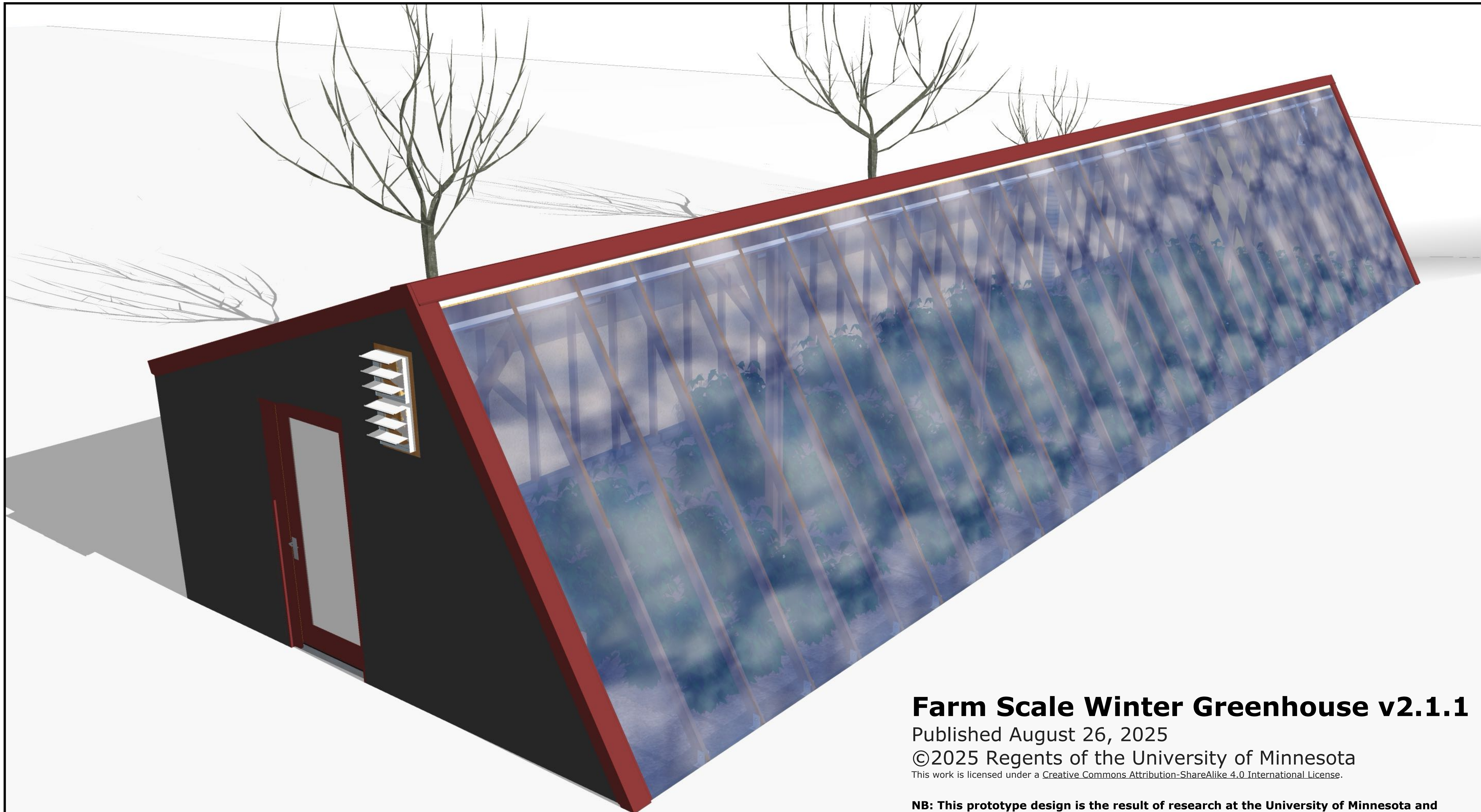


Farm Scale Winter Greenhouse v2.1.1

Published August 26, 2025

NB: This prototype design is the result of research at the University of Minnesota and performance has not been thoroughly tested. The University of Minnesota offers the design as-is and without warranty. Please see Section 5 – Disclaimer of Warranties and Limitation of Liability in the Creative Commons Attribution-ShareAlike 4.0 International License for details.

Farm Scale Winter Greenhouse Prototype v2.1
Published August 26, 2025
Please note that this design is subject to change, and the most updated documents can be found on the U of MN Extension website:
http://www.extension.umn.edu/rsdp/statewide/deep-winter-greenhouse/
NOTES:

Introduction:
This Farm Scale Winter Greenhouse is designed to allow users in cold climates to produce crops in cold seasons with reduced heating energy inputs. It is designed to capture solar heat energy through the glazing wall and retain it through thermal storage, coupled with a partially insulated enclosure. When the sun is shining, fans move hot air into an underground thermal mass of either rocks or soil. When the interior space cools at night, the underground heat is available to keep crops warm enough to grow. The reverse happens in the daytime, when the thermal mass absorbs heat and helps cool the growing area as temperatures climb.

This greenhouse is optimized for cold season growing at a modest construction expense. It is not intended to be used year round for growing crops, and modifications would be needed to do so.

Field Testing and Considerations:
This is a prototype design. The Regional Sustainable Development Partnerships have partnered with select producers who will build their greenhouses to these design specifications throughout Minnesota. Throughout this process, researchers will continuously tweak the building design to increase performance, decrease cost, and respond to issues that arise during construction. As a result, this document may be updated periodically in the future.

Reasoning and Rationale:
The design of this greenhouse is the result of input from current winter greenhouse operators, collaboration with consultants and engineers, and response to demands from MN winter greenhouse enthusiasts. Each aspect of the design has been considered with regard to building performance, energy efficiency, structural longevity, moisture management, ease of construction, material availability, and material cost.

Safety and Compliance:
Under MN State Building Code 326B.121, Agricultural Buildings built on agriculturally-zoned land are exempt from State Building code, with some exceptions.
It is up to you to ensure that construction of this building conforms to local zoning and complies with any codes under the local authority having jurisdiction.

Questions:
If you have any questions about winter greenhouse operation, construction, design, etc, please join the Facebook Deep Winter Producers Association group (you will have to request acceptance from the group's administrators, which will be granted). Questions addressed to this group will be answered by UMN researchers as well as a network of deep winter greenhouse (DWG) producers from all over the world.
https://tinyurl.com/DWGFBgroup

Use of this Plan Set:
This set of plans comprises a series of variations:

The structure that sits above ground (the "greenhouse") is on the "A" series pages. Energy models indicate that the above-ground structure alone would provide a 40% reduction in heating energy requirements as compared to a conventional high tunnel of the same footprint. The remaining components of this greenhouse system (F series pages and TM series pages) provide additional, but yet untested, reductions in heat energy usage.

On the "F" series pages, a number of different foundation types are presented in response to the variability of site conditions and budgets that may be present for any given operation. They are presented in order from lower complexity, expense, and heat retention capacity to higher complexity, expense, and heat retention capacity. Any of the foundation types will be compatible with the above-ground structure on the A pages. Please note that local codes may dictate which foundation may be used, or determine specific requirements that the foundation must meet.

The "TM" series pages comprise various types of thermal storage options, also presented from lower complexity, expense, and heat retention capacity to higher complexity, expense, and heat retention capacity.

Use the A series in combination with one page from the F series and one page from the TM series.

Materials and Cost:
Materials required to build the greenhouse should be available from a combination of local hardware stores, specialty lumber yards, and greenhouse supply companies. Local specialty construction companies may have some of the materials at better prices. Availability and price of construction materials has been extremely volatile, and can vary considerably from location to location. People in remote locations might expect to pay more for delivery charges, labor, and materials. It is advisable to consult multiple vendors to find the correct materials at the best prices. Total price considerations will depend on local material cost and availability, labor costs, and the capacity to carry out some or all of the construction oneself.

Material Substitutions:
Many prospective winter greenhouse builders or materials estimators may feel the need to substitute materials on the list for other materials. Note that the materials listed in this document have been chosen to perform specific functions, and substitutions may have detrimental consequences. It is advised that no material substitutions be made without first consulting with the Deep Winter Producers Association on the Facebook group available here: https://tinyurl.com/DWGFBgroup You will have to request acceptance from the group's administrators, which will be granted. Often, participants on this forum have experience with winter greenhouse operation and construction and can provide reasoned explanations for why some materials may or may not be substituted.

Humidity and Moisture:
This is a greenhouse, and we can expect high and widely varying amounts of humidity. Condensation is also expected, so we attempt to predict and manage where it will occur. In the greenhouse, we can expect condensation primarily in two areas: 1) On the interior of the glazing wall; and 2) in the thermal mass. The glazing wall is detailed with sealant and a waterproof sill to prevent damage to structural members. Latent heat is released into the thermal mass as humidity condenses. The condensate is allowed to drain into the soil below.

