# Using Compost as a Heat Source for Growing Seedlings on Hot Beds and in Greenhouses

Grow your own seedlings in winter using compost as your heat source!

Learn how to use compost heating as a simple, reliable, and sustainable alternative to fossil fuels.

Click here to view our YouTube videos that accompany this guide.

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## Introduction

In February 2021, as I was finishing writing this guide, we experienced record-breaking cold temperatures in Oklahoma City and the central US. After almost two weeks of temperatures well below freezing both day and night, plus overcast skies and several days of snow, the sun returned to bless us with its warmth and light. I could not have designed a better stress test to check the resilience of our system of heating with compost. To my great relief, our hot beds served to keep hundreds of seedlings warm and protected.

In a happily decomposing compost pile, heat is a natural by-product as microorganisms break down biodegradable materials. We take advantage of this fact to use the composting process as a heat source in our greenhouse and low tunnels. Under the right circumstances, compost heating can be a simple, effective and reliable alternative to heating with fossil fuels. This guide, and the accompanying video, are designed to teach you the methods that have worked for us at CommonWealth Urban Farms.

Our small urban farm is located in a residential neighborhood in central Oklahoma City. We started with a tiny plot of land, an equally tiny group of people, and a boundless enthusiasm for growing food and working together. Composting was an essential part of our farm from the very beginning, thanks to the commitment and passion of several community composters in our core group.

Starting with a single vacant city lot in 2011, our farm has continued to evolve and grow far beyond our original dreams. It now encompasses a quarter acre in vegetable and cut flower fields, plus a hoop house, greenhouse, food forest, multiple pollinator and rain gardens, and, of course, a community composting operation.

We are a neighborhood based urban farm, powered largely by volunteers. We love working together, trying out new ideas, and following one thread as it leads to another. Education is interwoven into all aspects of our farm: we offer monthly tours and weekly hands-on volunteer opportunities, gardening classes, special workshops and educational videos.

Necessity is indeed the mother of invention, and in the fall of 2018, our need for a greenhouse had become pressing. After doing considerable research on sustainable methods of heating greenhouses, we put our best ideas together and began constructing a compost-heated greenhouse. As it turned out, this was the launch of an ongoing adventure exploring the potential of compost to provide heat for indoor and outdoor growing.

The principles presented here are nothing new. The concept of hot beds, warmed by decomposing manure, was used by peasant farmers in China more than 2000 years ago, by the ancient Romans, by French farmers in the 1800s, and many other enterprising gardeners and farmers around the world. Nor are humans the only species to take advantage of composting. Australian brush turkeys build large mounds of decomposing leaf litter, twigs and dirt to incubate their eggs, and the males regulate the internal heat of the pile by adding or removing material.

We have borrowed from these tried-and-true strategies, and adapted them to create a greenhouse design that fits our particular needs, capabilities and style. In addition to using compost to heat our greenhouse seedlings, we also use compost to make hot beds under low tunnels, a truly simple method of creating a heated outdoor growing space.

All of this is a work in progress! We are constantly learning, trying new ideas, failing at some, revising, and learning more. I hope you will take these ideas and experiment with them to find your own best applications of this remarkable natural heat source.

Elia Woods
CommonWealth Urban Farms
Oklahoma City, Oklahoma
February 28, 2021

## Why Choose Compost as a Heat Source?

Our foremost reason for choosing compost as a heat source is because it works! One of our favorite party tricks for visitors to the farm is to open a hole in an active compost pile and invite them to reach a hand inside (spoiler alert: too hot to touch.) Even in mid-winter, we frequently see steam rising from the hot compost piles.

Secondly, we know that we must all find alternatives to fossil fuels in order to turn around climate disaster, and we were committed to finding renewable methods for heating the greenhouse.

Finally, we looked at our organizational assets. We have several veteran composters and a team of volunteers who build and manage compost bins every week. We already had an established supply stream of compostable materials. Composting is one of our favorite activities!

All of these factors combined to give us a greenhouse and low tunnel heating system that is reliable, sustainable, low tech, and inexpensive.

## How It Works

A well-built compost pile will provide a steady, reliable, moderate amount of heat, but not nearly as much as provided by gas or propane heater, or a wood stove. Using compost as the heat source calls for careful planning; you can't just 'turn up the thermostat' on a compost bin!

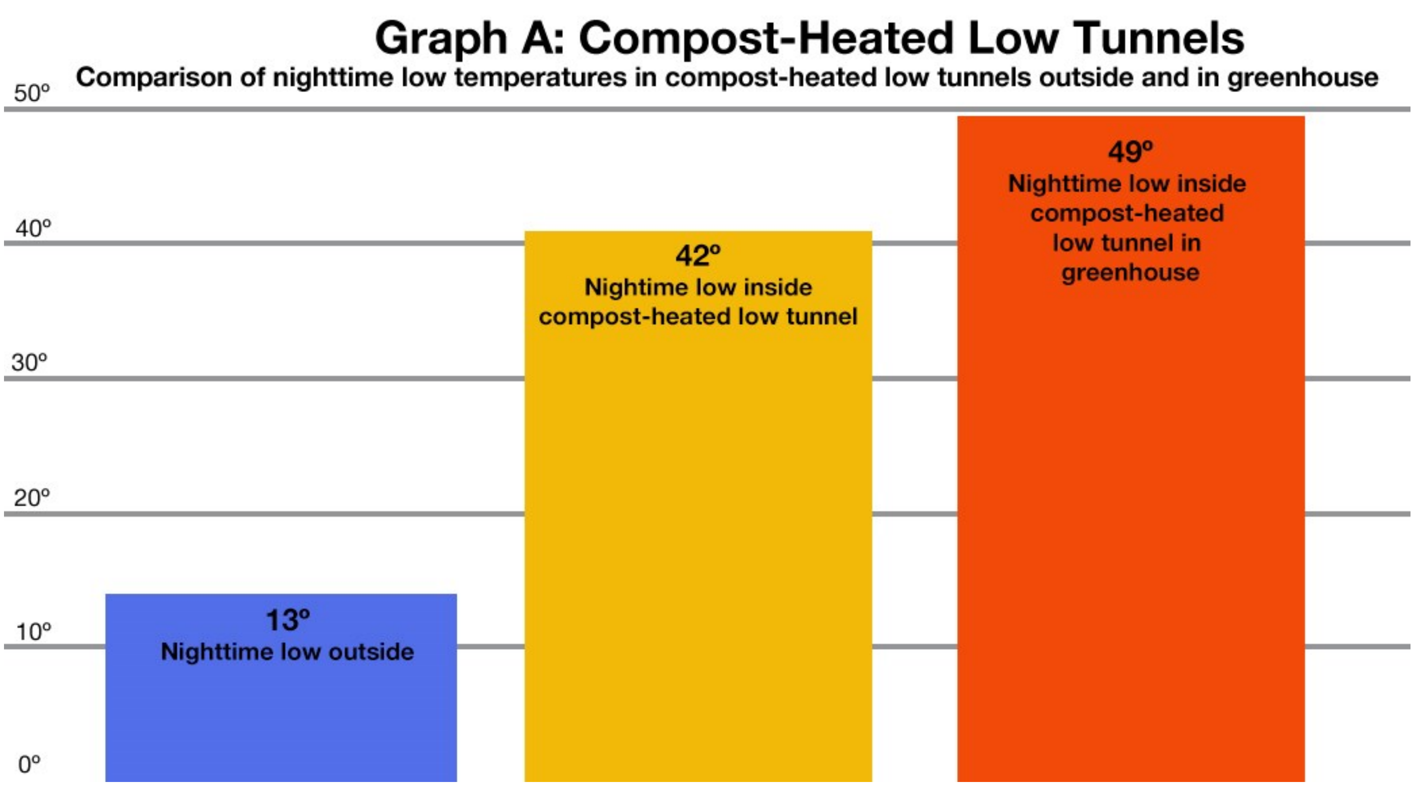
In order to make effective use of the heat generated by compost, we aim to capture that heat right where we need it. We're not trying to keep an entire greenhouse toasty; we only need to keep the seedling beds warm. Our method works because we retain the heat of the compost pile by covering it with a low tunnel made from hoops and plastic; our heated growing area is limited to that space under the low tunnel.

