

EXHIBIT C1

Climate Battery System: Design Description and Technical Justification

LCMG Earth-Sheltered Growing Dome — City Planning Department, Site Plan Review

1. Purpose and Scope

This exhibit provides a complete technical description of the Climate Battery system proposed as an integral component of the LCMG earth-sheltered growing structure. The Climate Battery is a passive, ground-coupled thermal storage and air-exchange system engineered to moderate interior growing-space temperatures, extend the viable growing season through the Cheyenne shoulder-season periods, and eliminate the need for active fossil-fuel or electric-resistance heating.

This document is submitted to the City Planning Department to demonstrate structural and thermal soundness to reviewing engineers and inspectors. All design decisions are driven by thermal performance, biological health of the growing environment, and long-term system durability.

2. System Overview and Operating Principle

A Climate Battery operates on the principles of thermal mass storage and ground-coupled heat exchange. The system functions in two complementary modes:

1. **Charging Mode (Warm Season / Daytime):** Warm, humid air generated inside the growing dome during periods of solar gain is drawn downward through the vertical manifold and distributed through a network of buried perforated pipes. Thermal energy is transferred from the circulating air into the surrounding soil/gravel medium, where it is stored as sensible heat. Ground temperature in the battery zone rises incrementally over the warm season.
2. **Discharge Mode (Cold Season / Nighttime):** As ambient temperatures drop, cooler air entering the manifold passes through the pipe network and recovers the stored thermal energy. Pre-warmed air is returned to the growing space, elevating the minimum nighttime temperature and extending frost-free conditions well beyond what would be possible in an unheated enclosure.

The system requires no combustion, no refrigerants, and no fossil fuels. Primary energy input is limited to the low-power fan(s) required to assist airflow through the pipe network.

3. Physical Configuration and Dimensions

3.1 Excavated Pit

The Climate Battery is installed within a 17 ft × 17 ft square excavated pit, 4.5 feet deep. A square pit is preferred over a circular one: a hydraulic excavator cuts naturally in straight passes, producing predictable, measurable walls that are faster to execute and easier to inspect than a circular target. Each side is measured from a center stake and is verifiable at any stage of construction.

The four corners of the square that fall outside the 10-foot pipe-boundary radius from dome center are not excavated to full depth, preserving undisturbed soil beneath the dome bearing ring at the corners. The active thermal battery occupies 264.1 ft² within the square, bounded by that 10-foot radius constraint.

Field instruction: Before excavation begins, mark the dome center stake and spray-paint a 10 ft radius circle on the ground surface. Brief the operator that the four corner areas of the 17 ft square that fall outside this circle are not cut to full depth. The main square body is excavated to 4.5 ft.

3.2 OSHA Compliance

Per OSHA 29 CFR 1926.652, excavations in soil other than stable rock exceeding 5 feet in depth require a protective system (sloping, shoring, or trench box) before workers may enter. Excavations between 4 and 5 feet require a competent person to assess soil stability before entry; excavations at or below 4 feet in stable soil may be entered without a protective system.

The 4.5-foot pit depth keeps this installation below the 5-foot shoring threshold. Workers installing Layer 1 pipe at 4.0 feet below grade may enter the pit without shoring or a trench box, provided a competent person has assessed the soil and confirmed stability. In Cheyenne-area native soils (typically silty clay loam to sandy loam), a 4.5-foot excavation with near-vertical walls is generally achievable in dry conditions subject to that assessment.

The 4.5 ft pit depth is selected specifically to keep the installation below the OSHA shoring threshold, allowing safe volunteer-built construction without specialized excavation equipment or contracted shoring services.

3.3 XPS Perimeter Barrier and Moisture Film

Immediately after excavation, a continuous moisture film (6-mil polyethylene sheeting) is installed against all four native soil pit walls from floor to above grade. Two-inch extruded polystyrene (XPS) rigid foam boards are then stood vertically against the moisture film, with joints taped and corners adhered. This assembly serves three functions:

1. Thermal boundary insulation: 2-inch XPS provides R-10 lateral insulation, eliminating the continuous sidewall heat loss that occurs when thermal medium is in direct contact with surrounding native soil. Stored heat is directed upward through the air circuit into the dome rather than bleeding laterally into the passive soil mass.
2. Moisture exclusion: The moisture film prevents groundwater and capillary moisture from native soils from migrating laterally into the thermal medium during snowmelt and spring precipitation, maintaining the designed blend composition and aerobic pore environment.
3. Compaction form: The XPS boards provide a clean, rigid wall for the thermal medium to compact against during installation, preventing native soil fines from contaminating the 60/40 blend at the perimeter.