The wall assembly is designed with continuous exterior insulation and ventilated cladding. There is no cavity insulation or interior wall finish, and it should be maintained as such to allow drying of the wall and roof structure.

As a general rule of greenhouse operation, irrigation should be precise in order to avoid wasted water and generation of unnecessary humidity.

Ventilation:
On clear sunny days, we can expect heat gain in the greenhouse that will exceed the rate that the thermal storage system can utilize. In such cases, exhaust of excess heat (ventilation) will be required. This can be achieved with conventional greenhouse fans and louvers, but they typically do not insulate or seal effectively. Also, it is not recommended to use metal louvers or metal frames around operable vents because these materials will collect condensation and frost, and be rendered inoperable. A dedicated system of fans and ductwork to bring in outside air is recommended. For purposes of illustration, awning-type windows are shown for ventilation in this drawing set.

Project support provided in part by the MN Department of Agriculture.

Farm Scale Winter Greenhouse Prototype v2.0
Published August 26, 2025
Please note that this design is subject to change, and the most updated documents can be found on the U of MN Extension website:
http://www.extension.umn.edu/rsdp/statewide/deep-winter-greenhouse/

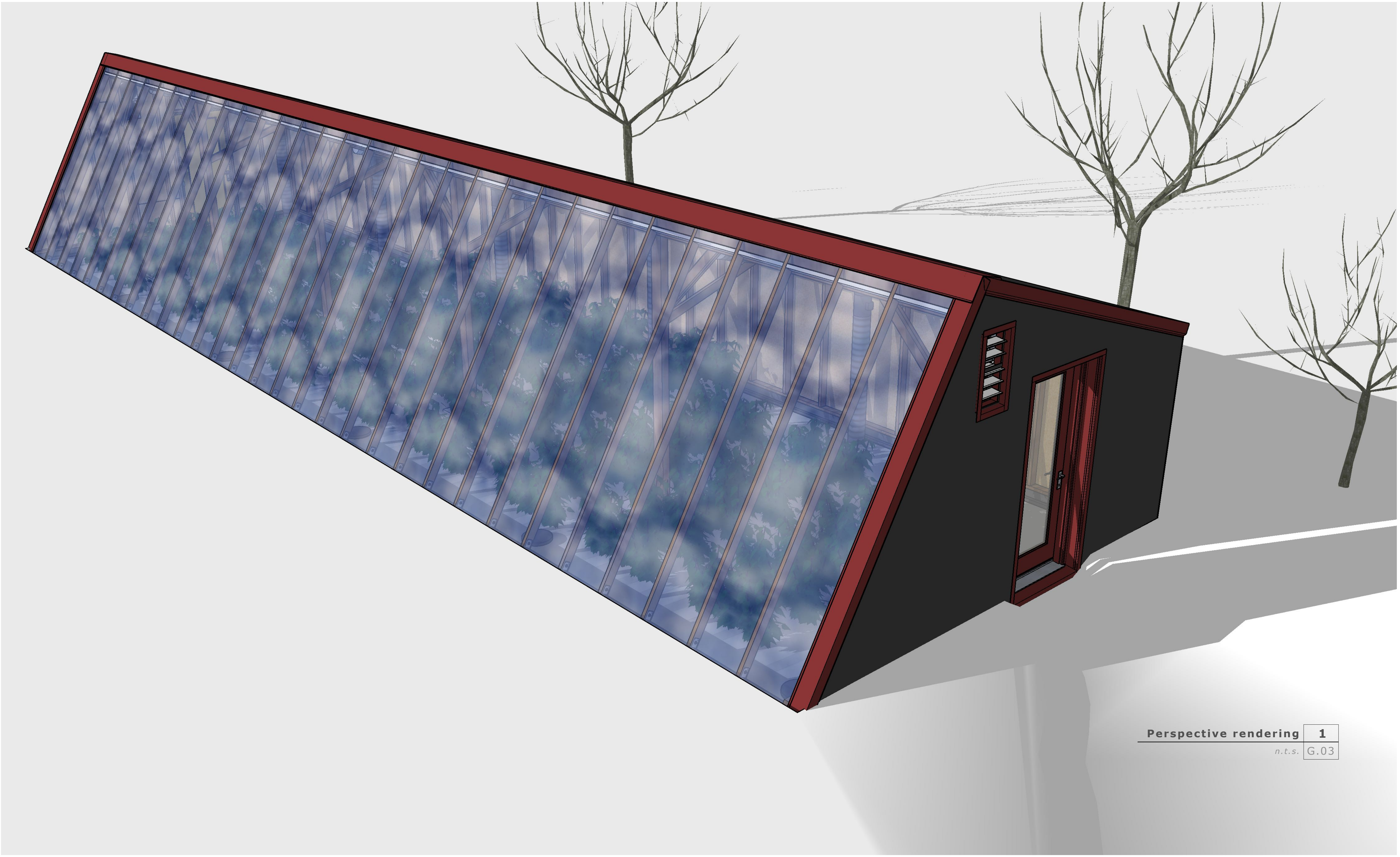
This materials list describes the majority of items needed to construct the above-ground greenhouse (“A” pages), coupled with the F.1 foundation and TM.1 thermal storage methods.

Cost for this list of materials as of August 26, 2025 is approximately $35,000.

Selection of other foundation and thermal storage methods will require additional construction materials not shown in this list.

PLEASE NOTE: This list may have unintentional omissions, and will be updated as necessary.

Glazing	16mm triple-wall 6'x20' panel	10
Glazing caps and splines	For glazing panel ends and seams	
Glazing wall studs	12' 2x4 spf	32
North wall studs	8' 2x4 spf common studs	44
North wall connectors	Simpson KBSZ	31
End wall and interior studs	12' 2x4 spf common studs	6
Rafters	12' 2x8 spf rafters, cut to length	32
Exterior sheathing	4x8 7/16" ZIP Sheathing (approx 60 shts.)	60
Sheathing tape	ZIP tape 3.75 x 30ft	8
Tape roller		1
Weather barrier	such as Tyvek Drainwrap	2
Insulation	2" x 4' x 8' R-10 GPS panels	120
Ridge beam	2x8 x 12' LVL	10
Ground Screws		12
Columns	4x6 x 10' PT timber	4
Post base	Simpson ABU46Z	6
Post cap	Simpson AC6RZ	8
Columns	4x4 x 10' PT timber	2
Post base	Simpson ABU44Z	2
Post cap	Simpson AC4Z	4
Concrete anchors for columns	Hilti 5/8 x 6" sleeve anchor (2-pack)	3
Column footing	such as Quikcrete 80# bags	35
Rebar for column footing	#4 rebar	6
Doors	metal-clad insulated security	4
Extension jamb mat'l	10' 1x8 spf	5
Sill plate	12' 2x4 UC3 treated wood	16
Sill plate	8' 2x4 UC3 treated wood	2
Grade beam	4x4 8' poly timber	21
Grade beam	2x8 12' poly board	21
FPSF Insulation	2" x 4' x 8' R-10 XPS panels	23
Furring strips	1x4 spf or similar	84
Side wall cladding	corrugated metal 12' long	10
North wall cladding	corrugated metal 8' long	20
Roofing	Corrugated metal 12' long	20
Shear wall sheathing (int)	4x8 1/2" CDX plywood	19
Ridge cap trim	10' lengths	7
Exterior metal trim	10' lengths	10
Flashing	Coil stock	1
Fasteners	misc. screws and nails	1
Ducts and connectors	8" and 3" ductwork, caps, and tees	5
Duct Fans	such as terrabloom 8" inline duct fan	6
Controllers		6
Windows	22x8x3 basement casement windows	5
Ventilation fans	such as Ventisol 20"	2
Backup heaters	such as King KB ECO2S	3