Building a hot bed takes some time and effort, quite a bit more so if it's a large bed like we have in our greenhouse. The trade-off for all that work up front is that once it's built, it takes care of itself and keeps emanating heat, quietly, safely, and reliably around the clock. Once the pile is finished, there is no need to worry about power outages, running out of fuel in the propane tank, tripping an electrical breaker, or refilling the wood stove.

The charts that follow illustrate how compost heating has worked for us here in Oklahoma City, planting zone 7a. An unheated low tunnel tightly covered with plastic sheeting or heavy row cover will generally stay several degrees warmer than outside air. The colder it is outside, the more of a temperature differential the low tunnel makes. Placing that tunnel inside a tightly sealed unheated structure such as a hoop house (high tunnel) gains a few more degrees of protection which works beautifully for growing cool season crops like spinach, kale or carrots. However, we need much warmer temperatures for most seedlings. By building a hot bed underneath the low tunnel, we are able to stay well above freezing at night in an outdoor hot bed/low tunnel, and even warmer with a large covered hot bed inside a small, tightly sealed greenhouse structure (graphs A and B.)

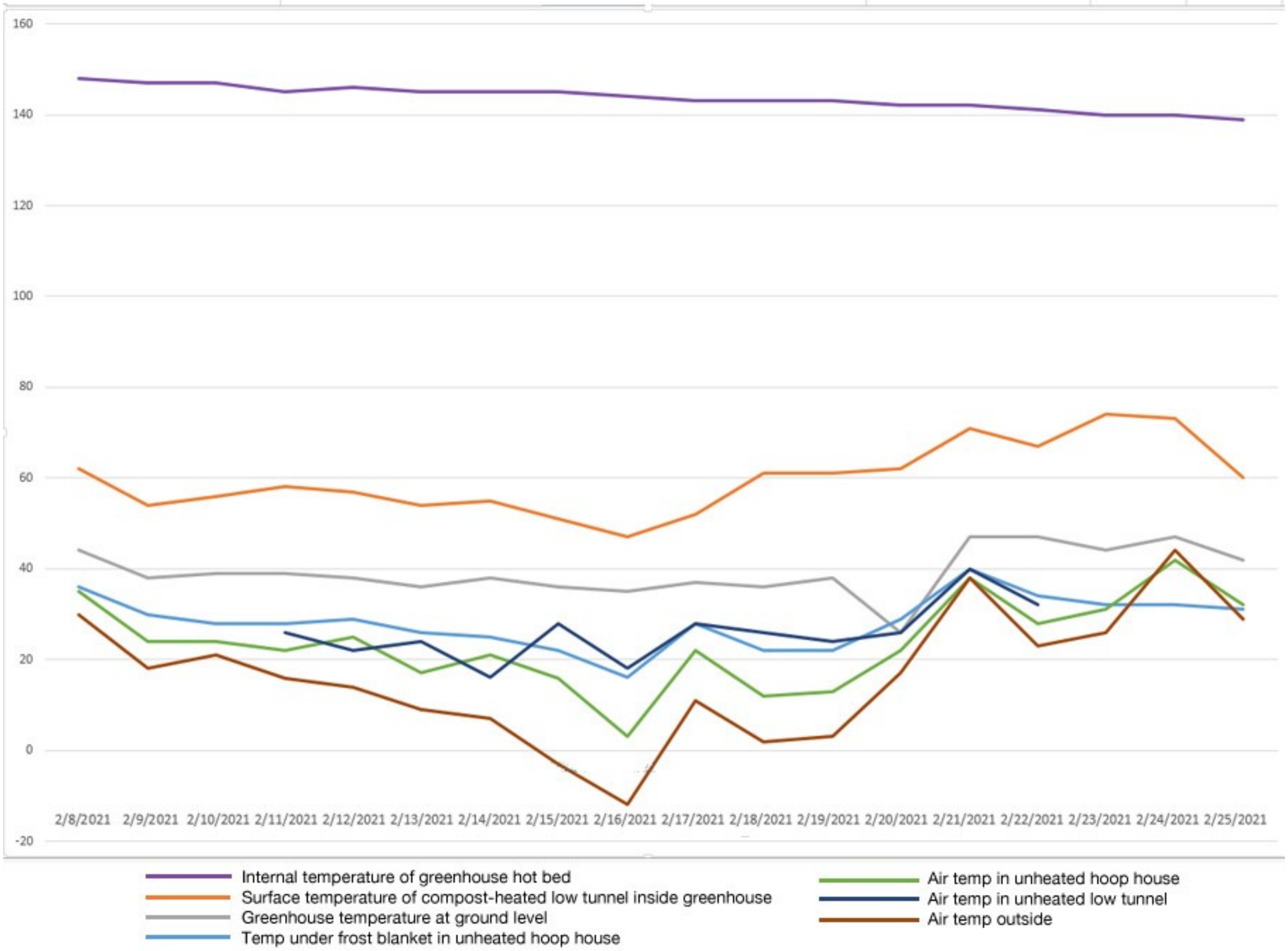
A key word here is "tight." It is essential to close all gaps and make sure there is no air leakage. Just imagine leaving your front door cracked open a half inch on a cold night. Even a small draft can chill the air considerably.

The arctic front that we experienced as I was writing this guide gave me the chance to collect an abundance of new data. I admit to being a bit anxious as to whether our compost heating system was up to the task with weather far colder and more prolonged than what we normally experience. To my delight, even as outside temperatures plummeted to -12 degrees, temps inside the hot bed/low tunnel in our greenhouse never got below 47 degrees, an almost 60-degree difference (see graph B). It's deeply satisfying when one's practices do, in fact, hold water — or in this case, heat!




Note - Both low tunnels were covered with 2 layers of plastic and heated by a compost hot bed. The hot bed (yellow bar) was newly constructed and at its hottest phase. The hot bed (red bar) had been built a couple months earlier but was still decomposing and producing heat. These temperatures were recorded in early March, 2019.