The 2-inch XPS reduces the interior working dimension from 17 ft to 16 ft 8 in per side, trimming the effective battery area by 7.2 ft² — a minor dimensional trade for significant thermal and durability benefits.

3.4 Climate Battery Core

The active Climate Battery — three-layer pipe network, thermal medium, manifold connections, and geotextile filter fabric — occupies an effective area of 264.1 ft² within the square pit interior. At a composite fill depth of 3.0 ft spanning the three pipe layers, the thermal medium volume is 264.1 ft² × 3.0 ft = 792.4 ft³.

3.5 Dome Structure and Bearing

The LCMG growing dome measures 22 feet in diameter at its base. The dome base ring bears entirely on undisturbed, unexcavated native soil beyond the 17-foot pit perimeter. At the side midpoints of the square pit, the undisturbed margin between the pit edge and the dome bearing ring is 2.5 feet.

For a 4.5-foot excavation, the H/2 guideline — a conservative field heuristic recommending a horizontal clearance between an excavation edge and an adjacent load-bearing surface of at least half the excavation depth — yields a target of 2.25 feet. The 2.5-foot margin satisfies this guideline at all side midpoints. The four corners of the square are not excavated to full depth, so no full-depth excavation approaches the dome bearing ring at the corners.

This arrangement completely decouples the structural bearing surface from the backfilled thermal zone, eliminating differential settlement risk between the dome foundation and the engineered fill. No structural load from the dome is transferred to the backfilled pit area.

Dimensional summary: 17 ft × 17 ft square pit, 4.5 ft deep | 264.1 ft² active battery core | 22 ft dome base on undisturbed native soil | 2.5 ft undisturbed margin (pit side to dome bearing ring) | H/2 = 2.25 ft ✓

3.6 Excavation Spoil

The 17 ft × 17 ft square pit produces $289 \text{ ft}^2 \times 4.5 \text{ ft} \div 27 = 48.2 \text{ yd}^3$ of excavated material. Per OSHA 1926.651(j)(2), no spoil may be placed within 2 ft of the pit edge. All excavated spoil should be staged well outside the dome footprint or removed from the site.

4. Three-Layer Pipe Network: Layer Structure and Design Rationale

The Climate Battery employs a vertically staged, three-layer pipe network. Each layer is positioned at a distinct depth to exploit a different thermal characteristic of the ground, creating a system with both high total thermal storage capacity and rapid thermal response time. The layered approach allows the battery to simultaneously bank long-term heat at depth and cycle heat rapidly near the surface in response to daily solar gain.

4.1 Layer Structure

Layer	Depth	Purpose	Components	Design Notes (Cheyenne)
Layer 1 (Deepest)	4.0 ft below grade	Long-term thermal storage; most stable soil temperatures; winter heat banking	4" perf. corrugated drain tile; straight parallel runs; 60/40 gravel-soil blend	At conservative Cheyenne frost depth (42–48 in). Sump provision via manifold. Maximizes BTU banking.
Layer 2 (Mid)	2.5 ft below grade	Intermediate thermal exchange; faster response than Layer 1	4" perf. HDPE tubing; balanced airflow from manifolds	Bridges deep storage and fast-cycling upper layer. Moderates temperature spikes.
Layer 3 (Upper)	1.0 ft below grade	Fast-cycling exchange; day-to-night temperature management; shoulder-season performance	4" perf. HDPE tubing; higher airflow velocity zone	Most responsive to daily solar gain. Critical for Mar–Apr and Oct–Nov shoulder periods.
Manifolds	Vertical — full depth	Connect all three pipe layers; provide access and airflow distribution	18" dia. corrugated metal culvert risers; sealed, insulated, interior-accessible	Sump access for Layer 1 condensate. Fan mounted at top. Insulation prevents thermal short-circuit.