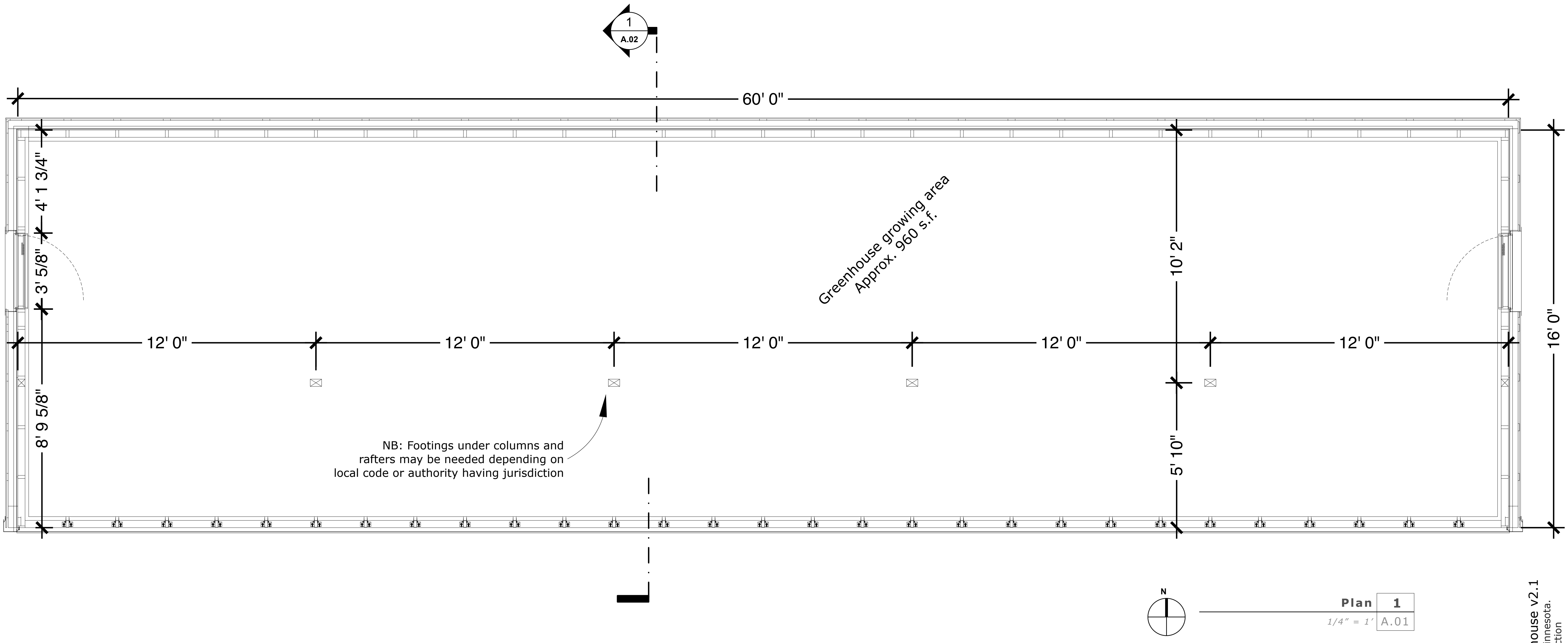


Perspective rendering | 1
n.t.s. | G.03

Farm Scale Winter Greenhouse v2.1

August 26, 2025 Not for Construction

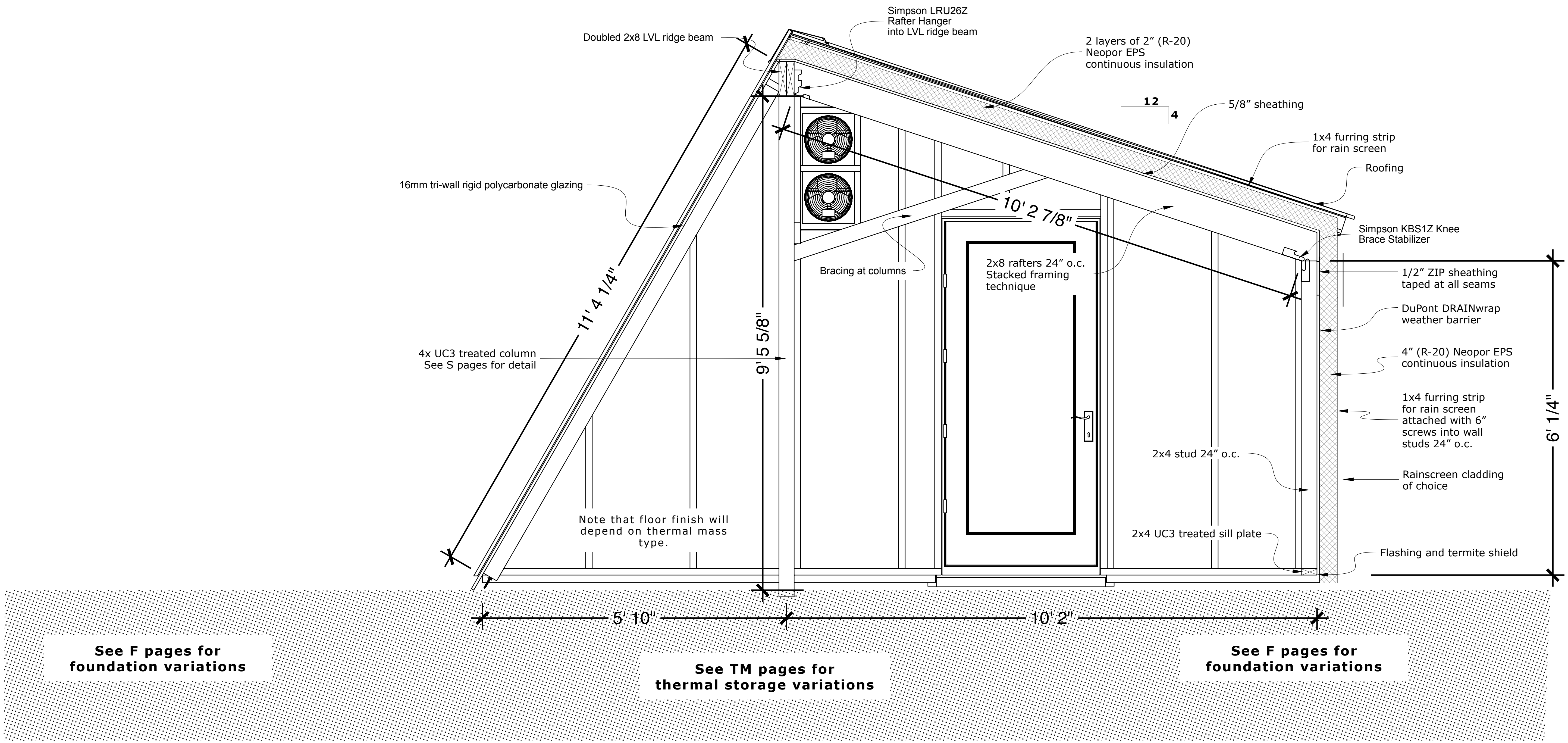
G.03



Farm Scale Winter Greenhouse v2.1

August 26, 2025 Not for Construction

A.01



