

ENGINEERING GREENHOUSES FOR SOLAR SLUDGE DRYING

DESIGN CONSIDERATIONS FOR WASTEWATER TREATMENT FACILITIES

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EXECUTIVE SUMMARY

Solar sludge drying greenhouses offer wastewater treatment facilities a practical way to reduce the moisture content, volume, and weight of sludge before its final use or disposal. By using solar energy to create a warmer, controlled drying environment, these systems can reduce hauling and disposal requirements while providing year-round protection from rain and other weather conditions.

But effective solar sludge drying takes more than putting sludge inside a greenhouse and letting the sun do the work. The greenhouse itself becomes part of the treatment process. The type of structure, its ventilation, controls, materials, and systems all influence how effectively the facility can move air, remove moisture, handle sludge, and maintain reliable operations.

That makes early design decisions especially important. Key decisions about the greenhouse structure, environmental controls, material handling, day-to-day operations, and provisions for future expansion should all be made with the drying process in mind.

This whitepaper examines the major considerations involved in designing a greenhouse specifically for solar sludge drying. The goal is to help wastewater treatment facility operators and engineers understand the decisions that should be addressed early in the planning process and how those decisions affect long-term performance.

The key is to design around the process from the beginning. When the greenhouse, processing equipment, environmental systems, and facility operations are planned as one integrated system, the result is a facility better equipped to dry sludge reliably, efficiently, and consistently over its service life.

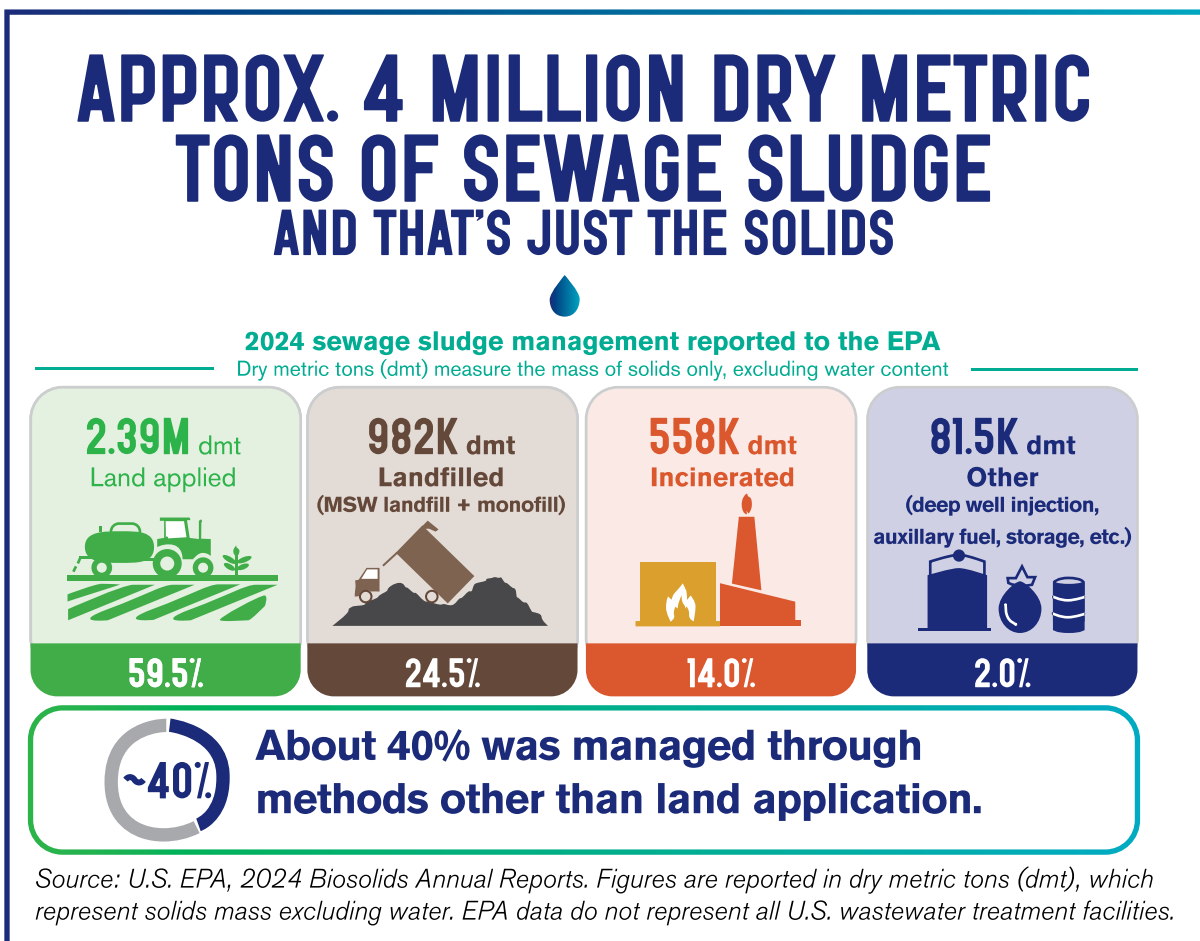


INTRODUCTION

Wastewater treatment inevitably produces sludge, and the U.S. produces it at an enormous scale.

Based on the 2024 Biosolids Annual Reports from roughly 2,350 reporting wastewater treatment facilities (WTFs) in 41 states, the EPA estimates that approximately 4 million dry metric tons (dmt) of sewage sludge were generated. That equals about 4.4 million U.S. tons of dry solids (U.S. EPA, 2025)

Dry metric tons represent the weight of the solids in sewage sludge, excluding its water content. The actual weight and volume of wet or dewatered sludge handled by WTFs is considerably greater.



But the sludge problem isn't only about solids; it's about water. The more water that remains in the sludge, the more material a WTF may have to handle, store, transport, and process.

Moving and processing wet material costs money. Since much of sludge's mass before drying is water, removing water from sludge fundamentally changes the economics of managing it.

Solar sludge drying greenhouses (SSDG) offer a way to remove that water using a renewable energy source.

