# Off-Grid Garden Infrastructure

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**The Underground Center**

**www.theundergroundcenter.org**

***All UGC artwork by Katie Fisher***

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**<u>Off-Grid infrastructure overview</u>**

Even among environmental and justice-oriented food growers, concessions are made when it comes to industrial products like tractors, electric powered irrigation systems, plastics for greenhouses and row covers. These are taken as necessary evils (if they are even considered a problem at all). The "practicality" of economics or labor saving takes priority over embodied energy costs, negative impacts of these technologies, or efforts to build no fossil fuel alternatives.

**A common image on "sustainable" farms. Gas powered tractor, plastic row cover as mulch substitute, and plastic tubing for irrigation. All with relatively short lifespans.**

**Photo from duboisag.com**

In our other texts, we argue that localizing compost production and growing our entire diets within our communities can minimize and ultimately eliminate the need for fossil fuels in fertilizing soil and transporting food, but what about the infrastructure to maintain our gardens? From our perspective, there are both moral and practical reasons to rapidly transition to off grid systems. We believe that it is possible and ultimately more efficient to create these systems. By using natural, local materials and removing our dependence on exploitive industrial processes we can eliminate costs and grow food even with long term power outages and supply chain shortages.

**What we offer in this text**

The goal of this text is to share our thought process and principles that guide our work creating off grid garden infrastructure. Specifically, we will be focusing on fences, watering systems and greenhouses. Over the last decade we have experimented with various systems and met people locally that have developed ingenious solutions that we hope others can adopt in their gardens. As with all our resilient infrastructure our goal is to create it without hired "experts," build and maintain it without fossil fuels, and get rid of the need for continual money inputs.

We hope that by sharing our experience and example of off-grid systems, you can gain confidence in putting your own hands and minds to work at developing non exploitive infrastructure. Like all the knowledge we share, our off-grid infrastructure is a work in progress. Every season, we improve, change or all together abandon systems in our garden. We are not "experts" in these fields, but we are dedicated to thinking, getting to work and moving toward a vision that is more just. In this text, we will share our thought process, mistakes, and ideas we will pursue in the future. If there is anything we hope others will emulate form our work, it is this process of experimentation and application. Break free of the cult of the expert![1]

**Counting real cost: embodied energy and externalities**

Why is it important to create off-grid infrastructure around our farms? Some might argue that we are being dogmatic and impractical. A lot of people scoff at the idea of taking hours and hours making a handmade fence out of trees from the forest or using reclaimed windows for a greenhouse. The argument is that industrial products are cheap enough that it is impractical to do it from scratch. People believe it's fine for an art project or hobby, but if we are serious about growing food, we need "modern" technology to get the job done. But is this true? Is global industrial capitalist production more efficient than local craft, reclaimed materials and need based economies?

The reality is, we almost never count the time and energy that goes into making products we buy in a store. It is a lot more work to mine materials, ship them across the globe, process them in a factory with exploited labor, ship them again to a place where they are assembled, then ship them again to a retailer across the globe. We don't count all the work and fuel that goes into products before they hit the shelf: the ***embodied energy***. The energy and the amount of coerced labor that is required to maintain this "practical" system is mind boggling. It is not more efficient, but more convenient for the consumer and beneficiaries of exploited labor.


**Photo from freightwaves.com**

[1] That being said, please consult with people who know what they are doing and do research! One feature that plagues the DIY community is rickety, ugly and sometimes dangerous systems. Let's do our part in making our handmade systems beautiful and well made.

The fact that these products are cheaper than something made close to home, despite all the extra labor and resources that go into it proves that exploitation plays a major role in its production. By relying on workers from countries that haven't had labor justice movements, we can create cheap products even though it takes more work.[2] What is called "economy of scale" usually just means displacing the burden on workers abroad.

We end up using way more resources than necessary and negatively impacting the environment. These costs are not counted by corporations that profit and aren't covered by the consumer who buys the cheap product. These "invisible" costs to workers and the environment are called *externalities.* Not including these costs in analysis of food production contribute to the myth that global industrial production is a more efficient way to meet people's needs. These hidden costs in production make us conflate *financial* sustainability and efficiency with *actual* sustainability and efficiency.

**Practical Vs Moral**

The unfortunate reality is that externalities of exploited labor and pollution are not a sign that the system is failing, they are a sign that it is working. The goal of capitalist production is not to efficiently meet people's needs, it is designed to produce money for business owners and shareholders and create cheap products for consumers. This system is working well for people who can get cheap goods (for now). We realize that trying to convince these people to change on behalf of the "out of sight" poor and devastated ecosystems is too abstract and moralistic to work. The system is too convenient for consumers to change. From our perspective though, transforming our infrastructure to eliminate exploitation of people and the land is not just moral, it is practical.

There are multiple reasons to quickly transition to resilient off-grid infrastructure in our gardens and design replicable systems. First, our agenda is to get many more people seriously growing food in our communities. Overhead investments are a huge hinderance, especially for people without disposable incomes. Being able to transform any land to a farm, even if it doesn't have electric and a well on site is a big benefit to this cause. To install conventional infrastructure will set you back 10's of thousands of dollars. This further incentivizes farmers to sell their food to wealthy customers instead of sharing it with the community to recoup expenses. By creating a system that lowers the barriers to entry is a practical way to make change more accessible. This creates the possibility for poor people to become food producers. Poor farmers will have much more incentive to change the system than the middle and upper classes who currently have land access and control food production**. A society where the poorest people can produce food is a secure one.**

[2] For the most part, if you see a cheap product that was made in the US, it is likely produced with prison labor. The 13th amendment abolished slavery *except* as a punishment for a crime. Hence, prisoners remain a source of cheap or free labor.

Another practical reason to transition to off grid infrastructure is destructive storms. Every year there are periods where the electric is out from winds, or water is compromised because of contamination. This is likely to increase. There is little profit incentive for capitalists to invest in our infrastructure when they can make much more money consolidating what is already there and charging you more money for it.[3] Last year a tornado touched down less than a mile from shagbark gardens! This year there was another in the southern part of the county. Poor communities can be neglected from federal aid for months or more. Parts of Puerto Rico were offline for a year after Hurricane Maria. Flint Michigan has been without potable water for 6 years despite constant "awareness raising" of their plight. Although racism and classism always play a strong role in infrastructure security, even affluent areas of New York City and New Jersey were out of power for weeks after hurricane Sandy. Climate change and infrastructure for profit create a situation where short-term outages are inevitable and long term or permanent infrastructure collapse are increasingly possible.

**Resilient vs Efficient**

A useful concept to guide the creation of sustainable farms is understanding the difference between *efficient* and *resilient*. Efficient systems are fine-tuned, specific and generally have high output. They are adapted to a very specialized set of conditions. Resilient systems are non-specialized, don't necessarily work at full output and are flexible. Resilient systems can use different types of fuel and can be adapted for varied uses.

Our current economic system depends on specialized factories and supply lines that can produce a constant supply of goods from fine tuned factories. They are efficient at generating money though economy of scale: large systems that are expensive and resource hungry but produce huge amounts of products constantly. This is how products become cheap in capitalism. A few workers can produce so much. At such a large output, companies can sell the product at a low price, and still make a profit. Unfortunately, if there is a decline in demand for the product or a general economic depression, these large scale factories or shipping docks, or giant farms are no longer profitable.

The problem with these huge efficient systems, is that they can't scale back or adapt. If suddenly there isn't such a large demand (like what happened during the 2008 recession) giant factories or docks, can't just work at a slower rate. A farm designed to produce 10,000 tons of corn a year can't just start producing 10 tons. It won't be profitable given how expensive it is to power such a huge operation. This is why we see giant malls closing down all over the United States. They are too big and costly to turn a profit when less people are shopping. Just running the air conditioners and cleaning the floors might cost more than the profit they are bringing in!

[3] For examples of this tendency look at telecommunications, water and railway infrastructure in the US.

