THERMAcity

Multi-Unit Residential Facility
Energy System Analysis

300,000 sqft | Ontario, Canada

Annual Heating	1,954,617 kWh
Annual Cooling	370,968 kWh
Peak Heating	855 kW
Peak Cooling	633 kW

Overview

Large multi-unit residential buildings are quite common in densely inhabited cities. These facilities have unique thermal energy loads to serve the needs of their occupants.

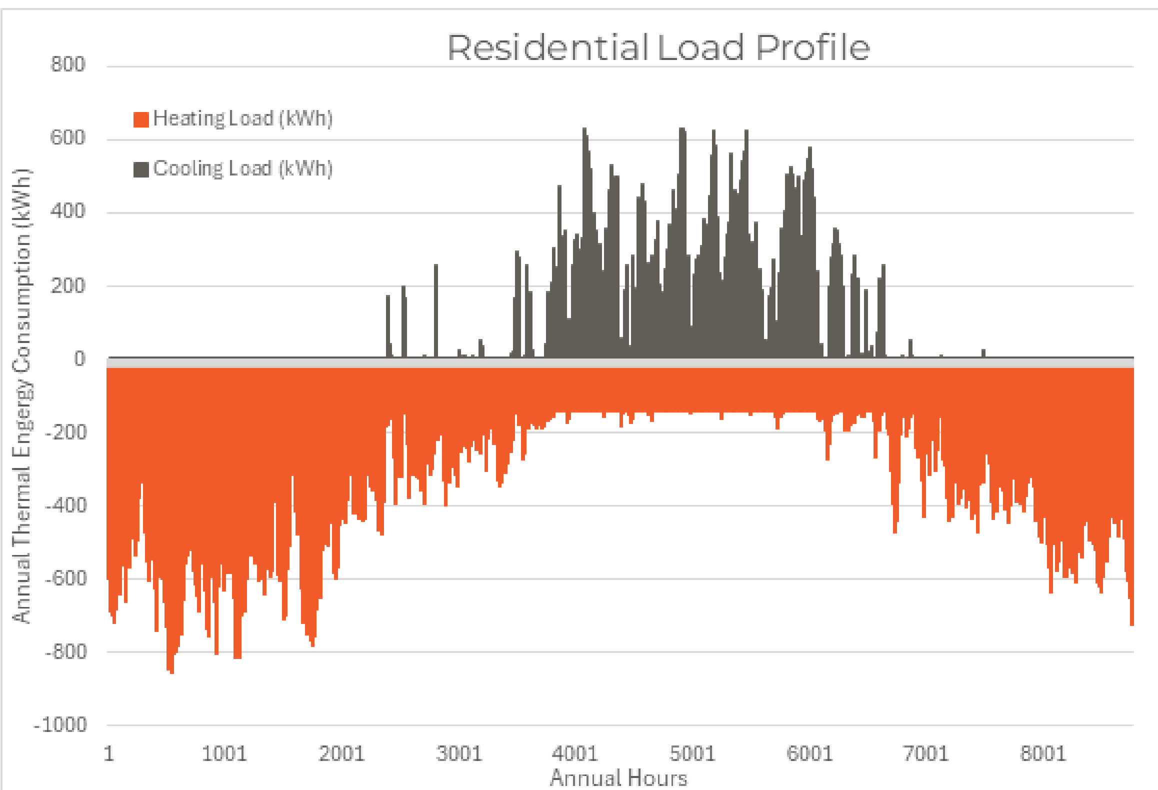
Heating loads consist of space heating, large domestic hot water loads, fresh air ventilation, conditioning, and in some cases snow melt. Cooling loads are often significantly smaller than heating, only being used for space cooling, however recent architectural design trends are seeing more glazing and curtain wall being used in construction, driving peak cooling loads larger, sometimes exceeding heating peak loads.

This analysis is modeled with real hourly data from a representative 11-storey apartment complex in Ontario.

