initially, we built some of our most important items for the homestead from wood. It was aesthetic and was something we understood. But as time showed, wood has a limited lifespan and eventually all of those things failed. It was a combination of insects, fungus, handling, and weather.

Case in point is this pepper stand. From experience, we already knew that simple wire cages were inadequate for our vigorous plants. The same applied to our tomatoes. These stands worked well for about five years until the legs started to rot out and this was pressure-treated lumber. Likely our insect buddies were recycling the wood into humus.



Meanwhile, we tried our hand at making low hoop winter growing cages and built up two large water catchment systems. These were all with Schedule 40 PVC pipes and fittings. It was no surprise that none of these systems failed due to any of the above reasons. We also learned how to put them together.

The beauty of working with PVC is weight, durability, flexibility, simplicity, and repurposing. As to weight, PVC is much lighter than wood. For durability, it has never failed with 24/7 UV exposure and rough handling. Building with PVC allows you to make custom-sized projects unique to your requirements. And when putting the project together, everything is automatically square. When something doesn't work out as planned or requirements change, simply take it apart and build anew. This beats out wood every time.

Caveat on Low Hoops

Do not use very stiff Schedule 40 PVC. Instead, use flexible electric conduit PVC. It's grey and found in the electrical area at big box stores.

It can be installed by simply pushing the ends into the soil. It comes in 10-foot lengths—cut off two feet from the female end. This provides enough arch with extra to anchor down standard 10-foot-wide winter plastic and mesh covers. Hold the covers in place with small spring clamps, available online.

Electric PVC conduit is UV tolerant and has never failed with 10 years of 24/7 exposure outdoors.



What We've Built

Tomato Cages – Sized to accommodate our vigorous plants.

Pepper Cages – Two sizes with taller for greenhouse plants and shorter for field plants.

Critter Cages – Sized for specific requirements and our garden beds.

Small Trellises – For growing cucumbers and peas in greenhouse beds.

Removable Fences – Allows access to a garden bed that was difficult to service.

Clough Storage – Holds 40+ containers when not in use and mounted to the barn garage.

Chicken Tractor – Modeled after a much larger design from Eliot Coleman.

Kayak Rack – Slides onto our large trailer for carrying up to six boats and gear.

Water Totes – Piping that was custom fit for particular installations.

The Basics of PVC Construction

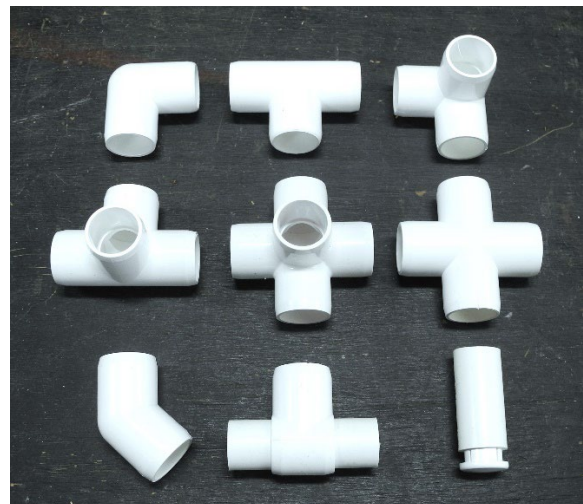
Type of PVC – At the big box stores, you'll find two wall thicknesses. There will be a thin-wall type that's used for light duty drains. This is inadequate for homestead work.

Schedule 40 is the thick-wall type that should be used. They cost about the same.



Type of Fittings – Avoid using Schedule 40 plumbing fittings. They cost too much and will likely not be found in suitable quantities for building multiple items, like tomato and pepper cages. Look online for furniture-grade PVC fittings. See the end of this article for an excellent source. These are adequate for homestead work, but not for plumbing, and are easily obtained in large quantities.

Shown are the furniture fittings available. The most used are on the top row, special purpose fittings are on the middle row, other fittings on the bottom row. The slip joint and end cap fittings work with the size of pipe being used.



