



**TRANE®**

# Parallel Central Geothermal System Blueprint

Large Office Retrofit using Packaged and Modular  
Heat Pump Chillers

Harnessing the earth's stable and moderate  
temperatures for heating and cooling using heat  
pumps helps provide highly efficient, year-round  
operation

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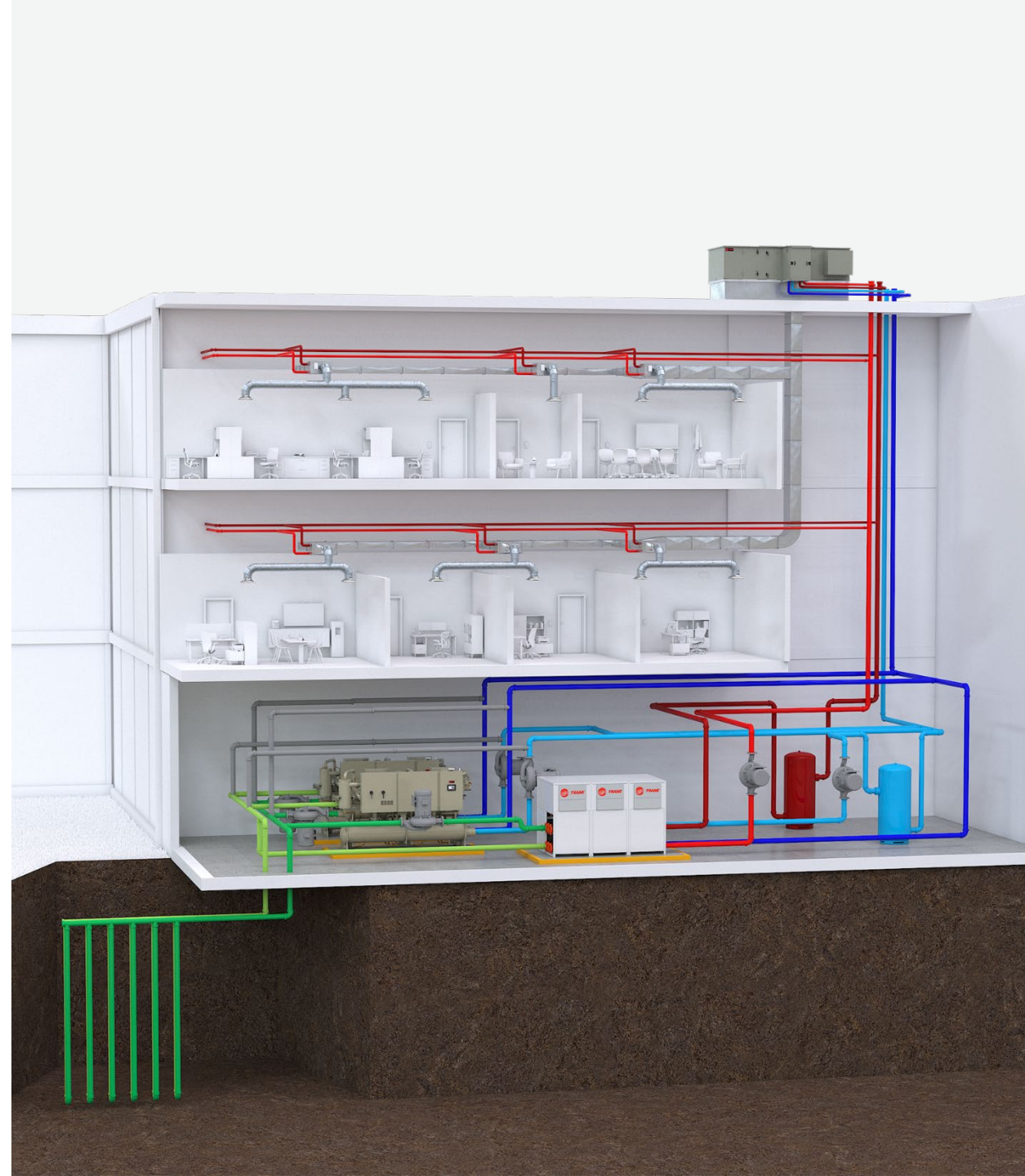


# → Introduction

Geothermal systems deliver highly efficient, reliable heating and cooling by leveraging stable ground temperatures. This document provides a proven framework to guide borefield, equipment, and system integration decisions—helping engineers streamline design while giving owners and contractors confidence in performance and best-practice implementation.

## This document provides:

- A practical concept for applying a central geothermal system in office building retrofits, fully integrated with a vertical geothermal borefield.
- Guidance on key design elements including borefield sizing, packaged and modular heat pump chiller selection, and specification of pumps, valves, and hydronic components.
- Details on how a central geothermal plant ties into a building's multi-zone VAV air distribution system.