An analysis of four energy systems was performed to create a base model for large residential facilities, looking at feasibility and financial cases for each and to evaluate a decarbonized alternative to building heating systems. Traditional systems including natural gas fired boilers and electric chillers, electric air source heat pumps, and an underground Geoexchange system with peaking boilers to meet additional heating loads, were compared to borefield thermal energy storage.

Looking just at space conditioning, the heating load is 2.5x larger than cooling meaning traditional Geoexchange that requires seasonal balancing would have to be supplemented by boilers. The large domestic hot water load used in residential facilities introduces simultaneous loads and heating demand all year. The hot water load is close to the magnitude of all space heating required in the facility, adding it to the analysis eliminates the viability of Geoexchange completely. With over 5 times more kWh of heating required than cooling annually, most of the heating load would have to be supplemented by boilers or other systems. Thermal energy storage on the other hand can support the entirety of the building's heating load and any additional loads such as snowmelt.

Simultaneous load requirements present in residential facilities help to reduce the size of borefield required for thermal energy storage as this load does not need to be stored. The simultaneous needs are met by heat pumps that move the heat from cooling systems where it is not needed, to heating systems where it is needed throughout the building. This process is assumed to run at a higher efficiency for all systems using heat pumps.



- **5x more heating demand than cooling**
- **Significant domestic hot water load**
- **Heating needed year-round, only seasonal cooling**

Advanced Geostorage

Smaller Field | Longterm Storage | Adjustable Sizing | Direct Supply

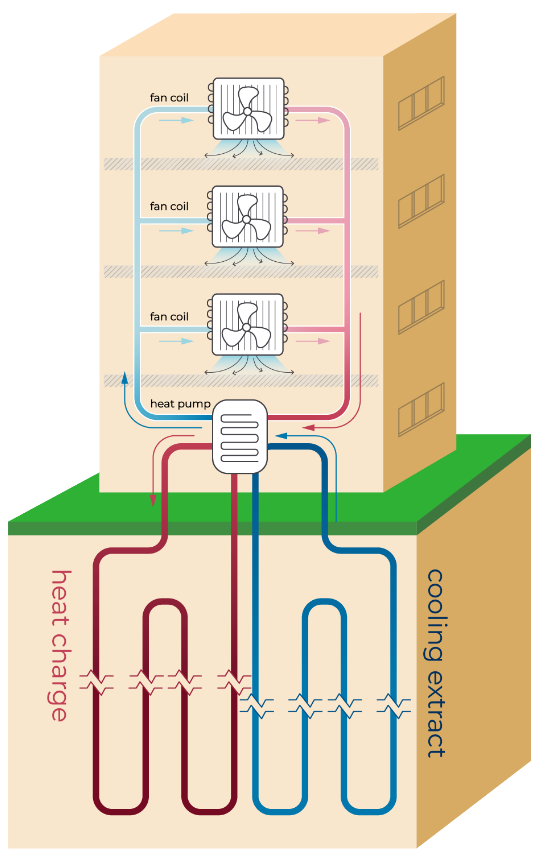
THERMAcity's Advanced Geostorage system uses the earth under a building as a thermal battery for longer term heat storage. The borefield is split into two separate heating and cooling fields with boreholes arranged in concentric circles. The Geostorage boreholes are designed to be much closer together than in traditional geothermal, reducing the footprint and allowing higher temperature storage. The size of each field can be easily mismatched to meet the building's specific heating and cooling needs. During warm summer months the hot borefield is charged from warm ambient conditions with a high efficiency air source heat pump. This heating energy is stored over the summer and fall until the heat is needed during the winter months. The outer rings work as insulators for the inner most boreholes allowing the rock to hold high temperatures that can directly supply the building needs when heating the building. The same process exists for cold storage where cold ambient conditions are leveraged to lower the temperature of the cold borefield during winter months, and energy stored through the winter and spring, until it is needed for air conditioning through the summer months.

