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IX - Thermal Mass: The Heart of the Passive Heating System

On a clear winter day, the sun will heat your car when parked in the open, but will not retain much if any heat to keep it warm long after the sun sets. The materials used to build a car do not absorb and store heat very well, and a car isn't well-insulated. The same is true for standard greenhouses and hoop houses; they quickly overheat on sunny days and lose all their warmth once the sun sets (see the example of the hoop house in Chapter 1). Rather than relying on fossil fuels to heat a greenhouse during the winter, passive solar greenhouses are designed and built to make fuller use of the sun for both photosynthesis AND heating the structure. With sufficient thermal mass, a passive solar greenhouse can moderate daily temperature swings, reducing the need for venting in the day and virtually eliminating the need for nighttime heating.

Solar Heat Storage

To maintain an optimal range of temperatures for crop growth during the winter in a greenhouse, there is a need for storing heat collected on sunny days for heating the structure at night and on cloudy days when solar space heat is unavailable and the structure is naturally cooling. In nature, sunlight serves three primary functions:

1. Photosynthesis in plants and algae, upon which all other living organisms depend for their energy; both direct and diffused sunlight can be used for photosynthesis.
2. Warming the atmosphere (space) directly; and
3. Heating surfaces and structures which in turn store the heat, which is most effective when sunlight falls directly on them.

Essential to the performance of a PSG is the inclusion of sufficient material(s) that absorb and store sunlight in the form of heat during the day then release that stored heat at night. Thermal mass helps prevent the greenhouse from overheating during the day, and prevent it from cooling off too much at night and on cloudy days. The soil, floor, plant containers and almost everything else in the greenhouse can serve at some level as thermal mass.

Almost any material can convert part of the sunlight's infrared spectra into heat and then re-radiate or absorb and store that heat. The amount of heat converted, absorbed and stored depends on the type, nature and color of the material - some materials heat up fast and retain that heat for longer or shorter periods (ex., bodies of water; road surfaces, brick/concrete walls creating the so-called urban heat island effect). Other materials heat up when struck by direct sunlight, but cool off fast when the sun goes down.

How Thermal Mass Regulates Greenhouse Temperature

During cold nights and on cloudy days when the PSG's interior temperature drops, the thermal mass releases its heat (primarily as infrared radiation) to help maintain a suitable temperature for the plants inside the PSG. The thermal energy stored in the PSG's thermal mass keeps the interior temperature of a well-insulated greenhouse well above the outdoor (ambient) temperature. Figure IX.1 shows of the impact thermal mass on slowing the cooling rate inside a solar structure on a cold winter night..

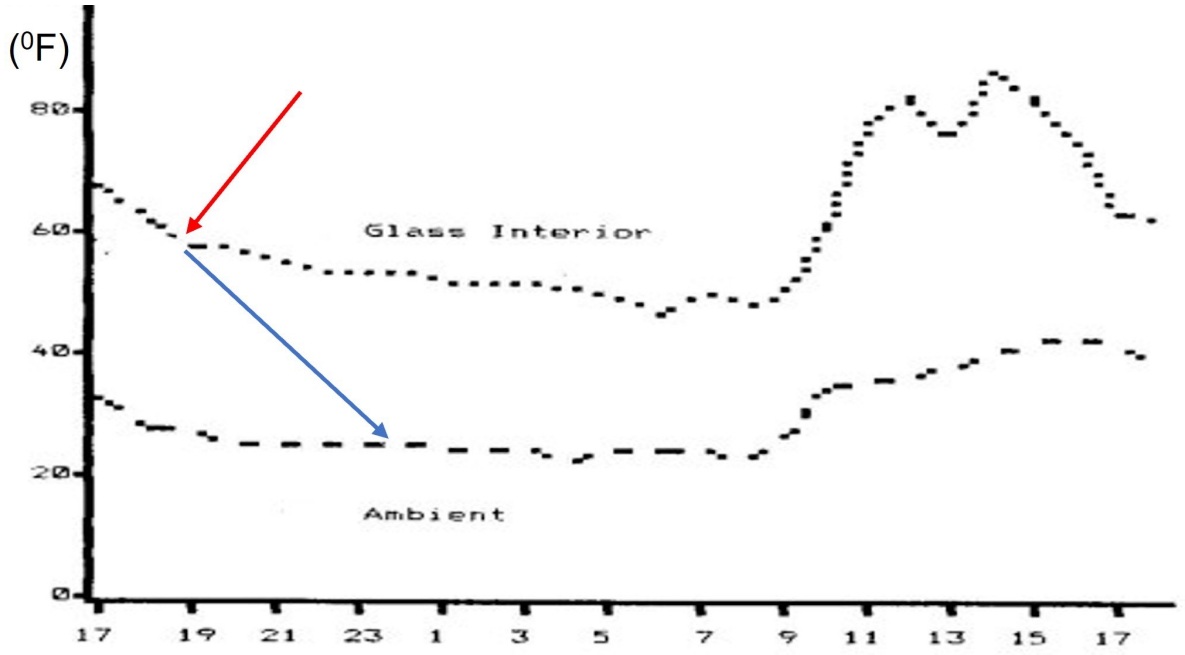


Figure IX.1 Interior and ambient temperatures of a glass-faced experimental structure with thermal mass, 5pm February 4 to 5pm on February 5, 1983. Graph © 2007 SunCatcher Design Group. Source: Carroll 1983.