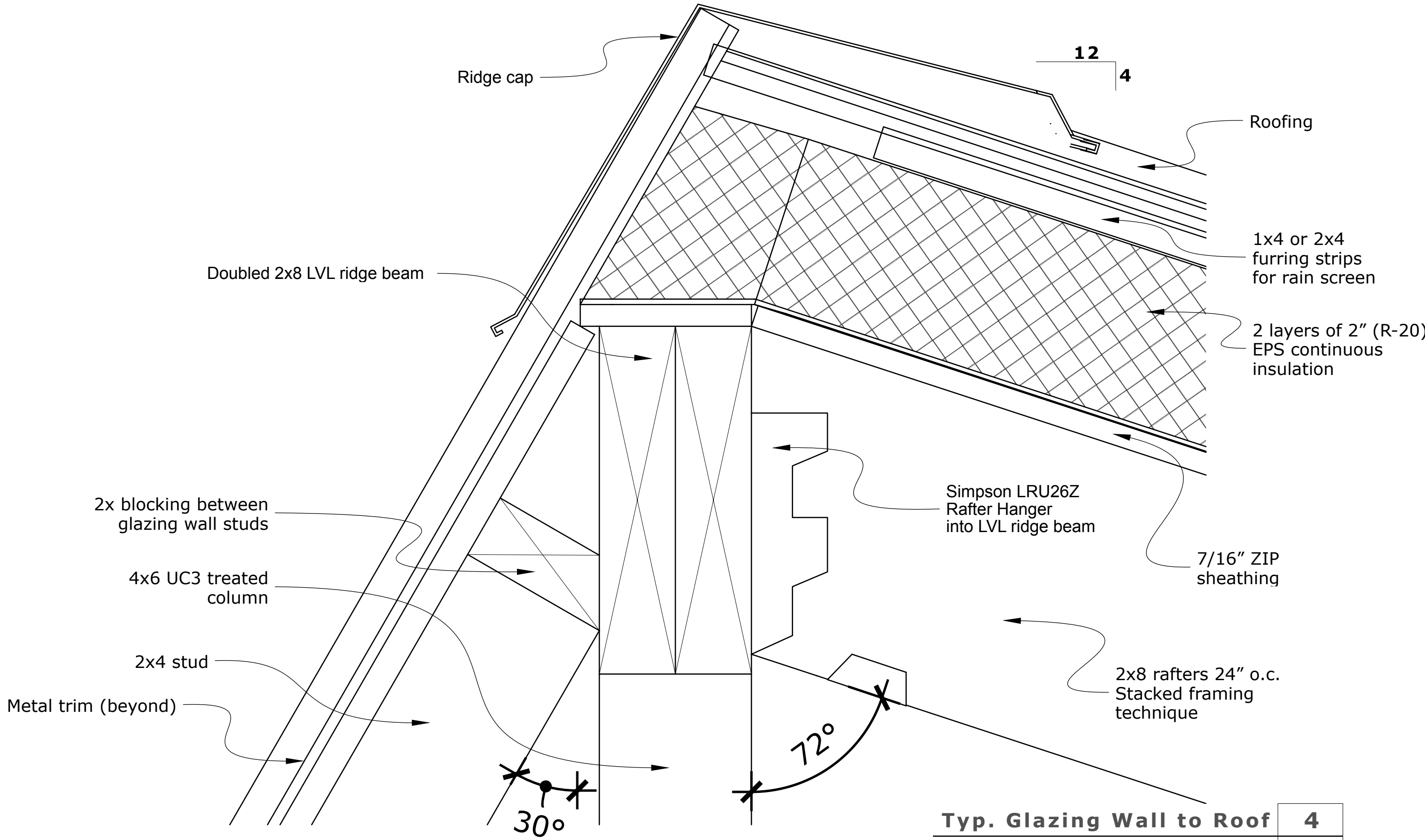
Typ. wall section 1

1/2"=1' A.02

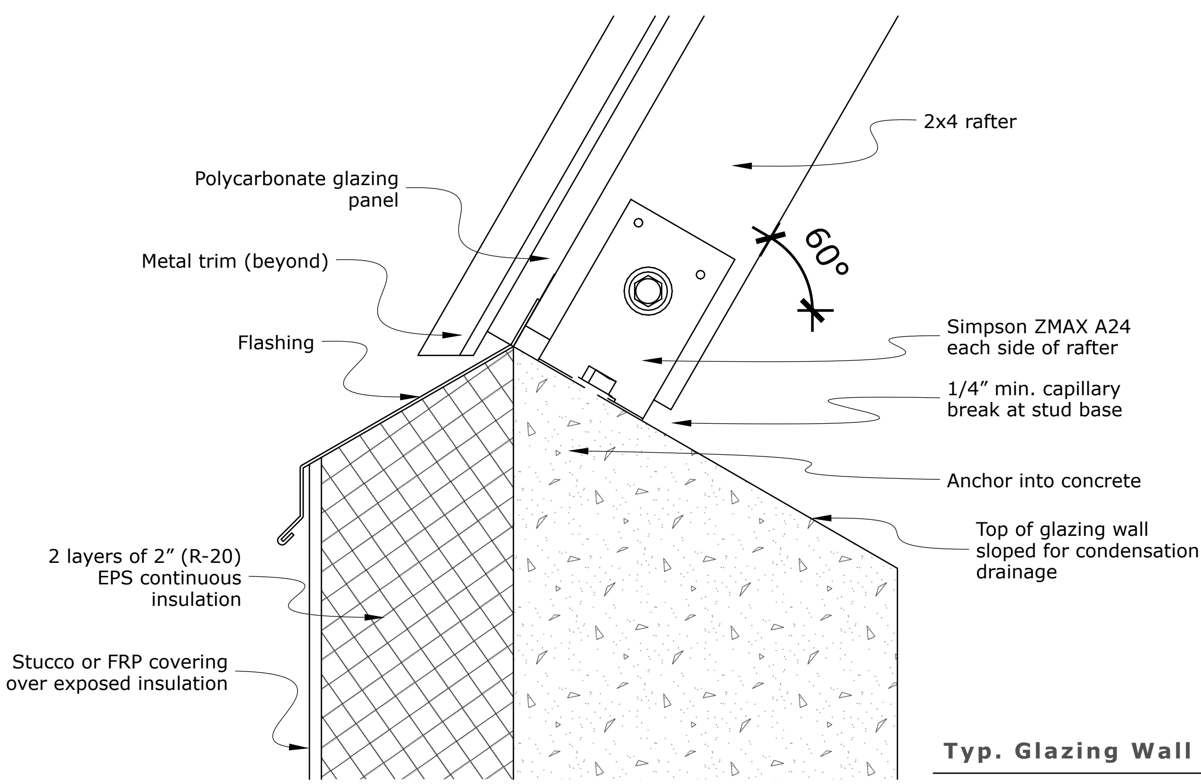
Farm Scale Winter Greenhouse v2.1

August 26, 2025 Not for Construction

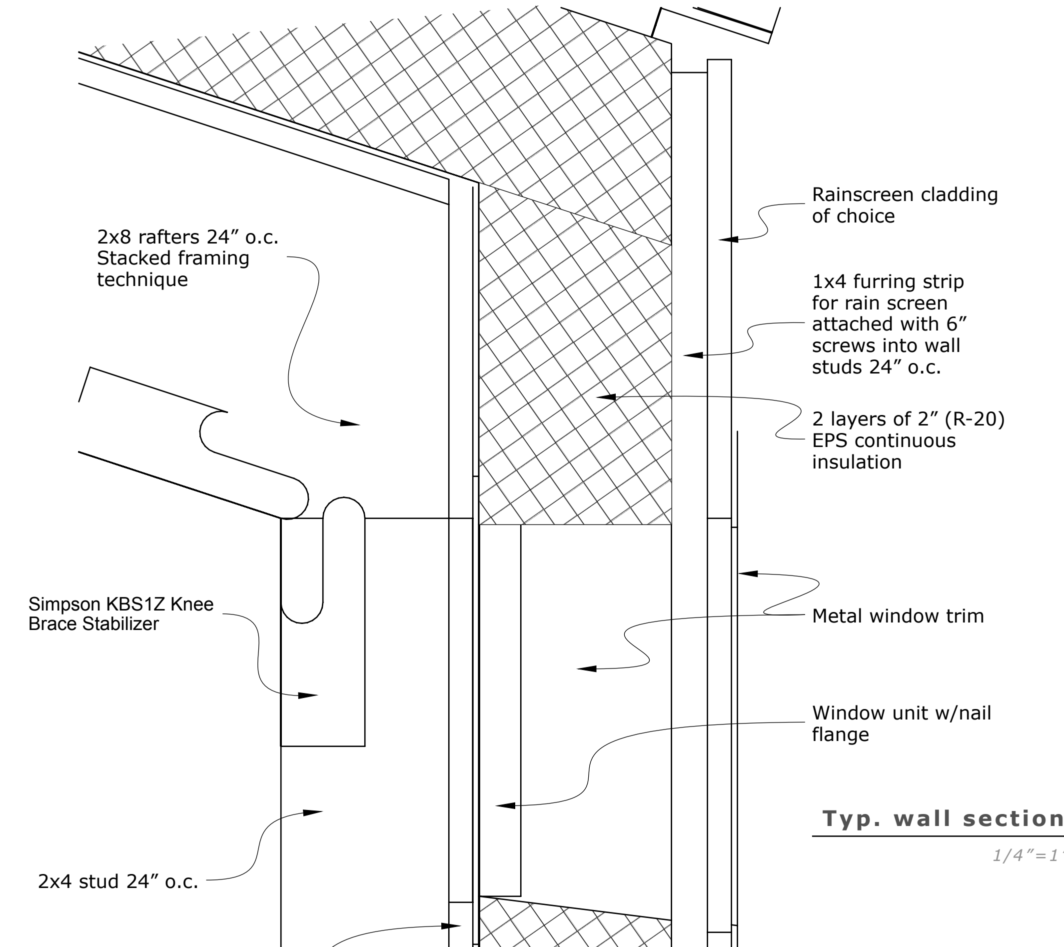
A.02



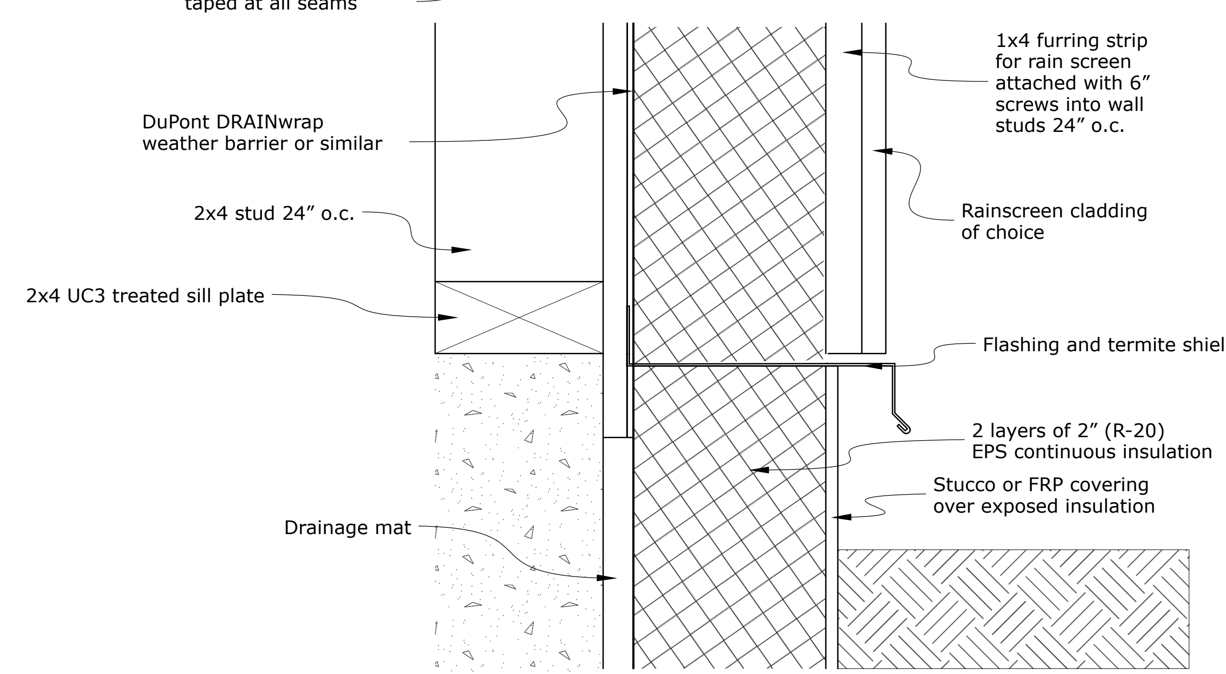
Typ. Glazing Wall to Roof 4
1/4”=1’ A.03