Optimized Charging Algorithm

- Avoid expensive global adjustment charges
- Lower electricity cost with off-peak hour charging
- Reduce CO_2 emissions using off-peak or renewable grid electricity
- Improve heat pump efficiency taking advantage of ambient temperature
- Opportunity to add solar thermal roof mount panels to generate renewable electricity behind the meter

For this model charging occurs when electricity price is below $0.025/kW. The heating borefield is charging when temperatures are above 4.5°C, while the cooling field charges when temperatures are below -1.1°C to optimize production.

Global Adjustment charges have significant financial implications for larger residential facilities reaching upwards of $100,000 each year. Reducing overall electricity usage with more efficient heat pumps can lower the charges applied to the facility. While using mainly off-peak electricity further decreases the amount charged for Global Adjustment.



Advanced Geostorage Comparison

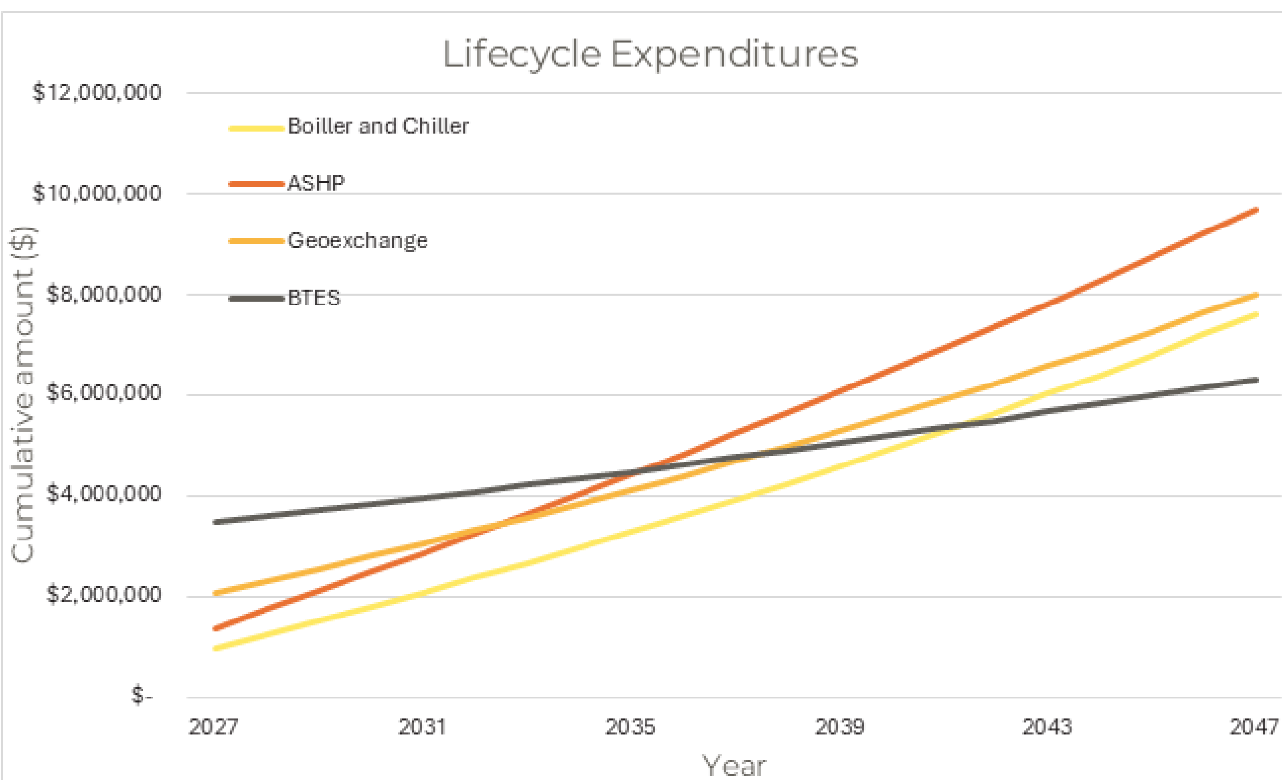
This innovative thermal energy storage system is able to support up to 100% of the facility's heating and cooling needs. Capital costs are higher than alternative, more traditional HVAC systems due to the construction and installation of the hot and cold borefields underneath the building, however, the heat pumps required to charge the fields can be significantly **smaller** than alternative designs. Working at a **high efficiency** during off-peak hours the Geostorage system operating costs are much lower than the other three systems. The small amount of electricity required to pump heating or cooling supply water to the building systems is the only electricity use expected during peak operation on design days. Over a 20-year lifetime the operational savings outweigh the capital costs of the system.