On the surface, a greenhouse seems pretty straightforward. But you can't just throw it up over the drying area and expect it to do its job.

In this application, a greenhouse needs to be a working part of the sludge treatment process that creates the conditions needed to effectively and efficiently dry the sludge.

That means early design decisions when planning a greenhouse can have long-term consequences.

Every decision, from the greenhouse's dimensions and equipment layout to its ventilation strategy affects its drying efficiency, operating costs, and long-term maintenance and expansion.

Yet, engineers and WTFs evaluating greenhouses have relatively few resources focused specifically on the structure itself.

This whitepaper points out the key items engineers and WTFs should understand when planning and specifying a SSDG.



BROAD OVERVIEW

A SSDG uses a combination of renewable solar energy, controlled airflow, and environmental controls to further reduce the moisture content of dewatered sludge through natural evaporation.

Solar radiation enters the greenhouse, warming the air, the sludge, and the concrete slab beneath it. As the greenhouse temperature rises, moisture in the sludge evaporates into the surrounding air. The warmer the air, the greater its capacity to hold water vapor, so it can absorb more of the moisture released from the sludge.

But as the air becomes increasingly humid, it must be removed from the greenhouse to facilitate the drying process. Exhaust fans and ventilation systems push the moisture-laden air outdoors while pulling drier outside air inside the greenhouse. This incoming air can then absorb more moisture from the sludge.

By continually adding heat, moving air across the sludge, and replacing humid air with drier air, the greenhouse maintains conditions that encourage evaporation and accelerate the sludge drying process.

In some facilities, automated sludge turning machines improve drying uniformity by stirring up the sludge at regular intervals. This prevents surface crusting and also speeds up moisture removal.

The sludge's volume and mass shrinks considerably as its moisture content evaporates. Less bulk makes the sludge easier and cheaper to handle later on.

Research has confirmed that in favorable conditions SSDGs can cut sludge volume by around 80% to 85%, with some systems reporting even larger weight reductions after drying (Belloulid, 2017), (Mathioudakis, 2009).

In simple terms, the main function of an SSDG is to keep relatively hot, dry air in contact with the sludge and move humid air away from it.



KEY BENEFITS

SSDGs offer several advantages over open drying beds and other drying methods.

Year-Round Weather Protection

Close-sided greenhouses protect their contents from rain and snow and allow WTFs to process sludge uninterrupted year-round in a wide range of climates.

Rain protection also eliminates the added weight and hauling costs that come with water-soaked sludge.

Free Solar Energy

Solar radiation provides the primary heat input. Unlike conventional thermal dryers, the greenhouse can use a large amount of free solar energy to drive the evaporation process. Supplemental heat may still be justified in cases where winter production, throughput, or target solids requirements cannot be met with solar energy alone.

Lower Hauling and Disposal Requirements

Removing water reduces both the weight and volume of the sludge that leaves the facility, which can reduce truck trips, transportation costs, and disposal costs.

Depending on the treatment level, biosolids quality, and applicable regulations, dried biosolids may be suitable for land application, composting, land reclamation, and other uses rather than disposal.

Long Service Life and Easy Expansion

A properly designed and maintained greenhouse can provide decades of service. Planning for future growth from the start allows additional bays to be gutter-connected and internal systems to be extended as capacity needs to increase.

This gives smaller facilities the flexibility to build for what they need today while preparing for tomorrow, rather than investing in the entire future system upfront.



PART ONE:

SITE AND FACILITY DESIGN CONSIDERATIONS

Start With the Right Orientation

In the Northern Hemisphere, a north-south ridge orientation is often advantageous to make the best use of available sunlight. But while this is ideal, it is not always possible for every site.

Evaluate greenhouse orientation during the planning and design phase to maximize solar energy capture while accommodating ventilation requirements, site constraints, and material flow.

Because these factors vary by location, facility layout, and operational needs, determine the optimal orientation on a project-specific basis.

Design Your Facility Around Material Flow

Every design decision, from a SSDG's dimensions and equipment layout to its ventilation strategy, affects its drying efficiency, operating costs, and long-term maintenance and expansion.

This is not a simple building you throw up quickly to cover the sludge; it's a working part of the treatment process infrastructure and needs to be treated as such.

Start by mapping out the path the material will take through the building, beginning when the sludge enters and following it through drying, final product handling, and transport off-site.

The goal is for the material to move through the facility in a logical path with as little unnecessary handling and cross-traffic as possible. A basic material flow might look like this:

1. Dewater the sludge and discharge it to a conveyor, loader, or other transport system
2. Move dewatered sludge into active drying area
3. Turn, mix, and advance material through the drying process
4. Remove dried material without interfering with active drying operations
5. Load the product for storage, beneficial use, or disposal

A long gutter-connected greenhouse can support this linear process well, with dewatered sludge entering at one end and dried materials exiting at the opposite end. The exact layout will vary with each operation, but planning the flow before you design the greenhouse and adjoining buildings reduces unnecessary material handling and prevents trucks, loaders, equipment, and employees from getting in each other's way.



Planning material flow early helps minimize loader travel, handling time, and traffic conflicts

Plan for Operations and Maintenance Access

Don't design a SSDG separately from the equipment that will operate inside it. Greenhouse designers and engineers, wastewater treatment engineers and operators, and equipment suppliers should coordinate early, so the structure, process equipment, and material flow work together.

Sludge turners, conveyors, loaders, and other equipment affect greenhouse width, gutter height, truss geometry, floor layout, electrical service, drainage, and structural clearances. Plan for these requirements before the greenhouse design is finalized rather than trying to make equipment fit later.

Provide enough clearance to operate and maneuver sludge turners, skid steers, forklifts, dump trucks, cranes, and other equipment used at the facility. Size doors and overhead openings for the largest vehicle or component that may need to pass through them, including equipment brought in for maintenance or repairs.