Assembly – No glue. Use standard 1¼-inch exterior construction screws. These are good for all except large projects. If you were to glue and made a mistake, throw out your work and start over. Using these screws, we have PVC projects that have been in continuous use for 10+ years with no failures.

Cutting PVC Pipe – This stuff is slippery so trying to cut PVC with a hand saw can be difficult and time consuming. A chop saw makes this easy with straight perpendicular cuts. After each cut, there will be a load of small chips inside the pipe. Rap the cut piece to clear these out or suck them out with a shop vac. Eventually, you'll have a lot of chips to clean up. Do this before tracking them all over the work area.

Alternatives for Cutting – There are pipe cutting tools that work like heavy-duty pliers and copper pipe

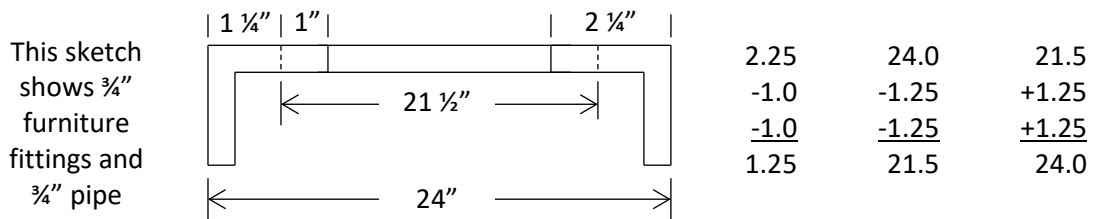
cutters that rotate around the pipe. Both are slower and require much more effort than a chop saw. When attempting to cut PVC pipe with a saber saw, it jerked around requiring multiple clamps to a work table.

How to Build with PVC

Make a Sketch – Figure out the overall dimensions of what you want to build. Then make a sketch showing the position of each fitting. This could be each side, top and bottom.

Measure the Fittings – Inside each fitting will be a stopper ridge. This will be as far as the PVC pipe will go once tapped into place. For ¾-inch furniture fittings, this will typically be one inch. Then measure the entire fitting from the opening to the outside. These two measurements will determine the length of PVC pipe pieces to result in the desired overall project.

Do the Math – On the sketch, mark the internal stopper ridge with a dashed line and an arrow to that dimension. Then mark the overall dimension of the fitting. Do this for both ends of the sketch. Using a calculator, start with the overall dimension and subtract the outside dimension of the fittings. Then subtract the internal stopper ridge dimensions. The resulting number should be the length of the PVC pipe. Walk the dog backwards by adding the dimensions together. This should equal the desired overall dimension. If it doesn't, go back and double check your sketch and math.



With furniture fittings only, simplify pipe cutting dimensions by subtracting 2½ inches from the overall desired dimension. This will be the length of the pipe to cut. Plumbing fittings will require additional measuring with the fittings on hand.

12 inches	9½ inches	30 inches	27½ inches
16 inches	13½ inches	36 inches	33½ inches
18 inches	15½ inches	48 inches	45½ inches
24 inches	21½ inches	60 inches	57½ inches

Dry Fit to Be Sure – Cut the pipe and tap the fittings into place. Measure to be sure you've got it right. If not right, check the math. Once you're sure, make a cutting list with the correct dimensions.

Production – If making multiple identical projects, cut and assemble one complete set of pipes at a time. This makes the whole process go much faster.

Assembling a Project – Using a lightweight hammer or mallet, tap the pieces together. If the cutting was done correctly, everything should be square. Again, get out the tape measure and be sure. If something isn't right, tap the fittings off the pipe and refit until correct and you're satisfied. Update the cutting list.

Positioning PVC Pipe – This will have a long string of marks down one side of the pipe which can be unsightly. Do not expect to remove these marks. Simply position the pipe pieces so they will be less visible

such as inside of vertical pieces and on the bottom of horizontal pieces. When in use, these marks will basically disappear.

