

Phase 2 Geothermal Evaluation Report
for
The Town of Winter Park

03/26/2026



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The Town of Winter Park, Colorado

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1. Executive Summary

Technical Feasibility, Environmental Impact, Regulatory Compliance and Business Model: Ambient Temperature Loop (ATL) System for the Town Winter Park, Colorado

The GreyEdge Group (TGEG) was commissioned to evaluate the implementation of an Ambient Temperature Loop (ATL) geothermal system for district heating and cooling in Winter Park, Colorado, serving Town Hall, Cooper Creek Square, Viking Lodge and snow melt in selected areas. The ATL system advances beyond conventional geothermal designs by integrating multiple thermal assets into a unified network. Unlike traditional systems that rely solely on the earth for energy exchange, the ATL utilizes a one-pipe configuration, allowing the borefield to function primarily as a thermal storage asset. This approach reduces dependency on deep earth temperatures and leverages the ground's thermal storage capacity, quantified by diffusivity, to optimize system performance.

Engineered to operate within a controlled thermal envelope, the ATL enables distributed heat pump units to facilitate bidirectional thermal exchange and intra-network heat recovery. Modular expansion is supported through interconnected micro-districts, enhancing scalability and operational efficiency. Site-specific advanced thermal response testing confirmed favorable ground thermal conductivity (1.13 BTU/ft-hr-°F) and diffusivity (1.36 ft²/day), enabling long term storage and effective supply-demand balancing, reduced drilling and installation costs, and robust integration with renewable energy sources.

Environmental Impact Assessment

An ATL system which integrates geothermal heat pumps with solar thermal collectors, and natural gas boilers as peaking backup and a geoexchange system offers a substantially reduced environmental footprint compared to conventional fossil-fuel heating systems. The geothermal component leverages stable ground temperatures for highly efficient heat exchange and results in near-zero direct greenhouse gas emissions and minimal land disturbance beyond initial borehole drilling, which is reversible and occupies a small footprint. Solar thermal integration further displaces fossil energy with zero operational emissions, though embodied impacts arise from panel manufacturing and end-of-life recycling challenges.

By replacing conventional natural gas boilers for terminal heating and snowmelt with a high-efficiency ATL/Ground Source Heat Pump (GSHP) system, the project is expected to reduce heating-related CO₂ emissions by 87% relative to a high-efficiency natural gas baseline, equivalent to roughly 837 metric tons of CO₂ avoided annually or 181 cars off the road.

Properly installed geothermal boreholes pose minimal environmental risks to groundwater, as inert bentonite clay (NSA approved) is used to seal the borehole, preventing vertical water migration and isolating aquifers from surface water.

Regulatory Compliance

The regulatory framework for geothermal and ATL systems in Colorado is well established. Key compliance requirements include:

- **Installer Licensing & Permits:** Closed-loop geoexchange systems do not require a site-specific well permit, but installers must be certified and hold an annual permit from the State Engineer (forms GX02 and GWS72). The Board of Examiners is being renamed to include Ground Heat Exchanger Contractors and will license GHX contractors, updating rules for installation and abandonment (2 CCR 40214 revisions).
- **Well Permitting:** DWR well permitting timelines and processes apply to wells; closed-loop GHX typically follows the geoexchange pathway. Open-loop or deep geothermal systems may require additional coordination with DWR/ECMC.
- **Tax Credits & Incentives:** State and federal incentives are available, including the Colorado Heat Pump Tax Credit, Colorado Geothermal Energy Grant Program, Colorado Geothermal Energy (Electricity) Tax Credit Offering, CPACE financing, utility rebates, and the Federal Investment Tax Credit (ITC). Eligibility for certain credits requires that designs meet code and serve at least 80% of annual heating demand.

Business Models

Financing, Ownership and Operation of an ATL/TEN District Network

- The Thermal Energy Network System (TEN) at the Town of Winter Park requires alignment of project financing, asset ownership, and system operations, managed by the Town, Mountain Parks Electric (MPE), or a third-party EPC provider.
- **Business Model Options:**
 - Public Ownership: Town finances, owns, and operates or contracts the system; offers control and cost stability but assumes operational risk.
 - Utility Ownership: MPE finances, owns, and operates, recovers costs via service rates, and supports future expansion with the Town as anchor customer.
 - EPC Model: Third party designs, builds, finances, and may operate TEN; provider bears risk, Town pays predictable service fees.
 - Hybrid Structures: Mix of public, utility, and third-party roles to balance capital, risk, governance, and cost.
- **Cost Recovery and Rate Design:**
 - TENs must recover all costs through energy charges, demand-based allocations, avoided cost savings, or performance-based fees.
 - Payments should remain at or below conventional system costs for budget stability.
 - Rate design should ensure fair cost allocation, reflect seasonal usage, be simple and transparent, provide long-term stability, and allow for future expansion.
- **Customer-Side Investments:**
 - Building upgrades (e.g., heat pumps, controls) should be included in project financing and may be offset by grants or incentives to encourage adoption.

The estimated capital cost for the ATL and hybrid ground source heat pump (GSHP) system ranges from \$6 million to \$18 million and depends on the amount of use of existing assets and new renewable thermal assets.

Conclusion

- This study demonstrates that a one-pipe ATL/TEN integrated with a hybrid GSHP system is technically feasible, cost-effective, environmentally advantageous, and compliant with current regulatory requirements for Winter Park.
- The system supports full electrification, reduces on-site natural gas consumption, and improves operational efficiency through heat recovery and optimized pumping strategies. It provides a resilient, low-carbon thermal energy network aligned with Winter Park's long-term climate and operational goals.
- The ATL/TEN supports multiple business models; the best choice depends on lifecycle cost, risk allocation, regulatory feasibility, and alignment with the Town's sustainability and fiscal goals.

Review of the Ambient Temperature Loop Technology

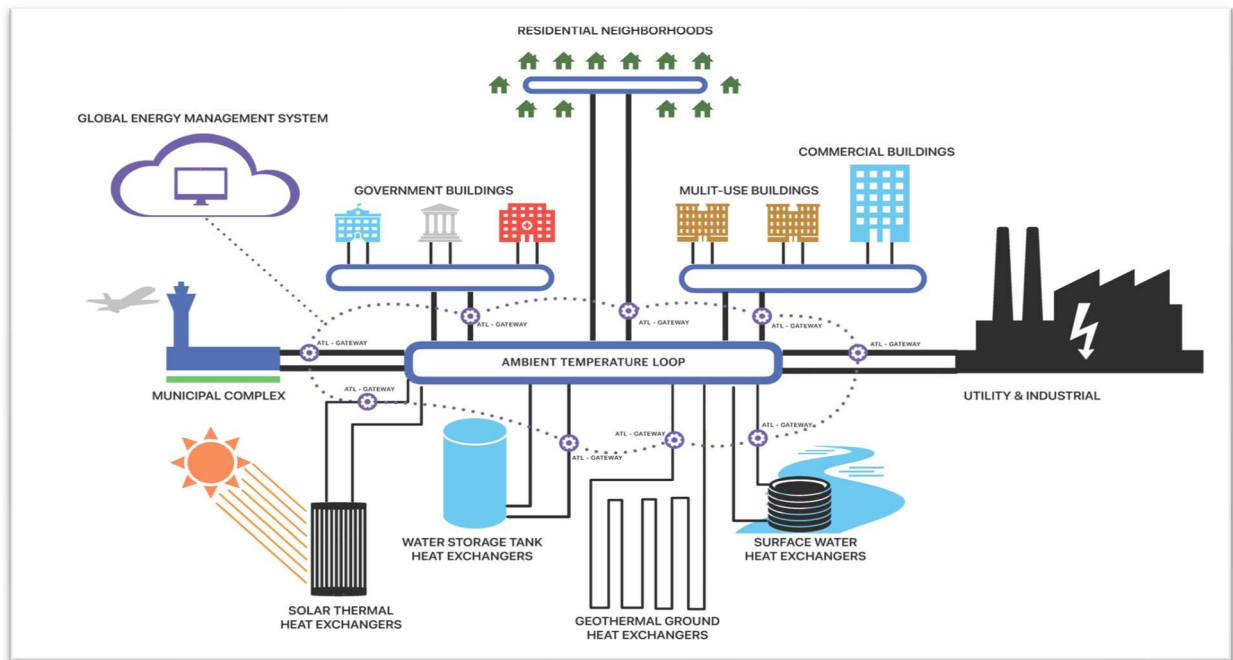


Figure 1: ATL Conceptual Schematic

The Ambient Temperature Loop (ATL) is engineered to function within a controlled thermal envelope of approximately 45°F to 85°F. Within this operational band, distributed heat pump units are capable of bidirectional thermal exchange, extracting and rejecting heat, and thus facilitating intra-network heat recovery between disparate building zones and the snowmelt circuit. This approach enables the efficient reclamation of low-grade waste heat and substantially reduces dependency on conventional mechanical cooling towers or dedicated heat-rejection apparatus. The system's low supply temperature profile minimizes conductive and convective distribution losses, while also simplifying hydraulic routing and infrastructure requirements.

The ATL employs a one-pipe configuration, inherently conducive to modular expansion via the integration of "micro-districts." Each micro-district is an autonomous hydraulic loop, interconnected through two-pipe transfer conduits. These interconnections allow dynamic

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hydraulic and thermal resource exchange among adjacent loops, optimizing load distribution and enabling advanced heat trading strategies. The system architecture supports theoretically unlimited scalability; as the network expands, aggregate thermal inertia and operational efficiency are enhanced due to increased diversity of thermal sources and sinks. The initial district, including the proposed buildings, snowmelt infrastructure, solar thermal collectors, geoexchange borefields, and both wastewater and potable water heat recovery systems, serves as the anchor node, establishing a foundation for subsequent, economically optimized district expansions.

The current development plans include the following ATL/TEN construction elements:

- Cooper Creek Square Area 88,465 sf
- Viking Lodge Building Area 14,007 sf
- Town Hall 15,091 sf
- Total All Buildings 117,563 sf
- Snowmelt Area 12,000 sf (41,500 sf to be added)

As part of this study, The GreyEdge Group prepared a hydrogeological report for The Town of Winter Park, reviewing local lithology and previous drill logs. One test borehole was drilled adjacent to Cooper Creek Square, as shown in Figure 2. The drilling reached a depth of 510 feet over twelve hours, encountering unconsolidated materials in the upper sections and transitioning to more stable formations at depth. The borehole was used to install a geothermal loop for thermal response testing, and the findings informed recommendations for future drilling strategies. A summary of the hydrogeological report is provided in Section 2, with the full report included in Attachment A.



Figure 2: Google Earth Map of test bore GPS location (red pin marker)

The drilling operation, overseen by TGEG's hydrogeologist Rich White, encountered significant challenges in the upper 130–160 feet due to unconsolidated materials; however, the target depth of 510 feet was achieved within twelve hours, with markedly improved penetration rates in the lower, more stable Proterozoic Metamorphic formations. These results indicate that future drilling efficiency can be enhanced by applying optimized techniques and utilizing fully equipped rigs.

An Advanced Thermal Conductivity Test (A-TRT) was performed on the installed geothermal loop on October 8, 2025. The test measured an average deep earth temperature of 46.5°F and accompanied by relatively high thermal conductivity (1.13 BTU/ft-hr-°F) and high diffusivity (1.36 ft²/day). Diffusivity is high (50% above average) indicating the feasibility of long-term thermal storage and effective supply-demand balancing within the borefield.