ACCOUNT FOR:

- Equipment operating envelopes and turning radii
- Loader, forklift, and truck travel paths
- Maintenance and washdown access
- Door, overhead opening, and gutter-height clearances
- Safe access to motors, drives, sensors, vents, fans, and controls
- Practical routes for removing and replacing large components

Don't overlook gutter height when designing your greenhouse. The gutters need to be high enough to provide clearance for tall vehicles and equipment.

Think beyond day-to-day operations. Eventually, a piece of equipment or other large component may need servicing or replacement. Designing a clear path to reach, remove, and replace that equipment from the start can prevent costly modifications and major headaches later.

Bring Supporting Operations Under One Roof

Your greenhouse does not have to stand alone. A pre-engineered metal building (PEMB), headhouse, or enclosed service area can be integrated with it to create one connected facility.

The adjoining space can house electrical equipment, utilities, screw presses and other dewatering equipment, conveyors, material-handling equipment, loading/unloading areas, and more.

Bringing these functions together shortens travel distances and protects employees and equipment from the weather. A connected design reduces the overall building footprint and streamlines traffic flow around the site. Instead of moving material between multiple structures, trucks and equipment can follow a planned route through the facility.

Once you have chosen the basic structure for your SSDG, such as an a-frame greenhouse, you can simplify your build by using the same frame style across all your core buildings.

This approach gives you the flexibility to adapt the same basic structure for different purposes by swapping out the covering and outfitting each building to fit its role.

Design for Current Needs and Future Expansion

Future expansion should be part of greenhouse design from day one. You want to choose a structure that can be gutter-connected, meaning it allows you to join multiple individual greenhouse bays side-by-side with shared gutters and walls to create one continuous indoor area. Your utilities and infrastructure also need to be able to grow with the facility.

A facility master plan helps you determine where utility mains, water and drain lines, electrical panels, gas lines, and other infrastructure should be located. Consider what you need today and what will be required if additional greenhouse bays are added later.



The same greenhouse frame style can be adapted with different coverings for different facility needs. Here an a-frame style structure is covered with metal decking to accommodate screw press equipment.

- **Electrical capacity:** Size electrical service, control panels, and backup power for current loads while accounting for future equipment and greenhouse expansion.
- **Plumbing:** Plan water supply and piping routes, so they can be extended as the facility grows.
- **Drainage:** Determine drainage requirements based on greenhouse application, equipment, and operating processes. Allow for future expansion when sizing and locating drains and discharge points.
- **Utility layout:** Position mains, connections, and equipment so future greenhouse sections can tie into them without relocating existing infrastructure or disrupting operations.



A gutter-connected greenhouse allows you to expand over time by adding new bays without disrupting sludge processing.

PART TWO:

STRUCTURAL CONSIDERATIONS

Choosing Your Structure Type

Once you know how the greenhouse needs to support the drying process, you can turn your attention to the structure itself.

For many SSDG applications, an A-frame structure with adequate clearance height, structural capacity, ventilation integration, and expansion capability can be advantageous. Prospiant's Vail A-frame is one example.

The Vail is a tough, workhorse greenhouse with a tall gutter height that provides plenty of clearance for large equipment, and tall vehicles and machinery. You can also opt for high-clearance trusses to gain even more overhead space or accommodate overhead/oversized doors.

The Vail accommodates different coverings such as polycarbonate, glass, or acrylic glazing. You can also cover it with metal decking and insulated metal coverings for use as a headhouse, storage building, or outbuilding.

We manufacture the Vail with durable triple-galvanized U.S. square steel for strength and longevity. This structure is durable enough to handle high wind, heavy snow loads, and even seismic activity, and we customize it to meet building codes in your specific area.

You can also gutter-connect the Vail, which allows you to add more greenhouse bays over time as your operation expands without disruption to sludge processing.

SPECIFICATIONS FOR VAIL A-FRAME GREENHOUSE

- Standard gutter heights: 10'-16'
- Standard widths: 15', 24', 30', 35'6", and 42' spans
- Standard bay spacing: 10' or 12', depending on code requirements
- Roof load ratings: 20#/sq. ft. or higher
- Non-standard widths and heights available

Other features of the Vail include:

- One-piece, factory-welded trusses for strength and easy assembly
- Standard 6/12 roof pitch helps shed snow and reduces condensation inside building
- In-house roof extrusion design with gasketing keeps leaks out and channels condensation out of the building

Our Venlo greenhouse with multi-peak a-frames can also be used for a wastewater treatment greenhouse. The main advantage of the Venlo is its glass glazing system or insulated metal coverings, which make it flexible for both SSDGs or other operational warehouse space.



Venlo greenhouses offer optimal light transmission and exceptional ventilation. Alternating skip vents on the roof allow for the release of heat and humidity at a controlled pace.

Structural Loads and Building-Code Classification

The American Society of Civil Engineers (ASCE) 7-22 establishes minimum structural wind, snow, and seismic loads based on what the risk factor is for each building project.

Risk Category rankings reflect the potential risk to human life, health, and welfare if the structure fails or becomes damaged.

Building codes and requirements vary with each municipality and region. Before you start your project, determine what those are in your area and which authority has jurisdiction.

Material Selection for a Corrosive Environment

SSDG are routinely exposed to constant moisture and potentially corrosive conditions, which can shorten the life of structural components, equipment, and electrical systems. Material selection should account for this environment from the start.

STRUCTURAL MATERIALS AND COMPONENTS:

- *Pre-galvanized/Galvanized steel* for primary structural members and other exposed steel components. The zinc coating provides a protective barrier and sacrificial layer that helps protect the underlying steel from rust and corrosion. Specify a galvanized coating appropriate for the expected exposure and pay particular attention to cut edges, welds, and other areas where the coating may be compromised.
- *Aluminum* for glazing bars, vents, and other components where a low weight material is beneficial. Aluminum naturally forms a protective oxide layer that provides good corrosion resistance.
- *Stainless-steel* fasteners and hardware in locations where repeated wetting or aggressive condensate could cause conventional hardware to seize or rust.
- *Protective coatings* such as epoxy, polyurethane, and other industrial coatings can provide an additional barrier against moisture, condensate, and corrosion.
- *Glazing/Coverings:* Consider both service life and resistance to the greenhouse environment. Glass can provide decades of service and typically requires replacement only when damaged.