4.2 Layer 1 — Deepest Layer (4.0 ft below grade)

Layer 1 is the primary long-term thermal storage layer. Positioned at 4.0 feet below finish grade — 48 inches — this layer reaches the conservative design frost depth for Cheyenne, Wyoming (minimum 36 inches per ASCE 7; conservative design depth 42–48 inches). Placement at this depth ensures that stored thermal energy is substantially isolated from surface freeze-thaw cycling, and that the layer operates within the thermally stable zone where soil temperatures remain in the range of 48–55°F year-round.

Layer 1 uses 4-inch perforated corrugated drain tile in straight parallel runs across the 16 ft 8 in interior span. A sump pump provision is incorporated into the vertical manifold at Layer 1 elevation to manage winter condensate. In cold climates, moisture driven out of warm dome air condenses in the deeper, cooler zones of the pipe network. This provision allows condensate removal without excavation and prevents standing water accumulation that would create anoxic conditions at the base of the battery.

A 0.5-foot base course of 60/40 gravel-soil blend is placed below the Layer 1 pipe before the pipe is set, bringing the total active medium depth to the pit floor. This base course is the lowest element of the thermal medium and ensures uniform support and thermal contact under the pipe.

4.3 Layer 2 — Mid Layer (2.5 ft below grade)

Layer 2 serves as the intermediate thermal exchange layer — the bridge between the long-term storage of Layer 1 and the fast-cycling performance of Layer 3. Responding more quickly to changes in dome air temperature than Layer 1, this layer absorbs and releases heat on a timescale of hours rather than days. Balanced airflow distribution from the manifold connections ensures that Layer 2 does not short-circuit the deeper layer, maintaining the thermal gradient that is essential to the system's effectiveness.

4.4 Layer 3 — Upper Layer (1.0 ft below grade)

Layer 3 is the fast-cycling exchange layer and the most critical for day-to-night temperature management and shoulder-season performance. Positioned 1.0 foot below grade, it interacts most directly with the diurnal solar cycle. During March, April, October, and November, the dome interior can reach 30–50°F above ambient. Layer 3 rapidly absorbs this peak thermal energy, preventing dome overheating during peak solar gain while maximizing heat recovery for overnight discharge.

4.5 Square Pit Layout: Pipe Routing and Coverage

In the 17 ft × 17 ft square pit, all three pipe layers are routed in straight parallel serpentine runs across the 16 ft 8 in interior span. Straight runs in a square pit are more efficient than chord-truncated runs in a circular layout: every run is the same length, manifold connections are predictable, and medium coverage is uniform. Each layer contains approximately 268 linear feet of pipe; three-layer total is approximately 804 linear feet.

For rows where $|y| > 5.5$ ft from dome center, pipe runs terminate at the 10-foot radius boundary rather than the interior wall, keeping all active pipe within the bearing margin zone. Terminated ends are end-capped.

5. Vertical Manifold System

The vertical manifold is the central connecting element of the Climate Battery. For the LCMG dome, an 18-inch diameter corrugated metal culvert riser is specified. The manifold connects all three pipe layers, provides the pathway for fan-driven airflow, and meets the following design requirements:

1. Sealed construction: The manifold is sealed at all pipe penetrations to prevent air bypass between layers, which would reduce thermal exchange efficiency.
2. Thermal insulation: The manifold exterior is insulated to prevent it from acting as a thermal short-circuit that bleeds stored heat upward to the surface.
3. Interior accessibility: The manifold is accessible from inside the dome for inspection of pipe connections, fan servicing, and sump pump operation at Layer 1 depth.
4. Sump provision at Layer 1 depth: A sump basin at the manifold base collects winter condensate for periodic removal, preventing standing water accumulation.

The 18-inch diameter provides a cross-sectional area of approximately 1.77 ft² for the required airflow volumes while maintaining structural rigidity and access to internal components.

6. Thermal Medium: Selection, Specification, and Storage Capacity

6.1 Engineering Criteria for Thermal Medium Selection

The material surrounding the buried pipe network must simultaneously satisfy three competing requirements: (1) sufficient volumetric heat capacity to store meaningful quantities of thermal energy; (2) adequate air permeability to allow moisture-laden dome air to migrate through the medium and exchange heat at the pipe surfaces; and (3) an aerobic pore environment that suppresses the anaerobic conditions which favor pathogenic fungi and harmful soil microorganisms.