Typ. Glazing Wall to Foundation 3
1/4”=1’ A.03



Typ. wall section 1
1/4”=1’ A.03

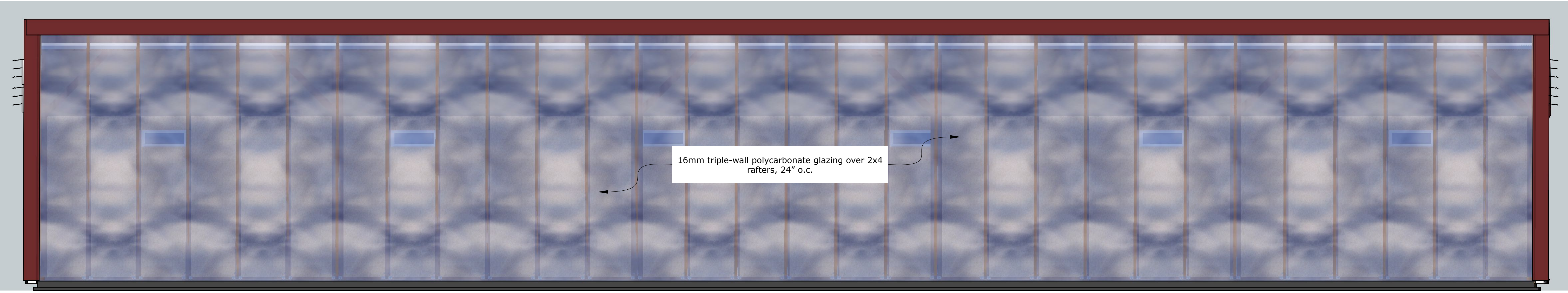


Typ. Insulated Wall to Fdtn. 2
1/4”=1’ A.03

Farm Scale Winter Greenhouse v2.1

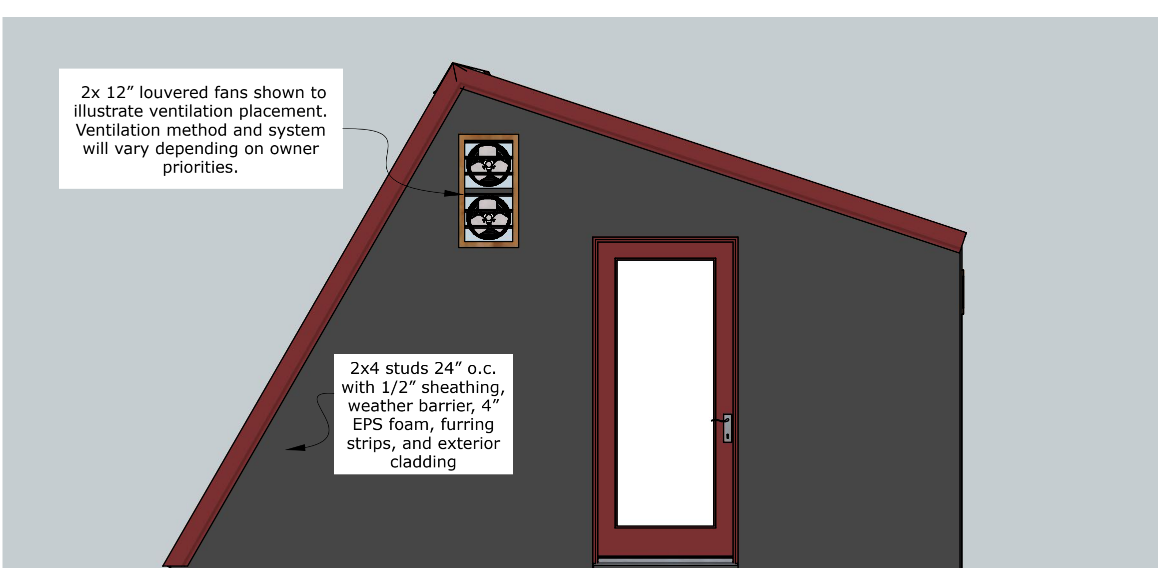
August 26, 2025 Not for Construction

A.03

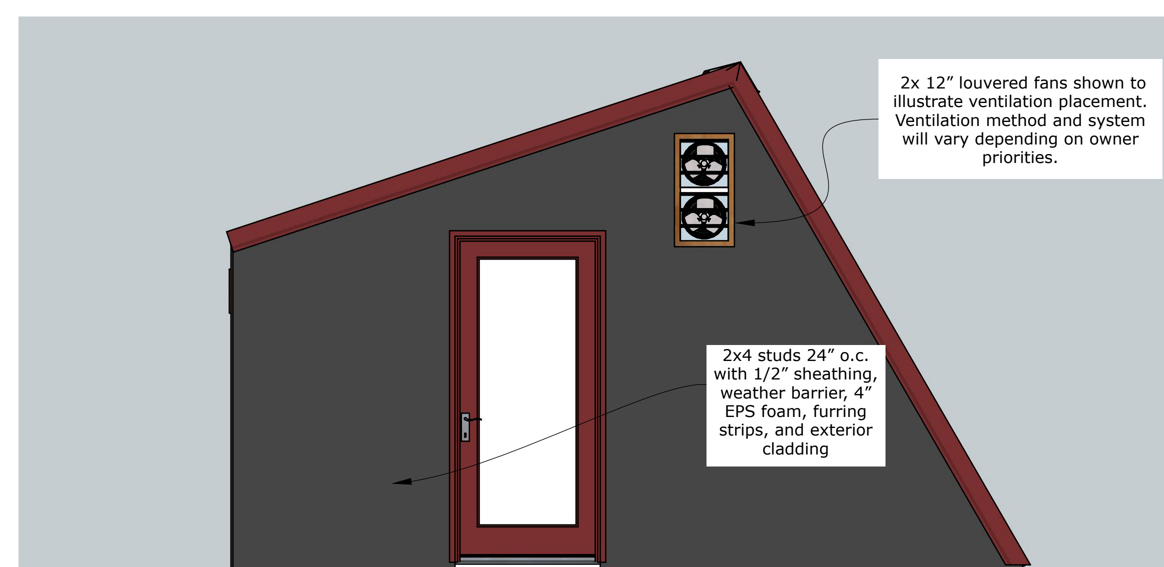


South Elevation 1
1/4”=1’ A.04

North Elevation 2
1/4”=1’ A.04



East Elevation 3
1/4”=1’ A.04



West Elevation 4
1/4”=1’ A.04

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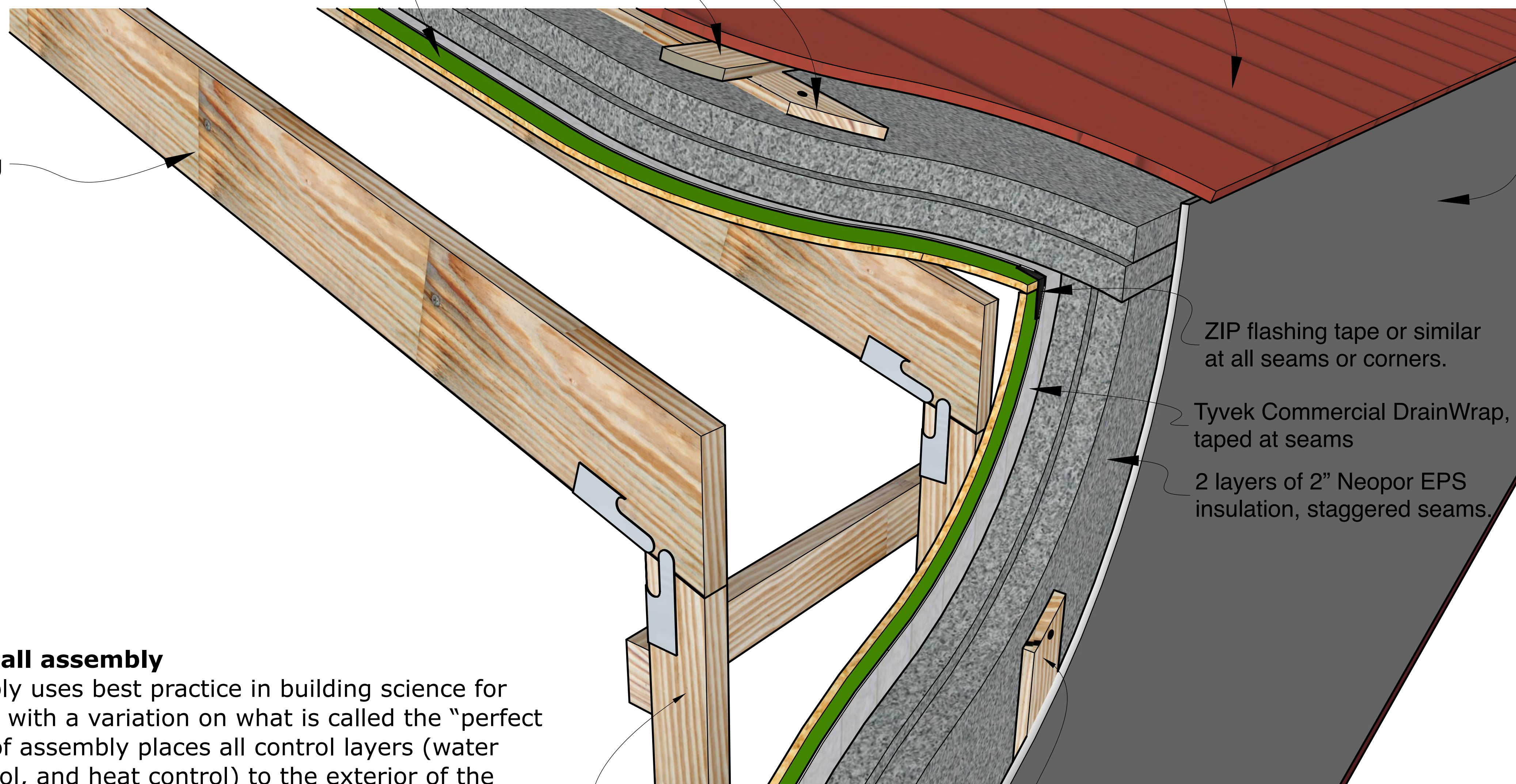
August 26, 2025 Not for Construction

A.04



Notes on the wall assembly