Structural details can further improve durability. Prospiant Greenhouses, for example, uses single-piece welded trusses, triple-galvanized steel components, and additional corrosion protection at welded areas.

Electrical equipment:

Select electrical components for use in a wet, humid environment. Specify properly rated enclosures for panels and controls based on their location and exposure to water, dust, washdown, and other conditions.

UL listings, NEMA, and IP Ratings provide different information about electrical equipment. UL listings address product safety, while NEMA and IP ratings address environmental protection using different standards.

Although NEMA and IP ratings are sometimes compared, they are not directly interchangeable. Use Table 1 for a quick reference for what each designation tells you.

All electrical equipment should carry the appropriate safety certifications required by applicable codes and the authority having jurisdiction.

Table 1. Electrical Equipment Ratings and Certifications

	UL LISTING	NEMA RATING	IP RATING
Primary purpose	Product safety	Enclosure protection	Ingress protection
What it addresses	Fire, electric shock, and other safety hazards	Water, dust, and other environmental conditions; some types also address corrosion, ice, oil, coolants	Protection against solids/dust and water
Standard/system	UL product safety standards	NEMA enclosure standards	IEC 60529
Commonly used	Primarily North America	Primarily North America	Internationally
What the designation tells you	Product has been evaluated to applicable safety requirements	Type of environmental protection the enclosure provides	Degree of protection against solids and water
Important distinction	Not an enclosure ingress rating	Not directly interchangeable with an IP rating	Does not address all conditions covered by some NEMA ratings

FOUNDATION AND SLAB DESIGN

The foundation slab of a SSDG is both a process surface and, in many facilities, part of the heating system.

It must support sludge, turning equipment, loaders, trucks, conveyors, and other concentrated loads without excessive cracking, settlement, or surface deterioration.

Concrete mix design, reinforcement, joints, surface finish, chemical exposure, moisture exposure, and structural and traffic loading should all be addressed by your greenhouse designer and engineer.

Concrete mix design can have a long-term impact on the slab's strength and durability. The mix should be designed for the conditions it will face, since the proportions of water and other ingredients can affect strength, permeability, and service life (American Cement Association, American Concrete Institute) For a SSDG, choose a mix designed to withstand moisture, heavy equipment traffic, and long-term exposure to biosolids.



The concrete slab must be strong and durable enough to hold up to heavy equipment, vehicle traffic, and concentrated loads without breaking down.

Keep the active drying floor level enough for selected turning equipment to operate properly. Where truck loading occurs inside the building, a localized sloped area of around 30 to 40 feet may be useful for easier loading.

Slab insulation

Don't skip adding insulation around and under your slab perimeter. Substantial heat loss can occur if heat migrates downward below the foundation slab or seeps out the edges around the perimeter.

Some sources say as much as 50% of heat can be lost out the perimeter of a heated slab without insulation. (n.d., NGMA, Heating Systems).

Place foam board insulation under the slab (beneath the frost line) and along its edges. Then cover it with a heavy-duty vapor barrier (such as a plastic sheet).

The best type of insulation to use is one of the extruded polystyrene boards, usually 1.5"-3" thick.

FLOOR HEATING

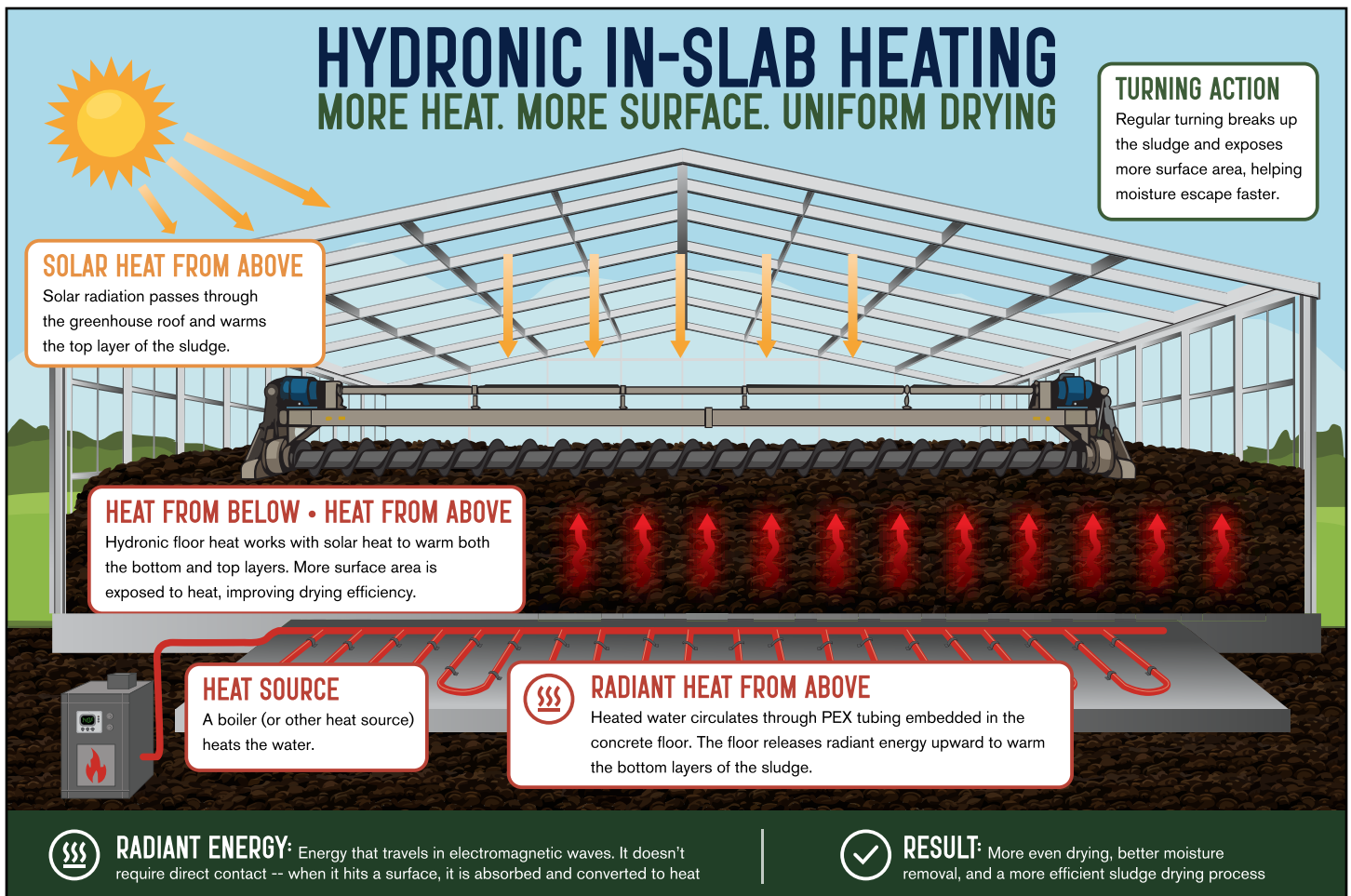
Solar energy coming through the greenhouse roof heats the upper surface of the sludge first. In deep beds or during low-solar periods like wintertime, heat transfer to the lower layers can be limited even when the material is regularly turned.