6.2 Comparative Analysis: Native Soil vs. Blended Medium

Property	Native Soil Only	60/40 Gravel-Soil Blend (Recommended)
Volumetric Heat Capacity (BTU/ft ³ /°F)	20–30	19–27 (modest reduction only)
Air Permeability Through Medium	Low to Very Low	Moderate to High
Risk of Anaerobic (Anoxic) Zones	High — sustained in clay/silt soils	Low — open pore structure maintains O ₂
Pathogenic Fungal Risk (Pythium, Phytophthora, Fusarium)	Elevated — anoxic zones favor pathogens	Suppressed — aerobic conditions inhibit
Long-Term Permeability Stability	Poor — compaction reduces over time	Good — gravel skeleton resists settling
Airflow Efficiency at Pipe Surface	Poor — fines block exchange	Excellent — open interstitial voids
On-Site Material Availability	Yes — 100% on-site	Partial — gravel must be imported
Overall Recommendation	Not recommended	RECOMMENDED

6.3 Thermal Storage Calculation

The 17 ft × 17 ft square pit with 2-inch XPS perimeter lining produces an effective thermal medium footprint of 264.1 ft². At a composite fill depth of 3.0 ft spanning the three pipe layers and inter-layer medium:

$$264.1 \text{ ft}^2 \times 3.0 \text{ ft} = 792.4 \text{ ft}^3 \times 23 \text{ BTU/ft}^3/\text{°F} \times 15\text{°F} = 273,387 \text{ BTU stored } (\approx 10.4 \text{ therms} / 80 \text{ kWh thermal})$$

This thermal reserve is sufficient to maintain meaningful temperature elevation over multiple consecutive cold nights without solar recharging, demonstrating the system's capability to buffer short cold spells entirely passively. The three-layer gradient — Layer 3 providing fast diurnal cycling, Layer 2 acting as an intermediate buffer, and Layer 1 providing persistent baseline heat at depth — ensures that the battery responds effectively to both daily solar cycles and extended cold periods.

The stored-BTU figure is a conservative measure of thermal medium volume only. It does not capture the additional performance provided by the R-10 XPS perimeter insulation, which eliminates the continuous

lateral heat loss that would occur in an uninsulated pit. A battery with R-10 lateral insulation retains its stored energy longer and discharges more efficiently into the growing space, making 273,387 BTU an understatement of effective in-service thermal performance.

6.4 Biological Rationale: Suppression of Anoxic Environments

In fine-grained or clay-rich native soils, sustained moisture in a closed subsurface environment rapidly depletes dissolved oxygen, creating anaerobic zones. These are the primary driver of soil-borne pathogen proliferation in horticultural settings. The fungal genera *Pythium*, *Phytophthora*, and *Fusarium* — responsible for root rot, damping-off, and crown rot — are facultative or obligate anaerobes that thrive in waterlogged, oxygen-depleted soil.

The 60/40 gravel-soil blend maintains an interconnected pore structure with adequate oxygen exchange throughout the life of the battery. The angular gravel fraction creates a self-supporting skeleton that resists compaction and keeps void spaces open. This aerobic environment is biologically hostile to the primary soil-borne pathogens, providing passive biological protection to the growing environment above without fungicides or soil treatments. The XPS perimeter moisture film reinforces this protection by blocking lateral water migration from native soil into the thermal medium.

6.5 Building Fee Basis: Equitable Treatment of Volunteer-Built Structures

Every documented Wyoming growing dome installation — 33 sites on record — was built entirely by volunteers, with zero use of paid contractors. Permit fees in Cheyenne and across Wyoming are conventionally calculated on contracted construction value, not imputed volunteer labor hours. Applying a volunteer-hours basis here would be unprecedented across all 33 peer installations and inconsistent with the agricultural accessory structure classification established in Exhibit D. Fees, if any apply, should be calculated on actual material cost only.

7. Geotextile Filter Fabric and Backfill Specification

All perforated pipe runs in all three layers are wrapped in non-woven polypropylene geotextile filter fabric (pipe sock), meeting AASHTO M288 Class 2 or equivalent. The geotextile:

1. Prevents migration of soil fines into pipe perforations, preserving long-term airflow and thermal exchange efficiency.
2. Maintains the integrity of the gravel void structure adjacent to the pipe by preventing fine particles from infiltrating interstitial spaces.
3. Does not impede airflow — non-woven polypropylene geotextile has adequate air permeability for the low-velocity flows used in this application.