# → Design Overview

## Capacity, Temperatures, and Flowrates

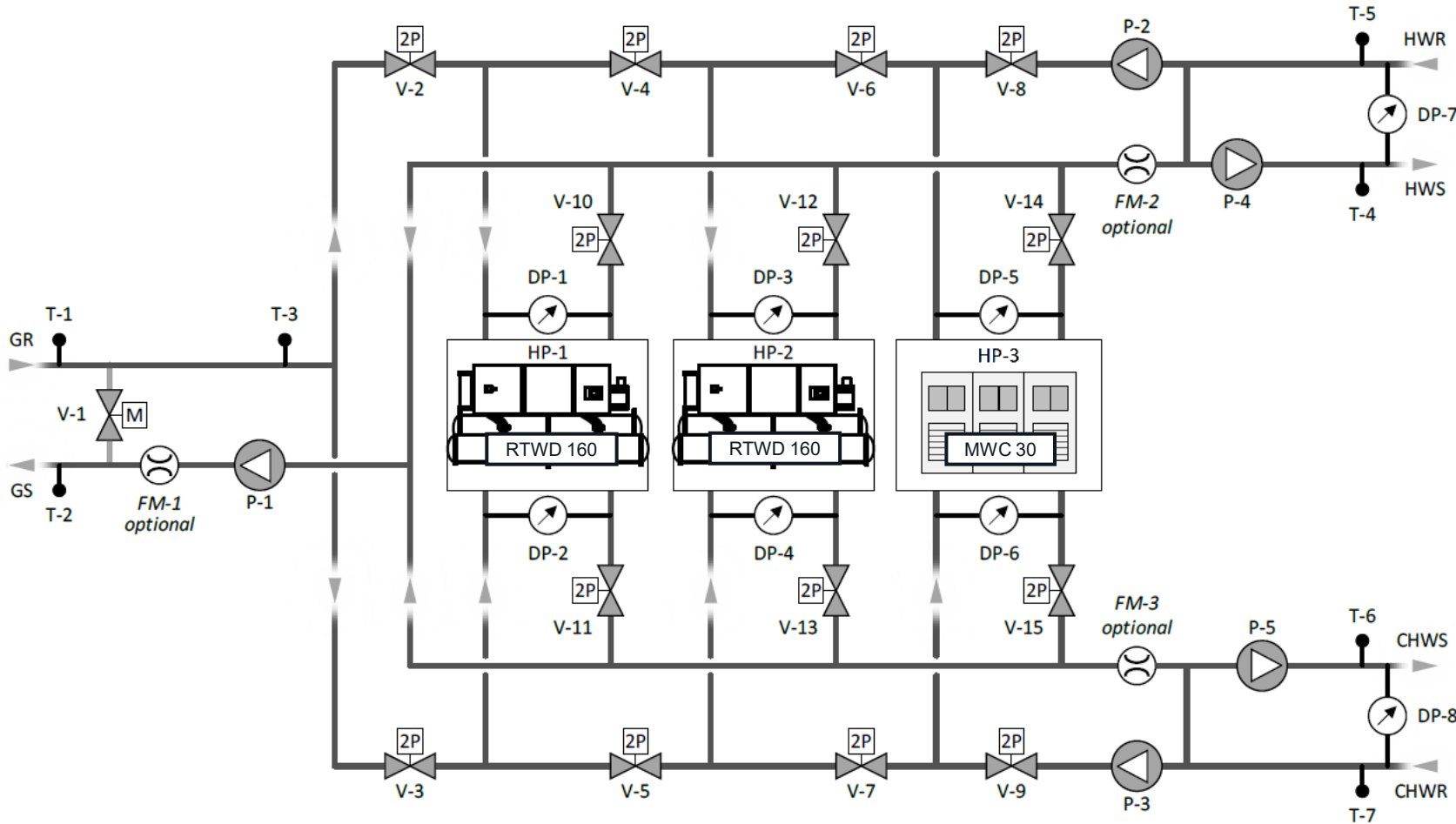
The geothermal system serving the 200,000 sq-ft office building in La Crosse, WI, is designed to meet peak heating and cooling loads while operating within chilled water, hot water, and borefield temperature ranges.

Design conditions in the table establish the basis for sizing heat pump chillers and hydronic accessories, determining borefield loads, and ensuring stable year-round performance.

System Design Summary	
Category	Design Parameters
System Capacity	Cooling: 330 tons • Heating: 4000 MBh
Chilled Fluid Design Conditions	Supply: 42°F (6°C) • Return: 54°F (12°C) Flow Rate: 2.1 GPM/Cooling ton
Hot Fluid Design Conditions	Supply: 120°F (49°C) • Return: 105°F (41°C) Flow Rate: 0.14 GPM/Heating MBh
Borefield Source/Sink Conditions	Heat Pump Entering Fluid Temp: 35–90°F Range (2°C–32°C Range)
Heat-Transfer Fluid	30% Propylene Glycol/Water (Freeze Protection to 9°F(-13°C))
Location – La Crosse, WI Design Days	Cooling: 92°F (33°C) DB / 74°F (23°C) WB Heating: -20°F (-29°C) DB

# Design Overview

## System Schematic Diagram



- ✓ Centralized equipment simplifies maintenance
- ✓ Mixed heat pump technology improves loading flexibility
- ✓ System is scalable to high capacities
- ✓ Heat recovery improves system efficiency during simultaneous cool/heat loads
- ✓ Packaged Heat Pumps (HP-1/HP-2) sized for peak cooling or heating load
- ✓ Modular Heat Pump (HP-3) sized for simultaneous heat/cool load

# → System Requirements

- Multiple heat pump chillers with valves enable heating, cooling, or simultaneous operation
- Ground loop mode switching utilize (2) 2-way valves (V-2, V-3)
- Heat pump operating mode selected via 2-way boundary valves (V-4 thru V-9); Heat pump layout requires specific left-to-right or right-to-left arrangement
- Ground loop pumps (P-1) modulate flow to optimize delta-T while maintaining minimum flow based on DP sensors
- Heating and cooling loops use decoupled primary/secondary pumping for simpler control
- Each heat pump includes 2-way isolation valves (V-10 thru V-15); modulating valves optional for flow balancing or head pressure control
- Ground loop bypass valve provides head pressure control, especially in cooling-dominant operation (V-1)

# → Design Overview

## Customer Outcomes

### Lower Operating Costs

- Modular heat-pump chiller efficiently handles low and simultaneous loads, reducing cycling and improving system turndown.
- Heat-recovery capability boosts overall system efficiency when simultaneous heating and cooling loads are present.
- Heat-pump staging optimizes performance by lowering compressor lift for units not operating in heat-recovery mode.

### Flexible Operation

- Parallel configuration allows modular and packaged units to operate independently or together.
- Systems can easily accommodate load diversity and seasonal variations common in office buildings.
- Modular units deliver precise load-matching and built-in redundancy, while packaged units provide high-capacity output during peak periods.