Positioning PVC Fittings – Plumbing fittings will have smaller marks so you'll just have to live with them. Furniture-grade fittings, however, have no marks. Another reason not to use plumbing fittings.

Securing with Screws – If making multiple small projects, like pepper cages, wait until all of the items have been assembled. Then follow the below procedures for final assembly. This will be much faster than setting up and breaking down for each project assembly.

Putting It Together

Squaring Up – This is easy because the fittings are on fixed 90° dimensions. What makes this work is a flat work surface. It doesn't have to be level, just flat.

Where to Start – This will be the foundation for the rest of the project. First assemble the top with three-way fittings. Lay the fittings and pipe on the work surface and push in the pipe. Lift the assembly to vertical and tap the fittings together. Check that each has reached the stopper inside the fittings. Check to be sure both fittings are flat to the work surface. If not, tap to remove them and reposition. Set this piece aside and repeat. Then, insert the remaining top pieces into the assemblies and tap into place on the vertical. Monitor the progress from the marks on the pipe. The result should be flat. If not, tap or wiggle into place. If there will be an intermediate horizontal assembly, repeat the above.

Going Vertical – Tap all four vertical pieces into the top assembly. Slow down to be sure the markings are in the least visible position. If there's an intermediate horizontal assembly, tap this onto the vertical pipes. Then tap the remaining vertical pipe pieces into this assembly. As this happens, the fittings will start to square up the entire structure. For taller structures, place the top assembly on the floor.

Finishing the Vertical – Look over the assembly and eyeball to see that it looks right. You may need to jerk some of the pieces around a little to get it right. This may also be where you make some design changes based on the finished product. If this project is going into the ground, tap the end caps into the final vertical pieces. Don't stress about it being a little wobbly—the soil won't care and will hold it steady.

Inserting Screws

Tools Required – Drill with 7/64-inch size bit. This is smaller than what would be used with wood. Have spares because these can easily break. Driver to fit the screw heads. Small container to hold drilling scraps. Lots of 1¼-inch screws. Flat work surface.

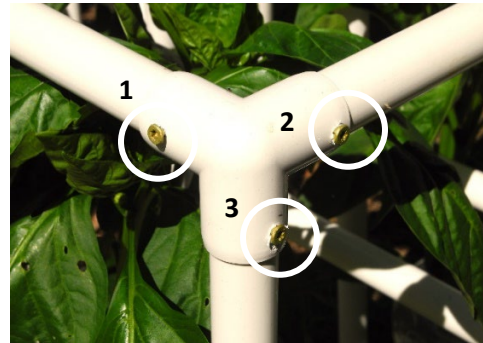
Efficiency – Only one screw is needed through the fitting into each pipe piece. Drill the holes first while catching as many of the strays as possible. Drilling slowly keeps bits from flying off; clean the bit after each hole. Then insert each screw. For tall projects, like tomato cages, lay the structure on its side.



Where to Start – Begin at the top or whichever end is convenient. Do the upper fittings and flip over the structure to do the other side. For large assemblies, you may have to work on all of the horizontal sides and then roll the structure to reach the opposite sides.

Putting Screws into PVC – This isn't like working with wood where fibers create grip. Be gentle with the driver using slight pumps as the screw goes in—three or four should do it. If too fast, the PVC will strip out and the screw will lose its grip. If this happens, it will not be possible to extract the screw. Make another hole and be more careful.

Do not expect the screw to go flush with PVC like with wood. Stop when about $\frac{1}{8}$ inch remains.