Hydronic in-slab floor heating adds heat underneath the sludge to improve drying uniformity and winter performance.

Hydronic heating uses radiant energy (energy that travels in electromagnetic waves) to warm the greenhouse floor. A heat source, such as a boiler, heats up water that circulates through PEX tubing embedded in the concrete foundation.

The floor heat radiates upward to warm the bottom layers of the sludge. This, combined with the solar heat coming through the roof that hits the top layer, increases the surface area of heat-receiving material.

Figure 1. Hydronic in-slab heating concept: Solar heat from above, radiant heat from below, and turning action to expose wetter material.



In-slab heating offers several additional advantages, including:

- Delivers heat directly beneath the sludge
- Distributes heat evenly for more uniform drying
- Provides precise temperature control
- Supports energy-efficient operation with a high-efficiency boiler
- Works with boilers using a variety of fuel sources, including biofuels

The performance of an in-slab heating system depends heavily on its design. Installation is complex and every application is different, so project-specific design and engineering are necessary for the system to work efficiently and properly.

Water temperature and pressure, flow rate, polyethylene (PEX) tube configuration, distribution manifolds, flooring material, and other variables all impact heat output. Proper sizing of the system requires calculating the process total peak heat required to ensure the boiler and floor tubing can maintain optimal conditions no matter what time of year.

In-slab hydronic floor heating has several components:

- Boiler or water heater
- Manifold
- PEX tubing
- Circulation pump
- Environmental controller
- Sub-slab insulation
- Glycol antifreeze to prevent frozen lines

Polyethylene (PEX) Tubing

Tube spacing design will be project specific and should be determined by a professional engineer.

PEX tubing needs to be durable enough to have a long service life. Use oxygen-barrier (EVOH layer) PEX tubing developed specifically for in-slab heating to prevent dissolved oxygen from causing corrosion in your boiler.

In structures with a smaller footprint, you often get higher heat loss along the perimeter. In those cases, spacing the PEX tubing closer together along the perimeter of the slab can help offset the heat loss.

The diameter of your tubing has a lot to do with getting proper heat coverage in your greenhouse because it impacts flow rates, and consequently, heat yield. The larger the diameter of the tubing, the higher the water volume it can carry, and the more heat you get per square foot of flooring. Larger diameter tubes also accommodate longer tube run lengths than shorter diameter tubes.

The ASTM F876 standard ensures cross-linked polyethylene tubing meets performance requirements for the following (ASTM, 2026):

- Dimensions and tolerances
- Density
- Sustained pressure
- Burst pressure
- Environmental stress cracking
- Degree of cross-linking
- Stabilizer functionality

One more thing: If you need anchors in your floor to secure equipment, mark out where the PEX tubing is located to avoid puncturing the tubes once they are installed.

Boilers, Heat Sources, and Piping

Radiant/Hydronic heating relies on a heavy-duty boiler to circulate hot water through the floor. Size and efficiency matter when choosing a boiler. Good things to look for include (Bartok, 2025):

- Thermal efficiency of 93% to 99%
- Stainless-steel heat exchangers for corrosion resistance
- BTU capacity sized for typical winter conditions, not extreme lows
- Modulating burners with adequate turndown ratio to prevent short cycling

It's also not a bad idea to install a secondary small boiler to create some redundancy in your operations. This ensures heating can continue uninterrupted if your main boiler goes down. (NGMA, 2010, *Heating*)

Take care to ensure your boiler has enough BTUs to supply both your hydronic heating system and under-gutter heating.

Under-gutter heating uses specialized heating cables or fin pipes installed directly beneath the connecting gutters of multi-bay greenhouses to melt snow, prevent ice dams, and keep water flowing. In the case of sludge drying, it helps to melt the snow to allow the sun in since sun is free heat.

Adding the necessary boiler capacity for under-gutter and floor heating from the start is typically easier and less expensive than discovering in the middle of winter that your boiler is undersized.

PIPING

Fin pipe has a high heat output, which makes it a great choice for under-gutter heating to rapidly melt off ice and snow. Fin pipes use a series of thin metal plates (fins) attached to the pipe to increase the surface areas available for heat transfer. This can boost heat output up to 5 to 10 times that of bare pipe. Heat output varies based on pipe diameter and the number of fins. (Bartok, 2013)

It also has excellent heat-transfer capabilities, allowing heat to move efficiently from the hot water to the surrounding area. Because aluminum is naturally corrosion resistant, it also holds up well in humid, moisture-rich environments.