Depending on supply lines that require exploited labor (often dependent on fragile government, corporate, and mercenary relationships), access to mines and factories, and continual supply of fossil fuels at profitable prices is the opposite of resilient. Any one of these factors can be disrupted because of political change, economic depressions, or just that the exploited workers decide to take a stand against the cruel systems they are forced to work under. This is exactly why we are advocating for *resilient* infrastructure. As harsh weather events, policy changes, and economic factors change our infrastructure will continue without interruption. Because we power our systems from the sun, the soil, wood or reclaimed materials, we can swap out parts made from homemade materials. When things are booming we can scale up, when things are slow, we can hunker down and continue producing food as needed. A bedrock of resilient infrastructure can be improved over time to become more efficient through expertise, locally adapted technology design, and a more intelligent understanding of our relationship to the soil, seeds, and ecosystem.

**“Progression of principles”**

We realize that the vision we are articulating, one where our infrastructure doesn’t depend on exploitation and can exist without the lifeline of industrial capitalism, is far from the reality we live in now. We rely on trucks to move materials around town, we use electric tools for our construction, we shop online for components for our off-grid systems that are made from petroleum products produced in exploitive ways. Instead of living in despair about this reality and either justifying our dependence on it or cynically embracing it as our right, we use a “progression of principles” to continually move closer to what we believe is right.

In practice, this means deciding what “living without exploitation” and “resiliency” means in concrete ways for different infrastructure in our gardens and then making steps to move toward that vision. To test the resiliency of our work, we ask ourselves “can we continue this work without industrial capitalism” or “can we still grow food if the power is out long term?” If you rely on tractors, plastic row cover, grow lights and electric pumps for water then the answer is no.[4]

Throughout the text, we will point out decisions we have made to minimize the negative impact of the infrastructure we use and propose ways we can continue to move closer toward our ideals. We believe resilient infrastructure is viable. In fact, it is possible that it will be the only way to meet our needs in the coming decades. What we are articulating will require less work than our current system if we consider all the hidden costs. An ecologically guided, need based economy is simple, but motivating people toward this change will not be easy.

[4] Not to mention coerced wage labor

**Off-Grid Garden Infrastructure:**

As a general principle at The Underground Center, our approach is to see how much we can grow by maximizing the health of the soil and developing smart ways to manage gardens. So far, we have been able to grow more food per square foot with many of our crops than an industrial farm can. Our approach encourages more people to grow food and utilize small spaces that they can manage with their own hands to create an abundance of food. This contrasts to the acres of cleared land being farmed with the help of machines and industrial products. We believe that by taking account of embodied energy, externalities and unaccounted labor, this will ultimately be less work to create more food.

With this in mind, the infrastructure we discuss in the following pages are meant to maintain that kind of growing space: gardens and small farms managed by a few people by hand. At most they will cover a few acres of land. We will explore fences, watering systems and greenhouses with this lens. These systems are all works in progress. We will discuss where we are in our journey and ideas of how to move closer to our principles. This text only looks at infrastructure to maintain the garden. We will be excluding the most important infrastructure, compost, which we already discussed in its own eBook “Compost: Foundation of a Nourishing Food System.” Also, in this text are not going to discuss other aspects of food production like wood fired stoves, solar dehydrators, solar cookers, root cellars or other infrastructure for cooking and preserving food.

**Off-grid farm in the forest**

## Fences

Where we do our gardening a fence or some kind of barrier is an absolute necessity. Deer are brutal foragers. We once built a gate that had a small opening on the bottom and a deer snuck in during the middle of the day. We were way from the garden for 20 minutes, but by the time we found the deer and chased it out, it had eaten a few hundred bean plants. If we were trying to survive off the land, that could have spelled our doom. Another ruthless garden pirate is the groundhog. These muscular beaver wannabes will rip up kale plants and eat them whole. Often, groundhogs will take a bite out of a tomato or squash but leave most of it to rot on the ground. The point is, our animal neighbors love garden produce at least as much as we do, so a fence is an unavoidable investment if you plan to grow food you want to eat.

**The dreaded groundhog**

Fences generally consist of **posts**, some **fencing material** and **gates**. Following are different ways we have approached combining these elements to make strong and attractive fences with a minimum of fossil fuel or money inputs

## Posts

All our methods of methods of building a fence start with strong posts. Eastern red cedar and black locust are our favorite tree species for posts, but white oak also works. Any pine and other local hardwoods rot quickly when they have contact with the ground. On two sites where we made gardens, the surrounding forest was full of standing dead cedar trees. Since they were dead, we didn't feel bad about cutting them down and they were still in strong condition because they were off the ground.

A commercial option is green metal posts with grooves designed to accept wire. These can be banged into the ground with a special tool or a sledgehammer. These tend to bend and twist if the soil has rocks in it. Also, it obviously does not fit our criteria of non-exploitive materials given its dependence on industrial processes, but if they are around, they work.

### Digging posts holes

A post hole digger is a great tool for digging uniform holes. Ideally, we like to dig holes 2 feet or more in the ground. Sometimes you hit rocks or other obstacles that make this impossible. We've gotten away with a 14 inch deep hole, but anything less than that will result in wobbly posts unless supported by some sort of external framing or rebar drilled into bedrock. We also use a heavy iron bar and a pickaxe to smash rocks out of the hole and loosen up soil for the post hole digger. A pair of loppers can come in handy if any roots protrude into the hole as you're digging. After the hole is clear to the bottom we drop in the post.

Setting posts is hard work. It is important to make sure the post is straight up and down. You can use a post level, but if your post has knots and bumps, it's not very useful. We usually work with a partner and have one person stand back to make sure it is straight to the eye.

Next is tamping. We use an iron bar or a heavy stick cut with a flat edge to tamp the soil around the post. It's important to tamp a few inches at a time. DON'T fill up the entire hole and then tamp. No amount of pounding will secure the post if you do this. Start with a few inches of dry dirt or gravel at a time and tamp down the soil, then add a few more inches and then repeat. The post will be solid if you follow this pattern. It will start to feel firm after ¼ of the hole is filled and tamped. If it isn't, then you need to pound more. It won't get firm if you keep adding on top of a loose bottom regardless of how long or how hard you tamp down the soil above. Don't rush tamping the initial 4 inches of material!

Alternate frequently with a partner so you don't get exhausted. By the end of setting posts for a fence, you will have very strong shoulders.

A well tamped 6 inch diameter post 2 or more feet in the ground is extremely strong. If you use a rot resistant post this will last many years.

<u>Common issues with tamping posts:</u>

If the dirt around the post is wet or muddy it is not possible to tamp down the soil properly. If you can't wait for it to dry, you can bring in gravel or dry soil to fill the hole. If you rush the tamping process of the first few inches (it takes longer than you think) the post will be loose no matter how deep you make the hole. As you are tamping there is a tendency to pound the post crooked. Make sure to keep checking by eye for level and correct as you go.

<u>Alternatives with fossil fuels</u>

The process of digging holes can be easier if you utilize an excavator or tractor equipped with a hydraulic post hole auger or a gas-powered post hole driller. As with any large-scale machine you need room to move around, likely destroying any small trees around your garden and compacting soil. It should also go without saying that this will add significant cost to your project, will create unpleasant noise for neighbors and will contribute to the perpetual stream of fumes into the atmosphere.

An alternative to tamping in the holes is to drill screws or nails perpendicular to the base of the post that will be underground. After that you can pour concrete into the void around the post. You will need about 100 pounds of concrete for each post. This will create a strong post quickly. The downside to this method is that you still need to haul these heavy bags of cement around. Our garden at Shagbark has 40 cedar fence posts. This would require 4000 pounds of cement! This would be a huge expense and have an environmental cost through embodied energy of creating cement. Also, when this post eventually breaks or you happen to want to change your fence lay out, you will have to dig out that mass of heavy concrete from the bottom of the post, load it in a truck and bring it to the dump.

**Fencing material**

**Wire fences**

The easiest material to use for fencing is some kind of metal wire. There are many different wire options. Utilizing wire is a good way to keep out pests without needing a lot of wood. As with any industrial product, there is always embedded energy cost. There is no "good" source of wire fencing. Whether you purchase it from the most evil big box store, or your local hardware store these products require problematic industrial infrastructure.