A continuous layer of non-woven geotextile is installed across the pit floor before any thermal medium is placed. The floor liner laps up against the base of the XPS perimeter boards on all four sides, creating a sealed base that prevents upward migration of native fines and lateral moisture intrusion. A second geotextile layer is installed above the Layer 3 medium zone before final backfill, preventing downward migration of surface fines into the engineered medium.

Backfill between and above the pipe layers consists of the 60/40 blend placed in compacted lifts not exceeding 6 inches per lift. The 4.5-foot pit is filled in 9 lifts from base to grade, each requiring approximately 4.9 yd³ of blended material.

8. Step-by-Step Excavation and Installation Sequence

Step 1: Site Layout

1. Locate and drive a stake at the exact dome center using surveyed or measured coordinates.
2. Mark the dome base ring: 11 ft radius = 22 ft diameter circle on the ground surface with marking paint. This is the structural bearing surface. No excavation may approach within 1 ft of this line.
3. Mark a 10 ft radius circle from center. This is the outer boundary for full-depth excavation and the limit beyond which pipe runs do not extend.
4. Mark the 17 ft square pit perimeter with stakes at each corner and chalk lines on all four sides. Confirm each side midpoint is 8.5 ft from center — inside the 10 ft radius ✓.
5. Mark a 2 ft spoil exclusion zone beyond the pit perimeter. Per OSHA 1926.651(j)(2), no spoil may be placed within 2 ft of the pit edge.

Step 2: Excavation

1. Excavate the main body of the 17 ft square to 4.5 ft depth. Work from one side to avoid the machine sitting on the spoil exclusion zone. Check depth frequently and do not over-excavate.
2. At the four corners: excavate only to the extent the corner remains within the 10 ft radius circle. The triangular corner areas beyond the 10 ft radius are left at grade or tapered shallowly. These areas carry no pipe or thermal medium.
3. A competent person must assess soil stability before any worker enters the pit. At 4.5 ft depth in stable native soil, the pit may typically be entered without a protective system.

Step 3: Perimeter Barrier Installation

1. Unroll moisture film against the native soil face of each pit wall. Secure the top edge to the ground surface outside the pit. The film must extend from the pit floor to at least 2 inches above finished grade.

2. Stand 2-inch XPS boards (cut to 4.5 ft height) vertically against the moisture film on each wall. Tape all butt joints with XPS-compatible foam board tape. At corners, overlap boards from adjacent walls and secure with rigid foam construction adhesive.
3. Install non-woven geotextile filter fabric across the pit floor. Lap the fabric up against the base of the XPS boards on all four sides.

Step 4: Layer 1 Installation (4.0 ft below grade)

1. Place a 0.5-ft base course of 60/40 gravel-soil blend on top of the geotextile floor liner.
2. Lay 4-inch perforated corrugated drain tile in straight parallel runs at 1 ft center-to-center spacing. Wrap each run in geotextile pipe sock before placement. Central rows run the full 16 ft 8 in interior span; outer rows ($|y| > 5.5$ ft) terminate at the 10 ft radius and are end-capped.
3. Connect all Layer 1 runs to the vertical manifold riser. Seal all penetrations. Perform an airflow test through each run before covering.
4. Begin covering Layer 1 with blended thermal medium in 6-inch compacted lifts. Use a plywood spreader board for the first two lifts over the pipe — do not apply compaction weight directly to the pipe.

Step 5: Layer 2 Installation (2.5 ft below grade)

1. Continue placing and compacting blended medium in 6-inch lifts until Layer 2 elevation is reached (2.5 ft below grade).
2. Install Layer 2 perforated HDPE tubing in straight parallel runs at 1 ft spacing with geotextile pipe sock. Apply the same pipe run length rule as Layer 1. Connect all runs to the manifold and airflow test before covering.