### Enhanced Reliability

- Multiple heat-pump chillers operating in parallel provide inherent system redundancy.
- Stable geothermal loop temperatures, paired with modular staging, ensure consistent hot-water and chilled-water delivery for multi-zone VAV applications.
- Capacity turndown from system ensures precise temperature control and improved occupant comfort.

## → System Benefits

Parallel central geothermal systems delivers meaningful performance, cost, and reliability advantages for office buildings:

- Higher efficiency from stable entering-water temperatures that improve year-round heat-pump performance.
- Lower operating costs through coordinated modular/package staging that reduces energy consumption and peak demand.
- Reduced maintenance utilizing centralizing heat-pump chillers in indoor mechanical spaces.
- Quicker payback enabled by geothermal tax incentives and utility rebates tied to electrification and reduced peak energy use.
- Long-term value from efficient heat recovery and seasonal energy balancing that support decarbonization and resilient building operation.



# → Key System Components

- **Series R™ RTWD Heat Pump Chiller**

A high-capacity packaged heat pump chiller that provides efficient heating and cooling at peak loads. It serves as the primary plant asset for large-capacity demands in the parallel geothermal system.

- **Thermafit™ Modular Heat Pump Chiller (MWC)**

A compact, scalable modular unit that delivers exceptional capacity turndown. It is ideal for handling shoulder-season and simultaneous loads while enabling flexible staging in parallel with the RTWD.

- **Vertical Geothermal Borefield**

Vertical boreholes that exchange heat with the earth, providing a stable thermal source and sink. The borefield supports year-round efficiency and reduces reliance on fossil-fuel heating.

- **Pumps, Valves, and Hydronic Accessories**

Pumps, isolation valves, strainers, expansion tanks, and controls optimize system flow, reliability, and serviceability. These components ensure proper distribution between chillers, the borefield, and the building.

- **Airside Integration Equipment**

Heat exchangers, distribution piping, and controls interface the geothermal plant with the building's multi-zone VAV system. This ensures consistent delivery of chilled and hot water throughout the office.

# → Key System Components

## Series R™ RTWD Heat Pump Chiller

Category	Typical Design Characteristics
Cooling / Heating Capacity	80–250 tons (1,200–3,000 MBh Heating), Depending on Configuration
Evaporator Temperature Range	Leaving Chilled Water: 10°F to 65°F (-12°C to 18°C)
Condenser Temperature Range	Leaving Hot Water: Up to 165°F (73°C) with R-515B; Up to 140°F (60°C) with R-513A
Compressor Type	Dual-Circuit, High-Efficiency Helical Rotary (Screw) Compressors
Refrigerant Options	R-513A or R-515B
Compressor Lift Capability	100°F (38°C) with R-513A 125°F (52°C) with R-515B
Power Options	200V, 230V, 380V, 460V, 575V, 3-phase, 60Hz

### Heat Pump Selection Best Practices



# → Key System Components

## Thermafit™ Modular Heat Pump Chiller (MWC)

Category	Typical Design Characteristics
Cooling / Heating Capacity	15–80 tons (200–1,100 MBh) per Module (Up to 12 Modules per Bank)
Evaporator Temperature Range	Leaving Chilled Water: 15°F to 75°F (-9°C to 24°C)
Condenser Temperature Range	Leaving Hot Water: Up to 140°F (60°C)
Compressor Type	Scroll Compressors (Multi-Compressor Modules)
Refrigerant Options	R-454B
Compressor Lift Capability	95°F (35°C)
Power Options	208V, 230V, 460V, 575V, 3-phase, 60Hz

### Heat Pump Selection Best Practices



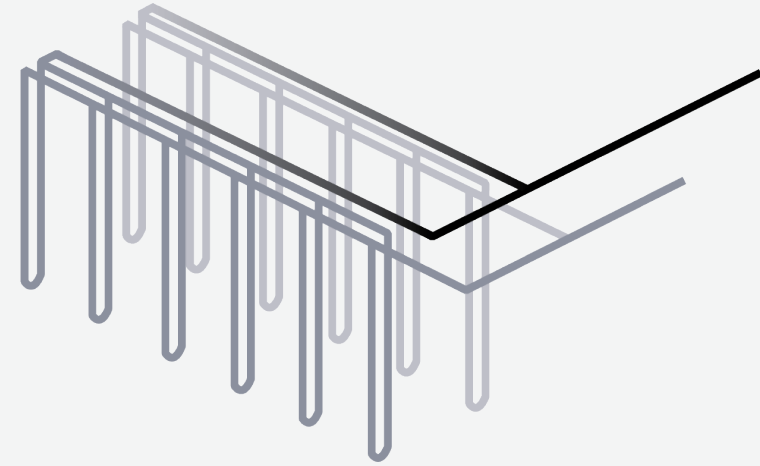
# → Key System Components

## Vertical Geothermal Borefield



Category	Design for 200k sq-ft office building
Number of Boreholes	90 Boreholes
Borehole Depth	500 ft per Borehole
Total Bore Length	45,000 ft
Borehole Diameter	4.5–6 inches
Borehole Spacing	25–40 ft Center-to-Center
Bore Pipe	1.25-inch HDPE Pipe
Grout Thermal Conductivity	1.2 Btu/hr-ft-°F
Design Entering Fluid Temperatures (EFT)	Heating EFT: 35°F (2°C) Cooling EFT: 90°F (32°C)
Heat Transfer Fluid	30% Propylene Glycol
Flow Rate per Bore	10 GPM