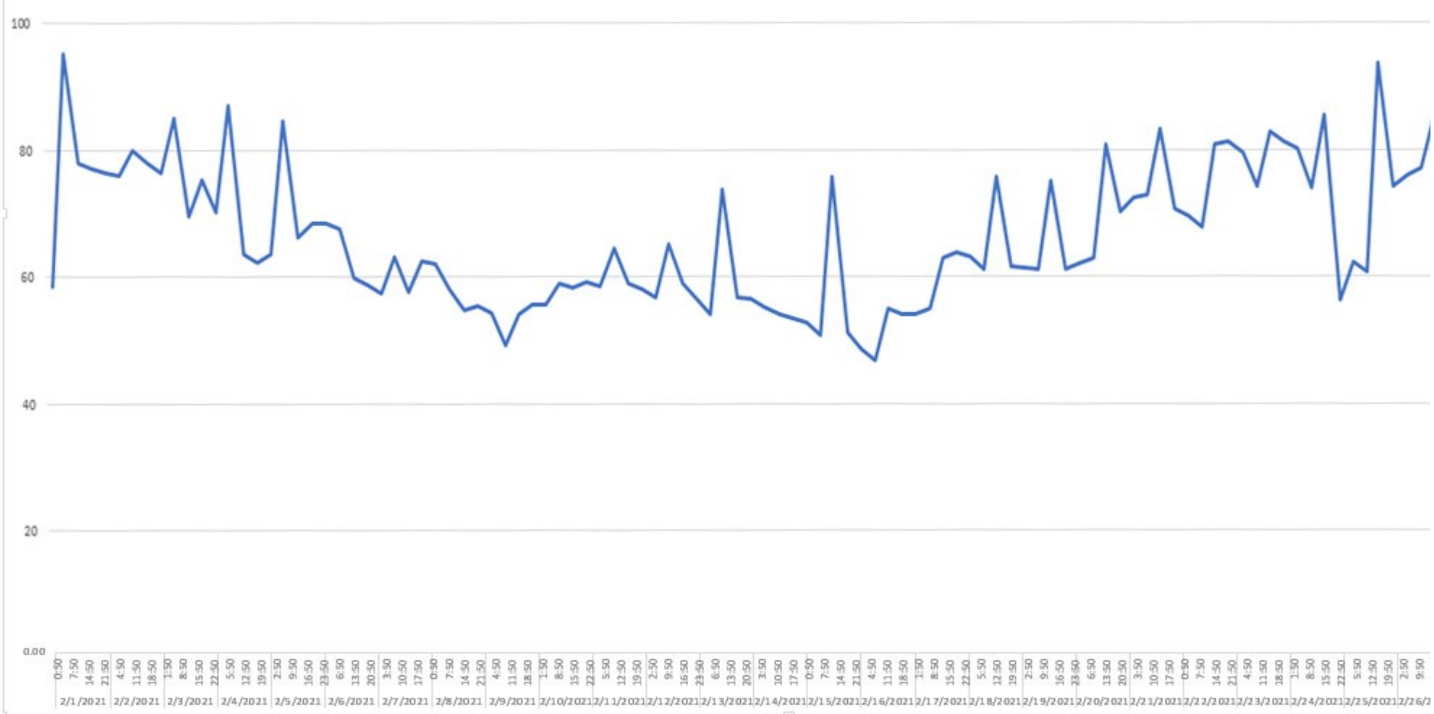
## Graph B - February 2021




Note - These temperatures were recorded during record-breaking cold weather in February, 2021. The internal temperature of the greenhouse hot bed (purple line at top) was recorded using a compost thermometer reaching 20” into the center of the hot bed. The surface temperature of the compost-heated low tunnel inside the greenhouse (orange line) shows the temperature on top of the greenhouse hot bed, where our seedling flats reside, and was covered with a layer of plastic and a layer of row cover over hoops each night. Our greenhouse has no supplementary heat besides the hot bed.

Before this extreme cold front arrived, we sealed all gaps in our 30 x 52’ hoop house. Normally, it isn’t that airtight. Sealing the hoop house definitely helped in keeping it warmer than the outside temperature. The unheated low tunnel was in an outside field with one layer of plastic. Starting on Feb. 15th, it was covered in a thick layer of snow which provided considerable insulation and actually kept it warmer than the frost blanket rows inside the hoop house. Every time it snowed, I knocked off as much snow as I could from the hoop house roof (standing inside the hoop house, using the soft end of a broom); even though it would have provided insulation, the weight of the snow could have caused the hoop house to collapse. We usually build our outside compost-heated low tunnels in late February each year, so we didn’t yet have one built to compare temperatures during this cold spell.

**Graph C - Daily Temperatures in the greenhouse hot bed and low tunnel**




Note: we lay our seedling trays right on top of the big hot bed in the greenhouse. At night, we pull plastic over the hoops on the hot bed to keep the heat from the hot bed contained within the seedling area. As you can see from the graph, the seedling bed is warmest during the sunniest part of the afternoon, then cools down at night but never gets close to freezing, even on the coldest nights. These temperatures were recorded during record-breaking cold weather in February, 2021.

## Planning

There are many options for how to use compost as a heat source. Home gardeners can build a small hot bed, add a couple hoops, cover with plastic, and have a warm, protected space for growing a half dozen or more flats of seedlings. Market gardeners might need a longer hot bed, essentially a compost windrow, covered by multiple hoops and a large sheet of plastic, to accommodate dozens of seedling flats.

For growers who already have a hoop house, placing a large hot bed and low tunnel inside of it will make it even more effective. For those considering building a greenhouse, our experience with the marriage of compost heating and greenhouse growing is detailed on page 21.

***What do you need? Consider your specific situation.***

- Do you plan to grow seedlings or microgreens or in-ground crops?
- What temperature range do your plants need?
- What are your space needs: How many flats or rows? All at once or succession planted?
- How long do your plants need to be under cover? When can they be moved outside?

***What are your resources and assets?***

In our case, we had a team of experienced composters, ready access to nitrogen and carbon ingredients, and many available hands. A compost-heated greenhouse was a good fit. Someone else might choose a different option, such as a climate battery (aka Ground to Air Heat Transfer.)

***What is the simplest way to meet your needs?***

Low tunnels over unheated beds or low tunnels inside an unheated hoop house may be sufficient for some situations.

We use our hot beds as one stage in the process of germinating, growing and hardening off our seedlings. Most seeds need warm to hot temperatures for germination, often 70 to 85 degrees. Once the seeds have sprouted, they generally grow best at somewhat cooler temperatures. This varies considerably according to the species. Broccoli prefers much cooler growing-on temps than zinnias! We use our warmest space for germination and the most heat-loving seedlings, then move the youngsters to progressively cooler areas as they get bigger. That could be an older hot bed that is starting to cool down, an unheated shelf in the greenhouse, or an unheated low tunnel outside. In this way, our hot beds don't have to be big enough to accommodate all of our seedlings for the entire season.

**When and Where**

A hot bed will give its greatest heat output in the first month after building it. With this in mind, we build the large hot bed in our greenhouse in late December. The outdoor hot bed is constructed in early March, when we're running out of room in the greenhouse but it's still too cold outside to set out our tender seedlings unprotected. If we didn't have a greenhouse, we would probably build an outdoor hotbed in February, when the seeds we started indoors have germinated and are ready to step up into larger cells or pots that need more space.

Hot beds generally require full sun, as seedlings need lots of light. Seedlings also need to be monitored and watered frequently. Maintaining the hot bed is a hands-on affair; at a minimum, it will need to be opened most mornings, and closed again most afternoons. That's fun for the first week or two, but it can get old after a while. Placing the hot bed in a convenient location and within reach of a water hose helps ensure success.

**Bigger is (sometimes) Better**

We recommend *at least* 4'W x 6'D x 3'H as the *finished* size. That means starting with a base that is at least a foot wider than those measurements, in each direction. It will get smaller toward the top. The bigger the bed, the longer it will stay hot. The large bed that we build in our greenhouse stays hot for months. A smaller 4' x

6’ bed will give its greatest heat output for only a month or two. Also, as the materials decompose, the hot bed will reduce considerably in height.

Since we grow seedlings to sell, we make long windrows as hot beds. Whatever the length, we keep the windrows to four feet in width. This makes it possible to comfortably reach across and access all of the seedlings.

**Challenges**


There are some potential obstacles with compost heating. Sourcing such a large quantity of nitrogen and carbon materials can be time-consuming. Backyard gardeners are unlikely to have that much garden and kitchen waste, so the next option is to reach out to near-by sources. There are many! In urban areas, juice shops, grocery stores, coffee shops, breweries, and restaurants are good options, as well as gathering bagged leaves from neighbors. Rural gardeners and farmers will be more likely to have access to manure and rotted straw.

It can be a bit intimidating to make a cold call to a store manager with a request for their food waste, and there’s no guarantee of a positive response, but oftentimes it leads to a satisfying partnership.