Key technical findings:

- **Drilling Performance:** Upper site drilling (130–160 feet) was hindered by unconsolidated soils but can be improved with advanced drilling methods and equipment.
- **Borehole Strategy:** Fewer, deeper boreholes (up to 1,000 feet) in the Proterozoic Metamorphic formations are recommended for cost-effectiveness and enhanced thermal storage capacity.
- **Thermal Properties:** The ground exhibits moderate potential as a thermal storage asset, with favorable conductivity and diffusivity values supporting efficient heat exchange.
- **Thermal Asset Integration:** Solar thermal collectors, potable water, and sanitary sewer heat exchangers are identified as highly effective heat generation assets when paired with ground heat exchangers, enabling year-round “trickle charge” of the storage medium.
- **Snowmelt Systems:** These systems represent both a substantial thermal load and an opportunity for solar energy collection, particularly when integrated with ground storage assets.

In summary, The GreyEdge Group's analysis confirms that the Winter Park project benefits from multiple high-potential thermal assets and geological conditions conducive to a robust Ambient Temperature Loop system. Further technical details and asset evaluations are provided in Section 6.

2. Hydrogeology Study

A hydrogeological report was developed by TGED member Rich White, PE. Excerpts from this report have been included below and the full report is attached as Attachment A.

Drilling Conditions Summary

Drilling operations exceeding 500 feet encountered a heterogeneous profile of unconsolidated soils and fractured lithologies, including cobbles, gravel, sand, and siltstone interbeds. The optimal borehole depth for geothermal exchange is 1,000 feet, targeting the Proterozoic Metamorphic formation, which offers superior thermal conductivity and diffusivity. If site-specific constraints preclude reaching 1,000 feet, borehole depths will be adjusted within the 500–1,000-foot interval. This adjustment does not adversely affect system thermal performance, but it necessitates an increase in total surface area to support the required heat exchange capacity.

Hydrogeological analysis confirms that the local subsurface conditions—characterized by moderate to high thermal conductivity (1.13 BTU/ft-hr-°F) and diffusivity (1.36 ft²/day)—are conducive to efficient long-term thermal storage and supply-demand balancing. The advanced thermal response test (A-TRT) validates these properties, supporting the design of a right-sized borefield and minimizing capital and operational risk. The consolidated nature of the Proterozoic Metamorphic layer reduces the risk of borehole collapse and groundwater migration, ensuring reliable drilling operations and environmental protection throughout the project lifecycle.

Anticipated Subsurface Conditions

The planned test hole location is adjacent to the Teverbaugh Municipal Building at an approximate elevation of 8800 feet (according to the Fraser, CO 7.5-minute topographic quadrangle map). Shroba et al. (2010) indicate that surficial materials at that location consist of poorly sorted glacial outwash gravel containing pebbly gravel, pebbly sand, and fine to medium sand with occasional cobbles in a silty matrix.

The Troublesome Formation underlies the unconsolidated materials at the test-hole location. This formation consists primarily of weakly consolidated siltstone, with interbedded sandstone and conglomerate. Locally, this formation contains lenses of unconsolidated silty, very-fine to fine sand and weakly consolidated sandstone. Shroba et al. (2010) indicate that this formation is at least 150 m (490 ft) thick near Winter Park.

Rhyolite tuff underlies the Troublesome Formation in the Winter Park Area (Shroba et al. 2010). This unit is weakly welded and contains pumice fragments and small (approximately 1-inch diameter) gas cavities interspersed within the typical tuffaceous materials. Figure 3 shows the locations of water wells in the general vicinity of the planned geoexchange test hole.

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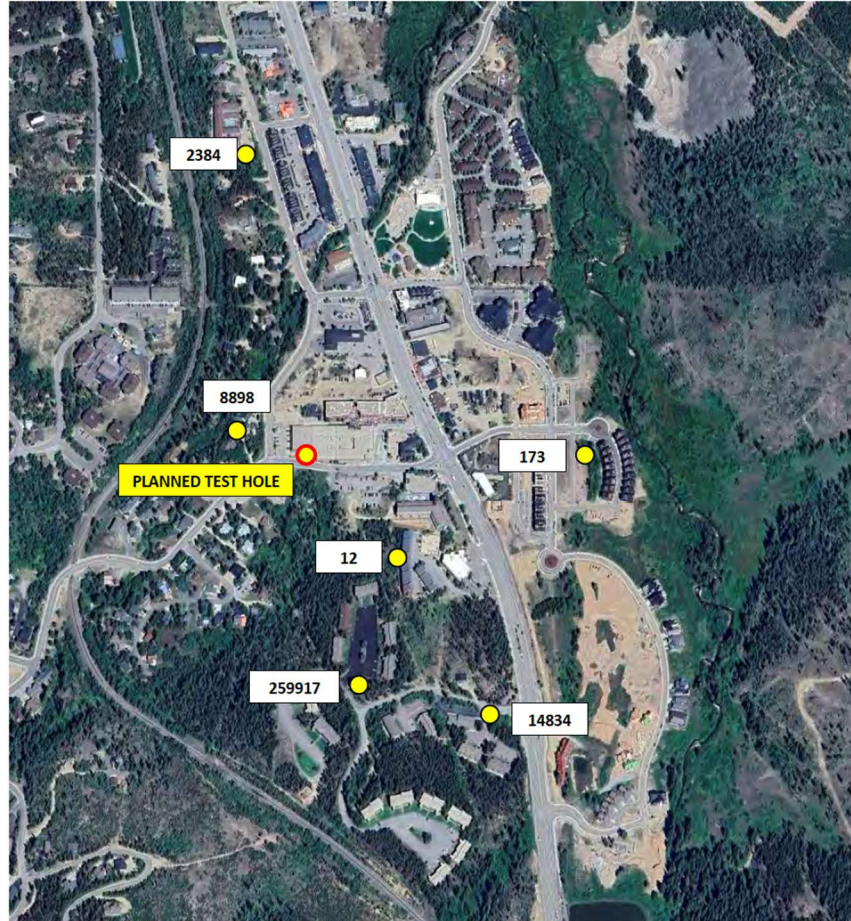


Figure 3 Locations of existing water wells and planned test hole.

Well logs associated with those wells (as downloaded from the Colorado Division of Water Resources well permit web site) are provided in Attachment A.

The published geologic map and data obtained from the water well logs suggest that the following subsurface conditions can be expected at the potential test hole location:

Upper 30 to 40 feet: Unconsolidated materials consisting predominantly of cobbles, gravel, and sand with minor silt and clay interbeds.

Below 30 to 40 feet: Weakly consolidated siltstone with sandstone and conglomerate interbeds, potentially with tuff at depth.

3. Test Borehole Drilling

The test borehole, located adjacent to Cooper Creek Square, was drilled between September 22 and September 25, 2025, to install a geothermal loop for thermal response testing and to assess the complexity of drilling at the site. While initial drilling conditions were favorable, operations were temporarily halted due to inclement weather. Significant challenges were encountered in the upper 100 to 190 feet, primarily due to unconsolidated materials; however, these issues are expected to be mitigated in future projects by employing improved drilling techniques and a fully equipped rig. Once drilling reached the Proterozoic Metamorphic layer below 200 feet, progress was smooth and efficient, indicating that deeper boreholes in this formation are preferable. Based on these findings, adopting a strategy of fewer, deeper boreholes is likely to reduce overall costs and improve drilling efficiency. The total drilling time for this test was 12 hours. With this experience, future projects are anticipated to require less time.

The Proterozoic Metamorphic layer offers several key advantages for geothermal boreholes in the Winter Park project. Its consolidated and stable lithology minimizes the risk of borehole collapse and ensures reliable drilling operations. Additionally, this layer exhibits superior thermal conductivity and diffusivity, which are essential for efficient heat exchange and long-term system performance. The environmental risks are reduced due to the layers' ability to prevent groundwater migration. Deeper boreholes in this formation are more cost-effective and maximize thermal storage while minimizing surface disturbance.

Because drilling in the Proterozoic Metamorphic layer is more efficient and less problematic, it is feasible to drill fewer, deeper boreholes rather than many shallow ones. This approach maximizes the thermal storage volume per borehole, reduces surface disturbance, and lowers overall drilling and installation costs. The predictable geology also allows for more accurate borefield design, minimizing the risk of unexpected delays or cost overruns. Metamorphic rocks, particularly those of Proterozoic age, often exhibit moderate to high thermal conductivity and diffusivity. These properties are critical for geothermal heat exchange, as they enable efficient transfer and storage of thermal energy between the ground and the heat exchanger. The advanced thermal response test (A-TRT) conducted at the site confirmed that the ground in this formation has favorable thermal conductivity (1.13 BTU/ft-hr-°F) and diffusivity (1.36 ft²/day), supporting the design of a right-sized, high-performance geothermal borefield.

Summary

These benefits collectively enhance the sustainability and operational efficiency of the geothermal system. The insights gained from recent test drilling should be applied to future installations, enabling more streamlined and economical project execution. To further improve outcomes, it is recommended to prioritize drilling in the Proterozoic Metamorphic layer, refine borehole design based on site-specific data, and incorporate lessons learned into planning and construction protocols.

4. Implications of the Advanced Thermal Response Test (A-TRT)

The A-TRT provides several key insights and benefits in the design and operation of a geoechange field. These are summarized in the sections below.

Optimized Bore Field Design and Cost Savings

The A-TRT provides a direct and more accurate measurement of thermal diffusivity, which is crucial for sizing the geothermal bore field. With up to 50% higher diffusivity values compared to standard tests, the project team can confidently reduce the number and/or depth of boreholes required. This leads to substantial savings in drilling costs, materials, and installation time. A right-sized bore field also minimizes land disturbance and streamlines construction logistics, making the project more feasible and less disruptive to the community.

Improved System Performance and Efficiency

Accurate thermal diffusivity data ensures that the geothermal system will operate efficiently over its lifetime. The ability to store and release heat effectively means the system can better balance supply and demand, especially during peak heating or cooling periods. Enhanced performance translates to lower operational costs, reduced energy consumption, and improved reliability for end users.

Reduced Capital and Operational Risk

By basing design decisions on precise, site-specific data, the project mitigates the risk of under- or over-sizing the geothermal infrastructure. This reduces the likelihood of unexpected costs or performance issues after installation. The test's confirmation of expected deep earth temperatures (46.5°F) further validates the suitability of the site for geothermal development, lowering uncertainty for stakeholders and investors.

Support for Hybrid and Renewable Integration

The improved understanding of ground thermal properties enables the integration of additional renewable thermal assets (e.g., solar thermal, wastewater heat recovery) with confidence. The ATL system can be designed to “trickle charge” the ground with low-grade waste heat, maximizing the use of renewables and minimizing reliance on fossil fuels.

Note: Thermal “trickle charging” is the process of slowly adding heat energy from various thermal assets-anytime heat is required-when the thermal asset is above the average earth temperature.

This supports the Town of Winter Park's sustainability and electrification goals, helping to decarbonize heating and cooling operations.

Environmental and Regulatory Benefits

A well-designed geothermal system, informed by advanced testing, reduces greenhouse gas emissions and environmental impact compared to conventional heating systems. The project is expected to avoid 40–60% of CO₂ emissions relative to natural gas baselines, contributing to local and state climate objectives.

Accurate data also facilitates compliance with permitting and incentive requirements, making it easier to secure grants, tax credits, and rebates for the project.

Strategic Planning and Stakeholder Confidence

The A-TRT results provide a robust foundation for further engineering, financial modeling, and stakeholder engagement. With reliable data, the project team can refine cost estimates, optimize resource allocation, and communicate benefits clearly to decision-makers and the public.

The implications of the A-TRT are far-reaching: it enables a more cost-effective, efficient, and sustainable geothermal system for Winter Park, reduces risk, and strengthens the case for investment and community support. These results should be leveraged in the next phases of design, permitting, and public engagement to maximize project success.