### Borefield Design and Sizing Best Practices



# → Key System Components

## Pumps, Valves, and Hydronic Accessories

	Component	Description
Pumps	Ground loop	Circulate flow through the ground heat exchanger and connected heat pump heat exchangers
	Condenser loop primary	Control condenser flow in heating or simultaneous modes
	Evaporator loop primary	Control evaporator flow in cooling or simultaneous modes
	Heating loop distribution	Distribute flow through the building heating loop
	Cooling loop distribution	Distribute flow through the building cooling loop
Valves	Ground loop bypass	Modulates to maintain head pressure with low ground temperatures
	Ground loop mode control	Direct ground loop flow to condensers (cooling) or evaporators (heating)
	Boundary	Route heat pump evaporators/condensers to ground, heating, or cooling loops
	Heat pump isolation	Isolate flow to heat pumps that are not operating
Sensors	Ground loop temperature	Measure entering and leaving ground loop temperatures
	Distribution temperature	Monitor heating and cooling loop temperatures
	Heat pump DP	Measure differential pressure for primary pump flow control
	Distribution DP	Measure supply pressure for distribution pump control
	Flow meters	Detect mismatched flow to identify fouling or flow issues
	Hydronic accessories	Strainers, expansion tanks, glycol fill equipment, buffer tanks, air/dirt separators

# → Key System Components

## Airside Integration Equipment

Features	Description
Air handlers	Configurable Performance Climate Changer® Units with variable aspect ratios
Construction	Low-leak, thermally isolated casing design
Supply fans	High-efficiency fans with VFD control
Filtration	Various levels of filtration available
Cooling coil	AHRI 410-certified coils with high-efficiency fins.
Preheat coil	Hot-water/electric coils with freeze-protect design
Energy recovery	Advanced Air-to-air total energy recovery options
Zone VAV terminal units	Airflow measurement, hot-water reheat coils, pre-programmed controls, Air-Fi® wireless communication



# → Best Practices

## System Capacity

- **Small systems (<100 tons):** Favor packaged or modular heat-pump units for simplicity, easy installation, and basic redundancy—avoid oversized chillers. Also, distributed water-source heat pump systems with a DOAS are suitable for small systems.
- **Medium systems (100–300 tons):** Use packaged or modular chillers to balance flexibility, part-load efficiency, and BAS integration with variable-flow staging.
- **Large systems (>300 tons):** Apply custom chillers or central plants for scalability, advanced controls, redundancy, and support for campus-scale distribution and decarbonization goals.

The table below provides high-level comparison of the five configurations outlined in Central Geothermal Systems Application Manual (SYS-APM009C).

	2-pipe changeover		4-pipe heating and cooling		
	Refrigerant Changeover Central Geothermal System	Hydronic Changeover Central Geothermal System	Modular Multi-pipe Central Geothermal System	Blended Loop Central Geothermal System	Parallel Central Geothermal System
Possible design range	20-960T	80-10,000T+	90-600T	80-500T	240-10,000T+
Typical systems	<200T	>100T	<200T	100-300T	>200T
Preferred Heat Pump Type	Modular (Scroll)	Packaged (Screw/Centrif)	Modular multi-pipe (Scroll)	Packaged (Screw)	Packaged (Screw, Centrif)
Relative Efficiency	Good	Good	Better	Better	Best
Controls Complexity	Low	Low	Med-Low	Med	Med-High

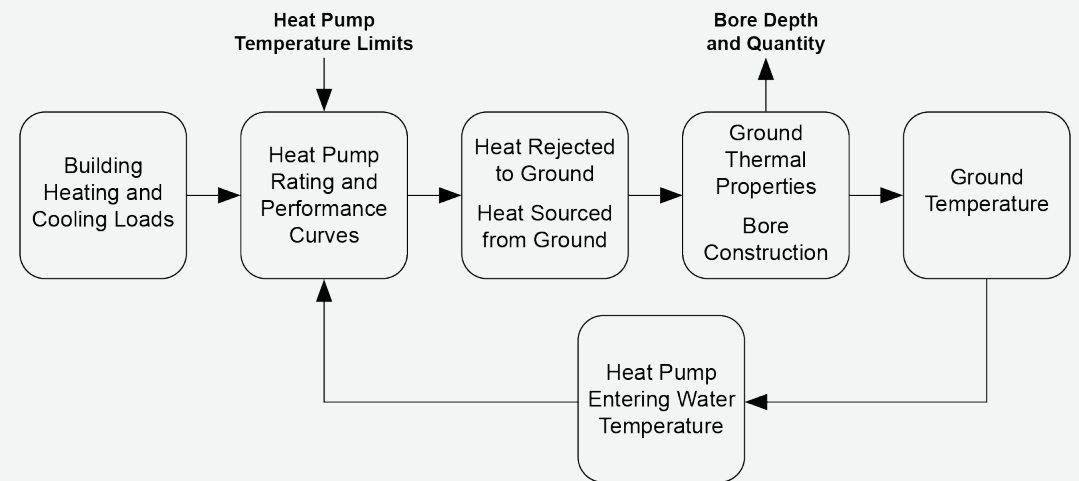
# → Best Practices

## Borefield Design & Sizing

The borefield is the system's heat source/sink and its most expensive component—making accurate sizing critical. Oversizing adds cost, while under sizing reduces performance. Best practices include:

- Use certified designers and specialized ground-loop modeling software.
- Model hourly loads, heat-pump performance, and total heat rejected/extracted (including compressor heat).
- Apply ground-loop simulation and ground thermal properties to design bore depth, quantity, and long-term temperature stability.
- Iterate design to optimize bore count, depth, materials, and heat-pump selections.