Building a windrow or even a small hot bed requires a chunk of time and labor. Having done it many times, I can say it gets easier with practice! For myself, I am often grateful for the nudge to get outside and stretch some muscles. Also, it is an annual event since the heat from the hot bed lasts only for one season. If filling a large bin or windrow, it’s wise to recruit some help. Actually, it’s great to have help even with a smaller hot bed, particularly for first-timers.

Making and using hot beds is a mix of science, experimentation and adaptation. It’s a very different approach than in high tech greenhouses where temperature and humidity are rigorously controlled. For those who enjoy playing with and learning from natural cycles, this method can be quite rewarding. I have found that our seedlings do very well, even when temperatures sometimes stray from the ideal; overall, it is a conducive environment for health and growth.

## Hot Beds, Cold Beds and Winter Vegetables

Some people use hot beds for growing crops, such as leafy greens or root vegetables. In *Hot Beds: How to Grow Early Crops Using an Age-Old Technique* by Jack First, the author gives a clear, thorough explanation of this approach and its benefits drawn from his extensive experience. Eliot Coleman in *The Winter Harvest Handbook* and *Four Season Harvest* gives detailed information on growing cold-hardy vegetables in unheated cold frames and hoop houses.

We grow and harvest vegetables all winter long in our unheated hoop house, covering them with frost blankets on the coldest nights. Before building our hoop house, we grew hardy vegetables outside under low tunnels. We could grow a wider variety of vegetables, and grow them more quickly, if we added compost heating to our hoop house, but it hasn’t been worth the extra effort. We are happy with the quantity and variety of food we are able to grow with minimal effort. Over the years, I have used cold frames, solar cones, low tunnels, hoop houses, and low tunnels inside hoop houses; every time, I am impressed with the tremendous increase in growth gained by a simple, unheated cover.

# Building the Hot Bed: Let's Make Some Compost!

Four ingredients are required for successful composting:

1. Carbon
2. Nitrogen
3. Air
4. Water

Essentially, we're preparing a big feast for some very special groups of microorganisms, who will eat, drink and be happy as they break down all that organic matter, providing us with a steady heat source as a by-product of their efforts. As long as all four ingredients are present, the feasting can continue!

Let's take a closer look at these ingredients, and where to source them.

*Carbon*

We use wood chips almost exclusively as our carbon ingredient, since we can get them delivered for free from local tree trimmers. Wood chips take longer to decompose than other carbon-heavy ingredients like straw, but in this case, our focus is on extending the time our hot bed provides heat, rather than hurrying things up to get the finished compost. Other good sources of carbon include straw from local farms or feedstores, shredded newspaper or cardboard, coffee chaff from local coffee roasters, sawdust from untreated wood, dried out garden debris, and bagged leaves from neighbors. Some cities offer free mulch, but check to see what it is made from and if the materials have been chemically treated.

*Nitrogen*

Building a hot bed requires a large quantity of fresh nitrogen ingredients, and that often means outsourcing some of it. In addition to fresh plant debris from our gardens and farm, we've obtained coffee grounds from coffee shops, food waste from grocery stores and our own kitchens, juice pulp from juice shops, and spent beer grains from breweries. Some restaurants collect their kitchen scraps. This is a good opportunity to put those hunter-gatherer skills to use!

Manure is a common source of nitrogen. However, as it decomposes, it emits methane which can injure plants. Manure from ruminants, such as cattle, emits far more methane than from non-ruminants, such as horses. We haven't used manure in our hot beds, but for many farmers, it will be the most easily available bulk source of nitrogen. In the aforementioned book, *Hot Beds: How to Grow Early Crops Using an Age-Old Technique* by Jack First, the author uses horse manure for his hot beds and gives detailed information on his methods. Other growers have added a biofilter to their systems to prevent methane damage.

Food waste can cause issues with the local wildlife. Ingredients such as coffee grounds, juice pulp, and spent beer grains don't usually attract unwanted visitors. Food waste, on the other hand, can attract many different kinds of animals. The raccoons in our neighborhood love avocado peels and will dig up a hot bed to get to them.

Constructing a large hot bed or windrow requires an impressive amount of material, both carbon and nitrogen. We are always on the look-out for sources of bulk waste; getting just a bag here and a box there would become an impractical amount of work.

*Air*

Good air circulation is needed to prevent the pile from becoming anaerobic and stinky. Using wood chips or straw as a carbon ingredient in the pile will usually prevent this from happening, since wood chips are bulky and straw has air inside the hollow stems. Bagged leaves tend to mat together when they get wet, and can cause anaerobic conditions, so shred them or mix them with other ingredients before adding them to the pile. Other bulky or hollow materials include sunflower stalks, cornstalks, brushy weeds, or tangled piles of tomato vines. We keep our piles to five feet or less in width to allow air flow from the sides to center.

Our outdoor hot beds are free standing, but we use pallets to build the large bin inside our greenhouse. Pallets or hardware cloth can also be used to contain an outdoor hot bed. Initially, we lined the pallet bins with cardboard to keep stray watermelon rinds and pineapple tops from peeking out at the sides. Over time, though, we discovered that the cardboard decreased air flow from the sides, and contributed to anaerobic conditions inside the pile. We now keep a thick lining of wood chips along the inside of the pallets. We have dubbed this the "bathtub" method; as we add each layer of wood chips, we build up an outer ridge of wood chips, so that when we add the next layer of nitrogen ingredients, they are kept inside the "bathtub" and away from the pallet sides. Since making that change, we have had far better luck with achieving healthy aerobic conditions in the center of the piles.

*Water*

The microorganisms that break down organic materials need moisture to be effective. A handful of compost mix from the pile should feel damp, like a wrung-out sponge. If the materials added to the pile are already moist, not much additional water is needed. If they're quite dry, then have a watering hose ready and give each layer a good soak.  Don't worry about hitting this nail squarely on the head; a pile that's a little on the dry or wet side will still work.

***Additional Amendments***

A few years ago, we started adding lactic acid bacteria (LAB) to our piles. One of our compost masters, David Braden, had been learning about Korean Natural Farming (KNF) which uses indigenous microorganisms as an alternative to chemical or outside fertilizers, and decided to try adding this amendment to our composting process.

David reports: *There are two ways in which I believe that lactic acid bacteria (LAB, L. bacillus, or lactobacillus) helps in the composting process. The first comes from the fact that L. bacillus is a type of microbe called a facultative aerobe. This means that it can actively break down organic matter in both aerobic and anaerobic conditions. If a compost pile has insufficient oxygen at its center, creating anaerobic conditions, LAB can still process the material and eliminate what would otherwise be bad smells. The second is that I believe that LAB significantly speeds up the composting process. I have not made scientific observations of this, but I have definitely noticed it in my home compost piles. The CommonWealth piles are too big for me to be as sure of the increased speed, but I think that it would be comparable to what I observed at home.*

*As far as compost for a heating source, including LAB would benefit someone who does not need the heat to last absolutely as long as possible, and who would be interested in harvesting the finished compost relatively quickly, without having to turn the pile.*

Visit our website for more information by David about LAB.

Adding a few shovelfuls of freshly made compost or garden soil to the pile as it is being built is a common way to seed the pile with a diversity of microorganisms and jumpstart the decomposition process. In truth, the wood chips, moldy bread and carrot tops headed for the compost pile are already full of microbes, as is the soil upon which the compost pile sits. However, there’s no harm in adding more! Making fermented amendments such as LAB is an effective way to ensure a healthy microbial environment in the hot bed.

