Greenhouses in Cold Regions

Traditionally, cold regions practiced a variety of food preservation techniques intended to help stretch the food they grew and foraged in spring, summer, and fall to last them through the winter. This didn't stop them from looking for ways to grow food out of season, or outside its hardiness zone, and they developed a number of clever techniques from fruit walls to pineapple pits.

Long supply chains and rapid intercontinental transportation made cheap through subsidized fossil fuels have reduced our reliance on these practices, to the extent that some are outside living memory for large swaths of the population, but they're still around, and have even been updated with modern technology. Whether your solarpunk setting is recovering from a societal collapse and broken supply lines, or is just much more conscious of the externalities of globalized shipping and prioritizes local food production, there are a handful of options it could call upon to maintain access to fresh food.

The Current Default

We use greenhouses to manage the temperature, humidity, and even atmosphere composition for crops all over the world but the basic design is fairly consistent, regardless of location. The most common industrial design is a metal framework with single- or double-ply plastic sheets stretched over it, often with plywood or corrugated plastic siding nailed to stick frame walls on the ends (though these are sometimes concrete block or similar). These 'fully glazed' greenhouses often have a garage door on one or both ends. As you can imagine, given the lack of insulation, large openings from the doors, gaps, etc, operating these in cold climates, especially into the fall and winter is expensive. It’s part of that one-size-fits-all-just-burn-more-gas approach a solarpunk society should generally reconsider wherever it finds it.

(Many greenhouses use glass instead of plastic, though they're usually single-pane and have similar problems with an overall lack of insulation. Greenhouses made from salvaged home windows especially modern, double-pane windows insulated with a layer of air, argon, or vacuum might get better results.)

In order to increase crop yield, growers usually aim to have the CO2-level inside the greenhouse at least three times the level outdoors. Because they already use wood or fossil fuel based heating systems, they can obtain the excess CO2 as a byproduct of combustion. This is part of why you don't see geothermal energy and electric heat pumps revolutionizing the modern glasshouse industry (outside of a few really cool exceptions) despite being far more efficient than diesel.

Passive Greenhouses

In colder climates, where low temperatures are your main concern, there are several ways to modify the basic greenhouse to greatly improve the heat absorbed and retained from sun exposure. Many of them are used effectively in industrial greenhouses set up in mainland China. These designs can be so effective that the greenhouse is able to operate through cold weather without using traditional heat at all.

This design fits the same niche as aboveground, freestanding greenhouses elsewhere in cold climates, just with some improvements:

- They feature three insulating walls, often made of mortared brick, clay, or concrete block with air pockets inside (although modern insulation such as polystyrene foam is seeing increasing use) and one taller plastic/glass wall/roof facing towards the sun (south, in the northern hemisphere, north in the southern hemisphere)
    - The back and sometimes side walls are often backed with a earthen berm for additional geothermal mass insulation
    - These thick walls also block the cold, northern winds, which would otherwise speed up the heat loss of the greenhouse
- At sunset, an insulating sheet/blanket is rolled out over the plastic/glass, increasing the isolating capacity of the structure. For best results, the insulation blanket has a reflective coating to further reduce heat loss from inside.
- The farther north the greenhouse is located, the steeper the slope of its sun-facing transparent wall/roof will be. The slope is angled to be perpendicular to the sun’s rays when it’s lowest on the horizon.

In many cold climates these structures aren't effective enough to be completely passive and will need some additional source of heat. Compared to the current design however, they are still far more efficient: one test found that to keep the temperature above ten degrees Celsius at all times a passive greenhouse required 3.6 kW for the building while a glass structure of equal proportions at the same interior and exterior temperatures would require a maximum capacity of 125 to 155 kW.

The downsides: Normal greenhouses are optimized for profits, and despite being more efficient to heat, the passive greenhouses produce less, making them two to three times less profitable per square meter.

Walipini / Pineapple Pit

Walipinis take these design changes a step further. Modern designs for cold regions use the same basic three-insulated-sides-one-glass-side format as passive greenhouses but set the structure down into the ground to use the earth for thermal regulation and to lower the greenhouse's exposure to the wind. They use insulated windows for the transparent wall and generally set them at a steeper angle than those on passive greenhouses. They may even have a partial roof on the north side (south if located far in the southern hemisphere). Inside they are similar except for the inclusion of a cold sump, a low point for the cold air to collect. This is often dug in as a trench in the floor but it may also show up as an aisle between raised beds.