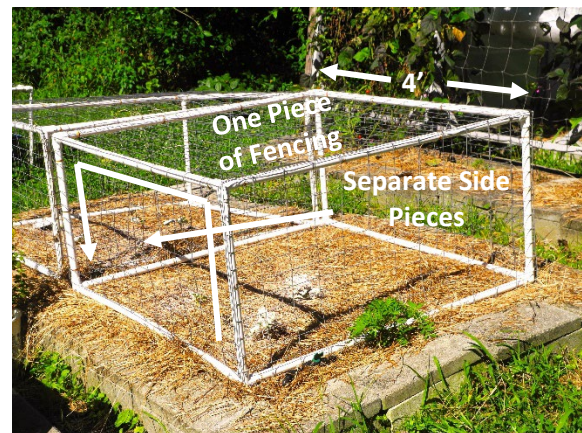
Finishing with Screws – Double check that every fitting has a screw into every pipe. When satisfied, set the assembly aside and go to the next. Clean up a little so there aren't small PVC shavings everywhere.

Adding Fencing to PVC Assemblies

This will not keep out squirrels. They easily slip in through the fencing. 1-inch steel mesh is required.

One of the most useful tools on homesteads are those which keep critters, like chickens, rabbits, and deer, from devouring veggie and flower seedlings before they get established. This means critter cages. For these, welded-wire goat fencing works best. Lightweight chicken wire is too flimsy and easily rusts, even with so-called galvanizing.

After lots of experience, this is how to make these cages with a minimum of fuss. It starts by working with the original dimension of the fencing, generally 48 inches tall. Then work with the dimensions of the welded fence openings, generally 2x4 inches. There is also smaller dimension welded wire fencing at 2x2 inches, but the smaller opening and extra expense have little advantage over 2x4-inch fencing.



Three pieces of fencing. The big piece that wraps over the frame and two side pieces. Dimensions should be in 2-inch increments to accommodate the construction of the fencing material.

Designing Critter Cages – To work efficiently with 48-inch fencing, it goes a lot faster to make the cage fit the fence. This is like building a structure where you design backwards from factory-dimension material to the actual structure. You'll be working with even-numbered dimensions—design accordingly.

Experience: Simplified Fencing – In retrospect after working with smaller dimension one-inch steel mesh, it will be much more efficient with a neater final assembly to cut panels for each side and the top. Then hold the panels to the frame with wire ties until final securing. One-inch mesh comes in 24-inch width. To bridge a gap of 48 inches, design in an overlap of two inches and stitch the pieces together with multiple wire ties. This will be suitably strong but requires monitoring as the wire ties deteriorate from UV.

Tools Required – Lots of 11-inch plastic wire ties. 20-gauge galvanized wire—maybe. Wire cutters. Electrician-type wire pliers. Container for removed wire ties and snipped off wire scraps.

Cutting the Fencing – Measure all three sides so that the fencing will wrap around from one edge, across the top, and to the opposite side in one piece. Then add an additional square or two to accommodate the bend around the PVC frame. Any excess will be cut off later. The pliers will be adequate for cutting.



Handling the Fencing – There will be a curl to the fencing after it's cut. Leave it because this will make it easier to do the wrapping. Side pieces, however, will have to be bent reasonably flat. If using individual panel pieces, it helps to have the arch of the curl on the outside of the frame for easier assembly.

Prepping the Fencing – When cutting, snip through the center of the squares. Before proceeding with attaching to the frame, bend all of the tails under the welds while straightening to the fencing as you go. Do this with each piece as you use them. It helps when handling critter cages to have the bent-over piece inside the structure so they don't catch on gloves and clothing.

Attaching the Main Piece – Position the large wrap-around fencing piece so the curl flops over the cage assembly. Using wire ties, secure the bottom edge to the frame. Then secure the fencing to the vertical pieces on that side. Bend the fencing at the top of the assembly so that it's reasonably square to the frame. Secure the fencing at the horizontal top with wire ties. Then work down each vertical side to secure the fencing to the frame with as many wire ties as necessary to bring the fencing to the frame. At the bottom, trim off the excess, bend in the tails, and secure with wire ties.

Attaching Side Pieces – Bend these smaller pieces to be reasonably flat. Using more wire ties, secure these to the frame. By now you will have used a lot of wire ties.