**Building the Bed**

A hot bed will work equally well whether it is freestanding or enclosed. Either way, start the bed with a thick layer of wood chips or other coarse material laid on the ground. This helps with aeration at the bottom of the pile. Next, add a layer of nitrogen material (green stuff), then another layer of carbon material (brown stuff.) Water that in, then continue alternating layers of carbon and nitrogen. On each carbon layer, build up an outer ridge along the sides, to keep the nitrogen materials from peeking through the edges. This “bathtub” technique also makes it easier to keep the sides of the bed vertical. Aim for a box-shaped bed, rather than a cone or mound, in order to have more room on top for seedlings. Finish up with a final layer of wood chips, and use a rake to make it as flat as possible.

*Thickness of the Layers*

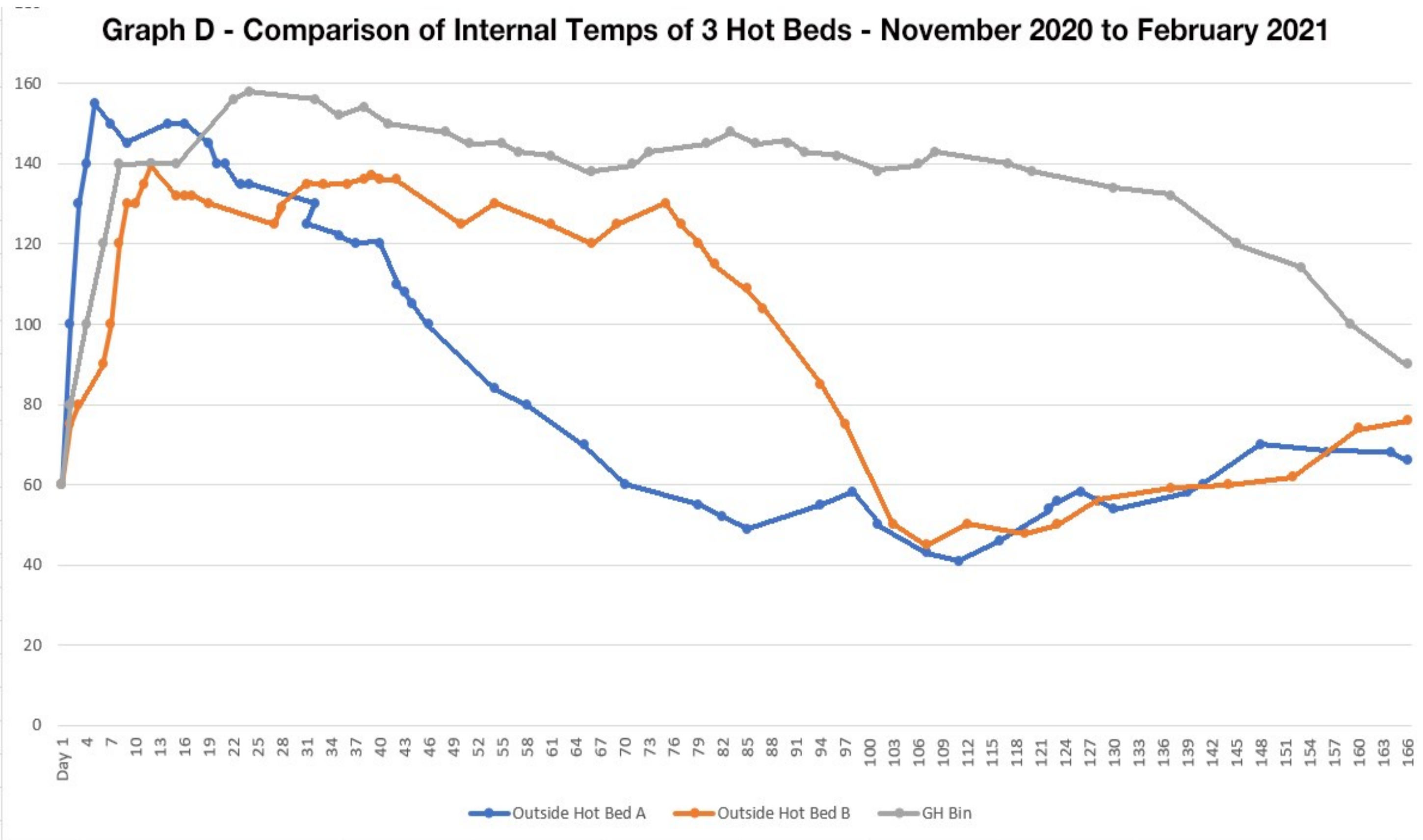
The usual recommendation is three to one by volume. (Or 30:1 by dry weight, but who weighs their compost ingredients?) Actually, it's not quite as straightforward as that. Wood chips, for instance, have a very high carbon content, so our wood chip layers are somewhere around 1:1 or 2:1 ratio, depending on the density of the nitrogen ingredients. There are charts that show the carbon and nitrogen density of different materials, but to be honest, we simply observed how our compost piles decomposed and tweaked the recipe as we built more piles and continued observing the results. The proof is in the pudding; harvesting a finished pile will give clear evidence as to whether the pile has decomposed beautifully, or if there are pockets of dried beer grains, or slimy spots of food waste. Take that information with you as you build your next pile.

I save my most finely-chipped wood chips for the top layer. If the wood chips have lots of little sticks mixed in, they'll catch on the bottom of the seedling flats and be quite annoying. Flatten the top of the final layer and it's ready for seedling flats.

*Temperature*

The temperature of the pile will start to increase within a day or two. Poke the long stem of a compost thermometer down into the middle of the pile to watch the show unfold. Mesophilic microorganisms get the ball rolling as they break down the most easily degradable ingredients. Their actions produce heat, and as the temperature rises above 110 degrees F, they are quickly replaced by thermophilic, or heat-loving, microorganisms.


The thermophilic phase (111-149 degrees F) can last for several weeks or months; this is the phase that we rely on for stable, continuous heat production in the hot bed. Eventually, the thermophilic microbes consume most of the food available to them in the hot bed, and their party is over. As the bed cools down, our mesophilic friends step back in for the final phase, slowly breaking down the remaining organic matter. In our compost piles, red wriggler worms then join the team and process the compost into worm castings.




## *Notes on Graph D*

Hot Beds A and B are outside beds, each measuring 4' x 6' and about 3' high. Hot Bed C is in our greenhouse, and measures 4.5' x 17' and about 4' high. The temperatures were recorded using compost thermometers that reached 20" into the center of each hot bed.

Although these hot beds were built at different times during the winter of 2020-2021, the graph shows the relative rise and fall in temperature for each of them.

Bed A had a higher ratio of nitrogen to carbon than Bed B. As a result, Bed A heated up more quickly than Bed B, but didn't stay hot for as long. The two beds were built by different people, which tends to give variation in performance.

Bed C was far larger than the other two, and for that reason, maintained its heat for a much longer period than either of the smaller hot beds.

Note: It is generally recommended to keep temperatures inside the hot beds under 150 degrees, because many thermophilic microbes will start to die off at that point, and few survive extended temps over 160 F. Smaller hot beds tend not to get as hot as that anyway, but with large compost piles or hot beds it's another matter. While our large bins do sometimes peak at temps above 150 degrees, as in this example, we often find pockets of differing temperatures within a large bed, and the microbes seem to be resilient enough to rebound.

*Final Thoughts*

Plan to build the hot bed all at once if it's a small bed, or within a few weeks for large beds. If too much time elapses between adding layers, nitrogen in the lower layers can leach out of the materials.

There are many, many resources available on composting, from this simple guide, to more in-depth information on the science of composting .

It helps to have some experience with composting before building a hot bed and depending upon it to keep baby seedlings alive. Composting is both an art and a science, and even at CommonWealth amongst our veteran composters, each of us does it a bit differently. Most piles, even if imperfect, will still heat up, at least to some extent. Years after I built my first compost pile, I read a book on composting. I was totally intimidated by the detailed instructions, and thought "I will never be able to do this!" Then I remembered I'd been doing it for years. I relaxed, added some new ideas from the book to my compost practice, and carried on. The more you do it, the better you will get at it.