## Borefield Sizing Workflow

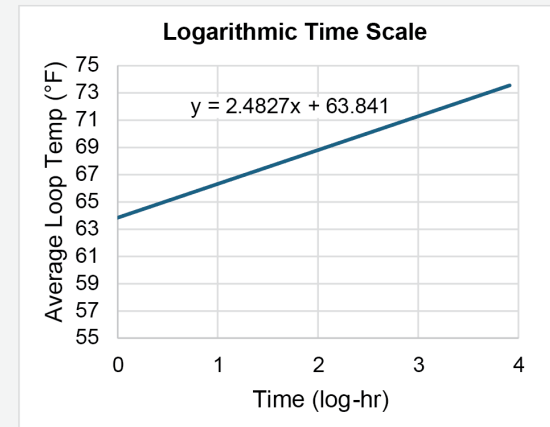
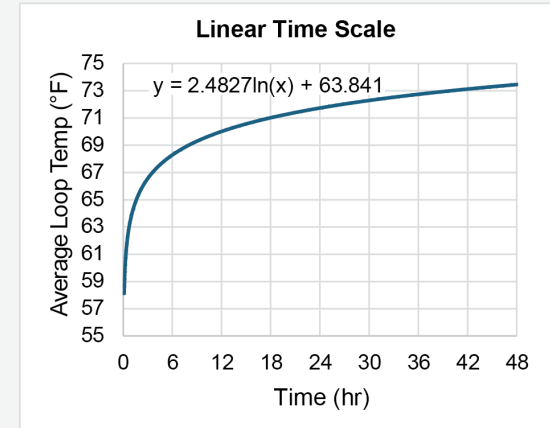


# → Best Practices

## Designing Ground Heat Exchangers

- Perform on-site thermal conductivity testing to verify soil conditions and heat transfer assumptions.
- Test using controlled heat input and continuous monitoring of temperature response.
- Compare results to ASHRAE-recommended testing standards.
- Use the field results to refine borefield design before construction.

## Temperature Rise During Thermal Conductivity Test



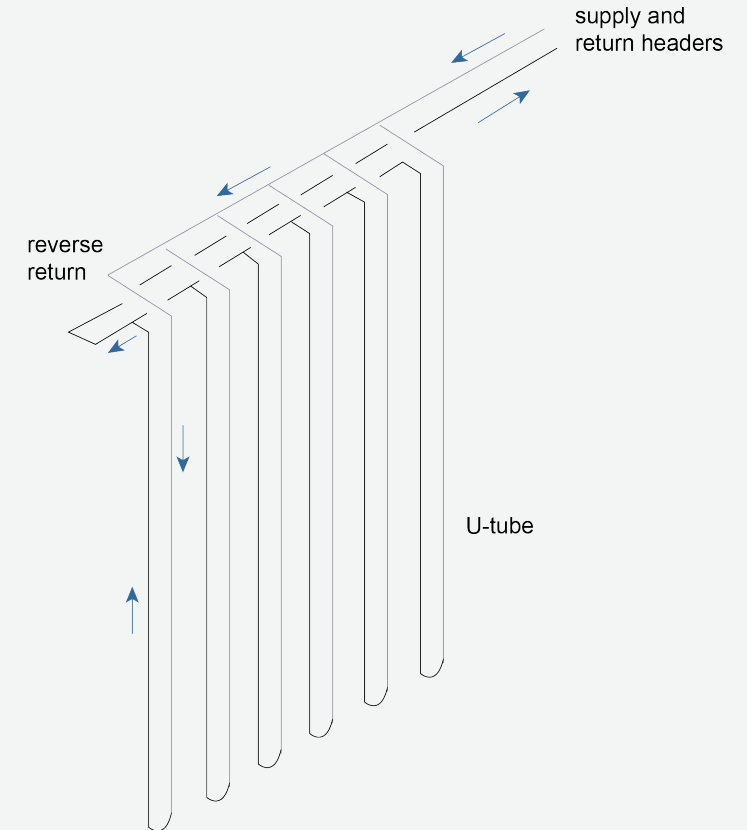
# → Best Practices

## Designing Ground Heat Exchangers

Designing ground heat exchangers requires using site-specific data and optimizing borefield layout to improve performance and reduce costs.

- Use thermal conductivity testing and size the loop based on “block” loads to reflect system load diversity.
- Maintain proper borehole spacing, use high-conductivity grout, and design for lower flow rates to reduce pump energy while minimizing antifreeze use.