Wire does not last forever. The longest lasting wire costs a lot of money. This may make sense, especially if you are sure this is where you want your garden long term. Unfortunately, since we are always transforming our gardens and adding new sections, we have relied on cheaper solutions. Our logic is that over time, we can replace sections with wood fences, or natural fences. Also, we have been able to scavenge a good amount of wire that people have left over from other projects. One fence we made that surrounded a 2 acre farm utilized a mix of different types of wire that resulted in a an effective Hodge podge design.

Wire fencing can be an effective deterrent for burrowing pests like groundhogs. To stop them, you can make a trench 1 foot deep against the posts. Bury the fencing to the bottom of the trench and bury it with dirt or stone. When the animal tries to burrow under, they will hit the wire. You can also do this with a line of flat stones for a natural alternative.

Types of wire

Chicken wire- The cheapest option is 2-inch spaced chicken wire. This is not very strong and starts to rust after 5 years or so, but when applied to a strong frame, it works well. It also has the benefit of being nearly invisible. The 2-inch spacing won't keep out chipmunks or small rabbits, but we don't usually have a problem with those critters. 1-inch spaced chicken wire is better but costs more money. Both options work well as a trellis for any climbing plant like cucumbers, peas or pole beans that you can plant along the fence.

Welded wire- This is higher quality wire that has a longer life span than chicken wire but is more expensive. Welded wire can support itself more than chicken wire. It also works great as a trellis.

Tension wire- This is a type of wire that is used for cattle fencing. It relies on a tensioning tool and specialized hardware. It provides additional structure to the fence and can even be electrified. This will work for keeping out deer if closely spaced, but it needs an additional barrier like chicken wire along the bottom if you hope to keep out smaller pests.

Again, wire does not fit with our principles of moving away from exploitation, but it does work as we develop better solutions!

**Wooden fence**

An option to keep out large creatures is just making a wooden fence. This can be done by attaching boards or timbers perpendicular to the posts. The wood can be notched in (like old cattle fences) or nailed, screwed or lashed to the posts. We have used pine slab wood and small cedar trees for this purpose.

**An example of live edge wood used to make the structure of a fence. In this case the board is just used to provide a surface to staple chicken wire and stabilize the posts, but 2 or 3 more rows of boards could be added to make a fence that would last many years without metal wire.**

**Woven fence**

A woven or waddle fence is a beautiful technique to create a strong barrier. It consists of weaving thin branches or saplings in an alternating way around a post. The smaller the branches, the tighter the barrier.

Materials

A woven fence requires no store-bought materials (a few nails or screws here and there can help you cheat). To make a woven fence you need freshly harvested material, it must be very pliable. If it is dry or brittle it will break as you try to weave it. An overgrown forest is a great place to find crowded saplings. Ideally, a rot resistant material like locust or white oak are perfect for this task, but we rarely have the luxury of finding enough. No matter the rot resistant wood you use, long as the fence has time to dry in the sun, it will last many years before needing to be replaced. Weaving around posts creates a strong structure, superior to any wire mesh. This process can also be used to build the walls of homes!

The process of weaving a fence requires a lot of material. It is startling when you start clearing all the straight saplings from the woods. You realize the impact that building with wood has on the forest.[5] For this reason, we try to minimize the number of saplings we need for this technique. For most situations, only the bottom of a fence needs to be tightly woven to keep out rabbits, groundhogs and other smaller critters. To stop deer, you can space saplings more widely or use boards.

Another way to deal with the material demand of this method is a type of forest management called **coppicing**. Coppicing is the process of cutting hardwood trees when they are dormant during wintertime. In the spring, the tree puts out new shoots. Since we have not disturbed the root system, the tree quickly regenerates. Within a year you have thin canes useable for trellises or baskets. Within 3 years, you have lot of material for woven fences. In 5-10 years you have material for firewood or round wood timber framing. After that, you can select a single cane to grow into the trunk of the tree. In 15-40 years, you will have a large tree which can be cut again or left to grow. By staggering the trees that coppice you can have a continual supply of lumber for fuel, charcoal, compost and building materials. In this way, you can put a forest into production without needing to clear it. Simply take what you need and stay within the limits of the forest.

[5] We find this is an important experiential education opportunity. We would never gain this insight if we just ordered a truck load of saplings and had them delivered to our garden.

When you coppice a tree, you bring light into the forest which stimulates growth for other trees and plants. This type of land management creates a beautiful landscape that wildlife and people can both appreciate. Like most of the resilient technologies we advocate, sustainably using wood products requires more than supporting the most moral company or transitioning to renewable energy sources. If we want to create resilient wood infrastructure, we have to transform our relationship to the woods. By using the forest, we can start to gain insight of how our actions impact it. Overtime, through intelligent forest management practices, we will develop a nourishing relationship where we can remove a continual supply of wood from the forest, without destroying our source, or disrupting the ecosystem.

**Above: A 40 year old maple 2 year after it was coppiced. Because it was cut 5 feet above the ground, deer could not eat the new growth.**

**Right: A 40 year old maple the spring after it was coppiced. Deer grazed on the new growth (it has since recovered and flourished).**

**Moving closer to our principles**

In the future, we envision creating wood fences harvested from forests. The ultimate dream is to utilize pleaching to create a living fence. Pleaching is the process of weaving together living trees so they grow together in a desired shape. Hedge laying is another technique of partially cutting living trees and bending and interlocking them so they grow sideways. Over time they create a living barrier. We can combine these concepts by planting black locust and willow around the perimeter of our garden, and weaving their branches together, to create an impenetrable hedge. In addition to being functional, this would create a multigenerational living art piece! What a great opportunity to create nourishing culture with young folks.

Creating fences from a combination of the methods above works to keep out animals so we can grow our own food. As we piece together fences and our industrial products begin to rust away, we can replace those components with natural ones when we learn to better manage the resources in our community and become more skilled in these nourishing practices.

**Photos from Wikipedia: Left- a living willow fence, right- an example of hedge laying**

## Gates

When designing a fence, consider what kind of access you will need for your garden. We use wheelbarrows and garden carts when we garden, so we always make our gates at least 3 feet wide. In large gardens, we often include a tall and wide main gate that can accommodate a truck so we can drop large loads of woodchips, compost or lumber close to where we will use it.

Gates can be made with different materials and techniques. We've made gates using round wood timber framing, simple carpentry using 2x4's, woven gates, and reclaimed pallets. For the mechanisms to hang the door, we've used store bought hardware, reclaimed materials like string from a hay bale, or hand-crafted handles and hinges made of wood.[6]

Beautiful gates make all the difference for an otherwise boring fence. This is a great time to get creative!

[6] One gate hinge a friend made was from a stick shaped to a point resting in a depression carved out of wood. He then wove branches around this stick. The gate worked great and required no industrial hardware. The idea for this hinge was borrowed from a 3,500 year old gate from Hammurabi's time seen in a museum in turkey! There are all kinds of ideas we can borrow from the past. (See picture on page 13)

**This gate was constructed by our summer apprentices with round cedar logs. It was an example of roundwood timber framing where the gate is joined with notching and carved wooden pegs. It uses minimal hardware. The gate was mounted with a pintle and eye hinge which is ideal for round posts. The door can be lifted off if necessary. The gate has chicken wire stapled to it, but if we wanted, we could join more timbers or weave saplings to block critters from the garden.**

This simple gate was made from rough cut 2x4 lumber and screws. Regular door hinges with chicken wire stapled over the face. Square blocks were added to the round knobby post for an easier surface to attach hinges

A curved branch cut flat where it attaches to the board makes a beautiful and functional handle. The doorstop is a piece of live edge 1 inch pine to help fit a square door to an organic shape.

Two of our summer apprentices stapling and trimming chicken wire on the gate.