## Building the Low Tunnel

Once the hot bed is built, it's time to add a low tunnel over the top. Hoops provide a framework that holds the cover above the hot bed. The cover helps contain the heat from the hot bed, and also protects the seedlings from the elements.

**Hoop Construction and Materials**

For the hoops, we use EMT conduit, ½" x 10' lengths from a hardware or electrical supply store. A hoop bender is needed to bend the EMT, and those cost $60-$70. Thanks to a couple of generous donors, CommonWealth bought two hoop benders which are available for public use. We invite anyone in the OKC metro area to email us at info@commonwealthurbanfarms.com to set up a time to come use them. Hoops can be made 3', 4', 5' or 6' wide. Hoop benders will also bend ¾" or 1" conduit when extra strength is needed.

Johnny's Selected Seeds has excellent directions on using a hoop bender. Instructions for 3' to 5' hoop bender.

PVC pipe is often used to make hoops, and it has an advantage in that it can be bent by hand. But PVC will photodegrade over time and turn into many pieces of plastic trash. Ugh. Also, PVC pipe will not hold up to a heavy snowfall. Polyethylene (PE) greenhouse film or sheet plastic may react with PVC and degrade more quickly.

Galvanized #9 wire can be used to make small, lightweight hoops. Although not as sturdy, they are a cheap and easy way to get started.

Match the size of the hoops to the width of the hot bed. To install, push the ends of the hoop about 10" into the ground on each side of the hot bed, or until the hoop feels stable and doesn't wobble back and forth. Install one hoop on each end for small hot beds, or every 5' along a long windrow.

**Low Tunnel Covers**

Plastic and other synthetic materials have made it vastly easier for us to effectively cover our hot beds. In Roman times, the royal gardeners for Tiberius used sheets of mica as glazing for cold frames. Later, glass became the standard material and was used extensively to cover greenhouses, until it was eventually replaced by fiberglass. Plastic film and floating row covers are much easier and cheaper to use than any of those materials.

Unfortunately, they are not biodegradable. We do our best to use them with care and extend their lifespan, but eventually they end up as trash. Plastic has revolutionized farming and has the potential to greatly increase production, but it comes with a disturbing ecological price tag. We must surely find biodegradable options in the near future.

*Clear Plastic.* Use clear plastic greenhouse film that is UV-resistant. A roll of plastic from the hardware store is cheaper but will disintegrate quickly with sun exposure. Don't even bother with that stuff!

In our climate, plastic covers generally need to be opened every morning and closed again in late afternoon. On a cold, sunny day, a low tunnel can quickly heat up inside and burn the plants inside it if left closed. We usually only leave them closed on very cold days, or when the sky is overcast.

*Floating Row Cover*. Spunbonded polypropylene row covers let in light, air and water, while giving two to eight degrees of frost protection. They can be placed over hoops, or simply "float" directly on top of low-growing crops. Row covers come in light to heavy weight. The heavier the weight, the more frost protection but the less light transmission. Johnny's Selected Seeds has a helpful comparison chart on different types of row cover fabrics.

We use plastic to cover our hot beds during the winter, because it gives the greatest heat retention without significant light reduction. A second layer of frost blanket (heavy weight row cover) can be useful to reduce the loss of heat energy from the tunnel on very cold nights. When temperatures warm up enough in the spring, floating row covers are particularly helpful. Because they allow air to pass through, floating row covers don't overheat in the same way as plastic, and can be left closed during the day. Both plastic and floating row covers provide quite a bit of wind protection, which has a significant impact on plant growth.

Covers need to be at least 10-12' wide to cover the hoops with some extra on each side. For length, measure the length of the hot bed and add at least 4' or 5' to each end so it will cover the ends, with enough extra to be weighted or tied down.

It's astonishing how easily wind can sweep off a row cover; it will need some weight on it! Be sure to pull it taut in each direction, so the wind can't easily catch a corner, then use something heavy to weigh down the cloth or plastic cover. Sandbags are our favorite, as they are easy to pick up and drop in place. We put one sandbag on each side of each hoop, plus both ends of the low tunnel. For areas that receive snow, it's best to tie and stake the ends for extra strength. We initially used bricks to hold down row cover, but they often bounce off in windy conditions, and can twist an ankle if accidentally stepped on in the dark. Snap clamps are another option for adhering covers to hoops, although if the plastic covers need to be pulled on and off frequently, it's a hassle to have to snap the snap clamps on and off each time. The hoop bender instructions from Johnny's, mentioned above, include very good directions on how to cover a low tunnel.

During warmer months, once the hot bed has cooled down, hoops can be used in a different way to protect seedlings, by covering them with insect fabric (ProtekNet Insect Barrier, micromesh, or very light weight row cover fabric) or shade cloth. If using shade cloth, be sure and use tall hoops or leave the sides open. Otherwise, the shade cloth can trap hot air inside the low tunnel, just the opposite of what's intended.

## Data Tracking

It's always gratifying to check our hot beds after a frigid night and find our baby plants humming away in their warm surrounds. Tracking these temperatures lets us keep an eye on our systems, and tweak them to provide the best growing environment for our plants. It's hard to judge temperature just by poking my hand inside the low tunnel, and I need to make sure it's staying warm enough for seedling health, especially during the night when I'm asleep in my own bed. Using sensors and thermometers gives us a precise, ongoing picture of our plants' environment.


There are lots of options, at all ends of the price spectrum. We use several types, so that we can track outside air temperature, the temperature inside the low tunnel, and the temperature deep inside the compost bed itself.

Starting with the cheapest and simplest, we have some small, inexpensive tube thermometers from the hardware store. These can be placed inside or outside the low tunnel, or hung on the wall of the greenhouse to read current temps, and are quick and easy to read when walking by. We also use them for double-checking another device if we have questions about its accuracy.

We use a compost thermometer with a 20" stem to reach into the center of the compost bed. This provides a view of the inner workings of the hot bed so we can monitor it as it heats up and cools down. We like Reotemp; there are cheaper compost thermometers on the market, but our Reotemps have lasted the longest.


When we built our hoop house, we bought a digital min-max thermometer, which shows the hottest and coldest temperatures over the last 24 hours, with a six-day memory. Ours has two probes, so we can compare highs and lows inside and outside a tunnel, or air temp and ground level temp, or under and over a frost blanket. Not as fancy as the kind of sensors now available, but it does the job.

When it comes to sensors (or real time data tracking and recording), there is a dizzying array of choices. Many can be linked to a smart phone or tablet to read temp and humidity remotely, which is really handy. Placing one inside a low tunnel means we don't have to open it up on a cold, snowy morning just to read the temperature. If buying several, it can get pricey, so we use them where most needed and supplement our data collection with low-cost analog thermometers. Unlike a min-max thermometer, these sophisticated sensors give continuous temperature and humidity readings; it's valuable to see when it gets coldest at night and for how long. A brief dip into chilly temps is not nearly as damaging to plants as a long, cold night. Our first foray into sensor-land was a SensorPush, a wireless sensor that is super easy to use, even for tech novices like me. They just came out with a more water-resistant sensor, useful in areas with lots of moisture, like seedling beds!

## Harvesting the Compost

Most people make compost piles in order to harvest the compost. In our case, we're double dipping! The compost is initially used as a heat source, then after it has finished its cycle of heating up and cooling down, we also get the benefit of a finished compost that is rich in nutrients and microorganisms.