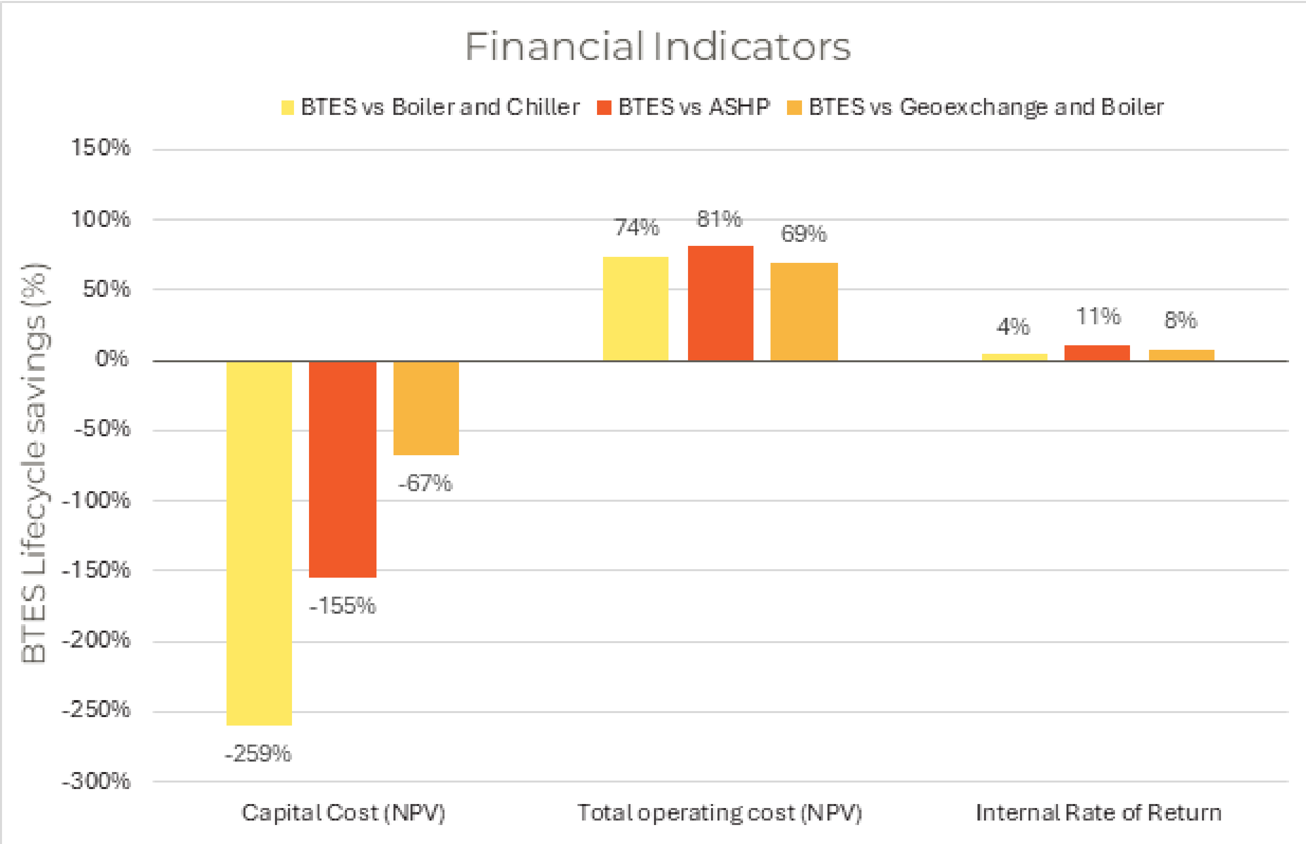
Boiler and Chiller

Minimal upfront cost to instal. This system relies on electricity for the chiller and natural gas for the boiler heat production. Boilers generating heat by burning fuel run at an efficiency of around 80% leading to a high usage of natural gas. Chiller cooling coincidence with top 5 peaks is expected at 100%. Over the 20-year period operating costs for this system are very high once utility escalations for natural gas and electricity are taken into account.

Air Source Heat Pump

This system eliminates the need for natural gas and its subsequent carbon emissions. Pulling heat from the air during the coldest days of the year when heating demands are the highest is inefficient for a large building. Coincidence with the top 5 demand peaks is expected at 90% with very high electricity usage during those hours. The electricity costs to operate this system over 20 years add up quickly, and depending on the design day heating ambient temperatures, supplemental boilers may be required for hours of the year when the heat pump output can not meet the buildings heating needs.