This wall assembly uses best practice in building science for enclosure design with a variation on what is called the "perfect wall". This type of assembly places all control layers (water control, air control, and heat control) to the exterior of the structure. The taped seams and green layer of the Zip sheathing provide a continuous water barrier. The rainscreen cladding system allows any water or moisture in the assembly to escape over time.

IMPORTANT: Please roll the tape per the manufacturer instructions.

North wall/roof extruded axon | 1

n.t.s. | A.05

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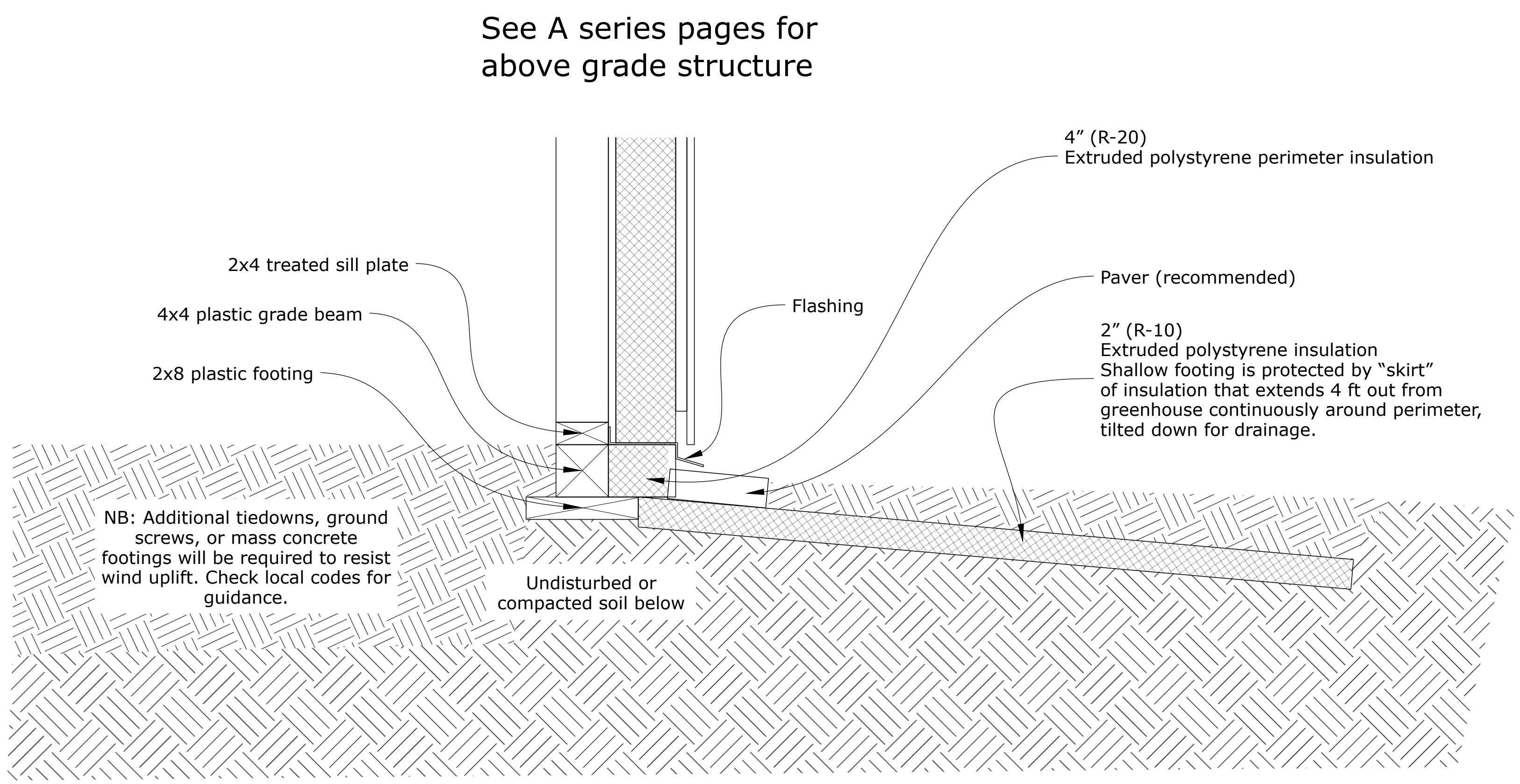