Step 6: Layer 3 Installation (1.0 ft below grade)

1. Continue compacted lifts to Layer 3 elevation (1.0 ft below grade).
2. Install Layer 3 perforated HDPE tubing in straight parallel runs at 1 ft spacing with geotextile pipe sock. Same pipe run length rule applies. Connect to manifold and airflow test before covering.
3. Continue compacted lifts to within 6 inches of finish grade.

Step 7: Final Backfill and Surface Restoration

1. Install a continuous non-woven geotextile layer above the Layer 3 medium zone before final backfill.
2. Complete backfill to finish grade with compacted 60/40 blend or clean native soil in 6-inch lifts. Trim XPS boards and moisture film flush with grade.
3. Inspect the dome bearing ring footprint — the 11 ft radius zone — to confirm it sits entirely on undisturbed native soil. The 2.5 ft undisturbed margin at the side midpoints should be visually distinct.

4. Allow a minimum of 72 hours before placing the dome base ring, preferably one week for initial settlement.

9. Airflow System: Fan Sizing, Ducting, and Controls

9.1 Fan Sizing for the LCMG Dome

The fan requirement is determined by the need to achieve a minimum of one complete air volume exchange through the pipe network within a defined charging or discharging cycle. For the 22-foot diameter LCMG dome, the interior air volume is approximately 2,700 cubic feet (assuming an average height of approximately 7 feet over the growing area). To achieve a complete air exchange in approximately 5 to 8 minutes, a fan capacity of 350 to 600 CFM is required:

Primary fan (×2): Low-voltage DC inline axial fan, 400–600 CFM rated capacity, weatherproof enclosure, mounted at top of 18-inch vertical manifold. One fan per manifold riser.

A fan in the 400–600 CFM range provides sufficient airflow to charge the battery during a 4-to-6-hour solar gain window and discharge it during an 8-to-10-hour overnight cooling period. Variable-speed or two-speed selection is preferred to allow lower-velocity operation during discharge mode. The 18-inch manifold provides a cross-sectional area of approximately 1.77 ft², yielding a face velocity of 225–340 FPM at rated output — within the 100–500 FPM range that optimizes thermal exchange between circulating air and the pipe-surface medium.

9.2 Ducting

Supply and return connections between the vertical manifold and the dome interior use 8-to-12-inch insulated flexible duct, rated to UL 181 or equivalent. Insulation prevents thermal losses and condensation on cold duct surfaces during winter discharge operation.

9.3 Control Logic

Airflow is controlled by a differential temperature and humidity controller with sensors inside the dome and inside the manifold at mid-depth:

1. Charging mode activated when dome air temperature exceeds battery medium temperature by 8–12°F AND dome relative humidity is above a minimum threshold (typically 50%).
2. Discharge mode activated when dome air temperature falls below battery medium temperature by 4–8°F.
3. Fan off when temperature differentials are within the deadband, or when dome temperature is above target maximum and battery medium is also warm.

This logic ensures the fan operates only when there is a net thermal benefit to circulation, preventing premature battery discharge and maximizing temperature elevation in the growing space during cold nights.

10. Complete Materials List

The following identifies all primary materials used in the Climate Battery system. No vendors or pricing are included.

Material / Component	System Role	Standard / Spec.	Placement	Key Notes
4" Perf. corrugated drain tile	Pipe — Layer 1 (deep)	ASTM F405	Parallel runs at ~4.0 ft depth	Geotextile sock required
4" Perf. HDPE tubing	Pipe — Layer 2 (mid)	ASTM F405 or equiv.	Parallel runs at ~2.5 ft depth	Balanced flow from manifolds
4" Perf. HDPE tubing	Pipe — Layer 3 (upper)	ASTM F405 or equiv.	Parallel runs at ~1.0 ft depth	Fast-cycle / shoulder-season layer
18" dia. corrugated metal culvert riser	Vertical manifold	AASHTO M36 or equiv.	Connects all 3 layers; interior accessible	Sealed, insulated; sump pump provision
¾" washed crushed stone	Thermal medium — aggregate	ASTM C33 coarse aggregate	60/40 blend with native soil	Clean; no fines; angular preferred
Native excavated soil (screened)	Thermal medium — soil fraction	Site-specific	Screened, debris >2" removed	60% gravel / 40% soil by volume
Non-woven polypropylene geotextile	Pipe sock / filter fabric	AASHTO M288 Class 2	Wrapped around all pipe runs	Prevents fines migration
2" XPS rigid foam board	Perimeter thermal barrier	Min. 15 PSI; FOAMULAR 150 or equiv.	All four pit walls, floor to grade	R-10 lateral insulation; ~12 boards
6-mil polyethylene moisture film	Perimeter moisture barrier	Standard vapor barrier film	Between XPS and native soil, full height	~375 ft ² ; one standard roll
Low-voltage DC inline axial fan (x2)	Airflow — primary	UL listed; weatherproof	400–600 CFM per manifold	Differential temp/humidity control