**Right: This was a large-scale gate created for a community garden as well as one of the easiest gates to build. This was made from large pallets. The hinges were simply repurposed string from a hay bale tied around the post. To open the door, you had to pivot the pallet on the corner close to the post. This gate was large enough to accommodate a truck.**

**This large gate was designed and created for another local community garden. It was cut from dimensional lumber. The pattern of the continually shrinking squares was based on the Fibonacci sequence. It was hung with pintle and eye hinges, a wooden handle and a hand-made wooden latch. It can accommodate a large truck.**

**This rustic gate was created by a friend this year for a neighbor participating in our community raised bed initiative. It shows what can be done with wood that would otherwise be discarded. The cedar slab wood pieces were joined to make a "saloon door" style gate. It was hung with a pintle and strap hinge and uses a horseshoe as a latch.**

**This large gate is the main entrance to our garden at Shagbark.**

**This gate was designed, built and installed by our apprentice Sasha Kay. It incorporates both round wood timber framing and woven saplings into the design.**

**She even managed to spell out "underground" on the top of the gate with flexible branches!**

## Water

Setting up a watering system is critical to ensuring you have healthy crops. Soil that is rich in organic matter, thick layers of mulch and smart garden bed design can maximize rainwater retention, but the ability to irrigate your garden will make the difference between stunted or flourishing plants. Unfortunately, setting up a conventional water system with a well or city water access is expensive, requires specialized maintenance and depends on lots of electricity.

Water without electricity or gas pumps is not something we see often in agriculture. Any water tap or spigot that a hose attaches to usually relies on an electric pump that pulls the water up to the tap and creates water pressure. With this system, if there is no electricity, there is no water! Also, well pumps are generally one of the biggest users of electricity in a home.[7]

This makes conventional water infrastructure very vulnerable. Aside from the major expense of digging a well and providing constant electric to a pump, there is always the chance of short term and long-term power outages that can stop you from being able to water your crops. These conventional systems do not meet our requirement for resilient infrastructure!

### Off-Grid Watering

Resilient water systems are a major focus of research at The Underground Center so we can have gravity fed systems for collecting and distributing water in our gardens. By eliminating the need for electricity, we are cutting costs and removing our dependence on fragile, harmful energy systems. In addition to collecting water for irrigating gardens, with proper filtration these systems can also be used for drinking, washing and cooking.

Learning from people in societies who don't rely on industrial systems is a great way to design off-grid water sources. We have a terrible habit in industrial societies to dismiss anyone who does not rely on modern infrastructure as "backwards". This is not always the case! Simple systems don't necessarily mean inferior. When Chase visited Haiti in 2009, he was impressed with all the water tanks he saw on roof tops. Electricity in Leogane was limited to certain hours in the day so communities took advantage of that time to pump water up to the roof. When the electricity was out, they still had water through gravity pressure. There was no interruption when the power went out. This is not backwards, this is smart! We should do this even though we "don't have to" in the US. This would minimize our electric use and prepare us for when electric is not available, unlike our current system in the U.S. where we rely on convenience so much that we design systems destined to fail.

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[7] When you search online for information on electricity use in a home, well pumps often don't appear on the list. This confirms the idea that we don't even consider these systems as part of the "home" and instead assume water just appears in our taps.

**Natural water sources**

One way we have watered our gardens in the past is with streams or ponds near the garden. The simplest way to do this is using a 5 gallon bucket to scoop up water and walk it over to your garden. If the garden is far away, you can use a wheelbarrow or garden cart. From this source you can use a smaller container or watering can to apply it to the plants. Don't water directly with the 5 gallon bucket or you will create a deluge that will wash away the soil around the plant's roots.

A more convenient way to get water from a stream is from a pump or a siphon effect. If the stream is at a higher elevation than the garden, you can draw water from it without needing electricity. If it has to go over a hill before it drops down to the garden, you may need to use a hand pump or electric or gas pump to "prime" the hose. Once it starts flowing, you can turn it off and it will draw water until it gets an air bubble in the hose. We used this concept to fill a 275 gallon tank, from there we connected a hose and watered the plants.

An even more sustainable system is a Hydraulic Ram pump that uses gravity pressure from a running stream to pump water up hill. It is totally mechanical and does not need any electricity. There are great resources to build one from scratch if you search online. Researching pre-industrial methods of irrigation is inspiring. There are lots of ingenious ways to get water from streams, ponds, or cisterns into gardens without electricity. We will continue to experiment with these technologies and improve our systems.

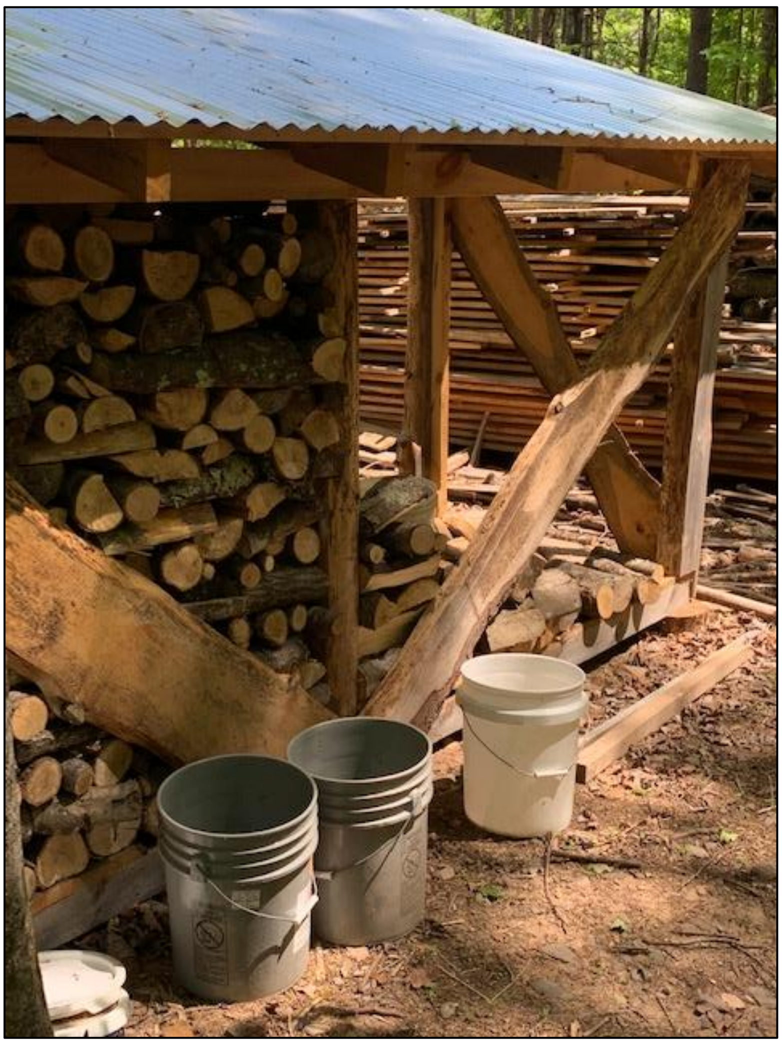
**<u>Rain Catch</u>**

Infrastructure to collect rainwater is one of the most important transitions we should be making in our communities. Aside from the cost of electric and the expense of labor to dig wells and piping, capturing water from our roofs takes pressure off our sewers and streams. The runoff from roofs carry deluges of water, washing away topsoil and leaching out precious nutrients for plants. It also carries whatever garbage and chemicals happen to be on the ground into water ways. In our town that means weed killer, fertilizer, antifreeze, petroleum products, plastics and who knows what else.

Rain catches are perfect for watering gardens. They can tie in perfectly to gravity fed watering systems and can be used for bathing, cooking and drinking water with simple filtration steps. With some cultural changes, these systems could be adopted with very little effort into existing houses. During a natural disaster or other emergency, these simple systems can provide us with water and allow us to continue to water our gardens. Everyone should have a rain catch![8]

**Rain collection**

A rain catch can be simple. The easiest way to get water from the rain is to put a bucket under the dripline of a structure like a house or shed. The roof directs water to the eves of the roof. If you line the entire edge with buckets, you can capture all the water that runs off the roof. The amount of water you can collect during a rainstorm depends on the size (surface area) of the roof and the amount of rain that falls.



We take advantage of the roofline of our firewood storage to collect water to clean compost buckets and keep our compost bin moist. At one point, we had had 12 five-gallon buckets under the dripline. After a small storm, they all overflowed which resulted in 60 gallons of water! This method works.