At about 19:00 (7pm), the slope of the interior temperature (top line) changed direction indicated by the red arrow. This would be the point at which the interior air temperature dropped to about the same temperature as the thermal mass, which kicks in and starts delivering heat to the structure so it doesn't cool off as fast. Without the thermal mass the structure would continue to cool off until it reached the cold outside temperature, indicated by the blue arrow.

There are several factors that determine the interior temperature and daily temperature swings of a PSG: (1) a tightly built and well insulated structure; (2) sufficient effective thermal mass; and (3) the number of hours of direct sunlight on the thermal mass - the longer, the more heat is absorbed and stored. The temperature of the thermal mass is a major indicator providing a "ballpark" idea of how much the interior temperature might drop in a 24-hour period. Reducing temperature fluctuations inside the greenhouse delays the need for daytime venting and nearly eliminates the need for nighttime heating regardless of the temperature outside!

Figure IX.2 below shows how interior and thermal mass temperatures "dance" together in the Parkway School PSG. At night, the interior temperature (red line) drops much more slowly once it drops below the thermal mass temperature (black line). When the sun comes up and warms the interior, the thermal mass starts warming once the interior temperature is higher than the thermal mass temperature. Note the slow decline of interior and thermal mass temperatures in the last three days. This is due to continuous cloud cover blocking the incoming sunlight (energy) for recharging the thermal mass.

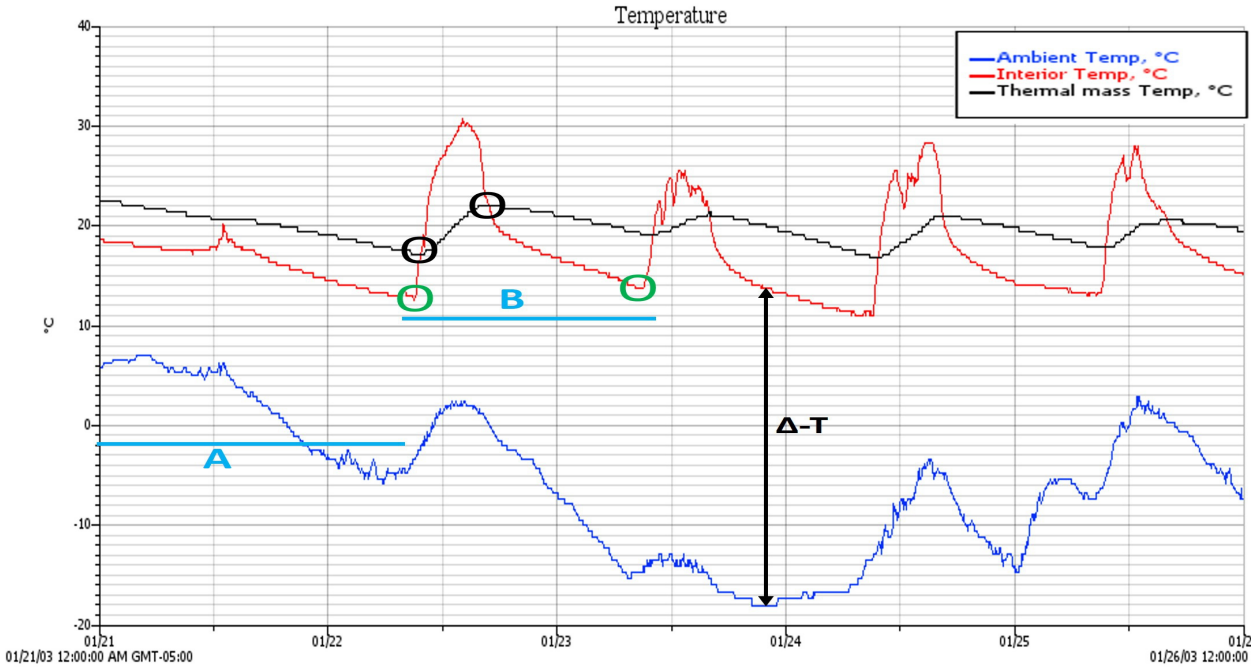


Figure IX.2 Thermal performance of the Parkway School passive solar greenhouse, January 20-36, 2003. During this period, the interior was an average of about 25^{0}C warmer than the ambient temperature.
A - Due to overcast conditions, the ambient temperature is in the 5-7^{o}C range (blue line). The thermal mass (black line) continues to cool as it does not recharge during the day. As clouds clear late morning, there is a brief rise in the interior temperature; however, with clear skies, the ambient temperature falls rapidly, but interior and thermal mass drop at a slower rate.
B - At sunrise, the ambient temperature is -2^{0}C (black line) under a clear sky; ambient, interior and thermal mass temperatures (green circles) begin to increase. As the interior temperature is equal to the thermal mass temperature (black circle), the latter starts storing heat. As the sun begins its descent, the interior space cools quickly until it reaches the temperature of the thermal mass (black circle); the interior cooling rate slows as the thermal mass releases stored heat (shown in the changing slope of the red line).

The arrow and Δ-T show the difference between ambient [-18^{0}C] and interior [14^{0}C] temperatures on the coldest night.

Characteristics of Good Thermal Mass

There are many options for thermal storage materials, and the choice for one versus another depends on heat absorption and re-radiation capacity, availability, aesthetics, (floor)space required, and costs of acquisition and installation.