Turning the hot bed as it cools will produce compost faster. We prefer to do nothing and just let it sit longer (9-12 months) before harvesting. Compost is ready to harvest when the pile is cold, indicating that microbial activity has slowed way down, and none of the original ingredients are still recognizable. Finished compost is dark brown and crumbly, and has a pleasant, earthy smell. It may still be a bit chunky, so we generally sift it. We use ¼" hardware cloth to sift it for a rougher compost and 1/8" hardware cloth for a very fine compost that is exceptional for use in potting mixes.

We use a worm harvester, a large rotating screened cylinder, to sift our compost. For home use, a box sifter is simple to build and use. There are many plans available online, such as this one. A trommel is a mini-version of a worm harvester. These are the directions we used to build our trommel sifter.

## Compost Troubleshooting

*My hot bed never got hot.*
Most likely, you need a higher ratio of nitrogen to carbon. More green stuff! It's also possible that the bed is too dry, a common mistake for beginning composters. The level of moisture should be like a wrung-out sponge. You could build a new hot bed, or turn your original bed and add more nitrogen and/or water as you rebuild it.

*My hot bed smells bad, like ammonia.*
That's a sign of excess nitrogen. Too much green stuff! Next time, go for a higher ratio of carbon to nitrogen.

*My hot bed smells bad, like rotten eggs.*
That's a sign that your pile is anaerobic, or lacking in the oxygen needed for the aerobic microbes to eat, breathe and be happy. Using wood chips as a carbon ingredient in the pile will usually prevent this from happening, since wood chips are unlikely to get compacted and airless. But if it does happen, you'll need to turn the pile and increase the air flow. Make sure you start with a thick base of wood chips, and increase the ratio

of carbon to nitrogen ingredients, or add bulky or hollow ingredients such as sunflower stalks, cornstalks, or brushy weeds.

*My hot bed worked like a charm, but it's starting to cool down, and we still have cold weather ahead of us.* Turning the bed and adding fresh nitrogen and water will give you another round of heat generation. Or you could add fresh layers of compost materials on top of your hot bed for a quick burst of heating, but it will also cool down more quickly than a full bed. The more layers of nitrogen and carbon that you add, the longer it will stay hot.

In a pinch, try watering your hot bed. If a bed has become too dry, the microbes will stop working and the pile will cool down; in that situation, adding water can reactivate the process. Start with an initial moderate watering, then watch the internal temps for a day or two with a compost thermometer. Too much water will push oxygen out of the bed, causing the microorganisms to become dormant (they need to breathe, too!), which will cool down the bed again.

Click here for more detailed information on solutions to your composting problems.

## Elements of the CommonWealth Greenhouse

On a cold, sunny day, the greenhouse warms up beautifully. Without question, the sun is the primary heat source for any greenhouse! The tricky part comes at night, when that heat rapidly escapes through the plastic sheathing, or on cold, cloudy days when there is little solar gain. A thoughtful design, including a tight envelope and an insulated north wall, combined with supplementary heat from the compost bin, allows our greenhouse to function well during those times.

There are many different ways to build a greenhouse. We're not going to cover greenhouse design in depth here, but here are a few elements in our greenhouse that are key to its success.

**Maximum solar gain**

We trimmed some trees and placed our greenhouse where it would get as much sun exposure as possible, morning to late afternoon.

**Insulated north wall**

This reduces heat loss substantially. We used straw bales as insulation. When we have the roof open for ventilation, they do get rained on, so we remove the top ones and replace them every year or two. The damaged bales make for great mulch on the farm, so they're not wasted.

**Tight fit on plastic and door, windows**

This is critical! Our initial winter we had a nice, tight greenhouse. That tight fit is harder to maintain after the first year. By our second year, it was not quite as snug, and I noted a small but real difference in heat retention. We're now in our third winter, and have replaced some torn plastic, filled up holes and tweaked the design to increase the roof ventilation on warm days while keeping a close-fitting seal when closed.

**Sizing the hot bed relative to the greenhouse**

Our greenhouse is 12' x 24', and 10' at its highest point along the north wall, sloping down to a 5' south wall. The hot bed inside the greenhouse is about 4.5' wide x 17' long x 4' high; it covers almost 1/3 of the floor space. The hot bed takes up a very large part of the greenhouse! But it's not wasted space; the entire top of the bin is the very center of activity, covered in seedling flats all through winter and spring.

The hot bed doesn't produce enough heat to keep the entire greenhouse warm, but there's actually no need to heat every square inch of air. Our focus is on heating the space where we grow our seedlings. Basically, we're creating a giant heat mat, and then covering it at night to keep the heat contained in that space.

I've noticed that our seedlings grow more rapidly thanks to the bottom heat provided 24/7 by the compost bin, even on days when the air temperatures are cool. I suspect that the plants are also getting some benefit from increased carbon dioxide levels created by the decomposing compost.

As the seedlings mature, they move to shelving along the south wall of the greenhouse, where they can get used to cooler temperatures. Later, they'll go to an outside low tunnel, and finally to an unprotected area to harden off.

**Ventilation: roof, doors, windows**

When we built our greenhouse, we underestimated how much ventilation would be needed. This year, we're altering our design to increase the amount of vent space. Our original design involved rolling back the top of the roof on warm afternoons. But we didn't have a way to open an equivalent amount of space at the bottom of the opposite (south) wall, so we didn't get good air flow through the greenhouse. The American Society of Agricultural Engineers recommends that the side vent area equals the roof vent area, and that each should be 15-20% of the floor area. It's also important to site the greenhouse to take advantage of prevailing wind direction; in OKC, that means planning on wind entering the greenhouse from the south then out through vents on the north wall or roof. Hot air rising, or thermal buoyancy, will help move hot air out of the greenhouse, but wind movement has a much greater effect.

Using a fan will increase ventilation, too. I was initially resistant to the idea of using a greenhouse fan because they are so noisy, and I love the quiet and tranquility inside our greenhouse. Solar fans, however, with a DC motor, are whisper-quiet!

Use this link for a helpful resource on [greenhouse ventilation].

**Building the Hot Bed in the Greenhouse**

We collect used pallets (free!) to enclose the large hot bed inside the greenhouse. The pallets keep the sides straight and provide a stable enclosure; it's actually sturdy enough to climb on if needed. (Very handy when patching a hole in the roof plastic!) We use leftover baling wire to wire the pallets together. Leaving one end temporarily open makes it easier to fill the bin; once it is almost full, the last pallet can be wired into place.


Look for pallets with HT stamps (heat treated) rather than unmarked pallets or MB stamps (methyl bromide, a toxic pesticide that has been linked to human health problems and ozone layer depletion.) Used pallets can be found at hardware stores, equipment stores, pet stores, grocery stores, construction sites, or just about any other business that has inventory. Or try a service like Craigslist, Freecycle, etc. Lining the bins with hardware cloth, preferably ¼", and using that to cover the top once it's finished, will help to keep out rodents.

Just as with the hot beds, build the compost bin right before needing to use it, rather than months ahead of time. The greatest heat output is in the first weeks after building it, followed by a steady, lower temp, for months.

Building the pile is the same method used for the hot beds, only bigger. Layer carbon and nitrogen, water generously, and make sure there is good air circulation. Building a bin this size takes an impressive amount of material! We have a couple of local tree trimmers who are happy to deliver their wood chips to us, so we're home free on carbon material. Sourcing that quantity of nitrogen ingredients has required us to think creatively about the waste streams in our community, and which ones could be an appropriate fit for our needs.

We fill the bin a few inches higher than the height of the pallets, since the contents will reduce in size as they decompose.

The same hoops and covers that we use on the outdoor hot beds can be used over the greenhouse hot bed. The ends of the hoops go through the top of the pallets forming the bin, with some 1" x 4" pieces of wood to hold them in place. When our seedlings are small, we push the hoops down to form a low tunnel, which keeps them warmer. As they get taller, we raise the hoops to give them head room.