We highly recommend fin pipes for under-gutter heating because they prevent snow from piling up between the greenhouse peaks and exceeding the load capacity of the frame.

You can also melt snow off the valleys quicker, so you don't miss out on solar heat gain during the winter when you need it most.

What to Avoid

We don't advise using radiant heaters, unit heaters, or forced-air heaters for sludge-drying greenhouses. They're inefficient because they don't direct their heat close enough to the surface of the sludge to make a difference. These types of heaters can also cause massive shadowing inside the greenhouse.

Ventilation and Air Movement

Ventilation is critical to get right for effective and efficient sludge drying. Your environmental controller, roof vent, and fans need to work in tight conjunction with each other to achieve your goals. Using passive ventilation alone doesn't work in this situation because you want the roof vent to release air at rates you can control.

WTFs are typically mechanically ventilated using powerful exhaust fans that pull humid air out of the greenhouse, creating a negative pressure that draws dry air inside through louvers or intake shutters.

With a SSDG, your goal is to get rid of humidity, not to factor in air temperature, as you would in a traditional floriculture greenhouse.



Exhaust fans pull moisture-laden air out of the greenhouse to make room for drier outside air.

During the winter months having cold air coming through your exhaust fans and louvers may not be ideal. The hottest air sits at the apex of the greenhouse, so in this case you may want a ridge/roof vent that you can crack open to force humid air out and pull fresh, drier air inside.

The overall objective is to create vertical airflow to direct as much hot dry air onto the surface of the sludge as possible.

You can create vertical airflow with the aid of reversible vertical airflow fans (VAF), which can push air upward or downward.

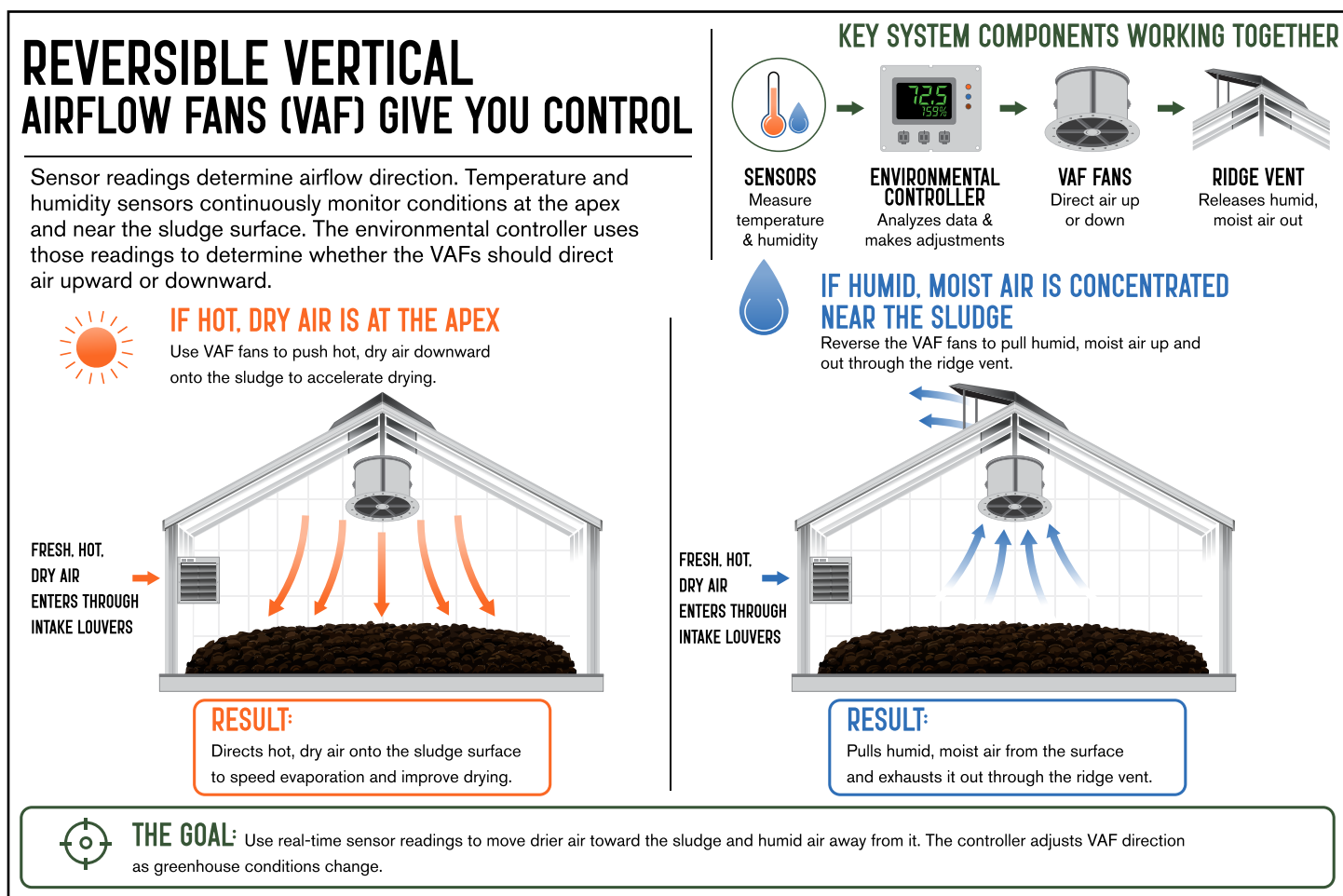
At times when you have hot, dry air in the apex of your greenhouse, you can use VAF fans to direct it downward onto the surface of the sludge, rather than using your roof vent to release it outdoors.

Conversely, if hot, humid air is sitting near the surface of the sludge, you want to reverse your VAF fans to create an upward draft that pushes air up and out of the open roof vent.

The key is to continually pull hot humid air away from the sludge and direct hot dry air towards the sludge (see Figure 2). Your environmental controller and sensors are key to managing all this, so you don't have to, more on that later.