- First and foremost, the thermal mass should be in containers with walls having good *thermal conductivity* (i.e., the ability to absorb and release heat quickly). Metal

Thermal conductivity	**W/m-^{0}C**
Carbon steel	36-54
Glass	0.933-1.05
Soil	0.33-1.4
Polyethylene-high density	0.42-0.51
-low density	0.33
Polyethylene terephtalate (PET)	0.03
Fiberglass	0.04
Polycarbonate	0.19

Source:
https://www.engineeringtoolbox.com/thermal-conductivity-d_429.html , accessed Oct 14, 2025.

containers (ex., 55-gallon steel drums) are best as the carbon steel of drums has a very high thermal conductivity (lower with higher carbon levels) as shown in the table at right. Metal barrels (most are made of carbon steel) are both excellent thermal absorbers when sunlight strikes them AND excellent thermal (infrared) emitters when the temperature of the space around them drops.

As the table shows, various plastics have a very low thermal transfer rate and are much less efficient in absorbing, storing and releasing heat than metal barrels. Black plastic 55-gallon barrels, clear fiberglass Sunlite tubes, or dark-colored plastic PCM covers would change light to heat at the plastic surface and immediately warm the air adjacent to it. This additional warm air adds heat to the PSG, but very little of that heat will be stored in the thermal mass. The rate of re-radiation from plastic containers back into the greenhouse will also be much slower compared to metal containers.

- The thermal mass material itself should have a high *specific heat capacity*, that is, the ability to hold a lot of energy per unit of weight. The table at the right lists specific heat of water and some common construction materials. As you can see, water has a very high specific heat compared to other materials, so it can hold a lot of heat in a relatively small space. Water is easily available, non-toxic and low cost, making it an excellent heat storage material.

Specific Heat Capacity	**J/kg-^{0}C**
Water	4200
Clay brick	800
Fire brick	880
Sand (dry)	753-799
Concrete (cinder)	657
Dry wall	1088
Granite	775-837
Basalt	627

Source: https://matmake.com/properties/specific-heat-capacity-of-construction-materials.html , accessed Oct 13, 2025.

- The Thermal Mass should be designed to release heat without being recharged for 4-5 days minimum for long cloudy periods (this varies by location and local climate/weather). Water-filled metal containers of various sizes can be added throughout the space to provide more thermal mass once you set up the growing area. Integrating more thermal mass in your PSG will reduce the temperature swings and increase stored heat for cold winter nights and long periods of cold, cloudy days. Smaller containers absorb and release heat faster than larger ones, but larger containers store more heat for longer periods. Given their more favorable surface to volume ratio, large water-filled metal containers provide the slow cool down needed but also require longer to warm up.

SunCatcher agrees with the early generation of passive solar designers (Yanda & Fisher, Mazria, McCullagh, Carter) that water in flat-black metal containers is the most efficient thermal mass available for the dollar. It does double duty: On sunny days, it absorbs heat that would otherwise overheat the interior; and, on cold nights, it releases that heat back to the interior as the temperature drops.

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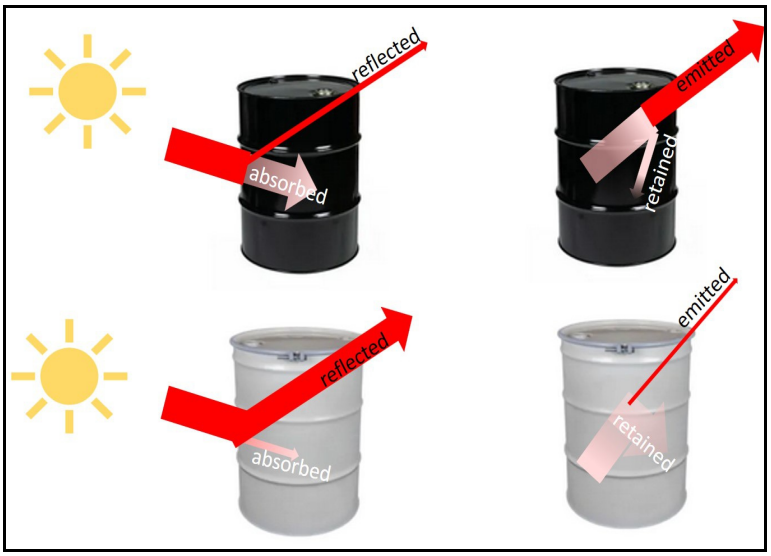


Figure IX.3. Difference between black and white barrels in heat absorption during the day, and heat emission at night or on cold, cloudy days.

- For the best results, the thermal mass should be placed in direct sunlight as it is three to four times as effective as mass that is shaded (Yanda and Fisher, 1980: 38). In terms of the interior space of your greenhouse, the thermal mass should be located where it receives the maximum direct sunlight during the winter period yet does not shade your plants. Thermal mass should be dark in color to maximize absorption. Flat black steel barrels filled with water are among the best and most efficient form of thermal mass out there for the dollar. They absorb solar radiation efficiently, store large amounts of heat, and then radiate that energy back into the greenhouse at night. Although flat black metal containers are best for heat absorption and re-radiation, other colors are possible as well. We experimented with thermal mass containers painted flat red and/or blue to reflect those wavelengths of light as plants use these colors of the light spectrum the most. Blue light stimulates vegetative growth (leaves, stems, roots/tubers), whereas red light induces flowering and fruit production. However, you may need to adjust the number of barrels for temperature control as red and blue light are about 10% less effective in converting light to heat as flat black.