## What Didn't Work

*Night Curtain* - Inspired by passive Chinese greenhouses that use an insulated blanket or curtain, we tried an exterior "night curtain." Ours was just an uninsulated tarp with not much air space between the tarp and the greenhouse plastic. It didn't make a big difference and it was a lot of work to pull on and off.

*Aeration Tube* - An aeration tube to draw heat from the center of the bed and warm up the ambient air in the greenhouse was a spectacularly bad idea! I'm not sure if the aeration tube was successful in drawing out heat, but it sure did draw out smells! Normally, the finished hot beds don't give off any unpleasant odors, because all that rotting vegetable matter is covered up by a thick outer layer of wood chips. The aeration tube gave us an olfactory peek into the center of the compost bin, and holy moly, did it stink!

*Small Compost Bins* - We tried a small compost bin, about a foot wide and two feet tall, under the shelving along the full length of the south wall of the greenhouse, to add just a bit more heat to that area of the greenhouse. David, our compost master, was sure that it would be too small, and he was right! It only heated up to around 90 degrees, and then cooled down very quickly. I still think this concept *could* work, if it was at least 3' wide and 3' tall, but that's too big for the space that we have. Digging part of that space out as a trench would solve some of the space issue, but that's a lot of work and there are easier changes we could make that would also increase the heat potential.

**Future Ideas**

*Thermal Mass* - Incorporating thermal mass, such as water tanks or a masonry wall, that absorb heat energy during the day and radiate it back out at night.

*Thermal Curtains* – Installing a retractable "energy curtain" or thermal curtain that pulls across the inside of the greenhouse, above the seedling area but lower than the roof plastic, to reduce heat loss on cold nights. Same idea could be used on hot afternoons for shading.

*Two Layers of Plastic* – Using double-layer inflated plastic or bubble type plastic on the roof and walls for greater insulative value.

## Other ways of using compost as a heat source

Years ago, when I was visiting Growing Power in Milwaukee, they used long mounds of compost to bank the outside of their hoop house walls, which both insulated and added heat to their hoop houses.

In *The Compost-Powered Water Heater,* Gaelen Brown takes a broad look at the potential of compost for heat generation, and explores two methods in detail. One approach draws from the work of Jean Pain, a French farmer in the 1960s and 70s who built huge compost mounds that produced both hot water and biogas. The book offers a scaled down version, with directions for building a large compost bin outside of the greenhouse, coiling hundreds of feet of pipe inside the compost bin, and heating water by pumping it through the hot pile. The heated water is then pumped into the greenhouse or other buildings.

The other method detailed in the book is a static aerated pile, or more specifically, negative aeration. In this approach, air is pulled down through an active compost pile, and that hot, steamy air is then run through a heat exchanger or bio-filter.

Both systems are far more complex and expensive than our hot bed and low tunnel method, but they also offer much greater heat potential and design flexibility.

We have experimented with the Jean Pain method. It was a heck of a lot of work, and a whole lot of fun, even though we failed. The author recommends building a compost pile that's 12' wide by 8' high; that's a really big pile! We tried a smaller-than-recommended version that was a mere 9' wide by 5' high. It initially heated up the water that we piped through the compost pile, but it didn't turn out to be big enough to maintain heat while cold water was pumping continuously through the pile. We hope to try it again at full scale with better results.

The more we work with compost as a heat source, the more possibilities it seems to hold. I hope you will bring your own experience and inspiration to help fertilize this field of sustainable, homegrown energy.

## Resources

*Low-Tech Magazine* offers thought-provoking articles on a wide array of topics, including alternatives to fossil fuel heating.

- *Reinventing the Greenhouse*
- *Fruit Walls & Urban Farming in the 1600s*
- *Local Heating*

**Composting How-To**
Composting basics: https://rodaleinstitute.org/blog/backyard-composting-basics-a-cheatsheet/
The science of composting: https://www.livescience.com/63559-composting.html
Solutions to common composting problems: www.planetnatural.com/composting-101/making/problems/

**Winter Growing**
*Hot Beds: How to Grow Early Crops Using an Age-Old Technique* by Jack First
A clear, thorough explanation of using hot beds for growing crops.

*Four Season Harvest* by Eliot Coleman
Beautifully written exploration of how to extend the growing season, written by one of the foremost practitioners of organic farming.

*The Winter Harvest Handbook* by Eliot Coleman
Includes an inspiring account of French gardeners in the late 1800s using horse manure for hot beds and growing enough vegetables to feed Paris and export to England. Builds on the information from his earlier book on growing cold-hardy vegetables in unheated cold frames and hoop houses.

David Braden on using lactic acid bacteria in compost piles
http://commonwealthurbanfarms.com/lab

*Cheating Winter: The Little-Known Truth about Frost and Freeze Tables* by Cathy Rehmeyer
Online article in motherofahubbard.com on the unique adaptations found in cold-tolerant plants that allow them to survive freezing temperatures, and why low tunnels are so effective for winter crop protection. http://www.motherofahubbard.com/cheating-winter/

*Winter Growing Guide* from Johnny's Selected Seeds has extensive information about winter growing using unheated hoop houses and low tunnels. https://www.johnnyseeds.com/growers-library/vegetables/winter-growing-guide-high-tunnel-scheduling.html

Greenhouse Ventilation: http://www.greenhouse-management.com/greenhouse_management/greenhouse_ventilation_cooling/natural_ventilation_systems.htm

**Compost as a Heat Source**
*The Compost-Powered Water Heater* by Gaelen Brown
A goldmine of ideas for anyone smitten by the potential of compost heating. The case studies show the tremendous innovation all over the country (and world, no doubt) by individuals and businesses harnessing the power of compost. Extensive information written in a down-to-earth style.

https://smallfarms.cornell.edu/2012/10/compost-power/ Overview of compost heating methods.

**Tools**
SensorPush.com –Smart Sensor (also optional Wi-Fi Gateway.) Excellent customer support!

Taylor Digital Min/Max Thermometer

Reotemp.com – high quality compost thermometers
https://reotemp.com/compost/reotemp-backyard-compost-thermometer/

Directions for a simple compost box sifter: https://www.homestead-acres.com/diy-compost-sifter-plans/.

Directions for making a trommel for sifting compost: www.instructables.com/Trommel-Compost-Sifter/

Hoop Bender Instructions at Johnnyseeds.com: Growers Library - Tools & Supplies - Low Tunnels (4'x4' or 6'x3' hoop bender)
https://www.johnnyseeds.com/growers-library/tools-supplies/9377-9520-quickhoops-low-tunnel-benders-instruction-manual.html

Hoop Bender Instructions at Johnnyseeds.com: Growers Library - Tools & Supplies - Low Tunnels (3' bender for 3', 4', 5' or 6' hoops)
https://www.johnnyseeds.com/growers-library/tools-supplies/quickhoops-3ft-low-tunnel-bender-instruction-manual.html

## **Appendix A— Video tutorials** (to review all the videos on YouTube, click here)

Video #1—Introduction to Heating with Compost
Click here: https://youtu.be/MvRaklkDPN0

Video #2—Building the Compost Hot Bed
Click here: https://youtu.be/f1ZMMY3YKro

Video #3—Building the Low Tunnel
Click here: https://youtu.be/zu8BCs9azUk

Video #4—Data Tracking
Click here: https://youtu.be/7rsKcBYhw3I

Video #5—Elements of the CommonWealth Greenhouse
Click here: https://youtu.be/PmK_A9IiRy8

Video #6—Building the Hot Bed in the Greenhouse
Click here: https://youtu.be/tSZefb7hLnY

Video #7—What Didn't Work
Click here: https://youtu.be/tU9DJnZjeR4

Video #8—Harvesting the Compost
Click here: https://youtu.be/JnsP-bhag-M