The downside to this is that you have to haul the buckets, which weigh 40 pounds when full. It's also hard to move them without spilling out water. Another issue is that open buckets of water are breeding ground for mosquitoes. If you are using this water frequently this shouldn't be a problem. Another solution to spillage and mosquitoes is to place a lid over the buckets when they are full.

[8] To explore how to use rainwater more in depth read the information from the "center for rainwater harvesting" web page on the reference page of this document.

A more refined rain catch adds a gutter to the drip edge of the roof to direct all the water to a collection tank. This basic system can be upgraded for filtration, distribution, automatic watering, etc. The system we use at Shagbark garden consists of a **gutter**, a **debris filter**, a **first flush diverter,** and a **collection tank**. From there we can fill watering sites throughout the property.

Gutter: These can be store bought or made of any curved material. The gutter doesn't actually need to be at the height of the roof-edge it just needs to be somewhere on the drip line. It's important to have the gutter pitched slightly toward your tank. We have found that lots of people throw out perfectly good gutters when they renovate their roofs. So reclaimed options are often available.

Debris filter: Roofs collect lots of debris that we don't want in our water tanks. For this reason, it's always good to have some kind of screen to keep out large particles like leaves, pine needles, bugs and sticks. These can be homemade or bought commercially. It is important to check your gutter and filter periodically. One time we had a long drought and desperately needed to fill our tanks. After a storm, we checked one of our rain catches and found that we got 20 gallons. Our other rain catch that had a similarly sized roof collected 150 gallons! We realized that the filter was clogged with leaves and other debris so most of the water ran off and didn't go into the tank. Keep your filters clean!

There are lots of commercial rain filters that connect to gutters or to the pipe that goes into the tank. A homemade filter made from a fine screen mounted to a box at a steep angle works well.

First flush diverter: This is an ingenious design component that will keep your water from getting funky. Between storms, roofs will collect pollen, bird poop, and other small debris. This small particulate will flow right through a fine mesh filter and end up in your tank. Over time the water will become discolored and smell foul. To avoid this you can install a first flush diverter which takes a predetermined amount of water based on the square footage of the roof and diverts it from your tank, essentially washing the roof before collecting the water that runs off it.

There are many ways to divert a specific amount of water from your tank. Commercial options rely on a floating ball inside a pipe. After the pipe fills with the first flush of dirty water the ball floats to the top and "caps off" the pipe. The now clean water then flows into the tank. A small hole at the bottom of the dirty water pipe allows water to slowly empty out of the diverter between storms. Otherwise you can add a valve and do it manually. The diameter and length of the pipe controls how much water is "flushed" before entering the tank.

There are other clever ways to make flush diverters on your own. The internet has some great DIY options. Over the coming years, we plan on working with our interns to design a DIY first flush diverter that is appropriate for our area made from commonly found materials.

Collection tank: Make sure to have a big enough tank connected to the rain catch to capture the water from a large storm. Our shed, which has 180 square feet of roofing, will collect over 100 gallons during a storm that drops an inch of rain. If you are collecting off the roof of a house, the amount of water from the same size storm will give you over a few thousand gallons of water! If you have a large enough collection tank, it can also serve as your storage tank. If you are connecting this to a pressurized system, or have your tank located on a very high spot, this makes sense, otherwise we suggest having multiple storage tanks.

A good source for collection tanks is reclaimed transportation tanks for food grade liquids. We have acquired tanks for relatively cheap or free that had olive oil, guava syrup, and food grade chemicals used in soda. The 275 gallon totes (pictured below) are a great option because they already have a built in valve which makes it easy to connect hoses and other fittings. Another possibility is connecting multiple 55 gallon drums together to make one large tank. You can also invest in a large potable water tank (see pg. 28), just keep in mind that those tanks can be expensive.

**A homemade gutter made from fiberglass roofing, and a makeshift filter and first flush diverter. Notice how the gutter is several feet from the edge of the roof. This design doesn't use any pipes to collect the water.**

**A commercial gutter, filter and first flush diverter. This is relatively inexpensive and should last a long time.**

**It's important to have a strong base to support your collection tank. Water weighs 8 pounds per gallon so this 275 gallon tank will weigh 2,200 pounds when its full! It's also good to have your collection tank high off the ground. This way you will be able to fill any water tank that is lower anywhere in the garden.**

**This tank will eventually have a box around it to shade it from UV rays and make it match the design of the building it's next to.**

Keeping tanks clean: One way we keep tanks clean (as well as hoses and the water that runs through them) is by having a valve a few inches above the bottom of the tank. This allows sediment and pollutants like heavy metals to accumulate on the bottom. Since the outlet to the tank is not at the bottom the sediment wont flow out when you water. Periodically you can empty the entire tank and remove any gunk that might accumulate on the bottom.[9]

Another way to keep tanks clean is making sure the water doesn't get direct sun exposure. If you have a clear water tank (like the 275 gallon tote above) it's important to keep sun from hitting it or else it will grow algae. Although this isn't harmful, it will look gross and gunk up your hoses. To avoid this, you can buy tanks that are opaque, or you can build a box or some other kind of barrier to block the UV rays of the sun from the tank.

[9] If the water is meant for drinking, it can go through a filter consisting of gravel, sand, and charcoal for potable water. Rainwater is clean when it falls from the sky (even acid rain is not harmful to drink) but when it falls on the roof and gutters, it accumulates things we don't want to ingest! After the debris filter, first flush diverter, elevated outlet, and charcoal filtration it will be potable.

**Storage and Distribution**

The next piece of off-grid watering infrastructure is a system for storage and distribution. When building your storage and distribution systems there are multiple design elements to consider.

The first consideration is how much water you need for your garden. We aren't used to *seeing* how much water we go through when we irrigate our crops. It is sobering to see a 55 gallon drum of water disappear in 30 minutes when you're watering the garden. Irrigating with limited rainwater has taught us that we need lots of water stored to keep our plants healthy. Unless you have a small garden you will need additional storage on top of the initial collection tank on your rain catch.

It's also important to consider periods with no rain. Over the last two years we had droughts that lasted many weeks. We prepare for this by having a large collection tank connected to the rain catch and multiple storage tanks distributed throughout the garden.


**This is a 550 gallon water tank. It is food grade and has connections for various valve options. It also has a large top that can give you access to clean the tank. Note how the exit valve is a few inches above the bottom. This allows any sediment, heavy metals, or other debris to settle to the bottom so the cleanest water can be pumped out.**

This box keeps out the UV rays from the 2 clear tanks. It also adds almost 2 feet of elevation to the bottom of the tank. Since the box is on a hill, we can level the box out by having the back legs shorter than the front. We can also include a filtration system within this box if we wanted to use it for cooking or drinking purposes. The box has a roof so it can catch water. (we use the roof runoff for cleaning compost buckets).

With all the tanks full this box weighs over 4,500 pounds. To make sure the support was strong enough we built a very strong white oak and black locust timber frame base. This is overkill, but better safe than sorry!

Alternatively, you can place your tank inside a building. One idea we have is to build a two-story barn. On the second floor we can have a large collection tank that is filled from the roof. This will provide some water pressure from the height (a barn on a hill could get you 15-25 psi) and protect the water from sun rays. If the barn is insulated and heated, it would keep it safe from freezing in the winter.

If you are lucky enough to have a hill overlooking the garden, you can dig into the hill and make an underground structure to store a water tank. This will keep it out of the sun, give you the advantage of some water pressure and protect it from freezing temperatures. For gardening, you rarely need water in the winter, so this is only necessary if you have a greenhouse or use rainwater for other purposes.

**Gravity pressure**

Watering with gravity pressure, vs a mechanically pressurized system takes some getting used to. Water flowing just from gravity can be very slow if your design is not right. To make an effective gravity fed system you have to understand the difference between *water pressure* (PSI: pressure per square inch) and *flow rate* (GPM: gallons per minute). Without getting too technical, it is hard to achieve the high pressure we are used to in conventional plumbing with gravity pressure.  The only way increase pressure is to have your tank higher in the air. To get 40 psi (which is common in a house faucet) the tank would have to be over 100 feet in the air. Since giant water towers aren’t feasible in our gardens, we can’t get those kinds of pressure levels without a pump.