Figure IX.4. Thermal mass of stacked barrels in the Newton-Conover SunCatcher: flat black ones on the bottom, and alternating red and blue barrels on the top. Note the plywood between the bottom and top rows of barrels.

Since there are no “forced warm air” or hydronic heating systems in a passive solar greenhouse, radiative heating from some sort of thermal mass must be optimized to maintain interior temperatures at adequate levels for the plants in the greenhouse. Without convective ventilation (as vents are closed), air will tend to stratify at night: warm air rises toward the ceiling of a greenhouse with cold air settling along the floor. Fans may be helpful in preventing such stratification by pushing warm air down to distribute the heat released from the thermal mass more evenly throughout the structure.

How much thermal mass you need depends on how tight and well-insulated your PSG is, and the best temperature range for the plants you intend to grow:

1. Cool-season vegetables require a minimum average soil temperature of 40°-50°F (4-10°C) for planting, and an average air temperature range of 60°-75°F/15-24°C (optimal is 70°F/ 21°C) for sustained growth. The maximum air temperature for cool-weather crop productivity is 86°F (30°C); above this temperature, cool-weather crops will bolt - meaning flower and set seed, or quit growing.
2. Warm-season vegetables require a minimum average soil temperature of 50-60°F (10-15°C) for planting and an average minimum air temperature of 75°F (24°C) for sustained growth. The maximum air temperature for warm-weather crop productivity is 90-95°F (32-35°C); above this temperature, most warm-weather crops will die, just as they are likely to die at 32°F (0°C).
3. All crops prefer night temperatures that are 9-15°F (5-8°C) cooler than during the day.

Placement of the Thermal Mass



A single 55-gallon metal drum filled with water weighs 484 pounds (222 kg), so a large number of barrels in a single or a stacked row add a lot of weight. Due to the heavy load from the thermal mass, the north wall floor (if concrete, pavers or tile) should be reinforced to support more weight than the usual building floor. To prevent heat loss (by conduction) to the floor (whether bare soil, gravel, tile or concrete,) the barrels should be placed on some insulating material (treated plywood, 2x4 in. or 2x6 in. treated boards). In double stacked barrels, plywood or wood boards should also be placed between the bottom and top rows of barrels as shown in the picture above. The barrels should be placed where they will be in direct sun for the best part of the day to be most effective.



Figure IX.5. Thermal mass positioned along the North wall in a commercial-sized SunCatcher. Flat-black on the bottom is most efficient at absorbing radiant energy while the red and blue barrels on top can reflect light that enhanced plant leaf growth, flowering and fruiting.

Size of the thermal mass

Earlier texts had several methods for determining how much thermal mass to include, some based on the glazing area, floor space, or internal volume of the passive solar greenhouse. However, there are several major factors to consider, such as how tight is the structure, how well walls and roof are insulated, location and placement of thermal mass, and even the weather. With only two winters of experience with the Hawk's Nest SunCatcher (the first without any thermal mass), we are exploring sizing the thermal mass based on how much heat needs to be stored on the coldest winter nights. Figure IX.6 presents a theoretical graph between interior temperature and size of the thermal mass. We found that an initial six 55-gallon water-filled barrels plus all the other thermal mass (soil/floor surface, raised beds, soil in plant pots, ...) kept the SunCatcher as much as 20^0F (11.1^0C) warmer on cold winter nights. Adding five more barrels kept the structure about 30^0F (16.7^0C) above the ambient temperature. So, each additional barrel kept the SunCatcher about 2^0F (1.1^0C) warmer.