An Advanced Thermal Response Test (A-TRT) was conducted on the installed geothermal test loop on October 9 and 10, 2025. Ewbank Geo-Testing, led by TGEG Member Garen Ewbank, conducted the in-situ test at the test borehole. The A-TRT improves upon the industry standard Thermal Conductivity test (also developed by Mr. Ewbank) and allows for the direct calculation of thermal diffusivity where the original test only provided an estimated value. Thermal diffusivity measures the volumetric heat capacity of the ground and describes how effective the local earth is at storing heat. The difference between the original and the advanced methodology's diffusivity numbers have been observed up to 50% additional diffusivity for the A-TRT. This allows us to accurately measure improved performance, reduced capital costs and a right-sized bore field. Additional to providing the conductivity and diffusivity numbers, the test also found a deep earth temperature of 46.5°F which matched expectations for the region.

The Advanced TRT process involves pumping plain water inside the loop-under-test, measuring the temperature of the water both entering and leaving the test gear, measuring the flow rate, sometimes adding heat to the water via heater elements or an on-demand water heater. The power is measured for pump consumption and water heating separately. Values for each parameter are recorded every second when testing starts, then decreases to 1 sample per minute once the system reaches a stable operational mode. During the one sample every second period, a detailed log of water temperatures is collected to determine deep earth temperatures.

A summary of the A-TRT test is provided below. The full report can be seen in Attachment B.

Summary

The results of the A-TRT analyses are summarized as follows:

Description	Ground	Grout	Units
Thermal Conductivity	1.13	1.10	BTU/ft-hr-°F (TC or K)
Volumetric Heat Capacity	20.0	64.0	BTU/ft3-°F (HC)
Deep Earth Temperature(avg)	46.5°F		
Calculated Diffusivity	1.36		ft2/Day
Total Testing Time: 48 hours			

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Temperature readings for the 48-hour test and digital twin calibration results for the test bore hole A-TRT is shown in the following figure.

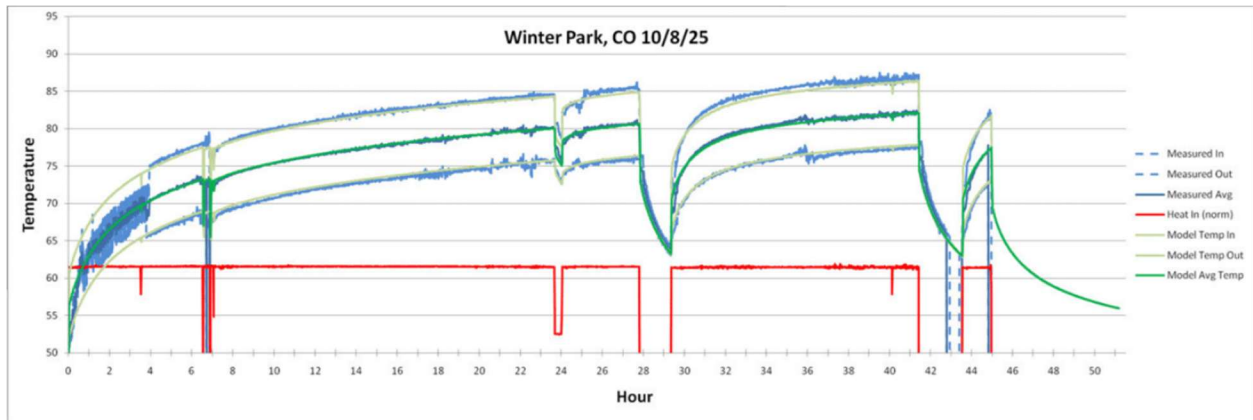


Figure 4: A-TRT Digital Twin Analysis Results

5. Key Operational Benefits

1. Cost Savings from Multiple Thermal Assets

One of the most significant advantages of the Winter Park ATL concept is the availability of multiple thermal resources that can work together to meet system demand. Rather than relying exclusively on a geexchange borefield. Thermal assets that can be implemented into the ATL are discussed in detail in the Thermal Asset Review section. Each of the resources, if implemented, can contribute thermal energy to the network at different times depending on need.

The economic benefit of this approach is that not every unit of heating or cooling needs to be supplied by the ground. A geexchange borefield typically represents the largest capital cost of a geothermal project and by utilizing lower-cost thermal resources whenever they are available, this approach lowers drilling requirements, reduces installation costs, and improves long-term economics without sacrificing reliability.

2. Operational Efficiency and Reliability

An ATL's operational efficiency is increased through several means. By transferring thermal energy between connected loads within the network the overall net load is decreased. Heat rejected from a building in cooling can be utilized by another building requiring heating, reducing the amount of energy that must be supplied or absorbed by the borefield and other thermal assets.

Designing a system with a multi-source approach gives the system additional resilience as one resource can be trimmed or augmented as changing demand requires. By pursuing the least-cost

path in selecting the mix of thermal resources needed to satisfy a project's needs, the first cost of a project can also be reduced and efficiency increased.

An ATL system offers a significant advantage over conventional Air Source Heat Pump (ASHP) systems by leveraging the Earth's naturally stable temperature rather than the highly variable outdoor air temperature. This distinction is particularly important in Winter Park, where elevations approaching 9,000 feet result in long heating seasons, frequent below freezing temperatures, and large daily temperature swings. Ground temperatures remain relatively constant throughout the year and closely reflect the regional average annual air temperature. Because of this, ground coupled systems like GSHPs operate under more favorable conditions during both heating and cooling seasons peaks, resulting in higher system efficiencies, lower operating costs, reduced electrical demand and more predictable year-round operation compared to conventional air-source technologies.

3. Environmental Sustainability

Winter Park presents a uniquely favorable environment for Ambient Temperature Loop deployment. The Town experiences long heating seasons, significant snowmelt requirements, high seasonal occupancy fluctuations and a climate characterized by large differences in winter and summer temperatures. These conditions create both substantial thermal demands and opportunities for thermal energy recovery. The proposed ATL leverages these conditions by capturing, storing, and redistributing thermal energy throughout the year rather than relying on natural gas with its underlying insecurity and costly electric resistance and ASHP heating.

The geoexchange borefield forms the foundation of the system's long-term thermal storage strategy. Unlike conventional geothermal systems that operate primarily as a heat source and sink, an ATL at Winter Park would utilize a borefield as a thermal battery that can store energy collected from thermal assets and loads and return that energy when it is more valuable. This approach is particularly well suited to mountain communities where seasonal demand changes significantly and energy resilience is critical.

From a community perspective, the ATL aligns closely with Winter Park's long-term sustainability and carbon reduction objectives. Mountain communities are particularly vulnerable to the economic and environmental consequences of a changing climate, including:

- Reduced snowpack
- Changing weather patterns
- Increased fossil fuel cost risks
- Substantial infrastructure costs

By reducing dependence on natural gas while creating a platform for future electrification, the ATL provides a pathway towards lower carbon operations without compromising reliability. The system's modular architecture also positions Winter Park to expand the network over time, allowing future public and private developments to participate in a community-scale thermal infrastructure.

Ultimately, the environmental value of the ATL extends beyond greenhouse gas reductions alone. The system improves energy resilience, creates a long-lived thermal asset, maximizes the use of locally available thermal resources, and establishes the foundation for a scalable thermal energy network capable of supporting Winter Park's long-term growth and net-zero aspirations.

4. Scalability and Flexibility

An ATL is a highly expandable system by design with the ability to add future loads or assets to meet future needs. Expansion to the system, load or asset, can connect directly with existing ATL infrastructure, or a micro-district can be tied into the main ATL to leverage its existing thermal resources.

This ability to expand or interconnect to different micro-districts gives the ATL flexibility to meet both current and future demands and resilience to fluctuating environmental conditions.

5. Community Support for Climate Goals

As part of TGEG's work with the Town of Winter Park, Project Manager Garry Sexton attended a community event scheduled to discuss the concept of an ambient temperature loop and the potential for implementation around the Town Hall area. The event was held in a local pub and was well attended by interested members of the community. Attendees were enthusiastic about the study and eager to see the Town make investments in clean and reliable energy systems. Winter Park regularly holds similar "Community Brews" events and actively supports sustainability and net zero initiatives.

6. Thermal Asset Review

The Winter Park geoexchange system, as part of the Ambient Temperature Loop (ATL) network, would be engineered to maximize the capture, storage, and retrieval of thermal energy across seasons. The operational strategy should focus on the following principles:

Thermal Asset Integration and Charging

- The ATL system integrates multiple renewable thermal assets, including solar thermal collectors, potable water and sanitary sewer heat exchangers, and snowmelt systems.
- During periods of surplus energy—such as sunny days or times of high wastewater flow—excess heat is captured from these sources and injected into the ground via the geoexchange borefield. This process is often referred to as "trickle charging," where low-grade waste heat is continuously stored in the earth for later use.

Borefield as a Thermal Battery

- The vertical boreholes, drilled into the Proterozoic Metamorphic formations, serve as the primary thermal storage asset. The ground's favorable thermal conductivity and diffusivity allow it to absorb and retain heat efficiently over extended periods.

- Stored energy can be retrieved during peak heating demand in winter or released for cooling in summer, effectively decoupling the timing of energy generation from consumption.

Seasonal Load Balancing

- The system's design enables it to balance supply and demand on both daily and seasonal timescales. For example, solar energy and waste heat collected in summer can be stored underground and used to meet heating needs in winter.
- The snowmelt system, which acts as both a thermal load and a solar collector, further enhances seasonal storage by transferring excess surface heat into the ground during non-melting periods.

Automated Controls and Monitoring

- Sensors and automated controls are installed to optimize when and how much energy is stored or extracted. These systems monitor ground and fluid temperatures, flow rates, and system performance to ensure efficient operation and maximize storage potential.

Hybrid System Flexibility

- The ATL's hybrid configuration allows for the integration of conventional heating equipment (such as high-efficiency natural gas boilers) to supplement renewable sources during periods of exceptionally high demand or when renewable supply is insufficient. This ensures reliability while prioritizing renewable energy for the majority of operational hours.

Environmental and Economic Benefits

- By leveraging seasonal energy storage, the system reduces greenhouse gas emissions, lowers operational costs, and enhances resilience against fluctuating energy prices and supply interruptions.
- The strategy supports Winter Park's long-term sustainability and electrification goals by enabling a significant reduction in fossil fuel consumption and maximizing the use of locally available renewable resources.

Summary:

The operational strategy for seasonal energy storage in the Winter Park ATL system centers on capturing surplus renewable heat when available, storing it in the ground via geoexchange boreholes, and retrieving it as needed to meet heating and cooling demands throughout the year. This approach ensures efficient, resilient, and sustainable energy management for the community.

As part of this analysis, TGEG identified several potential thermal assets that fit into the above strategy and may offer a cost-effective resource to tie into an ATL. Each is detailed below with its respective opportunities and challenges identified.

1. Sanitary Sewer Thermal Energy Heat Exchangers

Sanitary sewer heat recovery represents a cost-effective, year-round opportunity to enhance the ATL system's efficiency and sustainability. With proper coordination and further analysis, this asset can significantly contribute to meeting Winter Park's thermal energy needs.

Sanitary sewer lines offer a reliable thermal energy source, with average temperatures up to 60°F. Multiple pipelines are located near the anchor micro district, allowing flexible integration with the ATL system. The system's effectiveness depends on annual and daily flow rates, as well as pipe size. Implementation would require approval from the Water and Sanitation District and coordination with the Town of Winter Park Water.