If these designs sound reminiscent of earthships, it's probably because they share a general design philosophy. Both use the earth to regulate their temperature and one large wall of windows to provide light and heat - there are even some crossover designs that sort of mix both.

The concept of using a buried greenhouse to grow crops out of zone or season has been around for a long time, from pineapple pits in Britain, to citrus trenches in the Soviet Union. There's been a fairly recent resurgence in interest in the homesteading scene and some communities are already using them to great effect but it's likely that a solarpunk society, especially one where societal crumbles disrupted the supply chains that provide cheap, fresh fruit out of season, would see a much broader interest in the general population and industry. Especially if fuel is also scarce, or society is more concerned about the externalities of modern-day commercial shipping or heating uninsulated buildings through winter.

Salvage

One of the major cost points in building a walipini is excavating and reinforcing the pit which forms the structure. This work may require an excavator or a lot of time and sweat to do by hand and concrete is expensive (especially environmentally). Structures that meet this general requirement already exist though, and they're fairly common: in-ground swimming pools and basements. Neither is a one-to-one fit for the ideal walipini design, but they have lined, reinforced holes in the ground, stairs for access, and, in the case of basements, may already have drains installed. Swimming pools are expensive and wasteful to maintain, requiring large amounts of water, chemicals, labor, and electricity to keep clean. Furthermore, damage to a pool which prevents its use for holding water (like expensive cracks) don't prevent it from being repurposed as a walipini. A few people have already done absolutely beautiful swimming pool → walipini conversions, but a recovering society might see a huge number of these conversions for utilitarian reasons.

A residential basement is a bit less accessible, but they still become available fairly often, in the event of fire or demolition IRL, they're often left open for months or years. In a world where car-dependent regions are becoming less viable, and deconstruction efforts are disassembling abandoned buildings and salvaging the materials for reuse, we could even see some suburban neighborhoods repurposed into rows of walipini greenhouses.

Other salvage: Like with earthships, much of the modern homesteading-based walipini building scene places a heavy emphasis on repurposing existing *stuff*. Walipini pits are frequently reinforced with stacked old tires packed with rammed earth, and salvaged lumber, windows, thermostats/fans, wiring, and lights are all used wherever possible in their construction. This could be pushed even further in a solarpunk setting; perhaps the massive windows from car dealerships could be used for the sun-facing wall,

Downsides:

- **Cost** - Walipinis are a much more elaborate building than a traditional metal-frame, plastic-covered greenhouse. They require excavation, reinforced foundations, appropriate drainage, and safety mechanisms we'll get into shortly. These all mean that building a walipini from scratch will take more time and cost more in money or resources than a regular greenhouse.
- **Maintenance** - Nature abhors a vacuum and it tries to fill them with water, heavier-than-air gasses, and the surrounding earth, wherever possible. A walipini may not take more maintenance than a regular greenhouse, but it will still have issues, especially if the appropriate site prep is not done.

Safety Considerations

There are several new risks introduced by the design of a walipini - none of these are dealbreakers but they should be accounted for in the planning and construction phases.

- **Engulfment** - many images online show walipinis from inside with bare earth walls, with no reinforcement. This means the structure is essentially an unlined hole in the ground whose walls could decide to relocate at any time. OSHA and other safety organizations define this class of dangers as engulfment hazards. Engulfment occurs when a person becomes trapped by flowable materials — such as soil, sand, or grain — that can move rapidly, collapse without warning, or block escape routes. These incidents often lead to injury or death by strangulation, constriction, crushing, or suffocation. They are most commonly associated with confined spaces like trenches, silos, tanks, and storage bins. Engulfment hazards can still pose a serious risk even if your head is above the walls of the hole, as the soil can flow and settle around your chest and prevent inhalation, leading to suffocation. This pressure can also cause constriction/crush injury to buried parts of your body. Remember to shore, slope, or bench any excavation for safety!