In very dry climates, mechanical ventilation with exhaust fans and intake shutters allows you to exhaust all the moist air inside the greenhouse and quickly replace it with fresh, dry air from the outdoors.

Figure 2. Controlling Air Movement With Reversible Vertical Fans (VAFs)



Intake shutters or louvers work better than intake vents for this application because they require less maintenance.

For greenhouse systems with intake shutters and exhaust fans working together to maintain constant airflow, you want to dial in on your structures' fan needs.

Individually, your VAF fans should be powerful enough to complete five (minimum) air turnovers per minute and focus on a layout to prevent and reduce dead air pockets.

Glazing/Covering Choices

Light transmission is of utmost importance when it comes to greenhouse glazing because it drives the sludge drying. A high transmission rate equals more sunlight, which equals more heat gain.

Glazing materials have different lifespans and some coverings are more difficult to replace on a greenhouse than others. You may need to empty out your greenhouse to replace your covering, which cuts into your processing time, so consider how much downtime is needed for replacement when making your selection.

Not every greenhouse glazing is equal in performance across the board. Each one has different properties and characteristics. See Table 2 for a comparison of different covering types.



Controlled vertical airflow using reversible VAF fans helps prevent humid air from lingering near the sludge surface.

Table 2: Comparison of different covering types

TYPE	RIGID/ FLEXIBLE	LIFESPAN	COST	REGLAZE	R-VALUE (INSULATION)	LIGHT TRANSMISSION	RECYCLABLE (Y/N)
Glass	Rigid	Lifetime (if not broken); no reglaze	\$\$\$	✗	R-0.90-R-0.95 (single pane, 3-4mm thick)	88-94% (highest with low-iron glass)	✗
Acrylic	Rigid	20-25 yrs +	\$\$\$	✓	≈R-1.5 (twinwall)	-Single wall: 94% -Twin-wall: 87-93% -does not yellow or lose clarity as quickly as other rigid plastics	✓
8mm Twin-wall Polycarbonate	Rigid	-10-20 yrs (depends on climate) -10 yrs for yellowing	\$\$	✓	≈R-1.54-R-1.62	-Multi-wall: 76-80% -Panel options: clear, diffused, opaque, etc.	✓ (not bio-degradable)
16mm triple-wall polycarbonate	Rigid	-10-20 yrs (depends on climate) -10 yrs for yellowing	\$\$	✓	≈R-1.8	-Multi-wall: 76-80% -Panel options: clear, diffused, opaque, etc.	✓ (not bio-degradable)
Poly film (polyethylene)	Flexible	3-5 yrs (single layer)	\$	✓	R-0.85 to R-1.0 (single layer); R-1.4-R-1.5 (inflated double layer)	-UV-stabilized: 88-91%; -IR-AC film: 82-87%; -IR-AC w/diffusion: 77-88%	✓

Consider Service Life, Not Just Initial Cost

Poly film has a lower upfront cost than many rigid greenhouse coverings, but its shorter service life can make it less practical for wastewater treatment applications. Greenhouse-grade poly film typically requires replacement every four to five years, creating recurring material and labor costs over the life of the facility.

Replacement also means working over or around an active treatment process. Depending on the facility design, sections of the greenhouse may need to be taken out of service or operations adjusted while the covering is removed and replaced. For infrastructure expected to operate for decades, those repeated replacement cycles should be considered alongside the initial cost of the glazing.

Durability is another consideration. Long-term exposure to UV radiation, heat, wind, and the greenhouse environment gradually degrades poly film and can affect its strength and performance.

Poly film degradation may also contribute to microplastic shedding. This is worth considering when dried biosolids are intended for agricultural use, where any microplastics present could ultimately be introduced to soil. Agricultural soils already receive microplastics from several sources, including plastic mulch, sewage sludge, compost, reclaimed irrigation water, and atmospheric deposition. (Aslam, 2026)

Twin-wall or triple-wall polycarbonate?

Twin-wall/double-wall and triple-wall polycarbonate are lightweight glazing panels available in a range of thicknesses and sizes. They consist of multiple layers separated by hollow spaces in between.

Twin-wall has two outer layers connected by internal supports, while triple-wall has a middle layer and two outer layers separated by hollow air spaces, as shown in Figure 3 below.

The hollow spaces between the polycarbonate layers trap air, which slows heat transfer through the glazing. Adding more layers creates additional air pockets, increasing the panel's thermal performance as an insulator.

Figure 3. Internal Construction of Twin-wall and Triple-wall Polycarbonate Panels

Twinwall (Twin) Thicknesses 4, 6, 8, 10 & 30mm



Triplewall (Triple) Thickness 16mm



Condensation Management

Corrugated polycarbonate can cause a lot of condensate on SSDG but using twin-wall polycarbonate or glass glazing helps mitigate the problem.

It's important to note that a bit of condensation in a greenhouse is normal, but excessive condensation can create serious problems.

Light transmission is reduced when panels fog due to condensation. Mold, algae, and other diseases can develop. Trapped moisture also causes rust and corrosion.

Condensation forms when warm, humid air comes into contact with a surface, such as glazing or metal framing, that is at or below the air's dew point. The dew point is the temperature at which water vapor begins to condense. The greater the difference between the air's dew point and a cooler surface, the greater the potential for condensation.

When moisture condenses on the inside of your glazing, you want it to have somewhere to drain to, rather than falling back down onto the sludge. Under-gutter drip channels catch condensate running off the roof and channel it to downspouts connected to drains.

Good greenhouse design accounts for moisture removal through ventilation and for condensation management that provides a controlled path for water that collects on the glazing.

Ensuring you have adequate air movement also helps with condensation control. Pockets of warm and cold air form when air is stagnant. Constantly moving air mixes these, which keeps temperatures more even. It also makes it harder for a layer of warm, moist air to bump up against cool surfaces and cool enough for water droplets to form.

PART THREE:

AUTOMATION CONSIDERATIONS

We can't stress enough the importance of using an environmental controller designed specifically for greenhouse applications to run your greenhouse and using controllers specifically designed for processing equipment to run your processing equipment.