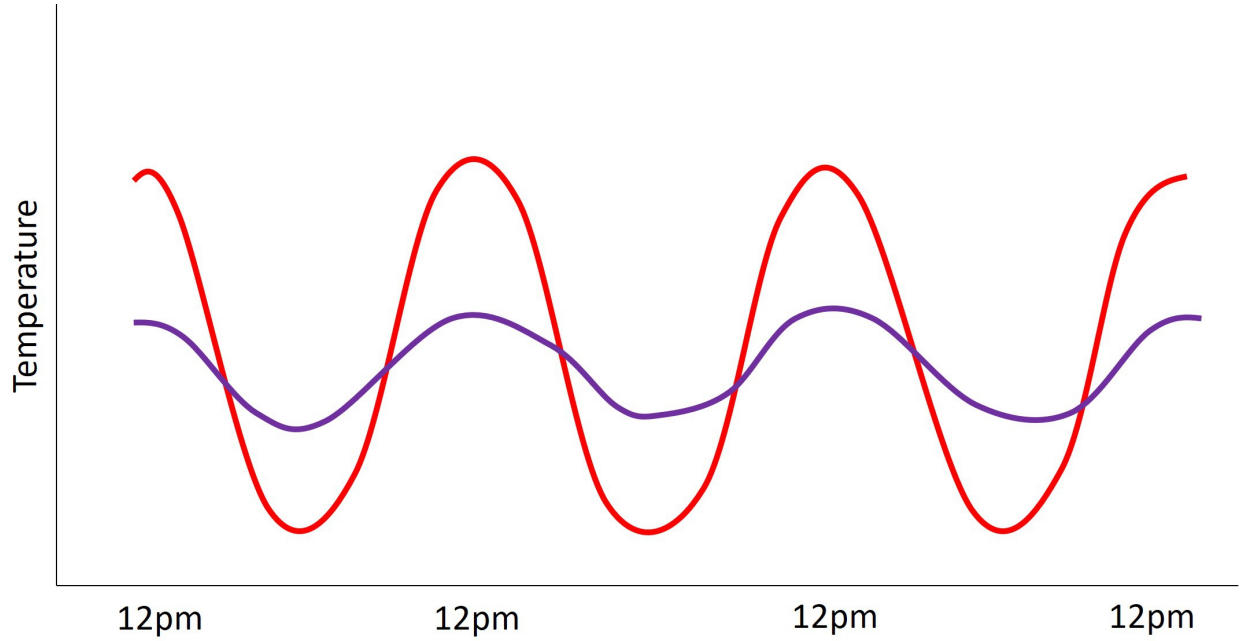


Figure IX.6. Theoretical graph of the interior temperature of a PSG with less thermal mass (red line) versus more thermal mass (purple line). More thermal mass evens out the day/night temperature swings and keeping a more stable growing environment.

We suggest that, after installing the initial thermal mass, you see how well the PSG works in the first winter to determine if any additional thermal mass is needed to reduce the temperature swings during a 24-hour period, especially lows in the early morning hours. If you plan to add a significant amount of thermal mass later, make sure to allow (1) adequate space in the original design to accommodate it, and (2) the floor can support the extra weight of additional barrels. Possibilities are placing additional barrels along the front knee wall (standing up or laying on their side), or (if growing your plants on raised tables), under the tables on the south facing side. Make sure, though, that the barrels can "see" the sun (i.e., are not shaded by any solid objects).

Sourcing and installing the thermal mass containers

You can find retailers that sell new barrels, but they are expensive to buy and ship. We recommend Craig's list or do an online general search for used 55 gal. or 30 gal. metal barrels. Food-grade barrels (used for cooking oils, high-fructose corn syrup, molasses, peppermint or cinnamon oil, …) are safest as they are coated on the inside to prevent rust and metal-food interactions, but may still contain some residual material. Both open and close top barrels are fine (make sure though you do get the lid and hoop to close the open barrels!).

> *Beware of any residual contents (often toxic) of drums from chemical and oil companies. Some of that stuff is absolutely deadly. And you shouldn't even think of having them in your greenhouse.*

Clean the outside of all used barrels with soap and/or gunk remover (for food grade ones, clean

the inside as well to remove any residues), treat them with a primer, then paint them a beautiful dark earth color instead of black. Use flat rather than gloss paint as the latter reflects more light.

Place the painted barrels in your greenhouse *before* filling them with water; add a small amount of non-toxic rust inhibitor (pink antifreeze or ChemWorld boiler rust inhibitor) to metal containers before closing to prolong their life. Once in place and filled with water and closed, you will not want to move them. With good sunlight on them, it may take several days to a week or so for them to fully charge with enough initial heat energy to start providing an optimal performance. Filling the barrels with warm water will speed the process.

You may be able to find creative uses for thermal mass like integrating it in the legs of platforms for planters or growing tables; installing [treated] plywood shelving on top of the barrels along the back wall for additional growing space - this is a good way to combine functions.

We do not recommend open water containers which allow water to evaporate raising the structure's humidity and reducing thermal storage. Raising humidity levels in the greenhouse higher than what occurs during respiration from normal plant growth can harm the plants. High humidity can also be a problem if you grow plants in hydroponic and aquaponic systems as it favors the proliferation of fungus gnats, mold, mildew, and fungal diseases on your plants (and also make you sick if allergic!).

For reasons discussed earlier, plastic barrels are discouraged. Yes, they won't rust but plastic does not transfer heat as well as metal; temperature measurements on a flat black metal and a black plastic barrel in den Biggelaar's sunroom showed that the latter remains about 10^0F cooler than the metal barrel.

While water in metal containers generally is the best thermal mass for performance and cost, there are two possible concerns: 1) For commercial growers, the space the containers occupy diminishes available floor space for growing crops; and 2) home/urban gardeners think barrels are ugly. Below we discuss several alternative thermal mass options and their pros and cons.



Source: https://www.gardenandgreenhouse.net/articles/greenhouse-article

Alternative options for thermal mass

SUN-LITE® Thermal Storage Tubes are polyester fiberglass-reinforced tubes of variable sizes; they are more decorative and aesthetically attractive when filled with water with an added blue dye. They have the same space issue as the barrels of water, and can only be placed on smooth, level concrete floors to prevent cracking. As they are filled with water, they do have a high heat capacity. However, the clear fiberglass tubes may not work as well as metal barrels for two reasons: (1) Polyester and fiberglass are poor thermal conductors limiting their ability to absorb and release

heat; and
(2) Some of the light (blue in the photo) passes all the way through the tube and is never converted to heat. Moreover, blue light stimulates vegetative growth, which is fine if you are primarily growing leafy greens and decorative plants but is not good for fruiting plants (tomatoes, peppers, eggplant, …). For information about these tubes
https://algaetanks.com/sun-lite-thermal-storage-tubes/

Rock and brick masonry are the main thermal storage used in Chinese PSGs. They can be made to be very attractive but store only about 20-30% of the heat stored in the same volume/ mass unit of water (note: 1 liter water = 1 kg). Concrete blocks with their hollow cores are not a good thermal mass.