## Components of a Vertical Ground Heat Exchanger

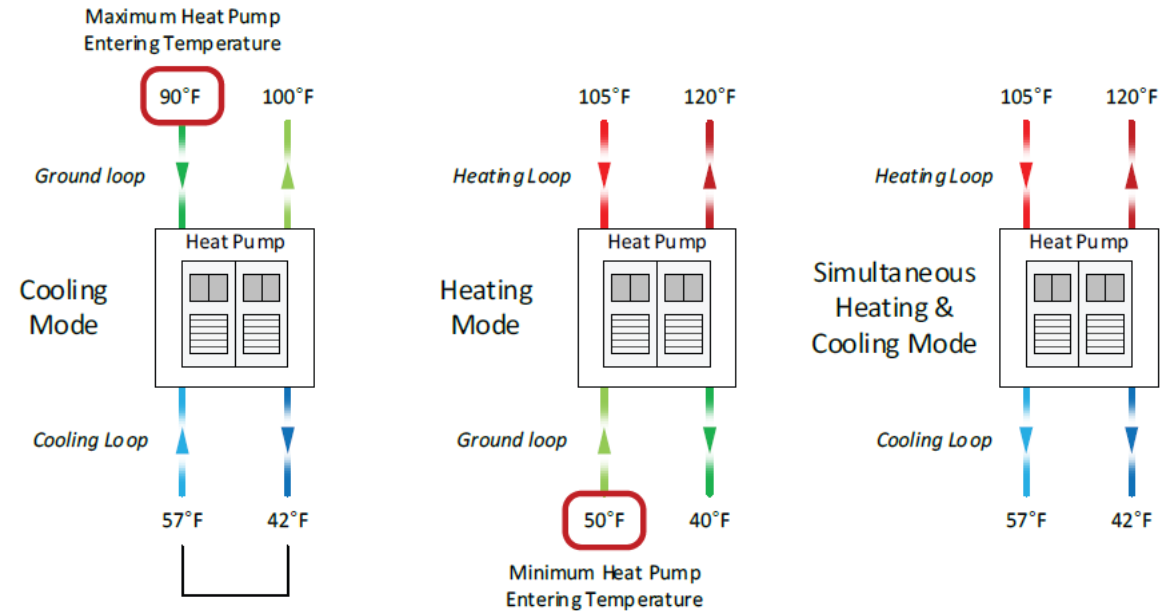


# → Best Practices

## Heat Pump Selection for Geothermal Systems

- Select heat pumps capable of operating across heating, cooling, and simultaneous heating/cooling modes, accounting for the full seasonal range of ground loop temperatures.
- Size cooling capacity at the warmest expected ground temperature, heating capacity at the coolest ground temperature, and simultaneous heating/cooling capacity at design conditions.
- Coordinate heat pump selection with ground heat exchanger design, recognizing that reducing ground heat exchanger size increases seasonal temperature swing and may limit heat pump performance.
- Consider that heating or simultaneous heating/cooling conditions often drive equipment selection due to higher compressor lift requirements.
- Allow for compressor lift safety margin when selecting heat pumps, ensuring reliable operation during extreme seasonal ground loop temperatures and avoiding operation near compressor limits.
- Consider series counterflow heat pump configurations for higher lift, higher efficiency, and larger  $\Delta T$  design opportunities.

## Example Heat Pump Rating Conditions



# → Best Practices

## Heating Fluid Temperature

- Use the lowest feasible heating-loop supply temperature to maximize system efficiency and minimize compressor lift.
- Avoid high lift whenever possible—doubling lift can roughly double heat pump energy use and significantly reduce efficiency.
- Maintain efficient heating performance to prevent long-term warming of the ground loop.
- For retrofits, perform a heating-loop stress test to identify coils that may require upgrades, enabling lower system temperatures.
- Apply reset-based heating-supply temperature control to reduce lift and improve efficiency during mild weather.
- Reserve booster heat pumps for specific loads that truly require high temperatures, rather than increasing temperature for the entire loop.

**Learn More:** [Heating with Lower-Temperature Hot Water Engineers Newsletter](#)

# → Best Practices

## Freeze Protection

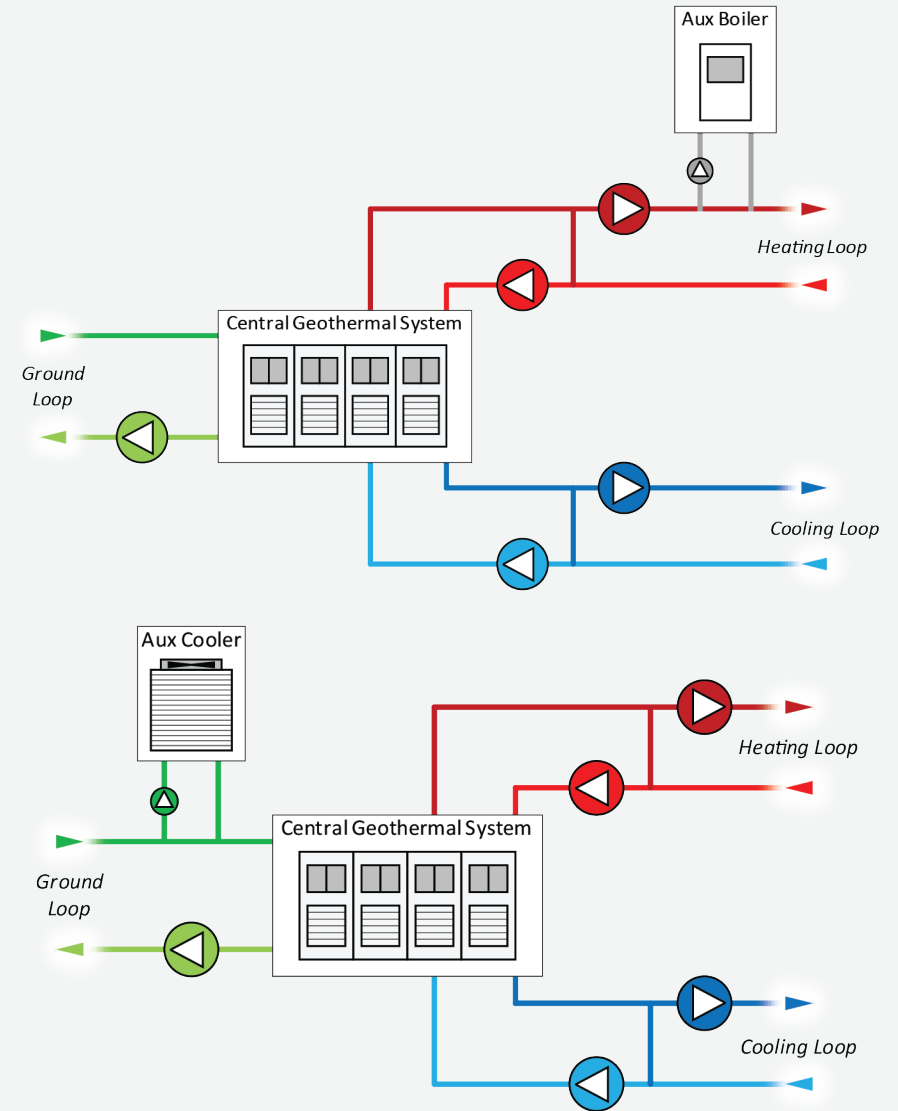
- Use antifreeze when fluid temperatures may fall below 40°F to protect the heat pump evaporator while in heating mode.
- Outdoor coils require freeze protection; consider alternatives like freeze-stats, continuous pumping, air-mixing, or pre-heating.
- Keep antifreeze concentration as low as possible to avoid reduced capacity and higher pumping energy.
- Use burst protection when some ice formation is acceptable; use full freeze protection only when fluids must remain completely liquid.
- Select glycol concentration based on the lowest expected temperature, with about a 5°F safety margin.
- Inhibited glycol in the system can inhibit microorganism growth, which improves water treatment by preventing the formation of biofilms and organic acids that cause fouling and corrosion.