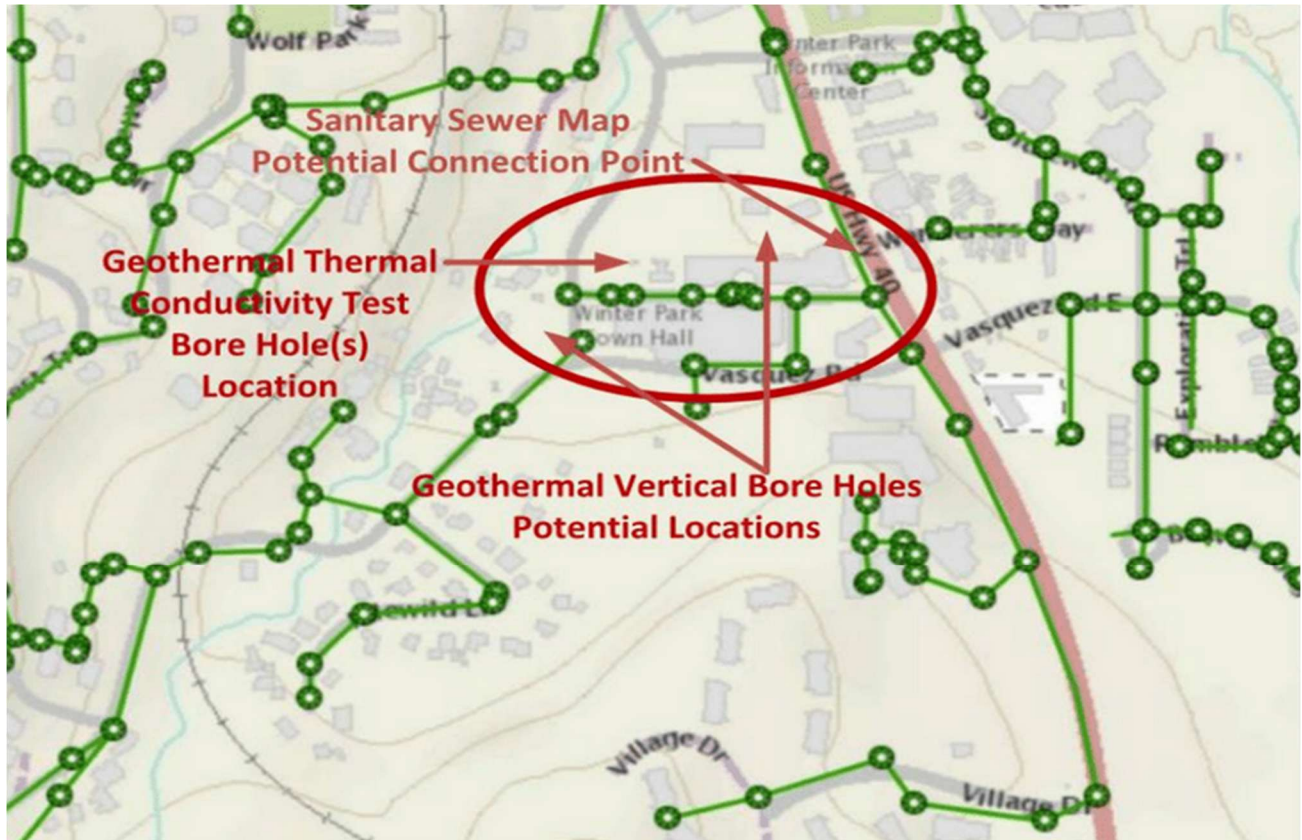


Figure 5: Sanitary Sewer Maps

Wastewater heat exchangers are low-cost and can provide continuous (“trickle charge”) thermal input to storage assets, increasing system capacity during peak demand. Peak flow occurs during ski season, aligning energy availability with periods of highest demand. During detailed design the daily and seasonal wastewater flows will be fully assessed to determine exact seasonal heat recovery potential. Final engineering and design will ensure influent temperatures remain suitable for plant operations.

2. Potable Water Piping System

Similarly, the potable water line from the town water treatment plant represents an excellent opportunity to remove unneeded heat energy and transfer into the ATL at low infrastructure cost. There are multiple locations within a short distance from the anchor ATL micro district. This asset would operate as a direct heat exchanger. In this system, potable water is temporarily diverted from the main supply line, passes through a closed-loop heat exchanger to transfer heat, and is

then returned to the potable water piping. This approach ensures that the potable water remains isolated from other fluids while efficiently capturing or releasing thermal energy. Water temperatures are higher than the earth temperature and typically between 43°F and 53°F, making it an ideal and low-cost thermal heat extraction opportunity.

Potable water piping is a cost-effective thermal asset that can be utilized year-round in conjunction with other storage options. Its extensive distribution enables efficient integration with the ATL main loop through heat exchangers. Peak potable water flow coincides with the highest heating demand during ski season, presenting an optimal opportunity for energy recovery. To accurately assess heat delivery potential, future studies should quantify daily and seasonal flow rates. Notably, Winter Park's domestic water system is configured as a continuous loop, eliminating dead ends and significantly enhancing energy harvesting capabilities.

Key Benefits:

- Year-round energy recovery potential
- Low infrastructure cost and efficient integration with ATL
- Peak flow aligns with highest heating demand
- Continuous loop configuration maximizes energy harvesting

Utilizing the potable water piping system for thermal energy recovery provides significant operational and economic advantages. Its design and flow pattern are well suited to support the ATL's heating requirements, contributing to efficient and sustainable energy management for Winter Park. As with sanitary sewer piping, potable water represents a low-cost asset and can be used as a year-long "trickle charge" device in coordination with other thermal storage assets.

NOTE: Maps of the potable water and sanitary sewer pipelines were provided by the local Water and Sanitary district.

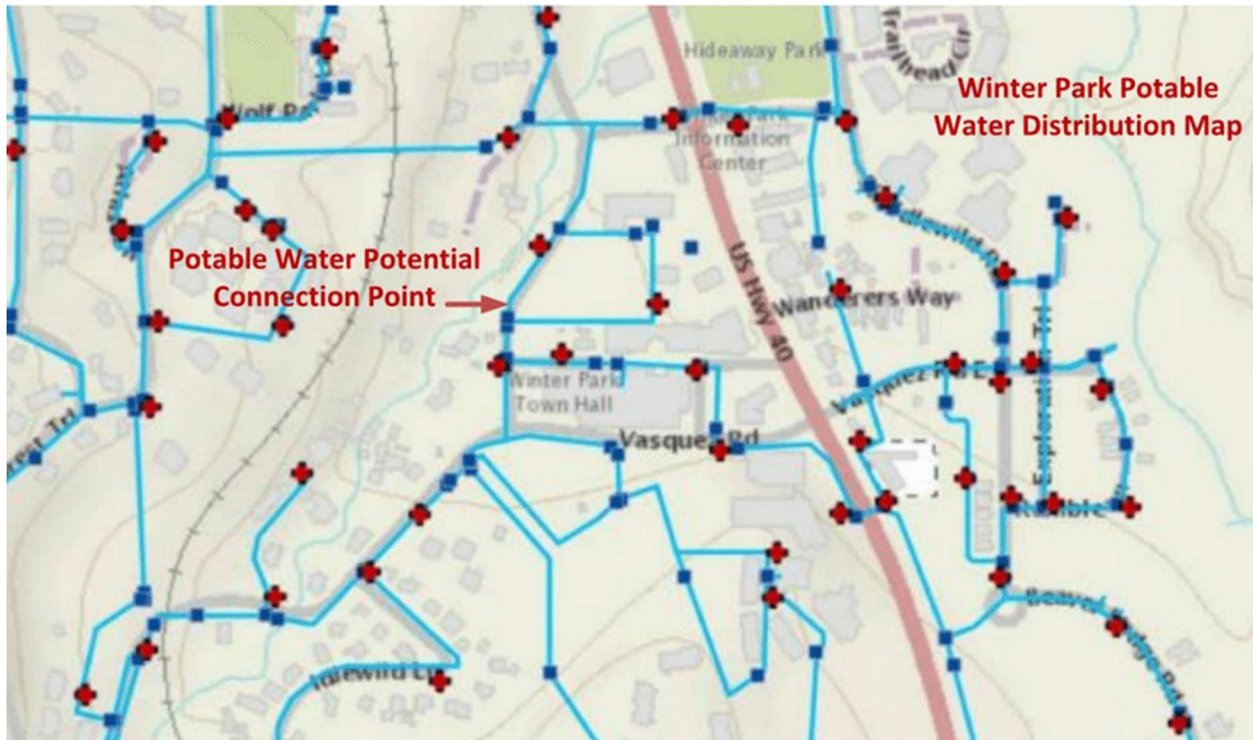


Figure 6: Potable Water Map

3. Geoexchange Boreholes

As discussed extensively in this report, geoexchange boreholes offer a sink, source, and most importantly an option for thermal storage within the context of a broader ATL. As shown through the results of the A-TRT, favorable properties exist and cost-effective drilling conditions have been verified with an onsite borehole down to 500’.

If this system is implemented, it is recommended that the design firm selected employ proper industry certifications beyond a PE including a Certified Geo Designer, as certified by the International Ground Source Heat Pump Association (IGSHPA) and that the system be commissioned by a Certified Geo Inspector in order to reduce project risk and ensure proper operation of the system.

4. Snowmelt System as a Solar Collector

The snowmelt system connected to the Ambient Temperature Loop (ATL) is not only a major thermal load, representing a peak demand of approximately 145 tons, but also a valuable opportunity for solar energy collection during non-melting periods. Observations show that dark-colored pedestrian walkways can reach temperatures above 80°F or more when outdoor air exceeds 40°F. By integrating these walkways with a thermal storage asset, such as a vertical ground heat exchanger (with boreholes up to 1,000 feet deep), the system can transfer excess solar energy into the ground whenever surface temperatures surpass the deep earth temperature (46.5°F).

This process enables the storage of solar energy for later use, with the ground’s thermal properties (conductivity 1.13 BTU/ft-hr-°F, diffusivity 1.36 ft²/day) supporting efficient long-term

retention. Depending on site conditions, a portion of this energy can be stored in the earth for days to months, elevating ground temperatures and improving heat pump efficiency. Implementing this strategy is projected to reduce heating-related CO₂ emissions by 40–60%. Using the snowmelt loop to “trickle charge” the ground in this way can significantly enhance annual energy efficiency and sustainability.

Implementation Recommendations

- Install temperature sensors and automated controls to maximize solar energy collection when walkway temperatures are optimal.
- Quantify annual energy storage and recovery potential through site-specific modeling.
- Expand borefield capacity as needed to optimize seasonal energy storage.
- Monitor system performance to verify efficiency gains and emissions reductions.

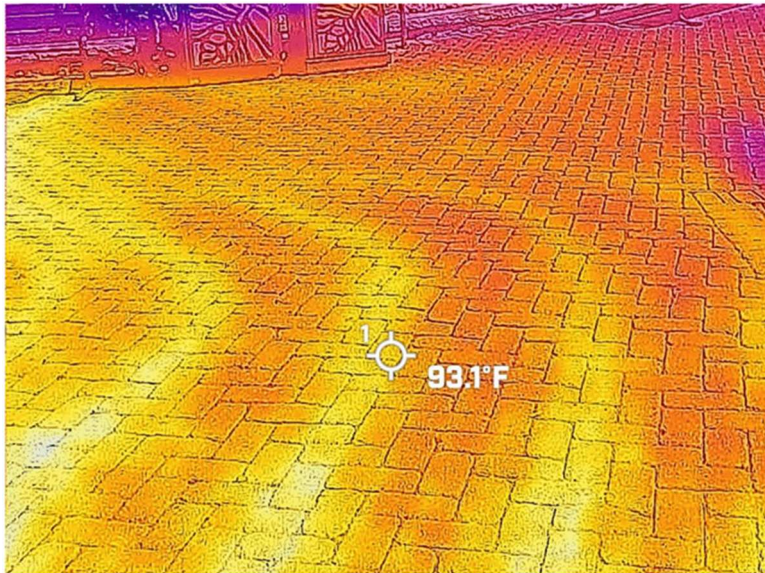


Figure 7: Snowmelt System as Solar Collector

5. Solar Thermal

Colorado’s climate, with over 300 sunny days each year, is highly favorable for solar thermal energy production. Solar thermal systems, either flat plate or evacuated tube collectors, can efficiently generate hot water using solar energy. For developments with sufficient roof space and a compatible thermal storage asset (such as a ground heat exchanger), integrating solar thermal technology can significantly enhance the performance of the Ambient Temperature Loop (ATL) system while reducing the initial costs associated with vertical borehole drilling.