What we can control more easily is flow rate. We do this by using hose with large diameter and big valves. This allows water to flower quickly out of the tank. Also, with gravity pressure, longer hoses tend to slow down the flow rate, so we like to have multiple tanks around the garden with shorter hoses.

Watering cans also work well! If you have a source of water that fills up the can quickly and is close by, this can be a convenient way to water. This can certainly become tedious if you have large garden. With a pressurized water hose, you can stand in one spot and spray the entire garden, but with a gravity pressure system you have to water each plant individually. By breaking up the garden into sections or “zones” you can make a schedule to water different parts each day. Since we always mulch our gardens and focus on building healthy soil, the beds retain water, so we don’t water every day. Unless the weather is extremely hot, we usually only water once a week and only if it doesn’t rain.

This is a system we set up around our garden at shagbark. These are 55 gallon drums (which are relatively easy to come by). They have 2 holes in them already, so we can attach a valve at the bottom with a garden hose attachment. The top hole has a pipe to let in air to allow the water to flow. (attach a screen to the hole so bugs don't move into the tank).

Because we have stumps scattered around the garden from clearing, we can place the tanks on them. We put two wooden "chucks" on the stump so the tank doesn't roll over. This gives us some height, allowing us to water any beds in the garden.

The spigot at the bottom of the tank is a few inches above the bottom to allow sediment to fall to the bottom.

The spigot is multi purpose. It can be used to attach to our collection tank for easy filling. Every time we have a big storm, we drain our large collection tank on the rain catch into our storage tanks in the garden freeing up catchment space. The spigot can be used to fill a watering can or 5 gallon bucket. It can also be used to wash dirt of your hands, or wet mulch before applying.

Because we have a garden hose adapter, we can attach a hose to water the gardens. Since they are placed throughout the garden, we don't need long hoses that can drag across garden beds, damaging plants. In the future we plan on attaching these to an automated watering system.

Another benefit of these storage tanks is that in a pinch you can fill them from an alternative source. When we first set up the garden at shagbark, we didn't have a rain catch set up. We had to bring in a 275-gallon water tank filled at a friend's well in a truck. With a lot of these tanks set up, we were able to fill them and have water available during droughts. This type of flexible system makes your irrigation more resilient. There are multiple ways to use it and, in a pinch, you can take a few hours to fill it up from a neighbor's well or a nearby stream and still have a convenient watering system.  A conventional electric powered well pump or municipal watering system will become completely useless if one mechanical part fails or the electric is out. Not smart.

**Upgrading your system for convenience**

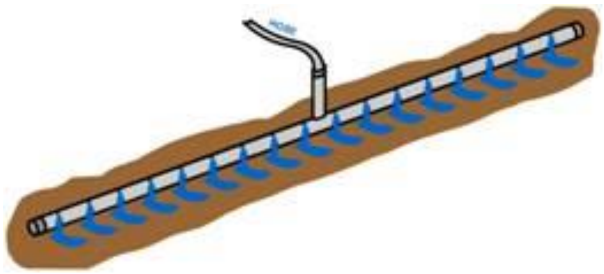
If you want to have water pressure with an off-grid system you can add a 12 volt pump to give it pressure or pump it to an elevated spot. These are powered by 12 volt batteries. At Shagbark we have solar electric that powers 12volt deep cycle batteries. Below is an example of a small 12 volt pump to add pressure. (this is actually for an outdoor shower, but it can be used for watering). This could be connected to a timer and a drip irrigation system for a very efficient and resource saving method.

**A storage tank with a garden hose adapter, an inline screen filter, a drinking water adapter and a 12 volt pump for added pressure.**

**Drip irrigation**

A great way to make watering more convenient and to save on resources is to utilize drip irrigation. This slowly releases water under your mulch, directly to the plants keeping the soil moist at all times. Drip irrigation with gravity fed water can be complicated because of the low pressure. We once tried just drilling a bunch of holes in a garden hose to make a homemade “soaker hose.” What we discovered is that without high water pressure, the water will drip out of the holes closer to the water tank before it gets to the end of the hose leaving that part of the garden bed dry.

To address this, you can buy special emitters and piping that are designed especially for gravity fed irrigation to have consistent water through the whole line. This is costly and it isn't clear if the imbedded energy in creating the hardware outweighs the benefit of energy savings.



An easy alternative is to attach your gravity line to a short pipe with many holes. This pipe can be laid down the middle of your garden bed. In theory this could also be made from wood or ceramic.

**Picture from thecenterforrainwaterharvesting.com**

In the future, we plan to connect our existing watering stations to a homemade drip irrigation system. Because each bed will need its own piping system, this will be a big material and labor investment. We don't plan on doing this until we are sure we have finalized our garden design. Another possibility is picking certain beds to do this and building irrigation systems directly into our future raised beds.

**Getting closer to our principles:**

Some of the weak points in our current off-grid watering system are industrial gutters, hoses, valves and holding tanks. We can reclaim lots of these while being careful about toxic contaminants from lead hoses or we can buy high quality components that will last a long time. Ultimately though, we hope to replace industrial materials with local sustainable industry on various scales, from homestead production to small local factories.

Wooden pipes and gutters have historical precedent. Our friend Camden acquired a bunch of small logs that were converted into hollow pipes that interlocked from a demonstration at a local fair. Our friend Jimmy uses bamboo cut in half for his gutters and they have been functioning for over a decade. Replacing hoses with wooden sleuths or aqueducts is a possibility, but like many natural solutions, this requires more permanent set ups.

Wooden holding tanks were the norm until less than 100 years ago. New York City still relies on Wooden 10,000 gallon tanks on top of buildings above 6 stories. These are more efficient and resistant to the elements than concrete or steel. Coopering, (the profession of making wooden barrels) was a huge industry in Saugerties and lots of other places until the early 20th century. We could bring that back! There is also potential for ceramic cisterns and jugs for storing and distributing water. Figuring out how to fire ceramic without using lots of wood fuel is an obstacle we need to figure out to make this option viable.

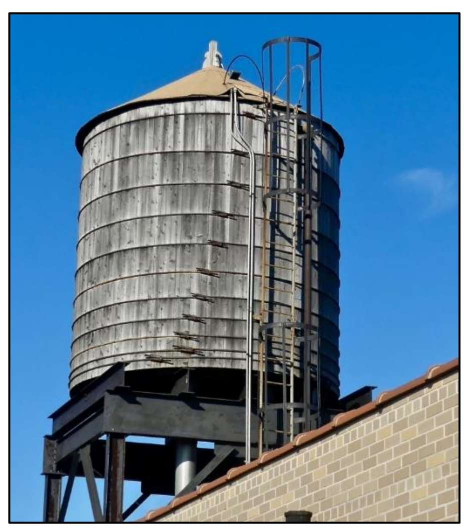


**Photo from newyorkitus.com**

## Greenhouses and other season extenders

In our area, we have a limited amount of time to plant seeds before we get hit with a frost. A greenhouse is a great way to get a head start extending the growing season. Also, by starting seedlings, you can have a more diverse diet. Lots of vegetables we love to eat during the summer need to be started early. Tomatoes, peppers, eggplants, watermelon, and cantaloupe require an early start, and by starting cold tolerant crops indoors we can be eating much earlier in the season. Some crops like onions would be very small if we didn't start them indoors, giving them more time to grow in our relatively short season.

Seedlings are another part of gardening that people often take for granted. They just head over to a local nursery and pick up seedlings for a reasonable price. A lot of energy and labor goes into the potting soil, heating of a greenhouse and/or grow lights, watering, and equipment. Finally, growing our own seedlings saves a lot of water and other precious resources.[10]

### Simple structures to extend the season

There are a lot of options for extending the season depending on your goals. One option is to dig a pit in the ground a few feet down and cover it at night with a blanket or a mat. Before windows were produced on an industrial scale, a popular technique for extending the growing season for fruit trees and other plants was called a "fruit wall." This was a stone wall facing the sun. The thermal mass was heated from the sun creating a warmer microclimate around the crops. Entire areas were enclosed in this way increasing the temperature as much as 20 degrees. The first greenhouses were likely just windows propped against these walls to extend the growing season even further. This concept can be integrated into a modern garden or against an existing home.