Securing with Wire – Do not count on plastic wire ties to hold up with 24/7 UV exposure. These will fail within 12 months or less. Working on one edge at a time, cut a length of wire to wrap around the frame and fencing. Twist the wire with the pliers and snip off the tails. On a 48-inch edge, five wires should suffice. Bend the twisted ends of the wire into the frame to minimize cuts when handling the cages. Try to secure the side pieces with the main piece to be efficient—it won't always work. Cut off the wire ties.

Experience: Faux Galvanized Wire – Although it would be ideal, we've never found any supposedly galvanized wire that does not rust. Every brand tried has failed. In the meantime we've using exterior-grade UV-tolerant plastic wire ties. These do eventually fail but not nearly as fast as the faux-galvanized wire. 11-inch wire tires are suitably strong and are easy to snug tight. Cut off the tails.

Finishing the Cage – Cut off all plastic wire ties. Check to verify that everything is reasonably tight. Any gap is an open door to a determined critter.

Securing with Hose Clamps and Black Plastic Mesh

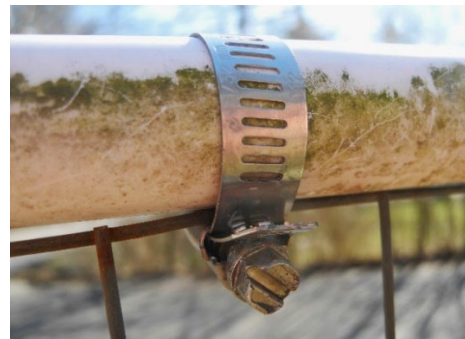
The ultimate in securing the fencing for good is with screw-type hose clamps. These are routinely made of stainless steel so no rust and no failures. They also work well to hold fencing on gates. Tack the fencing in place with wire ties before attaching the clamps and then cut them off. Hose clamps are more expensive than wire and wire ties and can be brought in as needed.

Types of Hose Clamps – At big box stores you'll likely find hose clamps intended for construction and mechanical purposes. These are heavy duty, expensive, and overkill for homestead work. Shop online (you know where) for lightweight clamps: for ¾-inch PVC look for ¾ - 1½ inch in sets of 25 for about \$10.00. They're a bit crude but will do the job.



Typical Hose Clamps

A: ¾-inch PVC B: 2-inch PVC C: 3-inch Diameter



Hose Clamp Installed on ¾-inch PVC. Note how the screw is on the inside of the frame.

Experience: Hose Clamps and Fencing – Fencing is not built to exacting standards. When attaching to PVC you'll often need to snug the parts together. The fastest way is to squeeze with channel lock pliers or use a larger hose clamp to pull it tight and attach a smaller clamp. Remove the larger clamp and use again. One-inch mesh, however is more exact in construction and easier to align with the frame.

Black Plastic Mesh

Little Critters – Probably the most energetic critters around veggie gardens are voles. These little guys can come up to the surface and sneak through fencing to get their food. When you find damage to new seedlings, especially peas and beans, critter cages need an extra layer of ½-inch mesh around the base. 12 inches of black plastic, like what's used around new saplings, works well.

Experience: Best Plastic Mesh – After using several different brands, the best is from **Everbilt**. It's stronger and the mesh is aligned square, unlike that from an exporting juggernaut some 13,000 miles away.

Experience: Keeping Out Squirrels – If you have squirrels in trees and they have no threat from guardian dogs, they will take this as an open invitation. Squirrels easily squeeze through 2x4-inch fence openings and will climb to the top to drop in for a meal. Covering an entire cage with black ½-inch mesh blocks too much sun so this is unacceptable. One-inch steel mesh retrofitted in place of standard fencing keeps them out. If there is even a potential squirrel threat, it would be wise to start with one-inch steel mesh.

Maintenance of Cages

When Things Break – If not using hose clamps occasionally you will need to replace rusted wire that fails and plastic wire ties that break. Check the connections every time they are handled and fix.