Photovoltaic thermal (PVT) panels, which produce both heat and electricity, are another viable and cost-effective option. For this project, a recommended installation site for either technology is the south-facing upper parking level of Town Hall, where panels can be mounted vertically to maximize solar exposure. The required area for solar thermal panels is equivalent to that of standalone photovoltaic panels, simplifying the design process.

The final number and configuration of solar thermal panels will be determined during the detailed design phase, considering site-specific factors such as available installation area, desired thermal output, shading, and integration with other renewable assets. This process will include detailed energy modeling, cost-benefit analysis, and coordination with structural and MEP design teams to ensure optimal system performance and alignment with project sustainability goals. Stakeholder input will be incorporated to refine system requirements and maximize project value.

Importantly, energy generated from solar thermal panels will decrease the reliance on geexchange boreholes, further lowering installation costs and improving overall system efficiency.



Figure 8: Flat Plate Solar Thermal Panels

6. Thermal Opportunities from Surface Water Resources

Although the ponds and wastewater storage lagoons are not immediately adjacent to the anchor micro district, they represent significant potential for future thermal integration with the Ambient Temperature Loop (ATL) system. Several ponds from 2-10 acres are present along the I40 corridor in Winter Park that would be suitable resources for future districts. These surface water bodies can serve as valuable sources or sinks for thermal energy in several ways:

- **Seasonal Thermal Storage:** Store excess heat during warmer months and release it in colder periods, aiding seasonal load balancing and improving ATL efficiency.
- **Heat Exchange Potential:** With proper engineering, surface water can be integrated via heat exchangers to supplement geothermal and other renewables, reducing reliance on conventional fuels and lowering greenhouse gas emissions.
- **Scalability for System Expansion:** As the ATL/TEN network grows, proximity to these water bodies allows for phased integration, accommodating increased thermal loads or new development areas.
- **Support for Renewable Integration:** Using surface water for thermal exchange can enhance the effectiveness of other renewable assets (e.g., solar thermal collectors) by providing an additional medium for energy storage and transfer.

Summary: While not prioritized for the initial ATL rollout, these resources should be considered in long-term planning to maximize the resilience, efficiency, and sustainability of Winter Park's district energy system.

7. Denver Water Pipeline: Strategic Expansion Opportunity

The Denver Water pipeline is a major utility asset (12-foot diameter) near the Moffat Tunnel, transferring water from the Winter Park drainage basin into Denver's municipal supply. This pipeline offers substantial potential for expanding Winter Park's district energy infrastructure, especially if Winter Park Resort pursues energy conservation or shifts away from fossil fuels.

Integrating the pipeline with the Ambient Temperature Loop (ATL) system could increase thermal energy exchange capacity and enhance flexibility for electrification and decarbonization goals. Realizing this integration requires careful management of political and regulatory complexities including managing multiple stakeholders (municipal authorities, utility providers, regional water agencies). Approvals and alignment with water resource policies are essential. For future ATL network expansion (e.g., serving Old Town Winter Park), a thorough evaluation of the pipeline's suitability and integration potential should be prioritized:

Summary: Proactive planning positions Winter Park to leverage the Denver Water pipeline as a key component of long-term sustainability and energy resilience. The Denver Water pipeline has sufficient flow to provide the majority of the thermal energy for the Town of Winter Park. This asset is too distant from the town to make it part of the current assessment due to the cost of piping required for connection. However, as the TEN network expands, it will become a valuable and viable component for full decarbonization.

8. Moffat Tunnel Dewatering: Strategic Assessment

The Moffat Tunnel dewatering system has been identified as a potential supplemental thermal resource for the Ambient Temperature Loop (ATL) network, though it is not recommended for immediate implementation. This asset may become valuable if Old Town Winter Park pursues sustainable energy or carbon reduction initiatives.

Implementation would require formal agreements with Union Pacific Railroad and compliance with all relevant water quality, environmental, and energy regulations. Early engagement with regulatory agencies is essential.

Summary: Integrating the Moffat Tunnel dewatering system with the ATL network could provide a valuable supplemental thermal resource for district heating and cooling in Winter Park. Technical options include direct heat recovery, seasonal storage, load balancing, and phased expansion, all requiring careful engineering, controls, and stakeholder coordination. While not recommended for immediate implementation, periodic reassessment and strategic planning would position this resource for future use as the ATL network expands.

9. Brewery Water Heat Recovery

The wastewater treatment plant is currently constrained in its capacity, particularly when serving industrial users such as local breweries. Brewery effluent, which is characterized by elevated temperatures and high nutrient loads, presents a potential opportunity for waste heat recovery to supplement the Ambient Temperature Loop (ATL) system and support Winter Park's sustainability objectives. Discussions with brewery operators indicate that the volume and timing of brewery discharges are too inconsistent and limited to justify installing a dedicated heat exchanger or integrating with the ATL. The sporadic nature and insufficient quantity of recoverable thermal energy do not offset the associated capital and operational costs.

Summary: Recommendation and Next Steps

Given these findings, it is recommended that the situation be periodically reassessed, especially if brewery operations expand or if process modifications result in higher or more consistent thermal discharges. In the interim, the project team should continue to explore other waste heat recovery opportunities within the community and maintain open communication with stakeholders to identify future synergies.

7. Load Estimation, System Design and Pre-Design Budgeting

Ambient Temperature Loop (ATL) Architecture

The ATL is engineered to operate within a controlled thermal envelope (45°F–85°F), enabling distributed heat pump units to perform bidirectional thermal exchange. This supports intra-network heat recovery and efficient reclamation of low-grade waste heat. The system's one-pipe configuration allows modular expansion through interconnected micro-districts, each functioning as an autonomous hydraulic loop. Two-pipe transfer conduits facilitate dynamic hydraulic and thermal resource exchange among adjacent loops, optimizing load distribution and enabling advanced heat trading strategies.

Geoexchange Borefields

Vertical boreholes, typically up to 1,000 feet deep, are drilled into the Proterozoic Metamorphic formations, which offers superior thermal conductivity (1.13 BTU/ft-hr-°F) and diffusivity (1.36 ft²/day). These borefields serve as the primary thermal storage asset, supporting long-term thermal balancing.

Thermal Asset Integration

As identified previously, four thermal assets are recommended for consideration in the ATL:

- **Solar Thermal Collectors:** Capture solar energy for direct heat input and seasonal storage.
- **Potable Water and Sanitary Sewer Heat Exchangers:** Recover low-grade waste heat from municipal water and wastewater flows, providing continuous “trickle charge” to the borefield.
- **Snowmelt Systems:** Act as both a significant thermal load and a solar energy collector during non-melting periods, transferring excess surface heat into the ground for storage.

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- **Geoexchange Boreholes:** Offers a sink, source and storage resource for the combined system.

Central Pumping Infrastructure

The system as currently understood would require a total flow of approximately 2,000 gallons per minute under peak conditions. A resilient N+1 pump configuration is suggested, with each pump sized to deliver 60% of the total design flow so as to benefit from pump affinity laws.

Load Estimation and System Sizing

The combined facilities present a peak thermal load of 665 tons (209 tons for building heating, 446 tons for snowmelt). Mechanical cooling is required but is a minor component. Load interaction modeling incorporates data from wastewater and snowmelt systems to characterize simultaneous and seasonal demand profiles. A hybrid system design leverages the “50/90 rule,” where 50% of peak capacity covers 90% of operational hours, with conventional heating equipment acting as peakers’ for the highest demand periods (10% of annual operating hours).

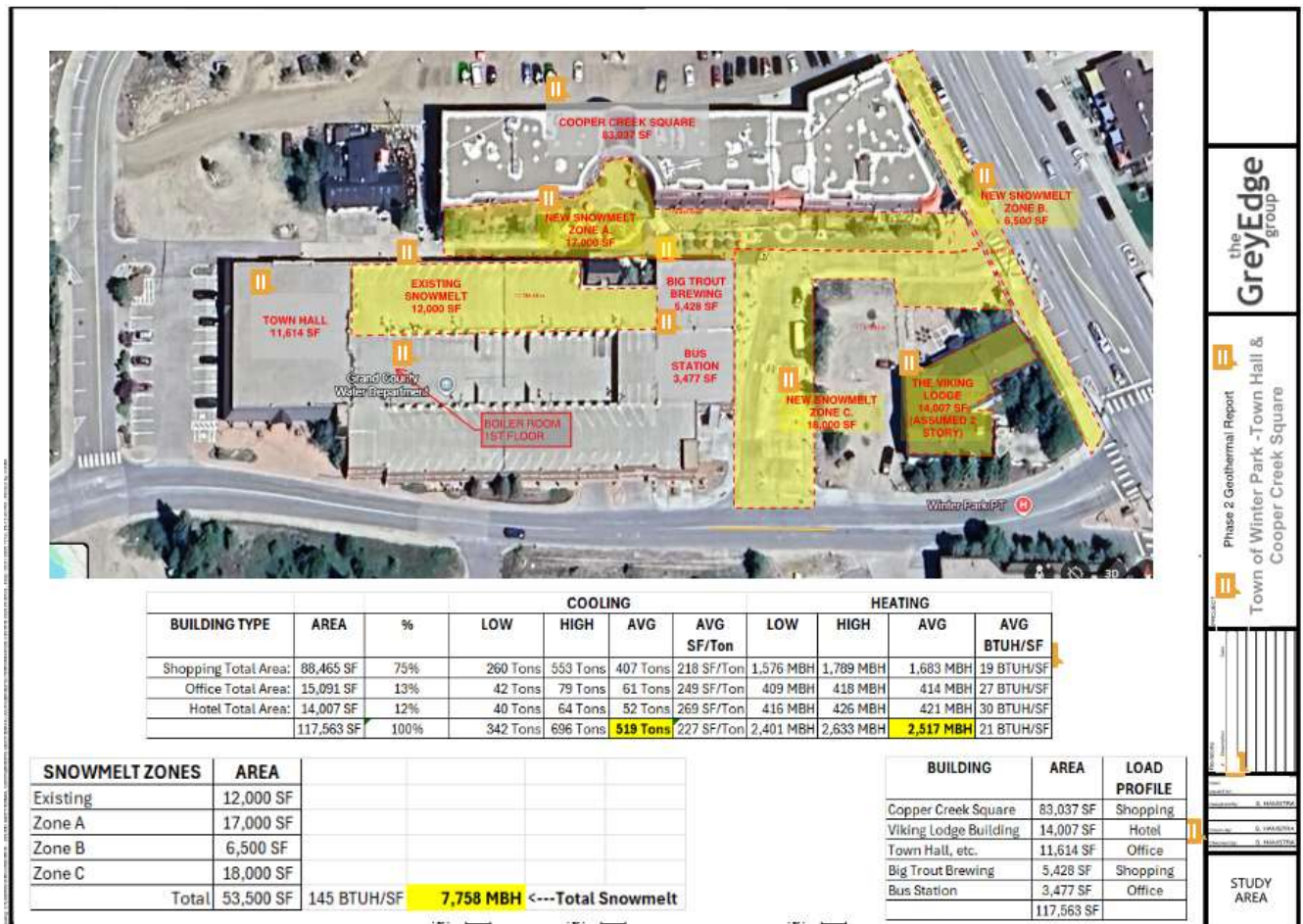


Figure 9 Thermal Loads of the properties including snowmelt.

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The total energy consumption was estimated for an ATL based system and compared to that of a Gas heating and air-cooled system. This results in an estimated savings of 57% in energy costs alone. Compared to a baseline all electric system, electric resistance heating, natural gas does offer operational cost savings but also significant risks. An ATL system, however, provides additional savings at a higher performance efficiency and eliminates the risks of a natural gas system.