Simple grade beam with frost protection | **1**

1”=1’ | F.01

Notes on the Grade Beam with Frost-protected Footing

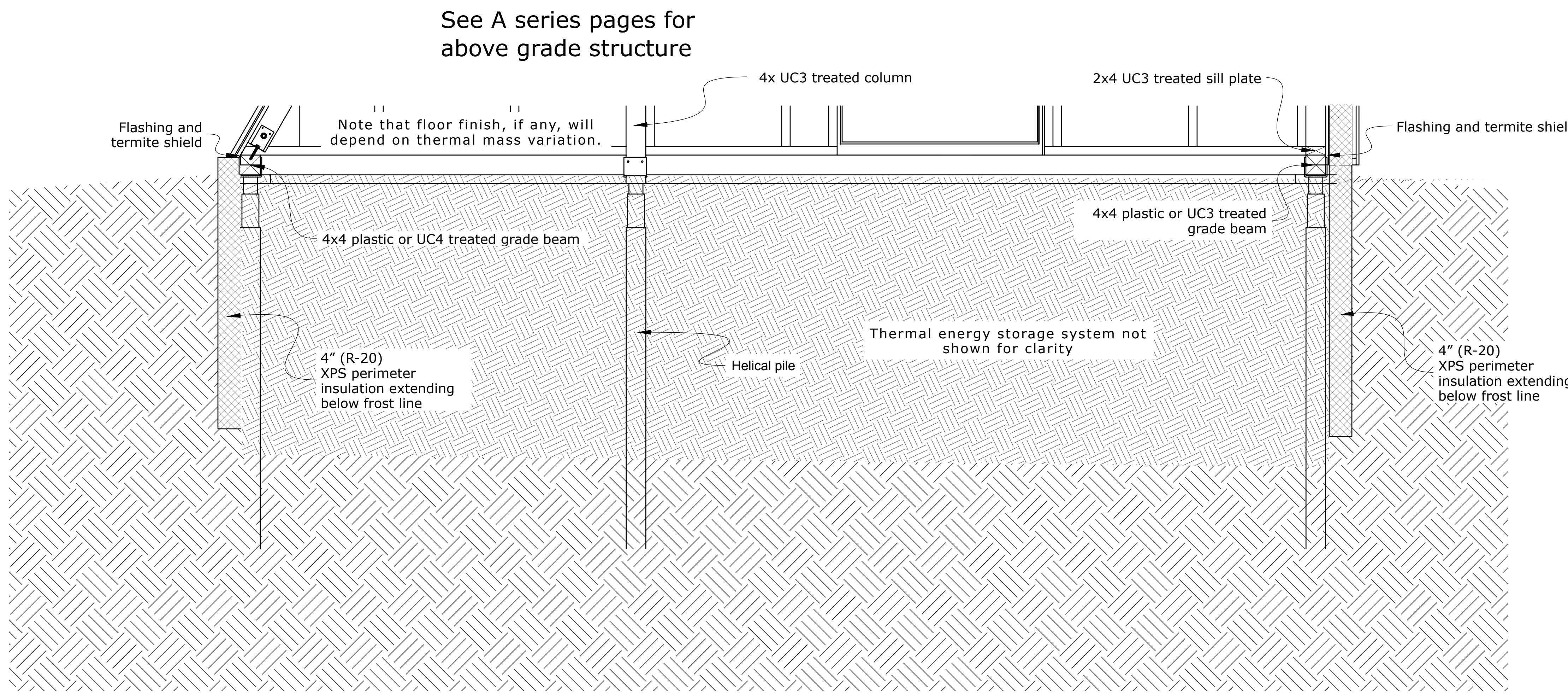
This foundation technique is the simplest and requires the least excavation, and may be suitable for locations where digging would be prohibitive, or locations where a less permanent structure is desired. It is low cost as compared to other foundation types. Be sure to follow local codes.

The grade beam with frost-protected footing would be most suitable for use with a shallow earth thermal storage system that uses transit ducting between intakes and exhausts (see page TM.1).

It does not retain heat underneath the greenhouse as effectively as vertical insulation in the ground because heat can continue to migrate horizontally under the horizontal skirt. More heat is lost as a larger volume of earth is heated.

Plastic landscape timbers have been recommended here because they are high in recycled content, are extremely durable, and are chemically inert. UC4 treated lumber could be substituted for greater rigidity, with the knowledge that chemical treatments may or may not be permitted under some certification programs.

IMPORTANT: Tiedowns, ground screws, or mass concrete footings will be required to prevent uplift in high wind events. Check local codes or AHJ for guidance.



Grade beam with Helical Pile Foundation	1
1/2"=1'	F.02

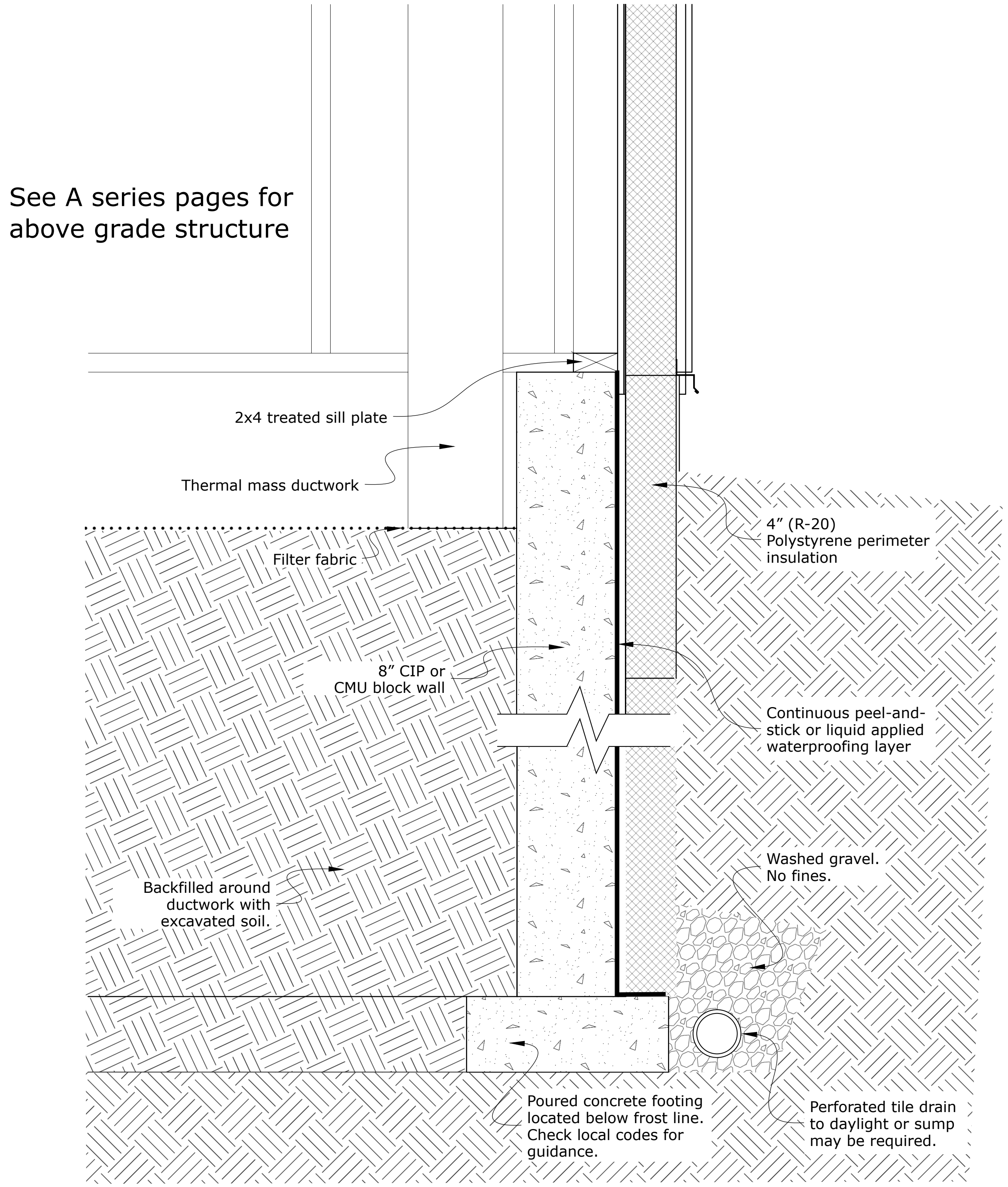
Notes on the Grade Beam with Helical Pile Foundation

This foundation technique is relatively simple, requires little excavation, and may be suitable for locations where a less permanent structure is desired. It has moderate costs associated with it. The helical piles should be located below the glazing wall rafters that align with the posts that support the ridge beam, at the corners of the greenhouse, and at 12' minimum intervals otherwise.

Extruded polystyrene insulation is installed vertically in a continuous trench under the perimeter of the greenhouse to prevent heat migration into the surrounding soil. It is compatible with a shallow transit duct system, a deep transit duct system, or a rock bed system.

Plastic landscape timbers have been recommended here because they are high in recycled content, are extremely durable, and are chemically inert. UC3 treated lumber could be substituted for greater rigidity, with the knowledge that chemical treatments may or may not be permitted under some certification programs.