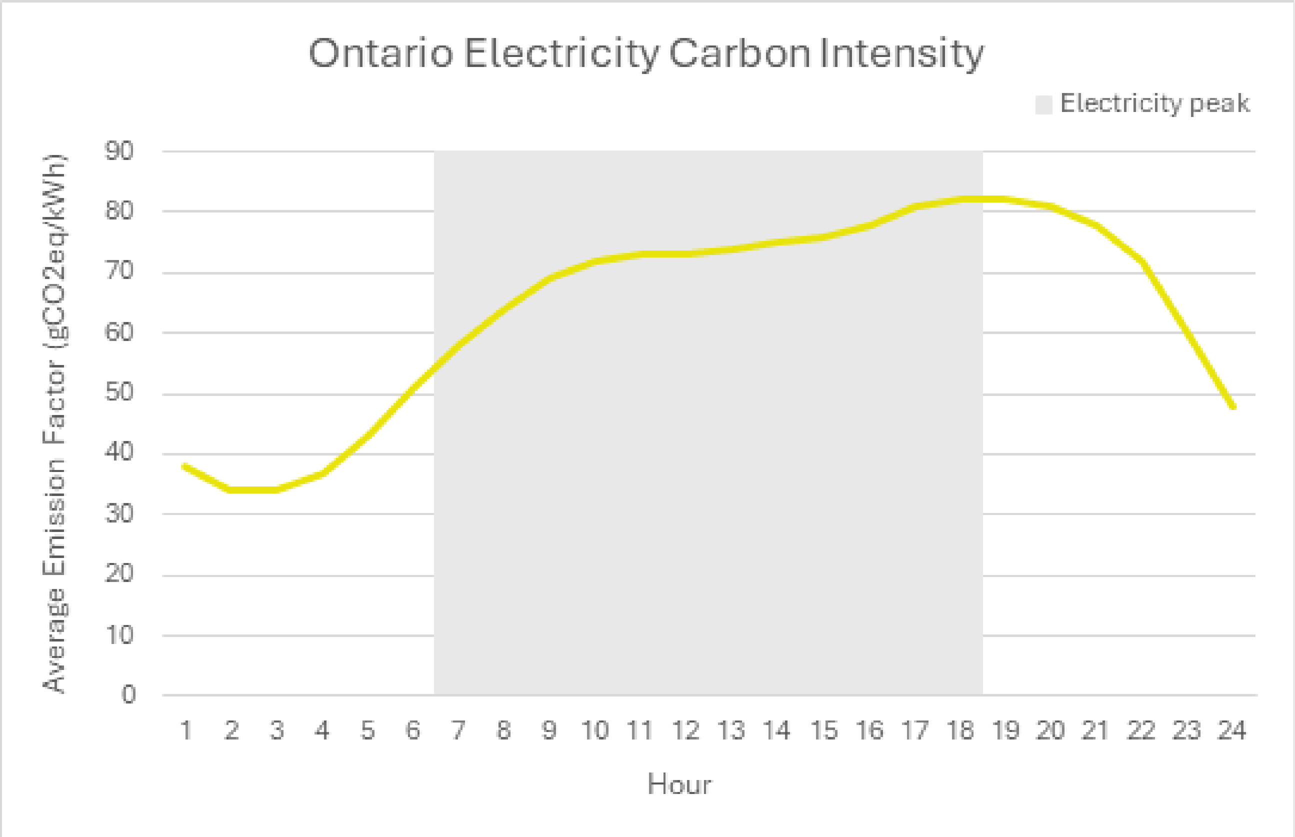


Geoexchange

Higher capital costs to build the borefield. The system requires seasonal balancing and is not able to support the unique heating loads of a residential facility. The system would be mainly using boilers or other systems to heat the facility reintroducing gas emissions and costs associated. Operating costs are lower than air source heat pumps because the ground source pumps used run more efficiently due to the steady ground temperature. Coincidence with the top 5 peaks expected to be 80% but with lower electricity usage during the hours. Geoexchange is not a feasable solution for the facility.

Financial Indicators

Large capital costs for the borefield are offset over a 20 year period by operating costs that are 70-80% lower allowing costs to be recouperated within 10 years compared against air source heat pumps. The total unadjusted expenditure of the BTES system after 20 years is more than 30% lower than all other modeled systems.
The internal rates of return of thermal storage compared to boilers and chillers, air source heat pumps, and suplemented geoexchange are 4%, 11%, and 8% respectively. Compared to an electric air source heat pump system advanced geostorage is modeled to result in 10% lifetime savings adjusted for net present value.



Carbon Emissions

Ontario's electricity grid is primarily supplied by nuclear and hydroelectric energy. Fossil fuel generation in the electricity grid increases during periods of high demand due to its ability to be ramped up quickly, leading to cleaner energy during lower demand hours. In 2024 the off-peak marginal emission factors in Ontario were less than half of the emission factors during peak hours.