**This is an example of a heated fruit wall from the 18th century. It has horizontal chimney flues to add even more heat to the wall. Designs of fruit walls became very complex to increase sun exposure and thermal mass before the advent of easily produced glass**

**Photo from lowtechmagazine.com**

[10] For more information about the benefits of starting seedlings check out our eBook "How to Plant a Subsistence Garden".

**Seedlings**

Starting seedlings helps extend your growing season and diversify your diet. To start seedlings you need to have trays for holding soil. Seedling trays should be 3-4 inches deep (they can be less for individual seedlings). They also need to have some sort of drainage so that water doesn't pool up and drown the roots. We like making seedling trays (also known as flats) out of eastern red cedar since it is rot resistant and abundant in our area (pine would work fine). We also reuse aluminum trays because they go through a lot of them at The Boys & Girls club. Sturdy plastic cups also work for individual plants. They require a lot of soil, but their size means you don't have to transplant the seedlings into a bigger container as they grow.

**Seedling flat made from ¾ inch cedar boards. We leave a small gap between the boards on the bottom to let excess water drain out. These trays can be heavy when they are full of soil, but they are sturdy and long lasting.**

**Combination of homemade and reclaimed seedling trays. The aluminum trays have holes poked in the bottom. They have to be moved with care because they can bend and disturb the roots in the soil.**

**Seed starting soil**

A lot of commercial growers use special sterilized soil for starting seedlings. This potting mix is usually expensive. We find this cost is unnecessary. From our experience, well broken down and sifted compost works great for starting seedlings. This can be mixed 50/50 with nice soil from the garden. Compost alone works well as long as it isn't "hot." For more info on making high quality compost check out our "Compost: foundation of a nourishing infrastructure" eBook.

**Cold frame**

A simple structure to start seedlings is a cold frame. Cold frames rely on glass or clear plastic to generate heat from the sun. This heating is known as "solar gain."

**This simple portable cold frame was built with 2x4's nailed at a 90-degree angle and 2x2's to connect the frame.**

**Reclaimed 6 mil plastic sheeting was stapled to the sides and top with a long board stapled to the plastic at the bottom of the frame to keep it from blowing up in the wind.**

**Both sides of the cold frame can be opened for ventilation and access for watering. If it gets too hot, the opaque plastic helps give it some shade. We shoveled some woodchips on the sides to minimize cold air penetration at night.**

A cold frame can also be used to protect hardy plants from hard frosts. This extends the growing season by letting you get plants in earlier in the spring or keeping plants alive into the late fall. Some crops like Kale or swiss chard can survive through the entire winter if they are protected by a cold frame.

**A cold frame can be built over an existing bed. A design like this can incorporate an old window or glass door. When the weather warms up, the window can be removed.**

**Photo from doorgarden.com**

**Hot house**

The benefits from thermal mass or solar gain can only take us so far. At a certain point without a heat source, frost sensitive plants will die during freezing nights. Back in the days when horses were used for transportation and farming, there was lots of manure laying around. A biproduct of decomposing manure is heat. Farmers realized they could keep their greenhouses warm during winter and early spring and came up with hot houses. Basically, a thick bed of hot (fresh) manure, possibly mixed with weeds or hay, was placed at the bottom of a box. A cold frame was built on top of that box and the heat from the decomposing manure kept seedlings warm through freezing nights. Some more complicated designs used pipes with water running through the manure into a growing bed to transfer heat into the soil.

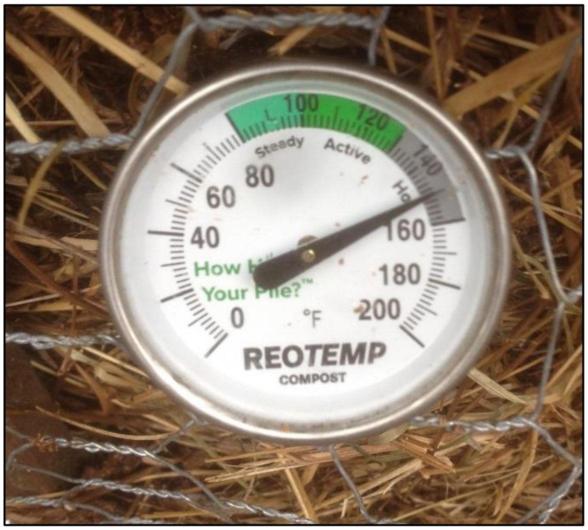
With the advent of gas powered cars and tractors, horses and their manure were less common. It became harder to get cheap manure. Also, low cost electricity made it easier to use light bulbs to generate heat in a similar way, creating electric hot houses. The heat generated by decomposition was no longer needed.

At Shagbark, we revived this practice. Since we don't have draft horses, or other farm animals, we relied on compost. We noticed our large compost bins (consisting of leaves, weeds, coffee grounds, food scraps, sawdust, and mushroom straw) reach sustained temperatures of 120-140 degrees. We decided to try to create a hot compost bin specifically for growing seedlings. Utilizing a two-week supply of our friends Lala and Jared's restaurant food scrap run, we were able to fill a large compost bin with a perfect mix of carbon and nitrogen rich materials.[11]

**The 4 feet wide by 6 feet long by 3 feet tall bin reached high temperatures in less than a week. We used meat and vegetable food scraps, mushroom straw, leaves, aged compost, and hay in alternating layers. We topped off the soil with 8 inches of hay to make sure we didn't attract flies and it didn't give off a bad smell. This worked perfectly as a smell and pest deterrent.**

[11] For more info on how to reach high temperatures with compost check out our eBook "Compost: Foundation of a Nourishing Food System"

**We made a "hoop house" with bent saplings, string from a hay bale, and clear plastic on top of the bin. On top of the hay, we placed seedling trays.**




**The high temperature inside the compost bin leveled off to about 125 degrees after 2 weeks. The temperature inside the hoop house stayed in the low 70's even during freezing nights. We were able to grow a few hundred seedlings in this small area without needing fossil fuels to keep it heated.**

**This concept has a lot of potential for keeping seedlings warm, heating water, or even heating a living space. After three months, the compost was mostly broken down and repurposed into a few mounds to grow corn, beans and squash.**

**Stand alone greenhouse**

A simple greenhouse can be made from reclaimed windows and will extend the growing season, but as a larger structure, it is harder to keep warm. Our friend Brian has had success with a small greenhouse by covering the bottom with old hay bales to limit air infiltration. During this mild spring, his seedlings didn't freeze at night and he was able to produce a lot of seedlings. In a colder year (which is more normal locally) the seedlings would die if temperatures dropped below freezing without an external heat source like a woodstove, electric or gas heater.

**Old windows and glass doors are easy to come by for a material scavenger. People are always getting rid of them. With some basic carpentry skills you can put together a simple, but attractive greenhouse to start lots of seedlings. A structure like this can also integrate a rain catch for watering seedlings.**

**Photo from offgridworld.com**

A more sustainable (but labor intensive) method of heating is to use earth tubes. These are tubes buried 6-10 feet underground that have one end in the greenhouse and another open to the air. Ideally the tubes go a length of at least 100 feet. Air is pulled into the greenhouse through the underground ventilation tubes with a fan or a vent stack. As the air travels the 100 feet underground, it is warmed (or cooled) to the temperature of the ground (around 55 degrees in our area). Variations of this concept can be used to both heat or cool a space by relying on the thermal mass of the earth.

Digging deep trenches at such long lengths takes a lot of effort and cost. This system is most efficient if it is integrated into an insulated structure and it must be carefully designed to avoid condensation and mold in the underground tubes. There are lots of examples online of failed attempts at using earth tubes. On the other hand, there are examples of greenhouses that incorporate this technology successfully that grow tropical fruit trees all year round in cold northern climates! We plan on integrating a system like this into our underground stone structure to improve ventilation and address moisture in the humid summer months.