Material / Component	System Role	Standard / Spec.	Placement	Key Notes
8"–12" insulated flexible duct	Supply / return ducting	UL 181 or equiv.	Manifold to growing space	Insulated to prevent condensation
Temperature + humidity controller	Airflow controls	Listed differential controller	Sensors in dome and manifold	Activates fan when ΔT threshold met
Rodent-proof screened cap	Inlet / outlet protection	Galv. or stainless mesh	All above-grade openings	Prevents pest infiltration

11. Seasonal Growing Season Extension: Thermal Performance Summary

The primary performance objective of the Climate Battery is to extend the viable growing season in the Cheyenne, Wyoming climate beyond the limits imposed by ambient outdoor temperatures. Cheyenne presents particular challenges: average last spring frost May 9–15, average first fall frost September 27–October 5, high solar radiation intensity, and diurnal temperature swings exceeding 40°F in the shoulder seasons.

A three-layer Climate Battery system with these design parameters has demonstrated, in comparable installations in USDA Zone 5–5b climates, the ability to maintain interior minimum temperatures 15–25°F above ambient nighttime lows during shoulder-season periods. This translates to an effective season extension of 6 to 10 weeks on each shoulder, providing approximately 3 to 5 months of additional frost-free growing time compared to an equivalent unheated enclosure.

With 273,387 BTU of stored thermal capacity — conservatively calculated from medium volume alone and not accounting for the lateral insulation benefit of the R-10 XPS perimeter — the battery sustains meaningful temperature elevation during multiple consecutive overcast or cold days without solar recharging. This multi-day buffering capacity is a critical design requirement for the variable spring and fall weather patterns characteristic of the high plains of southeastern Wyoming.

12. Engineering Summary

The Climate Battery as described constitutes a structurally sound, thermally optimized, and biologically appropriate passive thermal management system for the LCMG earth-sheltered growing dome. Key design parameters:

1. Pit: 17 ft × 17 ft square, 4.5 ft deep — below the OSHA 5-foot shoring threshold, allowing safe worker entry without a protective system

2. Perimeter: 2-inch XPS rigid foam (R-10) and 6-mil moisture film on all four walls — eliminates lateral heat loss and moisture ingress, maintains 60/40 blend integrity
3. Active battery footprint: 264.1 ft² (16 ft 8 in interior, bounded by 10 ft dome-ring radius)
4. Three-layer pipe network: Layer 1 at 4.0 ft (at Cheyenne frost depth), Layer 2 at 2.5 ft, Layer 3 at 1.0 ft — layered response from long-term banking to fast diurnal cycling
5. Thermal medium volume: 792.4 ft³ at 60/40 gravel-soil blend — 273,387 BTU stored (conservative; R-10 perimeter insulation provides additional effective performance)
6. Bearing margin: 2.5 ft undisturbed soil at side midpoints — satisfies H/2 guideline for a 4.5 ft excavation ($H/2 = 2.25$ ft)
7. Pipe coverage: ~268 linear ft per layer, ~804 ft total — uniform straight runs across the full interior span
8. Fan: 400–600 CFM low-voltage DC, two units — appropriately sized for dome air volume and manifold geometry
9. Medium: 60/40 washed gravel / native soil blend — high thermal capacity, aerobic pore structure, suppresses soil-borne pathogens
10. Differential temperature-humidity control — fan operates only when thermally beneficial

This system requires no combustion, no refrigerants, and no fossil fuels. All materials are standard, commercially available, and well-characterized in civil and horticultural engineering practice. The system is fully passive in thermal storage mode and requires only low-power fan operation to complete the heat exchange circuit.

End of Exhibit C1 — Climate Battery System: Design Description and Technical Justification