Handling Cages – Don't pick them up. Roll them on their sides. This is much easier and minimizes wear on wire and wire ties as well as cuts on fingers.

Excess Cages – When not in use, but where others are being used, simply stack them up—rain and sun pass right thru to your protected veggies. If stored on edge in grass, it grows through and pulls loose.

Building Large Projects

These require special techniques because there will be multiple fittings which would be weak points when handling and stressing the structure. The following procedures were learned through experience.

We have built a few large projects. These include a chicken tractor, a trailer kayak rack, and a kids jungle gym. The big question was how to make structures strong across multiple joints to avoid twisting and damaging fittings. The answer was layers and *lots* of screws.



Designing a Large Project – After making the initial sketch with all of the dimensions, look for the main stress points across various joints. These are where the internal liner PVC should pass completely thru the fitting. These will often be across multiple fittings. For all other fittings, the internal PVC will be cut to fit so that every connection receives support.

Single internal pipe running the length of each side across multiple fittings. Very strong.

Tools Required – Everything for small projects plus lots of 1¾ screws.

Materials Required – 2-inch PVC for the main frame and 1-inch PVC for the internal layer. Get more than you think you'll need and take back or store the rest. It's common to make adjustments and changes as these types of projects are built.

Assembling the Project – As the external pieces are being tapped into place, slide in the internal pieces across the stress joints. Then slip a tape measure into the alternate external pipes to measure and cut those pieces. The internal pieces will flop around a bit inside the external frame with the slack taken up with the 1¾ inch screws. This is why you need to measure and cut each of these pieces separately. If you have smaller internal pieces available, this works just as well. The key is strength across the joints.

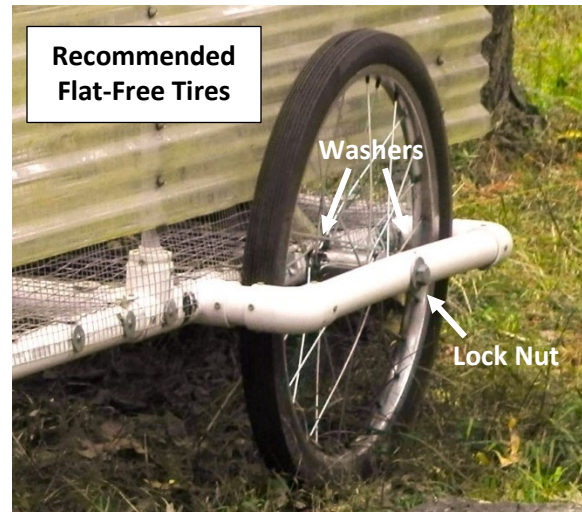
Checking the Project – After the structure is assembled, wiggle and wobble it around a bit to see if you were correct on the main stress points fittings. If not, take it apart and change the internal pieces.

Finishing the Project – Insert screws on all four sides of each fitting. In some cases, you will only be able to insert three screws like when a structure is being built on a trailer. The structure will now be extremely strong and is ready for use. You will likely need to climb inside larger projects.

Building with Wheels – These always need a minimum of two supports. Build a surrounding frame as part of the structure. After installation, drill holes through both pieces at the same time. This way the axle bolts will line up even if they are not perfectly square and perpendicular to the structure.

Axles – Obtain full-thread rods and sacrificial nuts. Before cutting the rod to fit, insert the nut below the cut. Then work the nut out over the cut to reestablish the thread. Dispose of the nut.

Attaching Wheels – Place large galvanized washers on the axle where wheel hubs rub the frame. Secure with lock nuts, not lock washers.



Odds and Ends

Vining Veggies – Squash, pumpkins, sweet potatoes, and melons put out vines when they are established. It's best to remove the cages if critters are under control by guardian dogs. Otherwise, reaching under the cages for finished veggies and fruit can become difficult without damage to the vines but tendrils can be snipped off from the cage without damage to the plant.