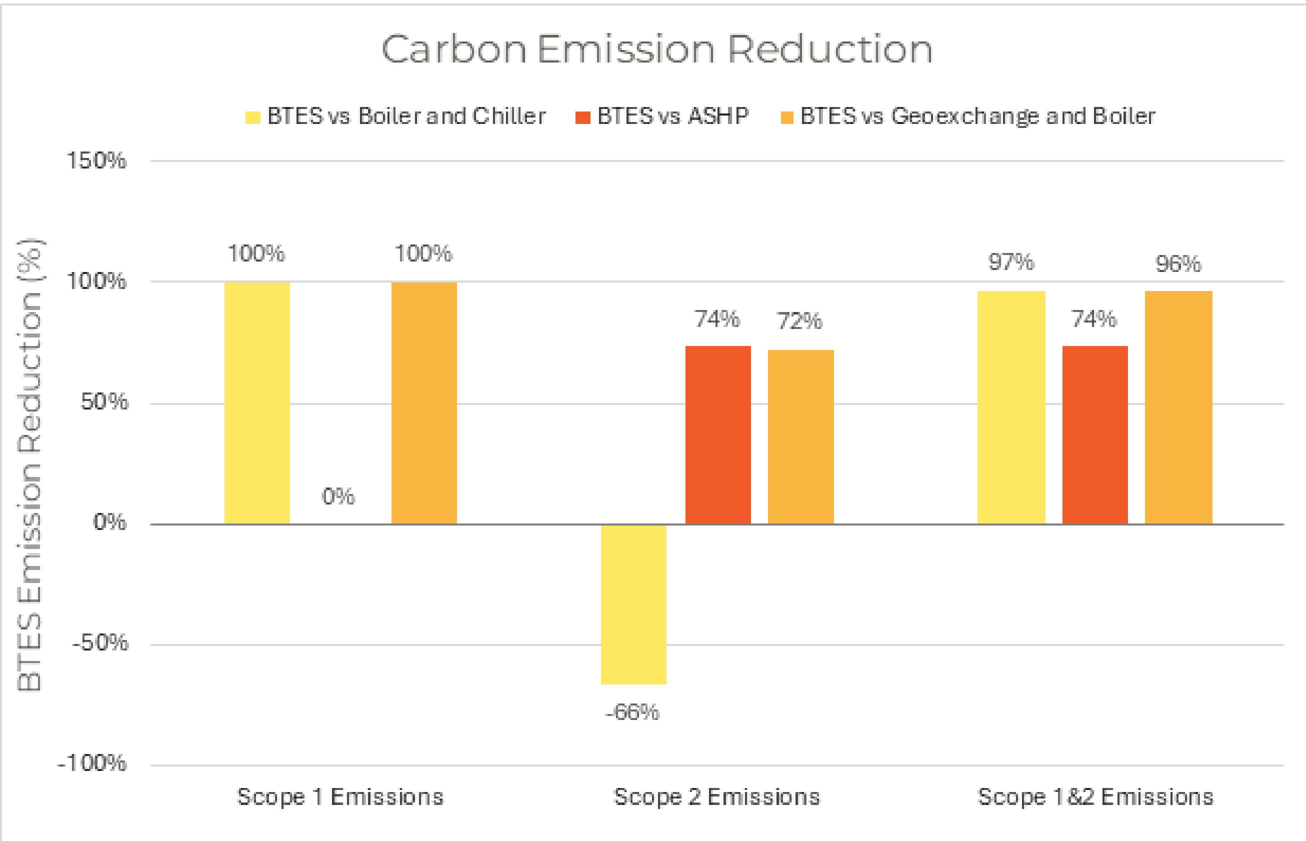
The thermal energy storage solution eliminates all on site fossil fuel usage and emissions (scope 1) caused by building heating and cooling systems. It also significantly reduces grid electricity related emissions (scope 2). Taking advantage of off-peak times to charge the thermal storage borefield saves on operating costs and helps to further reduce emissions associated with heating and cooling the building from grid electricity.

Total emissions are reduced by 74% compared to electric air source heat pumps and 96% compared to the Geoexchange and boiler combined system. Boiler and chiller systems have the highest emissions due to the burning of natural gas which can be reduced by 97% which is equivalent to stopping the emission of over 400,000 kilograms of CO_2 each year.

This system is modeled to limit emissions and electricity consumption. The effects of additions to the system such as solar thermal energy production on site, or water source heat pumps have not been included in the analysis however may help to further decrease energy use in the building.

Retrofit

In a residential building where displacing residents for construction is not a good solution the borefield thermal energy storage solution offers the ability to be built in a parking garage right underneath it with minimal impacts to building use. This is done with oil and gas drilling technology miniaturized into a Patent Pending low clearance drilling system. Mud cleaning and geological gas separation technologies have been developed and implemented in association with environment Canada to ensure safe and clean conditions for occupants.



Conclusion

Set up for success and a decarbonized future. Advanced Geostorage is the best solution to meet building decarbonisation targets and save on costs. Higher upfront costs lead way to 74% operating cost savings over boilers and chillers throughout the system lifetime. Completely eliminate on site natural gas use, reduce all building associated emissions by up to 97% and work towards a net-zero future with potential for on site renewable power and thermal generation. Build or retrofit for a comfortable, low cost, and carbon free future.

THERMAcityENERGY

GROUP OF COMPANIES

With our proprietary, semi-autonomous, low-profile drilling system we can **DESIGN**, **SUPPLY**, and **INSTALL** geothermal energy storage systems under different building types.

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SUPPLY — THERMAstor
SUSTAINABLE DESIGN

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