# → Best Practices

## System Options

- Borefields may become thermally "depleted" or "saturated" if the heat rejected is not balanced by the heat extracted over time.
- Add auxiliary coolers on the ground return line to prevent long-term ground-temperature rise in cooling-dominant systems.
- Place auxiliary boilers downstream of the heat pumps to trim heating-loop temperature and protect ground-loop temperature in heating-dominant systems.
- Use ground-loop free cooling when ground temperature is below the cooling-loop setpoint; ensure ground-loop flow exceeds cooling-loop flow to maintain decoupler surplus.

## Auxiliary Boiler and Auxiliary Cooler Options



# → Best Practices

## Parallel Central System Layout

- Use two 2-way ground-loop mode valves instead of a 3-way valve to support higher capacities and simplify sourcing of large valves.
- Arrange heat pumps so heating-only and cooling-only units stage left-to-right, and simultaneous heating/cooling (heat-recovery) units stage right-to-left. Alternatively, stage heating or cooling only right-to-left and simultaneous left-to-right.
- Applying decoupled primary–secondary pumping for heating and cooling loops is recommended to simplify controls; Variable primary flow can be considered but adds complexity.
- Include 2-way isolation valves at each heat pump for reliable flow control and easy maintenance; consider modulating valves for advanced flow balancing or head-pressure control.
- Provide a ground-loop bypass valve (or condenser-side modulating valves) for head-pressure control in cooling-dominant conditions.

# → System Controls

Trane system controls optimize central parallel geothermal performance by coordinating heat-pump staging, mode selection, and temperature regulation across heating, cooling, and simultaneous operation. Advanced logic manages flow, differential pressure, and ground-loop conditions to maintain stable operation, protect equipment, and maximize energy efficiency. For proper system controls, it's important to:

- Prioritize simultaneous heating and cooling (heat recovery) whenever possible for highest system efficiency.
- Use outdoor air temperature or BTU-based logic to identify heating- or cooling-dominant conditions and stage heat pumps accordingly.
- Maintain accurate differential-pressure sensing across evaporators, condensers, and distribution loops to ensure proper pump modulation and reliable performance.

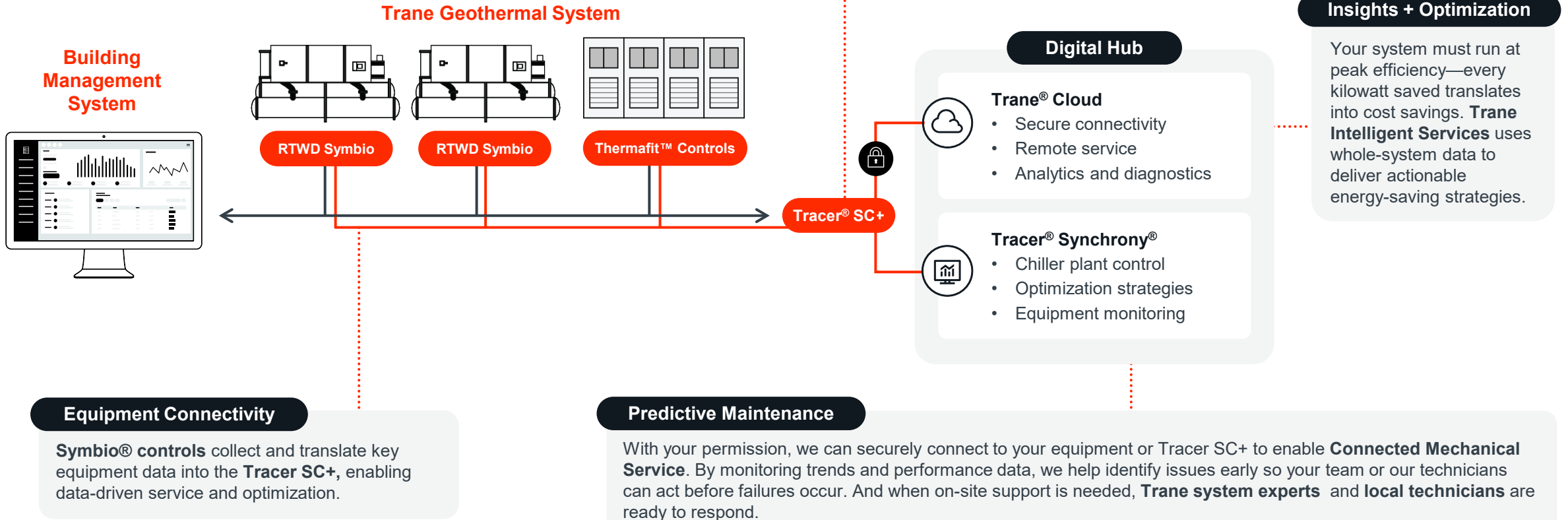
# → System Controls Diagram

## System Control

**Tracer®** is a unified control system that simplifies operations by handling heat pump rotation, staging, and sequencing with built-in tools that boost reliability and enable data-driven performance.

## AI Enhancements

Take optimization further with our AI-driven efficiency engine. **Trane® AI Control** blends decades of expertise with real-time data to continuously improve your system and capture energy savings.



## Building Management System

## Trane Geothermal System

## Digital Hub

### Trane® Cloud

- Secure connectivity
- Remote service
- Analytics and diagnostics

### Tracer® Synchrony®

- Chiller plant control
- Optimization strategies
- Equipment monitoring

## Insights + Optimization

Your system must run at peak efficiency—every kilowatt saved translates into cost savings. **Trane Intelligent Services** uses whole-system data to deliver actionable energy-saving strategies.