Phase Change Material (PCM) is a substance which absorbs and releases sufficient heat energy at phase transition to provide useful heating or cooling at a predetermined temperature. Generally, the transition will be to and from one of the first two fundamental states of matter - solid and liquid (Wikipedia, accessed May 14, 2024). Like other forms of thermal mass, the primary function of PCM in greenhouses is to provide heat during cold nights and cloudy days. However, as greenhouse thermal mass it should work differently than PCM used for other applications (food transport, cooling buildings, etc.).



PCM as thermal mass works differently than water (a temperature change material). Unlike water-based thermal mass which is always in a state of absorbing or emitting heat depending on the temperature of its surroundings, the PCM only absorbs heat at temperatures above a preset melting point and until all the PCM changes to a liquid phase. When the surroundings are cooler than the preset temperature, the PCM then gives up its heat, slowly changing to its solid phase again. Based on its chemical composition, the PCM can be set to store/release energy at different temperatures. For most greenhouses, the phase change typically needs to occur around 50-55^{0}F (10-13^{o}C). As you try to determine the minimum night-time temperature of your PSG, it is best to choose a PCM with a phase change temperature of 5^{o}F (3^{o}C) *above* the temperature you want to maintain due to time delays in phase change and heat dispersion as it moves away from the thermal mass (like it does with any source of heat). For example, if your plants need to stay above 50^0 F, consider PCM that starts releasing heat at 55^0 F.

On especially cold winter nights, PCM can function as back-up heat to help maintain the interior temperature. If the SunCatcher's interior temperature drops below the PCM's preset phase change temperature, the PCM releases its heat as infrared radiation as it changes into its solid state. On the next sunny day, the PCM absorbs and stores heat as it melts the PCM to its liquid state again leaving the PCM charged and ready for the next cold night it is needed.

An early experiment using phase change material was the Carolina Mountain SunCatcher which used them on the walls and ceiling (the white pouches (see photo to the right). White walls and ceiling are recommended in PSGs to reflect more incoming sunlight back into the structure for the benefit of the plants grown within. However, when light is reflected by the white plastic pouches, less light will be available to warm the phase change material inside the pouches. So, in the pictured configuration, it may be less effective at maintaining the temperature of the greenhouse.

As the main thermal mass in a greenhouse, PCM may not be sufficient to keep the greenhouse at desired temperatures. However, the slow thermal transfer rate in PCM can be a great property as a secondary (back-up) thermal mass because with a sufficient amount of PCM, it helps "hold" greenhouse temperatures above the cold outside temperatures over a longer period of time. PCM "heating up/melting" on sunny mornings also delays the morning venting process to allow more time for photosynthesis when an excess CO_2 may be available if the greenhouse is vented properly (we will discuss this in Chapter X on ventilation).

Some of the main concerns with PCM include cost, availability, packaging (plastic wrapper, as plastic is not a good heat conductor), color (white and silver do reflect more light within the PSG, but then that same sunlight is not available for conversion to heat absorption and storage within the PCM). A second major drawback of PCM is the limited number of phase changes before the materials become ineffective; PCMs may lose energy storage capacity at temperatures at which phase transitions occur or due to chemical and physical transformations over many cycles of use (Gao et al., 2013). For greenhouse applications, PCM should have the following properties:

- Flat black is the best of all colors for radiative heat transfer.
- Enclosed in metal foil, at least on the side exposed to the sun/facing the interior of the PSG. This will provide a more effective conductive thermal transfer through the packaging material itself.
- Other PCM properties required if used as a greenhouse thermal mass include: UV-stable packaging, long life (i.e., a high number of phase-change cycles), made of non-toxic material, high heat storage capacities, low cost, durable, and easy to install and maintain.

From our experiences we see two possible PCM container configurations:

1. Flat black, blue and/or red aluminum/metal foil "sheets" of PCM installed on the interior surface of the walls and ceiling, and/or
2. PCM "thermal storage blocks" of the same colors that can be stacked within a greenhouse. This is an opportunity to develop a much-needed product (thermal storage blocks/walls for greenhouses) not only for passive solar greenhouses but for everyone trying to cut their energy use.

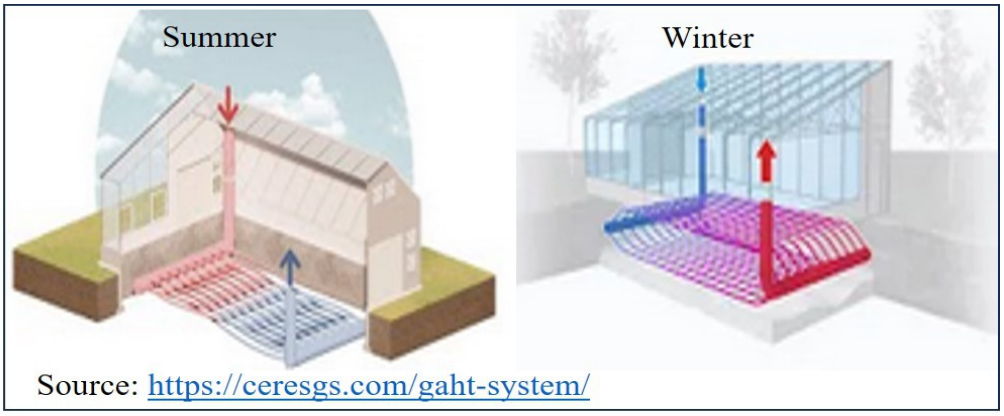
Unfortunately, at the time of this writing, PCM has not been sufficiently understood and developed for use in greenhouse thermal mass applications.