Keep the two separate but use a Modbus or a BACnet connector to allow the main greenhouse controller and the main processing controller to speak the same language, share data, and automate the entire facility as a single system.

Environmental Controllers

A common mistake with greenhouse operators is choosing the wrong greenhouse controller for their operation. It's important to match the level of control you need with the right type of controller.

Greenhouse controllers range from basic thermostats and step controllers to highly advanced climate computers.

In this case, you want an integrated greenhouse control system, also known as a climate computer.

Climate computers can manage multiple greenhouse systems or multiple greenhouse zones using unified logic. One SMART controller runs the entire greenhouse, bringing all the controls and equipment together into one integrated network.

Integrated controllers also provide valuable data, analytics, and predictive tools. These benefits often more than justify their higher cost.

Sensors

The two biggest things you need to closely monitor in a solar sludge drying greenhouse are temperature and humidity.

To get accurate measurements, place one temperature sensor at the apex of the greenhouse and one temperature sensor at sludge height. You'll also want to monitor the temperature readings from the slab itself.

Since the speed of the sludge drying process depends on the intensity of solar radiation, you can also take a measurement of that using a Pyranometer (solar radiation sensor), which measures watts per square meter.

It's also good to include a weather station with your greenhouse to get readings of the outdoor climate. This helps you determine if you want to use outside air or not.

Remote monitoring

Many modern-day greenhouse controllers have remote monitoring capabilities, which let you keep track of your greenhouse when you are offsite. They also allow you to make adjustments remotely and send alarm notifications when something goes amiss.

CONCLUSION

Solar sludge drying in a greenhouse may seem like a relatively simple process at its core: Add sun, evaporate water, and move that moisture out of the greenhouse. However, designing a facility that can do that efficiently and effectively year after year is more complex.

As we noted at the beginning of this whitepaper, engineers and WTFs have relatively few resources focused specifically on the greenhouse structure itself. Yet the greenhouse needs to be a working part of the treatment process, and the decisions made during its design can affect drying performance, operating costs, maintenance, and future expansion.

That's why a SSDG should never be designed in isolation. Greenhouse designers and engineers, wastewater treatment engineers and operators, and equipment suppliers should work together early to make sure the structure, process equipment, controls, and material flow all work as one integrated system.

A well-designed greenhouse can serve a WTF for decades and grow along with it. Getting the details right from the beginning can help avoid costly changes later and create a facility that dries sludge reliably and efficiently for years to come.

BRING GREENHOUSE EXPERTISE TO THE TABLE

If you're thinking about building a SSDG, make sure greenhouse expertise is part of the conversation early. Prospiant Greenhouses can work alongside your wastewater engineering team to help design and engineer the greenhouse structure and its supporting systems around your process equipment, site, and long-term operating needs.

Prospiant is an industry leader in wastewater treatment greenhouses, with successful projects in the field and in-house engineering capabilities to support them. Our experience gives us a practical understanding of the structural, environmental, and operational demands these facilities face and how to design for them from the start.

For more information or to talk with one of our experts, email Sales@prospiant.com or visit [Prospiant.com](https://prospiant.com).

REFERENCES/CITATIONS

- ASTM. (Updated Mar. 23, 2026). *Standard Specification for Crosslinked Polyethylene (PEX) Tubing*, ASTM F876-26. Advanced Standards Transforming Markets. (<https://store.astm.org/f0876-26.html>)
- American Cement Association. (Accessed Aug. 2, 2026). *Applications of Cement*. American Cement Association. (<https://www.cement.org/cement-concrete/applications-of-cement/>)
- American Concrete Institute. (Accessed Aug. 2, 2026). *Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete (ACI 211.1-91)*, Reapproved 2009. ACI Committee 211, Farmington Hills, Michigan: American Concrete Institute. (https://www.concrete.org/Portals/0/Files/PDF/Previews/211.1-91%2809%29_preview.pdf)
- Aslam, I., Bux, N., Yu, X, Bi, M., et. al. (2026) *Microplastics in agricultural soils: Impacts on soil microbial communities, nutrient cycling, earthworm health, and soil ecosystem functions*. *Environmental Chemistry and Ecotoxicology*. 8:1157-1175. (<https://www.sciencedirect.com/science/article/pii/S2590182626000251>)
- Bartok Jr., J. (2025). *Maximizing efficiency in greenhouse heating systems: Why now is the time to upgrade*. *Greenhouse Management*. (<https://www.greenhousemag.com/article/greenhouse-heating-system-upgrade-tech-solutions/>)
- Bartok Jr., J. (2013). *Greenhouse Heat Distribution*. University of Connecticut, College of Agriculture, Health, and Natural Resources. ([https://ipm.cahnр.uconn.edu/greenhouse-heat-distribution/](https://ipm.cahnر.uconn.edu/greenhouse-heat-distribution/))
- Belloulid, M.O., Hamdi, H., Mandi, L., et. al. (2017) "Solar Greenhouse Drying of Wastewater Sludges Under Arid Climate". *Waste and Biomass Valorization*, 8:193-202. <https://doi.org/10.1007/s12649-016-9614-1>
- Mathioudakis, V.L., Kapagiannidis, A.G., Athanasoulia, E., et. al. (2009, Nov 15) "Extended Dewatering of Sewage Sludge in Solar Drying Plants". *Desalination*. 248 (1-3):733-739.
- NGMA. (n.d.). *Heating Systems*. National Greenhouse Manufacturers Association. (<https://ngma.com/wp-content/uploads/2018/03/Heating-Systems.pdf>)
- NGMA. (2010). *Heating*. National Greenhouse Manufacturers Association. (<https://ngma.com/wp-content/uploads/2018/05/HeatSystem2010.pdf>)
- US EPA. (updated Sept. 26, 2025). *Basic Information about Sewage Sludge and Biosolids*. EPA, United States Environmental Protection Agency. (<https://www.epa.gov/biosolids/basic-information-about-sewage-sludge-and-biosolids>)

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