- **Heavier-Than-Air Gasses** In workplace safety terms, an enclosed, sunken structure like a walipini becomes a "confined space" where heavier-than-air gases can pool, causing a serious danger to anyone who enters. Such gases could originate from the drain system or flow from surrounding ground, such as adjacent leaking propane or sewage pipes. But it could also come from decomposition within the greenhouse, such as from compost. Urban Explorers, First Responders, and City Maintenance Personnel know the risks of Hydrogen Sulfide (H_2S) in a confined space - the gas is produced by the anaerobic decomposition of organic matter (such as you might find in sewage or storm drains, or poorly-managed compost heaps) and pools in low areas. With a heavy enough concentration the gas can knock you out immediately, sometimes leading to tragic chains of deaths as would-be rescuers are also overcome. Similar tragedies have also happened when gasses produced by rotting potatoes pooled in residential basements. The good news here is that this is preventable through detection and ventilation. Detectors are commercially available and fans and ductwork can draw air from the lowest point in the structure (usually the cold sump) out of the walipini. If the walipini is built into a hillside, you may also be able to include a passive ventilation system by using a pipe as a drain running downhill from the lowest point in the greenhouse to the outside.

Compatible (Symbiotic?) Practices

- **Thermal mass** is a big part of maintaining temperature in a passive structure with little or no additional heat. The back wall of a passive greenhouse or walipini usually absorbs heat from the sun during the day and radiates it at night. This can be increased by painting it black to absorb as much light as possible. A simple way to boost this heat storage further by is placing black-painted water storage tanks against the back wall inside the structure. These warm up during the day, capturing extra solar energy and release it during the night.

There are several ways to produce heat that also provide CO_2. This is helpful because it accelerates plant growth and boosts crop yields, and makes up for the

- **Compost** - Composting is an important part of agriculture likely already present wherever there's a greenhouse. As microorganisms break down biodegradable materials they naturally produces heat and CO_2. A compost bin can reach 140 degrees Fahrenheit or more inside the pile while it is in the hottest phase of decomposition. The effectiveness of the compost-as-heat depends on the amount of compost and how well the greenhouse is insulated - in some cases it may not be enough on its own to heat an entire greenhouse but might be built into the lower part of seedling beds to keep them warm and get a jump start on the growing season.
  - The downsides here are that using compost as heat requires some planning and monitoring - it's less convenient than a commercial heater. Additionally there's some additional risk: modern greenhouses are sometimes used to isolate and protect plants from threats like bugs and blights outside, and bringing compost into the greenhouse (especially in an open container) can cross-contaminate. If this is a concern setting up a fluid exchange system with an outdoor compost pile might make more sense.
- **Manure** The use of manure for heating small-scale greenhouses dates back several centuries in Europe, and in China it was practiced 2,000 years ago. A greenhouse can be entirely heated by compost if it is well-insulated, and that the method drastically enriches the CO_2-levels in the soil and in the greenhouse air. I haven't found a good breakdown on if there's a functional difference between using animal manure vs plant matter but all the ones I've found that claim decomposition meets all their heat needs appear to be using at least a mix of manure if not primarily that.

    - Downsides: still not as convenient as a furnace. Comparatively bad smell (though a layer of charcoal can help). Involves animals in agriculture which can be done ethically but vegan writers may prefer to avoid.
    - Manure-related fun fact: colonial farmers in the New England region of the US added manure basements to their ever-changing barn designs, making removal and storage of animal waste easier (just shovel it down a hatch right indoors). The heat of this manure decomposing kept the barn (and especially its foundation) warm. As the barns fell out of use, part of their rapid collapse came from fieldstone foundations which were no longer protected from expanding ice.
- **Co-location with animals** Another way to meet this need is to go right to the source. Pigs, chickens, rabbits, and fish all produce CO2 that can be absorbed by the plants, while the plants produce oxygen (and green waste) for the animals. The animals and their manure also contribute to the heating of the structure. It is estimated that a commercial hen can generate about 10 watts of heat. Research of such integrated greenhouse systems has shown that the combined production of vegetables, meat, milk, and eggs raises yields quite substantially.
    - Downsides: additional work with caring for animals. Possibly more complex structures - as far as I can tell the animals might not be in a pen in the greenhouse but in an adjacent room with cross ventilation.
- And absolute worst case, there are ways to make wood heat sustainable (and to produce biochar using rocket stoves or rocket mass heaters as a byproduct. This stuff can be tremendously useful in compost, and holds carbon for a comparatively long time.