## Taking advantage of existing heated structures

Another way to heat a greenhouse is to use an existing heat source. The simplest way to do this is to grow seedlings in a south facing window in your home. If you don't have that, you can put your seedlings outside when the temperature is warm and sunny and take them inside at night. If the temperatures are too low, you can put them in a cold frame during the day and put them in the safety of your warm home at night. This requires some babysitting as temperatures can drop quickly during the early spring, so this is not hands-off work.

### Greenhouse on wheels

A more convenient way of moving seedlings in and out is creating a greenhouse on wheels. During the day, you can wheel them out into the sun to take advantage of solar gain and at night bring them into a warm spot indoors. This is a great way to have growing space without building a large heated greenhouse. Obviously, this can only work if you have space in your home to accommodate the mobile greenhouse. Our friend Jessica has a beautiful greenhouse on wheels that has supplied the UGC with hundreds of seedlings over the last few years for fundraisers, seedling giveaways and for planting in the many gardens we assist with. This is in addition to supplying her own initiatives with local schools and community members. This small piece of infrastructure can produce thousands of seedlings in a growing season!

**This greenhouse is built on a small trailer that is easily moved by hand. The window panes can be opened for ventilation. Jessica pulls this greenhouse into her garage at night. The garage has a backup heat source that ensures it won't freeze. This could be built smaller to fit in a front door if someone doesn't have a garage or heated outdoor building.**

**Greenhouse attached to a heated structure**

Another method to take advantage of existing heat sources is a greenhouse attached to a home. If you are able to modify the home you live in and have a south facing wall, you can build a greenhouse. This can be a box over one or two windows, or an entire addition onto the home.

**Photo from mysanantonio.com**

What is great about this design is that it creates a reciprocal relationship between the house and the greenhouse. During the day, the solar gain from the greenhouse will create heat from the sun, which can help heat the home. At night, the hot air from the house can circulate into the greenhouse keeping it above freezing. This should be a requirement in all inhabited buildings! This would massively reduce energy use.

When building an attached greenhouse, make sure to design for potential moisture by having good ventilation and using building materials that can handle wetness. The ideal attached greenhouse has high and low vents to allow cold air in from the bottom and hot out through the top to create circulation and the reciprocal heat exchange between the house and the greenhouse.

Our friends Lala and Jared build a greenhouse similar to the one pictured above from reclaimed windows and glass doors. They have a window that looks out to the greenhouse from their kitchen where they built an additional box for starting seeds and greens when it is still too cold to start seeds in the greenhouse. This piece of infrastructure supplies many, many gardens with seedlings throughout the community!

**Getting closer to our principles: Underground greenhouse**

In the near future, we plan on incorporating many of the principles of greenhouse design into one structure. Thermal mass, solar gain, earth tube ventilation, reciprocal relationship between greenhouse and a heated structure. The greenhouse will be partly underground with the south facing wall made mostly of glass (large reclaimed thermal pane windows) and the north and east facing wall will be buried within a hill. The roof will be covered with a foot of soil. The structure will have an efficient wood burning stove to heat the space, cook and heat water.

**An underground structure we built that does not freeze during the coldest nights. By incorporating principles of greenhouse design in a similar space we can grow food and collect and store water without fossil fuels.**

This structure will have the benefit of not freezing during winter. We can incorporate a rain catch, year-round water storage, a root cellar to store food and possibly a living space. Since this greenhouse will be on a hill, we will be able to fill storage tanks throughout the garden for irrigation. Multi use structures like this are a great way to reduce energy use and transform marginal land into productive spaces.

## What the future can look like

This discussion of small-scale resilient infrastructure is just the beginning when it comes to developing a more nourishing way of meeting our needs. We need to develop new images of a Eutopian[12] society and possible futures.  A pathological obsession with "progress" creates a stunted image of what a sustainable future looks like. We either imagine a high tech, sleek plastic and metal, robot driven society or a "backwards" one where we give up all comforts and live a life of horrendous toil.

The "Star Trek" future that many technophiles dream of doesn't seem viable given our stubborn inaction on climate change and our reliance on profit driven corporations to lead infrastructural change. There is no real profit incentive to make a better society for all. To us, this doesn't mean the alternative of dystopian primitivism is our only option.[13] By creating local industry, tied directly to the systems that sustain us and powered by cooperation, we can develop labor saving technology without polluting, destroying ecosystems and demoralizing our people with exploitation. This industry can exist on various scales from the home, to neighborhood production, to small scale factories.

Figuring out ways to create the tools we need within a social and ecologically nourishing framework is possible. Schools that educate people in ecology, engineering, sociology and economics at the same time can exist. Workshops that develop winches, carts, levers, pipes, pumps, glass, water mills, windmills, lighting, heating and smelting devices without a permanent underclass of workers or a devastated ecosystem are possible! This balancing act has not existed in any consistent way since settlers colonized this land, but that doesn't mean it can't. This is the work we hope to pursue in our communities over the coming decades.

For more information, clarification, suggestions or assistance in designing off-grid garden infrastructure contact us at: **Info@theundergroundcenter.org**

[12] This is not a typo, we prefer this spelling to describe a place of ideal wellbeing. Taken literally, Utopia means "no place;" an unattainable reality. Eutopia means "good place;" something we hope to achieve in our lifetimes!
[13] Make no mistake, without immediate radical change, dystopian primitivism will be our only option. Mad Max will become prophecy instead of social commentary!

## Resources and References

Most of the information in this text is from a decade of firsthand experience building off-grid infrastructure on gardens and farms. Trial and error have taught us a lot of what works and what does not. As for the science, statistics, and history in this text, we referenced the following books, articles and websites.


**Books**:

*Moneyless Man* by Mark Boyle

* A manifesto and biography of a person who lived without money for a year. Lays out his concept of "progression of principles" to move toward ideals that seem radical from our current norms.

*Five acres and independence* by M. G Kains

*An in-depth manual of small-scale farming written during the great depression. Although some information is outdated, most is not. Kains was an authority of faming at his time with many years of experience working the land. He also includes studies and cool drawings from the USDA.

*The Woodland Way* by Ben Law

* A Detailed account of the techniques and lifestyle of someone who's livelihood comes from managing forest. The book gives great examples of coppicing and how coppiced trees can be used in sustainable local industry.

*Earth sheltered solar greenhouse book* by Mark Oehler

*An older book that holds up with time. The author follows principles of thrift and using natural and reclaimed materials to create a greenhouse that does not require fossil fuels

*The Year-Round Solar Greenhouse: How to Design and Build a Net-Zero Energy Greenhouse* by Lindsey Schiller and Marc Plinke

* Examples of greenhouses that use solar energy and other off-grid techniques to grow food and seedlings. The book has designs of various scales and lays out principles that can apply to lots of applications.

*Images of America: Saugerties* by Edward Poll and Karlyn Knaust Elia

*a photographic history of Saugerties. Contains images of Saugerties' early farming history.

*The World in 2050: Four Forces Shaping Civilization's Northern Future* by Laurence C. Smith

*A conservative prediction of where the world will be in 30 years based on forces of globalization, climate change, demographic shifts, and natural resource demand. Although the projections do not consider cataclysmic scenarios, it is still a sobering prediction!

**Articles:**

*Fundamentals of energy analysis for crop production agriculture* by Seyed Hashem Mousavi-Avval, Ashish Manandhar, and Ajay Shah

*Detailed analysis of embodied energy in agriculture on various scales. The authors develop a standardized methodology for measuring embodied energy and look at a range of farming styles from no-till, gravity fed irrigation to large scale fully industrial systems.

**Web resources:**

http://www.thecenterforrainwaterharvesting.org/index.htm

*thoroughly researched website that explores the pros and cons of different rainwater uses. Includes scientific studies, potential contamination, tank size consideration, roofing material etc.

https://www.lowtechmagazine.com/2015/12/fruit-walls-urban-farming.html

*Low tech magazine is a resource for information on pre-fossil fuel technologies. The site includes insightful articles of how these technologies can be applied to a possible postindustrial future.