## Equipment Connectivity

**Symbio® controls** collect and translate key equipment data into the **Tracer SC+**, enabling data-driven service and optimization.

## Predictive Maintenance

With your permission, we can securely connect to your equipment or Tracer SC+ to enable **Connected Mechanical Service**. By monitoring trends and performance data, we help identify issues early so your team or our technicians can act before failures occur. And when on-site support is needed, **Trane system experts** and **local technicians** are ready to respond.

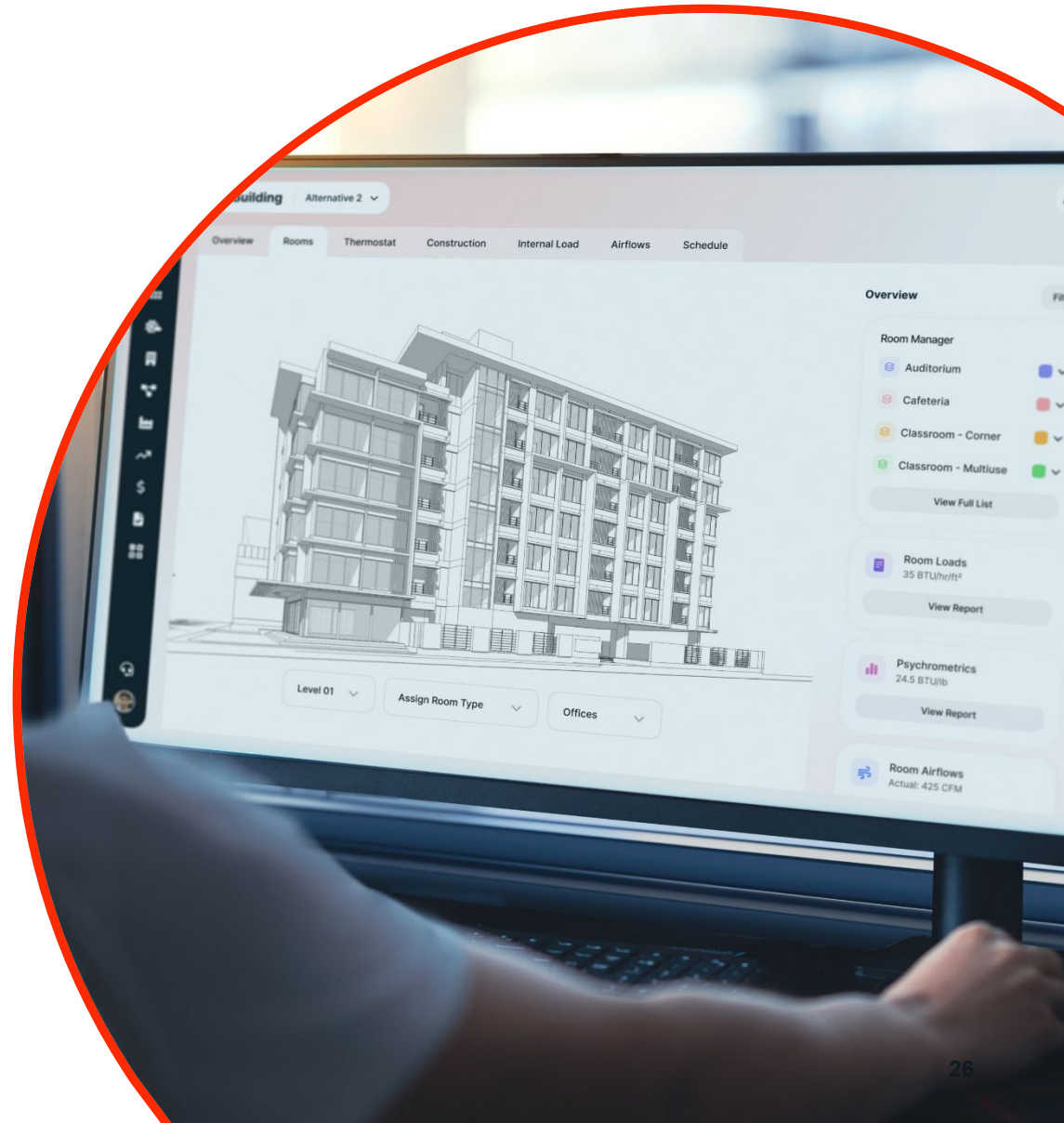
## → Trane Service

- **Trane Service** provides proactive maintenance, system optimization, and expert technical support to keep geothermal and building HVAC systems operating reliably and efficiently throughout their lifecycle.
- **Trane Digital Services** leverage connected equipment, remote monitoring, and data-driven insights to identify performance issues early, improve uptime, and continuously optimize system efficiency and occupant comfort.



# → Design Resources

- Trane provides comprehensive **energy modeling with TRACE®** to help engineers evaluate geothermal performance, compare system options, and optimize lifecycle energy and cost outcomes.
- **Trane Design Assist** supports engineers with system controls design, offering guidance on sequences of operation, integration strategies, and best practices for geothermal plant control.
- Trane offers detailed **application guides for both central and distributed geothermal systems**, giving designers proven design frameworks, sizing approaches, and installation best practices to streamline project development.



## → Helpful Links

- [Central Geothermal Systems Application Manual \(SYS-APM009C\)](#)
- [Central Geothermal Systems Engineers Newsletter](#)
- [Trane Engineers Newsletter LIVE: Trends in Geothermal Systems and Ground Loops](#)
- [Trane Design Assist™](#)
- [Trane TRACE™ HVAC Design Software](#)



# Geothermal Heat Pump Systems

## Trane Commercial HVAC

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SYS-PRC002A-EN  
05/05/2026