Table 1 Estimated Energy Consumption and Savings

Annual Energy comparison	Estimated Natural Gas consumption	Estimated Electric	Estimated utility cost*
Gas Heating/Air cooled HP**	178,537 Therms	805,401 kWh	\$ 213,812.00
*Utility cost based on \$0.132 per kwh and \$0.65 per CCF. Utility rate with ATL \$0.11 based on tariff. Tariff rate changes between baseline and ATL systems.			
** Gas Heating / Air cooled HP also considers the loads presented by the snowmelt system.			

With the system as proposed, savings of approximately \$125K/year noted in the above table, is unlikely to produce a favorable return on investment when evaluated on utility cost savings alone. If mechanical systems such as new snowmelt are being added, or systems are at their end of life, the first cost equation changes and economic prospect improves. However, the value of an Ambient Temperature Loop system extends beyond direct energy cost reductions. The ATL creates a long-lived thermal utility asset that improves energy resilience, enables phased electrification, reduces exposure to natural gas price volatility, and provides a scalable foundation for future district energy expansion.

The chart below demonstrates the balance between available wastewater heat and snowmelt demand. Positive values indicate periods when excess wastewater heat is available after meeting snowmelt requirements, while negative values reflect times when wastewater heat alone is insufficient. This analysis does not include the impact of terminal space heating loads, which would typically increase winter heat demand and reduce summer demand due to cooling. Additionally, the chart does not reflect the significant benefit of the geothermal borefield, which enables the storage of surplus energy from sources such as wastewater and solar thermal for later use. This storage capability allows the system to decouple energy generation from demand, enhancing operational flexibility and efficiency.

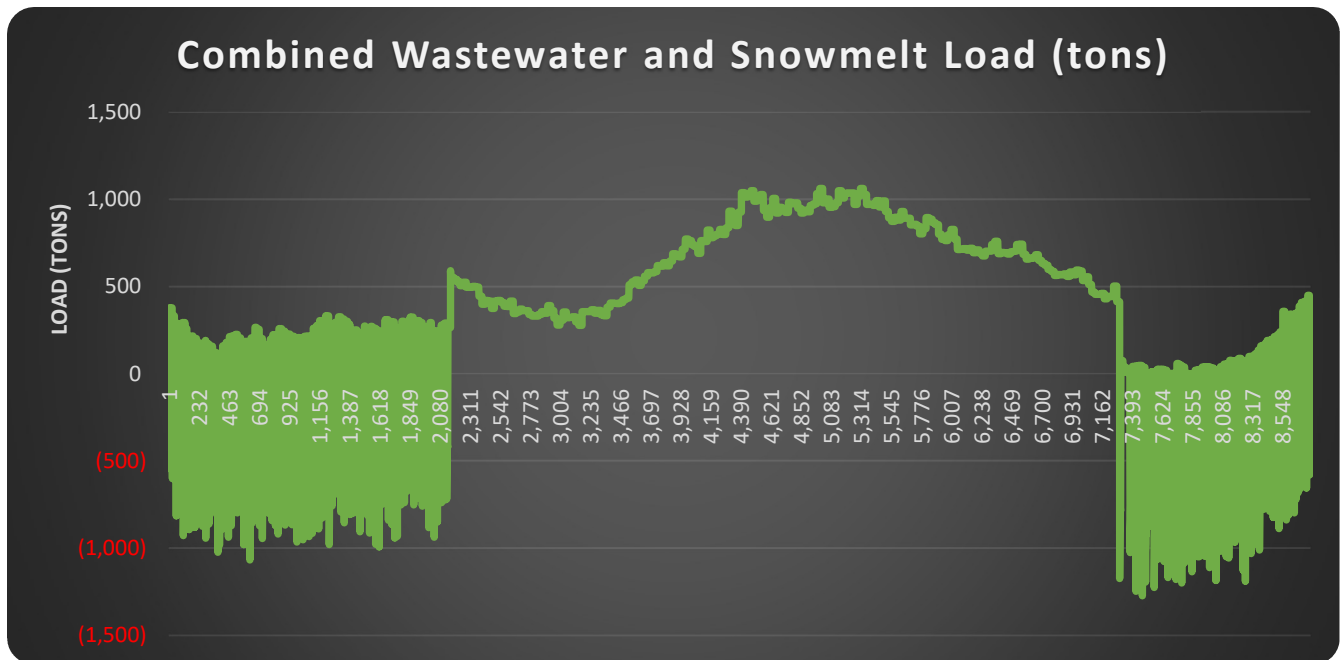


Figure 10: Wastewater and Snowmelt Load Profile

The recommended hybrid system integrates both renewable and conventional heat sources to optimize cost and environmental performance. The design leverages the “50/90 rule,” whereby 50% of the system’s peak heating capacity is sufficient to meet 90% of annual operational hours. In this configuration, the ATL’s renewable resources such as geothermal, solar thermal, and heat recovery from wastewater address the majority of heating needs. Conventional equipment, such as high-efficiency natural gas boilers, is utilized only during peak demand periods, acting as “peakers” to supplement the system when renewable supply is insufficient.

This hybrid approach offers several advantages:

- **Cost Efficiency:** By sizing renewable infrastructure for typical, rather than peak demand, capital and operational costs are minimized.
- **Decarbonization:** The system significantly reduces greenhouse gas emissions by prioritizing renewable energy sources for most operational hours.
- **Resilience and Flexibility:** The integration of thermal storage and multiple energy sources ensures reliable service and adaptability to varying load profiles.
- **Scalability:** The modular ATL architecture supports future expansion and integration of additional renewable assets as community needs evolve.

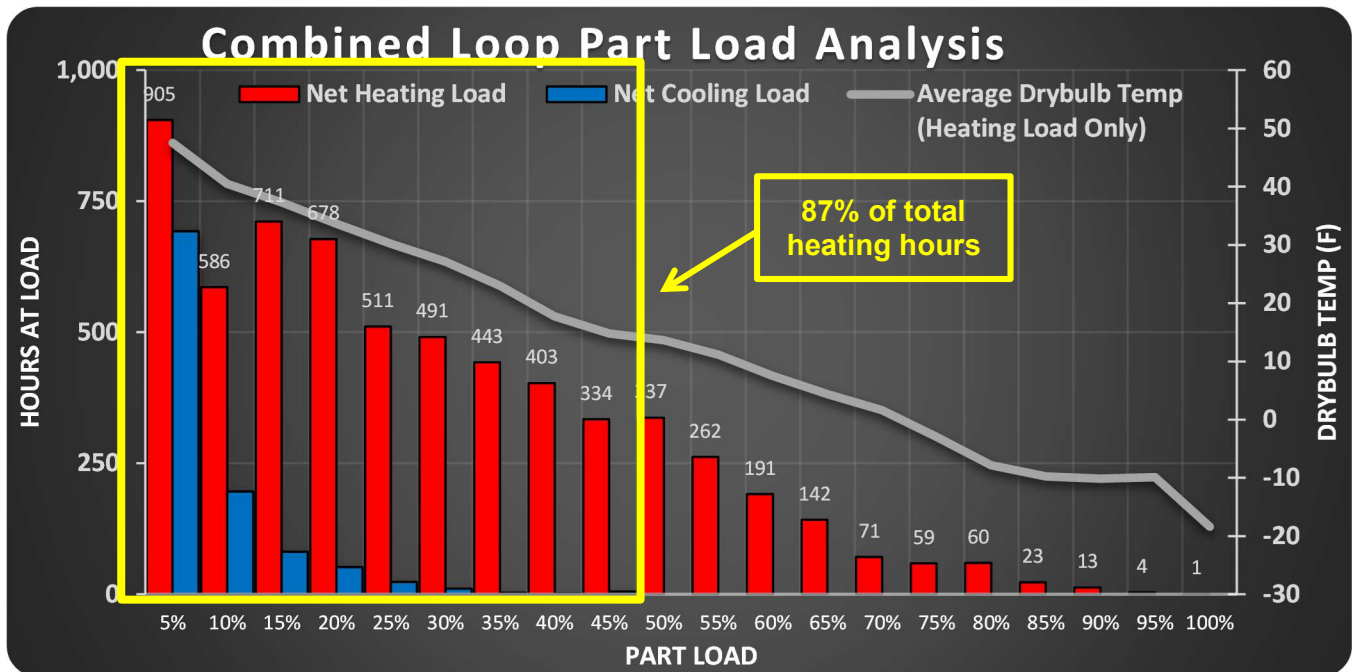


Figure 11: Example 50/90 Load Analysis

System layout planning identified suitable zones for the borefield and primary loop routing. The preferred borefield location is within the North battery yard area, which provides adequate offset from aircraft operations while remaining accessible for construction. A secondary borefield location near the southern apron edge could be incorporated if snowmelt heat-recovery functions are expanded. ATL mains, expected to range between 12 and 22 inches in diameter, will be routed parallel to the primary utility corridor. The central pumping and heat-pump plant may be located within the mechanical service core adjacent to the central utility plant, where modular heat-pump stations can be easily integrated and expanded.

Recommended Hybrid ATL System and Technical Overview

A hybrid Ambient Temperature Loop (ATL) system is recommended to optimize long-term thermal balance for the Winter Park project. By integrating both building heating and apron snowmelt loads, the system leverages heat recovery and enables ground heat rejection for seasonal storage. This hybrid approach significantly reduces the required borefield size compared to a fully ground-coupled system, resulting in lower drilling costs, reduced installation time, and stable ground temperatures.

Cost Estimates and System Components

The estimated capital cost for the ATL and hybrid ground source heat pump (GSHP) system ranges from \$6 million to \$18 million, excluding ITC tax credits, depending on the proportion of hybridization, timing of the project, and the inclusion of additional components such as effluent heat recovery and solar photovoltaic-thermal (PVT) panels. A cost estimation table is below:

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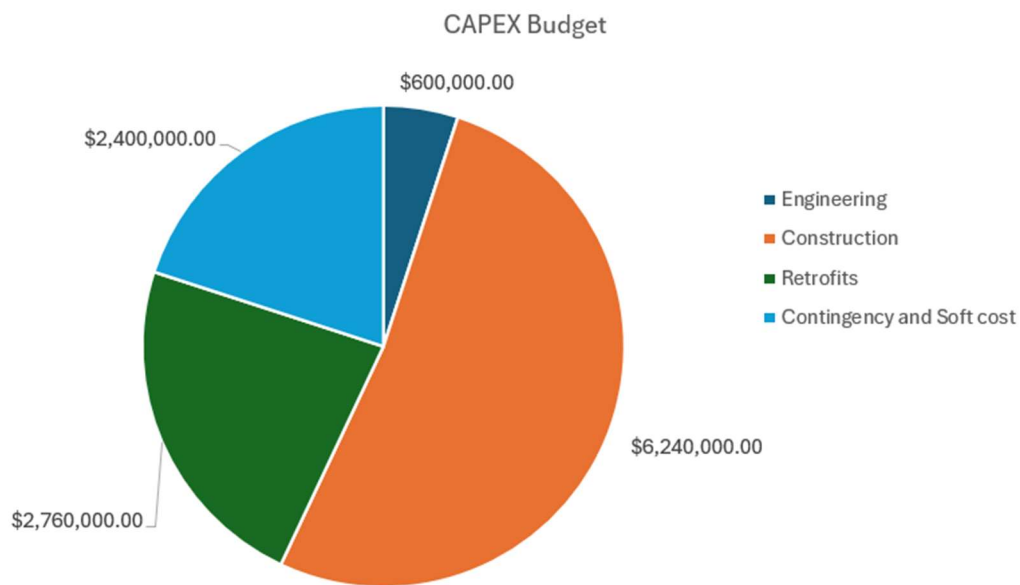
Table 2 System cost estimates

ATL with geothermal and snowmelt	665 Tons	\$7,315,000	\$11,305,000	\$17,955,000
ATL Hybrid (using existing gas for peak)	551 Tons	\$6,061,000	\$9,367,000	\$14,877,000

These estimates encompass the borefield, ATL piping, central pumping, control systems, and distributed heat pump equipment. Final costs will be refined as architectural programs, utility corridors, and construction phasing are finalized.