Earth bermed greenhouses - SunCatcher has not experimented with earth berms and do not address them in this text but we believe they can be effective if properly constructed. There are others who have studied and collected data on this topic and there is a lot of information on earth

berms on the web (a good source is Oehler, 2007). If you are considering using an earth-berm greenhouse, there are several things we suggest you keep in mind:

- Properly installed earth berms can help with both cooling & heating a greenhouse depending on the ambient & interior temperatures.
- Heat always flows from hot to cold.
- Insulation will block heat flow in both directions.
- Insulate the wall down to below the frost line (like you would for a house foundation in your area).
- Cinder blocks do not transfer heat very well – unless their holes are filled.
- The earth you're coupling to should be roughly 50-55^{0}F (10-13^{0}C) – warm enough to help heat in the winter and cool enough to help reduce interior temperatures during warm periods.
- Allow for sufficient air flow throughout the greenhouse since you will not have any low north wall vents. Make sure and include other ways to vent the structure quickly, such as exhaust fans.

Underground thermal storage systems - We often get questions about using a Ground to Air Heat Transfer (GAHT) system (also known as a "climate battery") in PSGs. The system consists of one or more layers of 4+ in. perforated ribbed polyethylene piping buried underground. During the summer and warm days in winter, fans blow moist, warm air from high in the greenhouse through the tubing to store excess heat in the gravel around the buried pipes. On cold days, the fans push warm air through the underground piping back into the greenhouse as shown in the diagram.



Source: https://ceresgs.com/gaht-system/

The theory is novel and very enticing. However, GAHT systems do require high-volume fans powered by grid electricity year-round to operate and are, therefore, not *passive* solar systems. After studying thermal performance data of one such system, we simply do not find it to be cost effective compared to passive solar heat storage systems. This is due to the high initial cost of the underground system, the on-going energy costs for operating the system (making it an active system requiring grid electricity) and, under certain conditions, the need for a lot of supplemental heat in a cold environment.

Another major issue with the underground system is the thermal conductive rate in the underground piping is slow due to several factors; two of the biggest being the poor thermal conductivity of the (ribbed) plastic pipe itself and its poor contact with the loose gravel in which the pipe is buried. The lack of good thermal contact and transfer means the system will be very slow to provide maximum heat on demand on cold winter nights when it is needed most. Some

of the heat being supplied to warm the greenhouse is produced from running the fans but additional heat may be required. The piping system is buried underneath the greenhouse and can be very difficult and costly to remove should one decide to remove it.

The underground thermal storage system does typically require grid electricity to operate, so what happens during electric power outages? Carroll experienced systems like this while he lived in the Four Corners region in the late 70s. They found these systems had major issues with mold and mildew developing in the buried pipes and medium surrounding them from the warm, moist air blown into the underground during the summer, creating air quality and disease (for plants and operators) issues over time. A farm in SE Minnesota discontinued their GAHT for similar reasons (the South-facing greenhouse was built into a hill, with the piping buried behind it).

Soil as thermal mass

Instead of installing a concrete, gravel or tile floor in your SunCatcher, you can grow crops directly into the soil (it probably needs to be amended after construction) or in raised beds. Research by Al-Kayssi et al. (1990) showed that an increase in soil moisture content reduces day/night soil temperature differences. They found that as soil moisture increased, solar energy absorption resulted in higher heat storage capacity. That doesn't mean you should saturate the soil – *water only as much as the plants need*. At the ASU Sustainable Development farms in both Valle Crucis, NC and Fleetwood, NC, soil temperatures in planting beds closely tracked the water barrel temperatures (Figure IX.7). Once the crop canopy closed and sunlight no longer directly hit the soil, soil temperature remained more or less steady.

An optimal thermal mass system

We believe an optimum thermal mass system for a passive solar greenhouse might include a combination of both water that absorbs and releases radiative heat on an on-going basis in a range of temperatures, combined with PCM (when it is properly developed for this application) that stores and releases radiative heat at a specific preset (minimum) temperature below which the plants won't do well. Each one works differently in the heating/cooling process. The water absorbs and releases radiative heat on an on-going basis, absorbing heat during the day as the sun warms the SunCatcher, and releasing that heat at night to warm the SunCatcher as needed. The PCM stores a large amount of additional or reserve radiative heat; it releases heat energy only when the greenhouse cools down to a specific predetermined (minimum) temperature. It functions much like a second heater coming on to increase the amount of available heat to the structure. This will help keep the temperatures inside the SunCatcher from dropping too low during periods of very cold outside temperatures preceded by several cloudy days in a row.

There are basically three weather scenarios we generally encounter:

1. The morning of a sunny day after a cold night (regardless of the ambient temperature) is a simple 24-hour heating and cooling cycle
    - Warms/melts PCM.
    - Water absorbs heat as temperature rises in SunCatcher.
    - The water thermal mass will increase its overall temperature if there are several sunny days in a row.