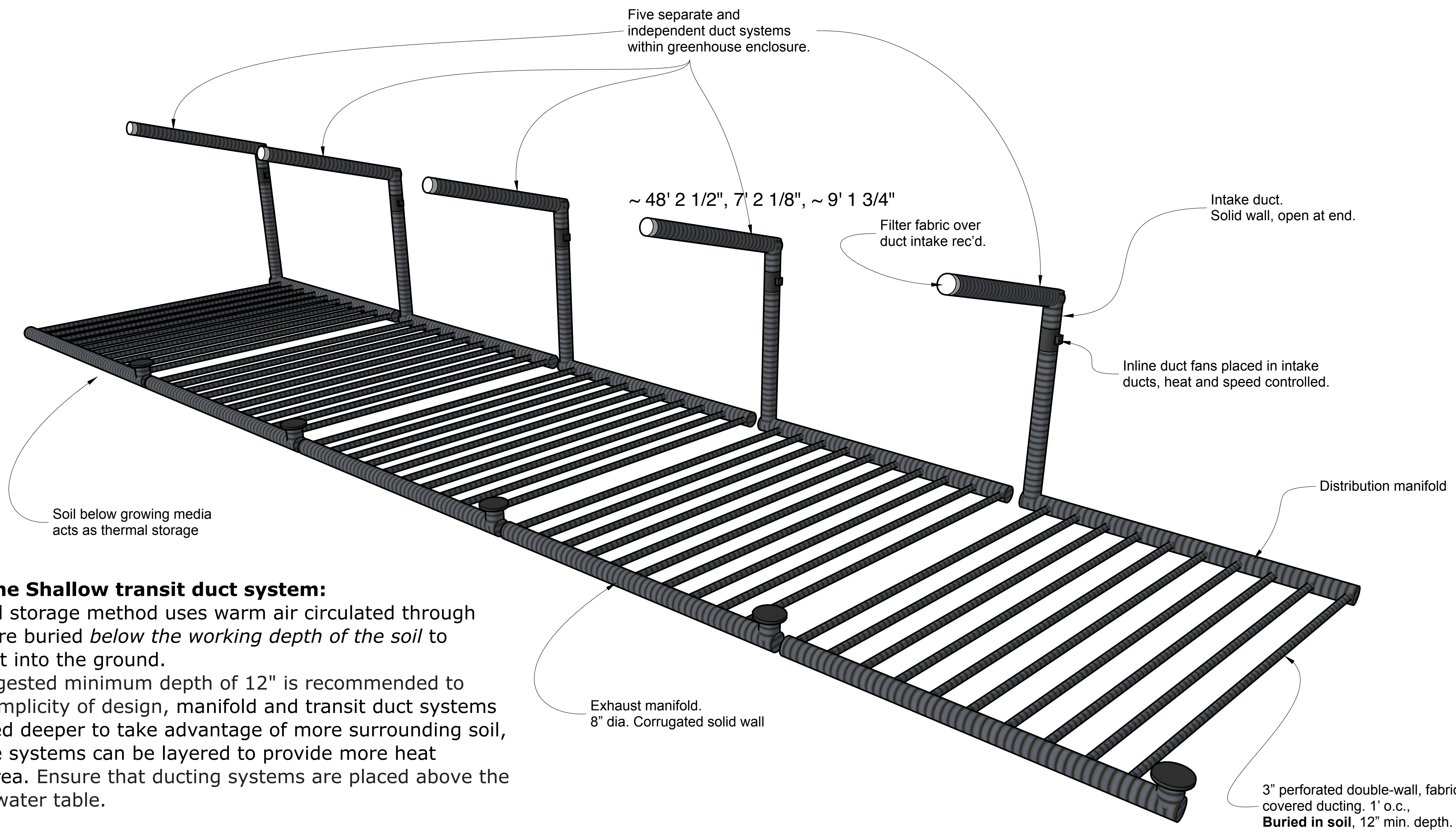
IMPORTANT: Helical piles do not require excavation to install, but do require a specialty contractor for installation. They provide excellent load support and uplift resistance, and can be removed at the end of use.



Concrete Block Wall	1
1"=1'	F.03

Notes on the Block Wall Foundation
This foundation technique is complex, requires extensive excavation and skilled labor, and is suitable for locations where a permanent structure is desired. It has the highest cost of the foundation options presented.
4” of extruded polystyrene insulation is installed vertically around the foundation of the greenhouse to prevent heat migration into the surrounding soil. The CMU Block wall is compatible with a rock bed or deep transit ducting thermal storage system.

IMPORTANT: Proper drainage is required to ensure that heat is retained within rock bed. Perimeter drain tile may be necessary depending on surface water flow and subsurface water conditions.



Notes on the Shallow transit duct system:
This thermal storage method uses warm air circulated through ducts that are buried *below the working depth of the soil* to transfer heat into the ground.
While a suggested minimum depth of 12" is recommended to maximize simplicity of design, manifold and transit duct systems can be buried deeper to take advantage of more surrounding soil, and multiple systems can be layered to provide more heat exchange area. Ensure that ducting systems are placed above the subsurface water table.

IMPORTANT: While it is the simplest to install, this system relies on conduction of heat into the soil around the buried ducts, which can vary considerably depending on soil type and moisture content. Higher density and saturated soils will conduct and store heat more readily, but may present challenges with drainage and crop production.

Thermal Mass Variation 1: Shallow transit duct system	1
n.t.s.	TM.1

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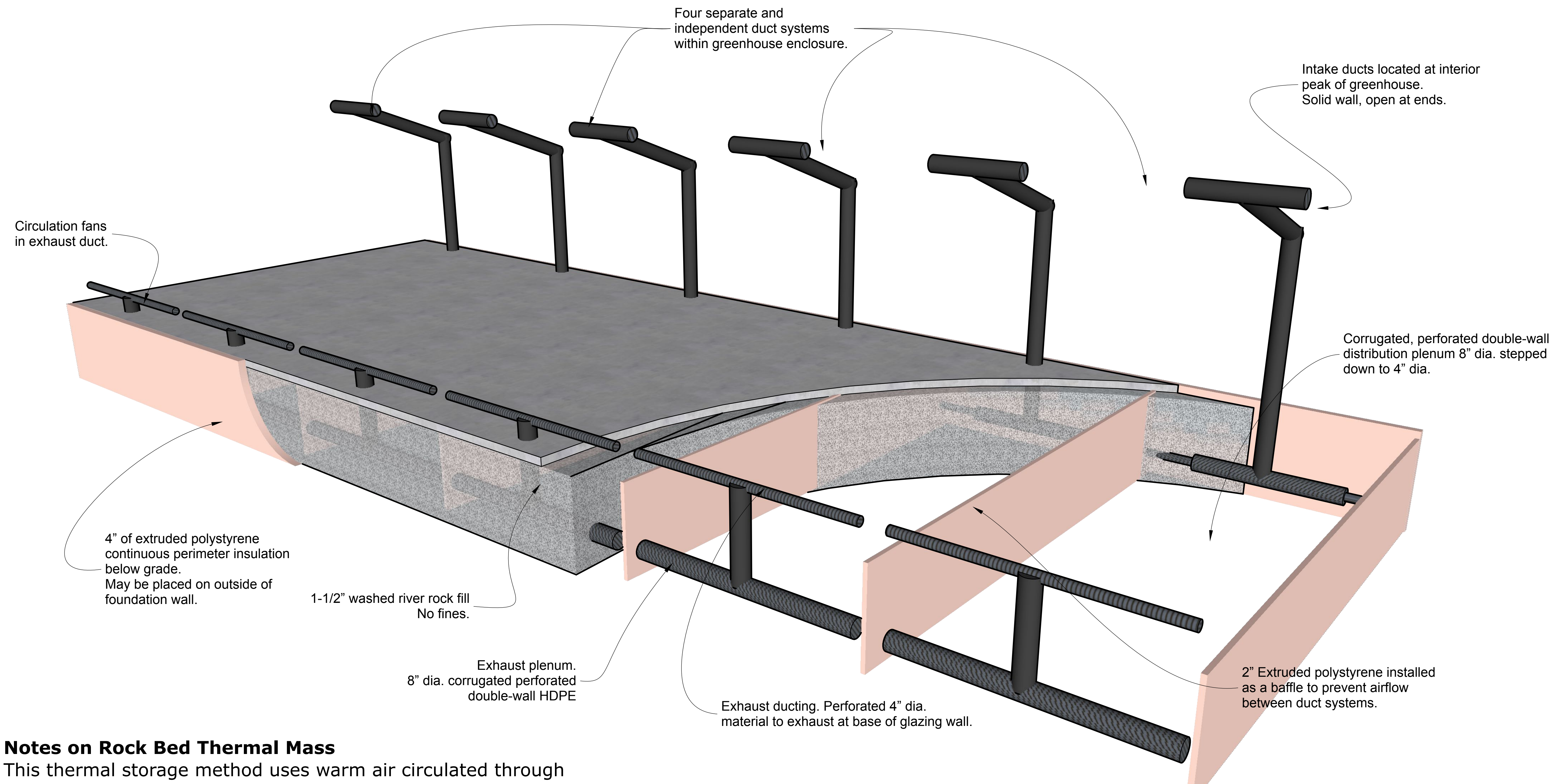
TM.1



Notes on Rock Bed Thermal Mass
This thermal storage method uses warm air circulated through rock beds that absorb and release heat. More information on the rock bed thermal storage is available in the DWGv2.2 plan set.

IMPORTANT: Success of this system requires that the rock bed acts as a sealed duct. Rock beds are typically topped with compacted fill or a concrete slab.
This thermal storage system is highly compatible with containerized growing.

Thermal Mass Variation 2: Rock bed system	1
n.t.s.	TM.2

Farm Scale Winter Greenhouse v2.1

August 26, 2025 Not for Construction