Capital Expenditure Assessment

The capital and operating cost allocations presented in this study are planning level estimates developed from publicly available thermal energy network (TEN) benchmarking reports. These percentage allocations are intended to provide a reasonable framework for evaluating project feasibility and comparing alternatives at the conceptual planning stage. The white paper, *Benchmarking & Budgeting: Improving Early-Stage Cost Accuracy for Thermal Energy Networks*, *Thermal Energy Insights, 2026*, was used as the primary reference for this assessment.



Budget Figure 1

CAPEX Budget pie chart represents the median projected values based on the estimated budget range.

Engineering design is expected to account for approximately 4% to 6% (\$240K – \$1,080K) of total project cost, which is consistent with industry benchmarks for thermal energy network development. This scope encompasses the full range of pre-construction technical activities. These activities are critical to validating system performance, reducing construction risk, and ensuring the thermal energy network can be integrated effectively with both existing and future energy infrastructure.

Construction activities are anticipated to represent approximately 39% to 57% (\$2.34 – \$10.3 million) of total project cost, reflecting the capital-intensive nature of developing the core thermal energy infrastructure. This includes installation of the ambient temperature loop distribution network, borefields and other thermal energy assets, utility interconnections, mechanical equipment, controls infrastructure, and associated civil works. As the primary physical component of the project, construction costs form the largest share of total capital expenditures and largely determine the long-term capacity, reliability, and operational performance of the system.

Building retrofits and recommissioning are expected to account for approximately 15% to 32% (\$900K - \$5.76 Million) of total project costs. While these activities represent a significant share of overall project expenditure, the cost can vary considerably depending on the characteristics of the buildings being connected to the thermal network. Retrofit requirements are driven by the scope of modifications needed to enable existing mechanical systems to interface effectively with the ATL infrastructure, including heat pump integration, distribution system upgrades, controls modifications, and commissioning activities. The magnitude of these efforts is highly dependent on factors such as building age, existing HVAC configuration, mechanical system condition, and the extent to which current equipment is compatible an ATL system.

For key thermal assets, a breakdown of anticipated costs is shown below.

- Geothermal well placement
 - 35-50% Drilling
 - 10-20% Trenching & Civil work
 - 10-15% Well equipment (headers, vaults, pumps, manifolds, controls)
 - 20-30% Transfer fluid and distribution piping
- Solar thermal Installation
 - 5-15% Equipment and installation

Contingency and soft costs are expected to account for approximately 18% to 25% (\$1.08 - \$4.5 Million) of the total project costs. These expenditures encompass a broad range of project development, management, and risk-mitigation activities that support successful implementation of the Ambient Temperature Loop system. Soft costs typically include project management, engineering support, permitting, environmental review, legal and procurement services.

Contingency funds are intended to address uncertainties that may arise during project execution, including unforeseen drilling conditions, subsurface utility conflicts, changes in construction sequencing, material price escalation, contractor cost revisions, schedule impacts, force majeure events, and other unforeseen circumstances. Collectively, these allowances provide financial flexibility to manage project risk while maintaining schedule and performance objectives.

Operational Expenditure (OPEX)

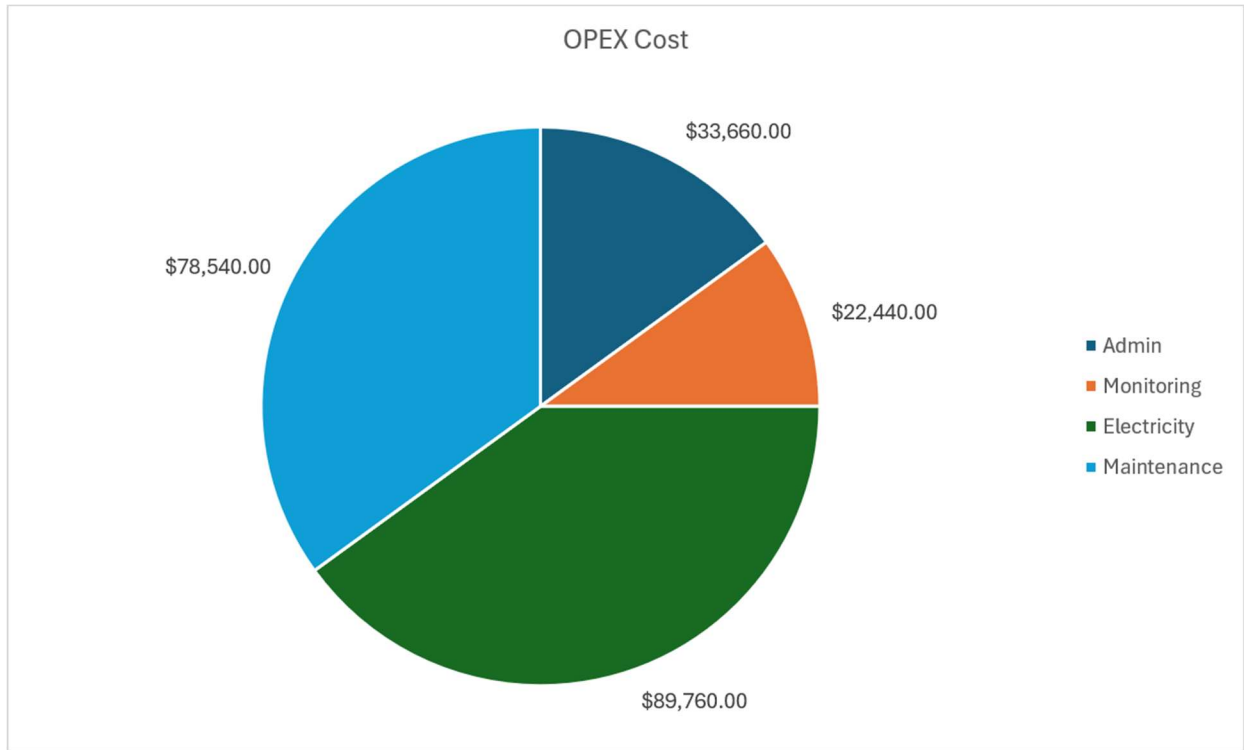


Figure 2 OPEX Cost

OPEX Budget pie chart represents the expected portion of the CAPEX expenditures spend annually on operations.

While much of the project emphasis is placed on capital cost, long-term operating expenditures ultimately determine lifecycle affordability. Unlike conventional heating systems that rely heavily on fuel purchases, ATL systems shift a larger portion of costs towards asset management, monitoring, network operations, and maintenance activities. This transition reduces exposure to future fossil fuel price volatility while providing greater predictability for long-term budgeting and financial planning.

Overall annual operating expenditures can be expressed as a percentage of CAPEX cost

- 0.5-2.5% Of Capex cost is the expected yearly OPEX cost
 - 10-15% Admin Costs (Highly depends on governance model)
 - 8-20% Monitoring and Controls
 - 30-50% Electricity
 - 30-45% Maintenance

Annual operating expenditures for an Ambient Temperature Loop remain difficult to benchmark because the U.S. market has limited operating history and industry-verified ATL cost data are still emerging. Recent NREL work notes that ATLs, or TENS systems, have not been extensively implemented in the United States and that industry-verified economic data are scarce. Based on limited case-study data for ATL systems annual operating costs can range from below 1% of

CAPEX for smaller community-loops systems to more than 8% of CAPEX for larger campus-scale systems, with higher values possible depending on the governance model.

Given the relative scale initially intended for Winter Park and for planning purposes, an OPEX range of 0.5% to 2.5% of CAPEX per year is a reasonable approximation when excluding the operation of customer-side equipment.

Overall annual operating expenditures can be expressed as a percentage of CAPEX cost

- 0.5-2.5% (\$30K - \$450K) Of Capex cost is the expected yearly OPEX cost
 - 10-15% Admin Costs (Highly depends on governance model)
 - 8-20% Monitoring and Controls
 - 30-50% Electricity
 - 30-45% Maintenance

(Benchmarking & Budgeting: Improving Early-Stage Cost Accuracy for Thermal Energy Networks, Thermal Energy Insights, 2026, pp. 12-24)

(Oh, H., & Beckers, K., Cost and Performance Analysis for Five Existing Geothermal Heat Pump-Based District Energy Systems in the United States, National Renewable Energy Laboratory (NREL), Technical Report NREL/TP-5700-86678, July 2023)

Annual revenue projections and LCCA are unavailable currently. The outcomes of both are contingent on the governance model and financial arrangements which have not been determined by the Town of Winter Park at this time.

Customer Support and Legal Agreements

Draft Contractual agreements between utilities, customers, contractors, and other relevant stakeholders have not been developed at this stage of the project and are anticipated to be prepared during subsequent design and implementation phases. The structure and content of these agreements will be informed by the selected governance model, financing approach, ownership structure, and operational responsibilities established during future project development.

At the time of this study, the Town of Winter Park has not selected a final governance model or capital financing arrangement for ownership, construction, operation, or long-term management of the thermal energy network. Multiple governance structures were evaluated as part of this assessment, and further refinement of ownership, financing, and operational frameworks is expected as the project advances toward design and implementation.

Similarly, long-term operations and maintenance responsibilities have not yet been assigned. Ongoing operational roles, maintenance obligations, asset ownership, and cost-sharing arrangements will be established in conjunction with the governance and financing framework selected by the Town and project stakeholders.

The Town of Winter Park is actively collaborating with Xcel Energy to evaluate implementation of the study findings as part of a Utility Thermal Energy Network. Opportunities for future network expansion and incorporation of additional buildings will be jointly evaluated by Xcel Energy and

the Town as system planning progresses. To support future expansion, appropriate provisions and accommodations are anticipated to be incorporated during subsequent design phases wherever practicable, allowing the network to grow as demand, participation, and economic conditions warrant.

Business Models for financing, ownership and operation of the ATL/TEN

The development of a Thermal Energy Network (TENs) at the Town of Winter Park campus requires alignment of three core functional roles:

- project financing,
- asset ownership,
- and system operations.

These roles may be filled by any combination of the Town of Winter Park, the local electric utility (Mountain Parks Electric, MPE), and a third-party Energy Performance Contract (EPC) provider, enabling a range of potential business and governance structures.

- **Public-Owner Model-** In a public-owner model, the Town could finance the project through voter-approved bonds, capital reserves, or other municipal funding mechanisms, retain ownership of the TEN assets, and either self-operate the system or contract operations and maintenance (O&M) services to a qualified provider. This structure offers maximum control and long-term cost stability but places performance and operational risk on the Town.
- **Utility Owner Model-** In a utility model, MPE could finance and own the thermal infrastructure as part of a future thermal utility function, recovering costs through thermal service rates similar to electric distribution models. Under this structure, the local electrical provider (MPE) would operate the system or subcontract O&M, while the Town would act as the anchor thermal customer. This approach leverages utility balance sheets, customer billing systems, and long-term asset management expertise, while enabling future expansion of the network beyond the initial municipal campus.
- **EPC Owner Model-** In an EPC model, a third-party provider could design, construct, finance, and potentially operate the TEN, delivering thermal energy services under a long-term performance-based agreement. This structure shifts capital, performance, and operating risk to the EPC provider, with the Town making predictable annual service payments tied to achieved heating and cooling performance.
- **Hybrid Models-** Hybrid arrangements are also feasible, including shared financing (e.g., municipal bonds combined with private capital), split ownership (e.g., utility ownership of distribution infrastructure with public or third-party ownership of central assets), or contracted operations layered onto public or utility ownership. The optimal structure will balance access to low-cost capital, risk allocation, governance preferences, and long-term cost to the thermal user.