Sweet Potatoes – The vines burst out of their bed and may even set tubers in the field. When harvested in October, cut back the vines to the edge of the cage, remove the cage, and finish cutting back everything else for the compost. Dig in with your hands—sweet potato skins are thin and easily damaged with tools.

Special Fittings – The project may require stepping down from a larger opening to accommodate smaller PVC pipe. These are mostly available as plumbing fittings. If your project calls for a hinge, obtain a larger diameter plumbing fitting that slips freely over the pipe. These also come with a step down from which smaller pipe can be attached. There are also couplings and step-down reducer plumbing fittings.

If You Get Stuck – When trying to put your project together, there may be conundrums with the fittings. At big box stores, look for the old guys and explain your situation. They will likely have some creative solutions to fix your situation. When your project is finished, take a few photos on your phone and then next time you see the old guy, show him the result. You'll make a new friend who will help you again.

Purchasing Furniture Fittings – Online only. These are randomly available through that huge supplier we all know but you'll have to hunt around and everything possible won't be there. Most of those sources are not from the main warehouse so selection and prices could vary. To get the most consistent price with the complete selection, go to **Circo Innovations** and select PVC Fittings under the category bar on their web site. If it's available, they will have it at a fair price.

Experience: Impact of Tariffs – PVC furniture fittings are manufactured internationally and this is reflected in the price. Since there is a limited market for these fittings, it's unlikely that this will ever be a domestic-manufactured product. This would require new molds and new equipment which would be prohibitively expensive. Plus, certain fittings used in projects are not allowed in plumbing codes. The only way to get these is with furniture fittings. So, expect the cost of furniture fittings to increase.

Design Details

For numerous projects built with PVC, check in Chapter 15 of the main publication or on the Green Learning Homestead website. You'll find basic dimensions that have been worked out through our experience and hands-on testing. Save yourself a bunch of time and get on with your projects.

Tomato Cages	Designed to hold full-size plants in the field and in a high-hoop greenhouse. Greenhouse growing is routinely heartier than in the field requiring additional vertical support with twine.
Pepper Cages	As with tomatoes, greenhouse growing is routinely more robust than in the field. Two different sizes have been proven to be the best options.
Critter Cages	These are all custom fit to various raised beds and for various needs. Some are kept in place throughout the growing season and others are moved around as required by critters.
Small Trellises	These are for growing cucumbers with the size determined by the width of field fencing. Height is to whatever is convenient. Trellises are mounted on rebar stakes which often require support with twine when heavy with vines and veggies. For this reason, these trellises are used in greenhouses.

Longevity with UV Exposure

All of these projects are exposed to UV 24/7 throughout the year. There has not been one failure over about ten years in the field.

Chemical Concerns with PVC

There are lots of issues proposed with the ubiquitous use of polyvinyl chloride (PVC) with main concerns being additives to make it flexible, the manufacturing process, and disposal. All of these can cause PVC to leech into soil and water when not handled properly. These concerns are most often exacerbated through careless handling and management of PVC during and after manufacturing.

As long as you maintain your PVC projects properly, there is little concern at the homestead level. The main issue is with large chemical manufacturing and the waste produced from these processes. By the time hard Schedule 40 PVC arrives at your homestead, environmental damage from manufacturing has already been done. Simply don't add to the problem caused by manufacturers.

Experience: Issues During Structure Fires – One day while on a practice field with a soccer team, smoke was in the air. A fellow coach who was a fireman noted that the odor smelled of plastic which meant this was a structure fire instead of a brush fire. PVC plastic was burning from plumbing, wire coatings, and window and door framing. Burning is the main concern with disposal of PVC.

The Future with PVC – Many European countries have taken steps to reduce the chemical processes used to make PVC flexible, like for gloves and bags. The jury is still out on this because alternatives have been shown to be worse. It's very likely that PVC for project construction will continue to be available but maybe not in other applications.