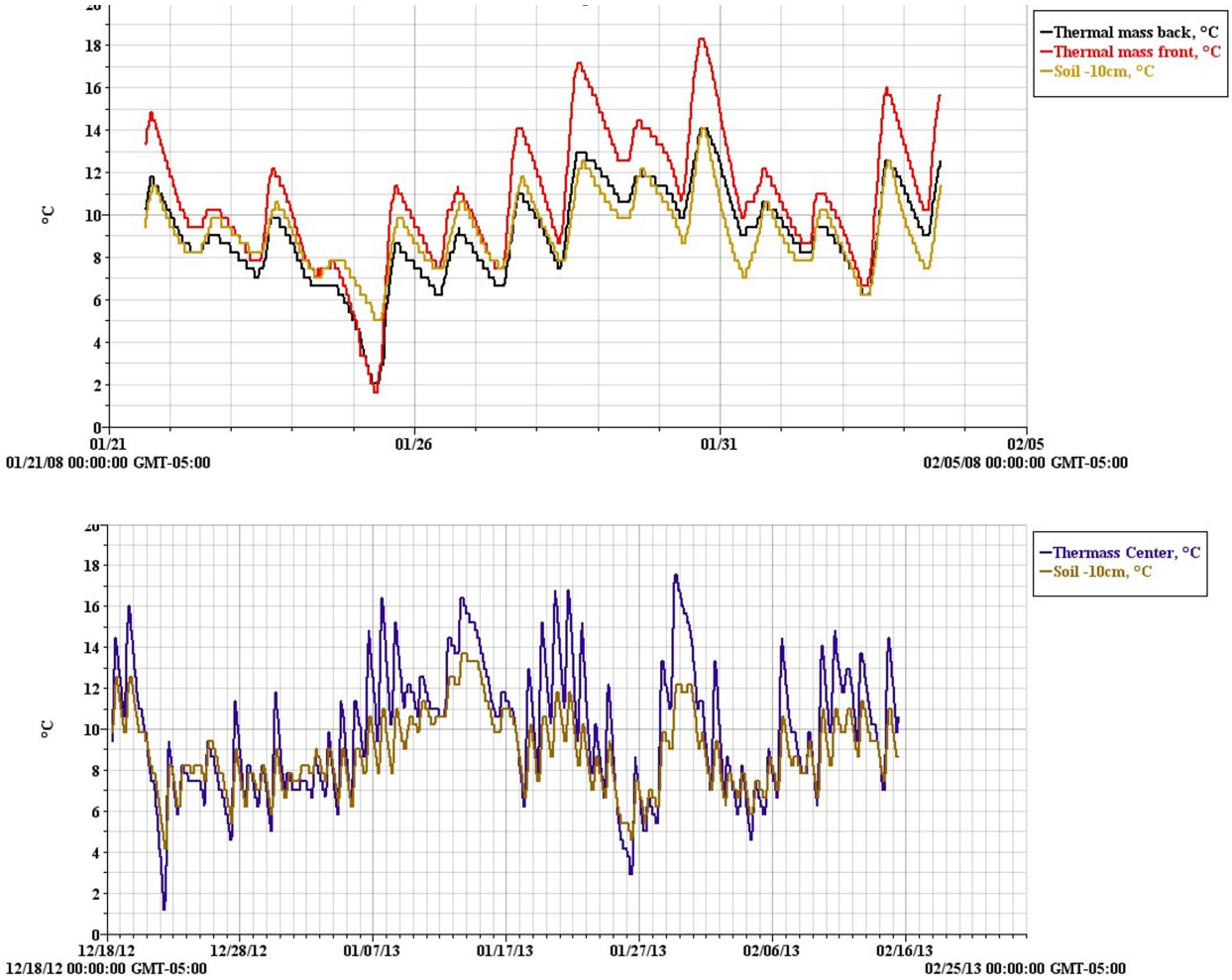


Figure IX.7. Moist soil acts similarly to metal barrels as thermal mass, results from two modified hoophouses at the SD Teaching & Research Farm. Above: Valle Crucis, NC Jan-Feb 2008. Below: Fleetwood, NC Dec 2012 through Feb 2013.

- When the SunCatcher reaches ~75^0 - 80^0:
  - The PCM is fully liquified and charged (and unable to absorb more heat).
  - Vents are opened to exhaust excess heat and humidity while bringing in cooler, dryer and CO_2-rich air.
  - Evening comes, vents are closed and the greenhouse cools until it reaches the water thermal mass temperature, which starts to radiate heat to warm the structure.
  - If the greenhouse temperature drops to the preset temperature of the PCM, the PCM "kicks-in" with additional heat to help keep the greenhouse warm.

2. A cloudy scenario is 3-4 overcast and cold days - the design allows for this now. The water thermal mass will continue to give up heat without being recharged but at lower and lower temperatures until it reaches the PCM phase change temperature. The slow thermal transfer rate in larger bulk PCM is a great property for thermal mass used in a greenhouse for this reason.

3. The worst-case scenario is extended cold and overcast weather for many days. This is unusual in most locations and the only feasible solution is some additional heat. We do not want to over-design the system to meet the occasional heating needs of this scenario. An easier and cheaper solution IF such a situation occurs would be to cover your plants with Remay frost blankets, or supplement heat with UL-approved space heaters as needed.

Thermal mass is the beating heart of a passive solar greenhouse. It makes the difference between a building that overheats by day and freezes by night, or one that provides stable, productive conditions year-round. For most growers, the most practical and effective solution remains water in flat black metal containers. With creative placement, thoughtful design, and the possible future integration of improved PCMs, thermal mass ensures that the SunCatcher PSG can deliver reliable, low-cost climate control for decades.

Reference

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Further reading

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