Regardless of ownership structure, the ATL/TEN must recover capital, operating, and lifecycle costs through a defined thermal revenue mechanism. Revenue would be generated by providing thermal energy services—heating and cooling—to connected municipal buildings, displacing conventional fossil-fuel and electric HVAC systems. In addition to reduced heating costs, the system enables mechanical cooling that improves occupant comfort and indoor air quality, particularly during periods of wildfire smoke when airside economizing is undesirable. Cost recovery approaches may include:

- thermal energy charges (e.g., \$/MMBtu delivered),
- demand or capacity-based cost allocation reflecting peak loads,
- avoided energy and demand cost savings, and
- performance-based service fees under an EPC agreement.

For the Town, payments would be structured to be at or below projected business-as-usual lifecycle costs, accounting for avoided boiler replacements, potential chiller additions, fuel costs, and maintenance, while providing long-term budget stability.

TEN utility rate models are evolving nationally. Because the initial TEN would serve only Town of Winter Park facilities, cost allocation across participating buildings is simplified and avoids complications associated with broader public/private networks. In general, thermal rate design should reflect both system economics and customer equity, including:

- Cost causation: allocation of fixed infrastructure costs through capacity or fixed charges and variable costs through energy charges.
- Load characteristics: recognizing diversity between heating and cooling loads and seasonal usage patterns.
- Simplicity and transparency: ensuring rates are understandable and predictable for municipal budgeting.
- Long-term stability: smoothing year-to-year variability and insulating customers from fuel price volatility.
- Expansion readiness: enabling future customers to interconnect without disadvantaging early adopters.

Load profiles developed in this study provide the basis for preliminary allocation of fixed versus variable costs and inform potential anchor-customer pricing under either utility or EPC ownership structures.

Connection to the TENs will require customer-side investments within existing buildings, including heat pump equipment, heat exchangers, controls, and internal distribution modifications. For this project, these costs are assumed to be integrated into overall network installation and funded through a combination of grants, municipal bonds, and potentially EPC financing. In general, such conversion costs can represent a barrier to adoption if born entirely by building owners. Accordingly, the business model may incorporate:

- direct capital contributions from project financing to offset in-building conversions,
- rebates or incentives from utility, state, or federal programs,
- inclusion of conversion costs within an EPC or thermal service agreement amortized over time
- grant funding targeted at decarbonization and public infrastructure.

This study assumes that partial subsidies or financed recovery of customer-side conversion costs will be required to ensure economic neutrality or savings for the Town relative to conventional system replacement.

The Town of Winter Park TEN is well suited to multiple business model pathways, including public ownership, utility ownership, EPC delivery, or hybrid structures. Final business model selection should be guided by comparative lifecycle cost, risk allocation, regulatory feasibility, and alignment with the Town's long-term sustainability, resilience, and fiscal objectives.

System Layout and Expansion

System layout planning has identified several reasonably near locations as the preferred borefield location, providing sufficient offset from operational areas and accessibility for construction. A secondary borefield near the southern apron edge may be incorporated if snowmelt heat recovery is expanded. ATL mains, ranging from 12 to 22 inches in diameter, will be routed parallel to the primary utility corridor. The central pumping and heat-pump plant will be located adjacent to the central utility plant, facilitating modular expansion and integration of additional heat-pump stations as the system grows.

8. Environmental Impact Analysis

Environmental Summary

An Ambient Temperature Loop (ATL) system, integrating geothermal heat pumps, solar thermal collectors, and backup natural gas boilers, offers substantial environmental and operational advantages over conventional fossil-fuel heating. The geothermal subsystem utilizes vertical boreholes drilled into the Proterozoic Metamorphic formations, which provides high thermal conductivity (1.13 BTU/ft-hr-°F) and diffusivity (1.36 ft²/day), supporting efficient long-term thermal storage and supply-demand balancing. Boreholes are constructed with high-density polyethylene (HDPE) piping and sealed with high-conductivity grout, minimizing groundwater migration and environmental risk.

The geothermal component leverages stable ground temperatures for highly efficient heat exchange (COP typically 3.5–6.0), resulting in near-zero direct greenhouse gas emissions and minimal land disturbance beyond initial borehole drilling, which is reversible and occupies a small footprint. Proper borehole installation minimizes environmental risks. The regulatory framework includes installer licensing, well permitting, and eligibility for state and federal incentives such as tax credits, grants, and utility rebates.

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Table 3 Carbon Savings comparison

CO2 Emissions Comparison:	Pounds of CO2 per year	Metric tons CO2 per year	% Reduction
ATL - Geo hybrid	266,488 # CO2/year	121 tonne CO2/year	87%
Gas Heating/Air cooled HP	2,111,316 # CO2/year	958 tonne CO2/year	

By using these values for CO₂ and replacing conventional natural gas boilers for a fully renewable ATL system, the project is expected to reduce heating-related CO₂ emissions by approximately 87% relative to a high-efficiency natural gas baseline, equivalent to roughly 837 metric tons of CO₂ avoided annually or 181 cars off the road.

Conclusion:

The ATL system is a technically advanced and environmentally optimized solution for district heating and snowmelt in Winter Park. Its adoption will facilitate decarbonization, improve operational efficiency, and ensure long-term resilience and scalability of the town's thermal energy infrastructure.

9. Regulations & Incentives

Regulations (current snapshot – verification to occur during permitting):

- Installer licensing & permits (geoexchange/GHX): Colorado DNR's Division of Water Resources indicates geoexchange (closed-loop) systems do not require a site-specific well permit, but installers must be certified and hold an annual permit from the State Engineer (forms GX02 and GWS72; see DWR/CEO geothermal resources page).
- Well & GHX oversight changes in 2025: The Board of Examiners is being renamed to include Ground Heat Exchanger Contractors and will license GHX contractors, updating rules for installation and abandonment (2 CCR 40214 revisions).
- General well permitting: DWR well permitting timelines/process apply to wells; closed-loop GHX typically follow the geoexchange pathway; open-loop or deep geothermal may trigger additional DWR/ECMC coordination.
- Sales/use tax definitions (heat pump systems) and state performance/eligibility criteria are codified in C.R.S. 3926732 and 3922554; designs must meet code and serve ≥80% annual heating if claiming certain credits.

Incentives and financing:

- Colorado Heat Pump Tax Credit (contractor-facilitated discount) – \$3,000 per ground/water/combined-source HP (2024–2025), prorated for nonresidential as one credit per 4 tons (up to 100 tons).
- Colorado Geothermal Energy Grant Program (Round 3) – grants for Thermal Energy Networks and single-structure geothermal; current (final) round closing Mar 31, 2025 (note: program sunset after Round 3).
- Colorado Geothermal Energy (Electricity) Tax Credit Offering – refundable credits up to 30% of investment (up to 50%/max \$5M) for eligible geothermal projects including thermal energy networks (through Dec 31, 2032, subject to funding).
- Colorado CPACE – up to 100% long term financing for eligible efficiency/renewables; repaid via property tax assessment.
- Federal ITC (IRC §48 / §48E) – base 6%; up to 30% with prevailing wage & apprenticeship (or small project exception), with domestic content/energy community adders where applicable.
- 179D (A&E/owner deduction) – model whole building efficiency for additional federal benefits.
- Action: Layer state contractor credits, utility rebates, CPACE, CEO Geothermal credits, and federal ITC to drive net cost down. Confirm stacking rules to avoid double counting.

10. Summary & Recommendations

Key Technical Findings

System Architecture & Feasibility

- The proposed Ambient Temperature Loop (ATL) operates within a controlled thermal envelope of 45°F–85°F, supporting distributed heat pump units for bidirectional thermal exchange and intra-network heat recovery.
- Modular micro-district architecture enables scalable expansion and dynamic load balancing.

Ground Thermal Properties

- Advanced thermal response testing confirmed ground thermal conductivity of 1.13 BTU/ft-hr-°F and diffusivity of 1.36 ft²/day.
- Average deep earth temperature measured at 46.5°F.

Recommended Borehole & Drilling Strategy

- Fewer, deeper boreholes (up to 1,000 feet) in the Proterozoic Metamorphic formations are recommended for cost-effectiveness and enhanced thermal storage capacity.
- Properly installed geothermal boreholes with HDPE piping and high-conductivity grout minimize environmental risks and prevent groundwater migration.

Thermal Asset Integration

- System integrates solar thermal collectors, potable water and sanitary sewer heat exchangers, and geoexchange borefields for year-round “trickle charge” of the storage medium.
- Snowmelt systems serve as both a significant thermal load and an opportunity for solar energy collection and ground storage.

Environmental Impact

- Projected to reduce heating-related CO₂ emissions by 87% relative to a high-efficiency natural gas baseline, equivalent to roughly 837 metric tons of CO₂ avoided annually.
- Near-zero direct greenhouse gas emissions from geothermal and solar thermal components.

Cost Estimates and System Components

- The estimated capital cost for the ATL and hybrid ground source heat pump (GSHP) system ranges from \$6 million to \$18 million, depending on the proportion of hybridization, timing of the project, and the inclusion of additional components such as effluent heat recovery and solar thermal panels.

System Sizing & Load

- Designed to meet a peak thermal load of 665 tons.

Regulatory Compliance & Incentives

- Closed-loop geoexchange systems do not require site-specific well permits, but installers must be certified and hold annual permits from the State Engineer.
- Eligible for Colorado Heat Pump Tax Credit, Geothermal Energy Grant Program, CPACE financing, utility rebates, and Federal Investment Tax Credit (ITC).

Recommendations & Next Steps

- Conduct detailed hourly energy modeling, refine borefield and system design, integrate additional renewable thermal assets, and engage stakeholders for technical, financial, and sustainability outcomes.

Overall, the study concludes that a one-pipe ATL integrated with a hybrid GSHP system is a technically feasible and cost-effective solution for The Town of Winter Park. The system may support full electrification, will reduce and/or eliminate on-site natural gas consumption, and improve operational efficiency through heat recovery, diversity, and optimizing pumping strategies. It provides a resilient, low-carbon thermal energy network capable of serving The Town of Winter Park's long-term climate and operational goals.

Engineering and Design Data Required for Next Phase:

- Additional Data Collection & Site Investigations
- Compile 24–36 months of gas & electric bills; export 15min interval electric data.
- Geotech/GHX feasibility, and groundwater notes.
- Underground utility mapping and identification of preferred ATL corridors.
- Concept Design & Modeling
- Hourly energy model (ventilation, dehumidification); size ground fraction (40–60% target) and pump heads.
- Controls sequences for TAM (DR, $\Delta T/\Delta P$ optimization, heat recovery).
- Permitting & Compliance
- Confirm GHX installer certification and any DWR/ECMC touchpoints, coordinate with Winter Park building officials.
- Validate eligibility under C.R.S. 3926732 / 3922554 for state credits.
- Incentives & Financing actions
- Solicit drilling & HDPE vendor quotes; refine ATL route; update costs and CAPEX stack; run CO₂e & kW scenarios.

TGEG Support

As part of the Colorado Energy Office Geothermal Energy Tax Credit Offering program, TGEG can support The Town of Winter Park in their public engagement efforts. Bringing potential stakeholders together including the public and private portions of Utility and others will be crucial to building a successful project.

If The Town of Winter Park elects to proceed with implementing ATL, The GreyEdge Group is also capable of supporting the project through the design, construction and continued sustainable operations development of the project.

We would recommend the following next steps:

- Integrate TGEG into the design team and ensure building HVAC systems are compatible with the ATL.
- Refine assumptions and costing for each potential thermal asset.
- Optimize the selected resource mix for generation and storage requirements.

- Engage TGEG to design all “out of building” systems.
- Engage TGEG to inspect the ATL and all connected devices/systems using a Certified Geothermal Inspector

Attachment A:
Hydrogeology Report

Attachment B:
A-TRT Report and Drill Logs

Phase 2 Geothermal Evaluation Report
The Town of Winter Park, Colorado