Ford Site Energy Implementation Plan

Achieving 21st Century Infrastructure for a Net Zero Site

October 2018



Acknowledgements

Ever-Green Energy would like to express our gratitude to the City of Saint Paul for their support and vision throughout this process. In particular, we would like to thank Merritt Clapp-Smith, Anne Hunt, Mike Richardson, and Russ Stark for their expertise and commitment to the potential and resilience for this site. Additionally, we would like to thank Mayor Chris Coleman and Mayor Melvin Carter for their leadership and dedication to creating a new future for this important city asset.

The plan and recommendations presented here reflect and incorporate a decade of work to develop innovative and implementable recommendations for the Ford Site. Our thanks to the many volunteers, technical advisory board members, community members, and local government delegates who have led this work to this important juncture. A special thanks to the team from Ramboll (engineering group) and Underground Energy whose work in 2015-16 set the stage for achieving net zero for the Ford Site.

Project Partners

In addition to the City of Saint Paul, a special thanks to Xcel Energy and the University of Minnesota Center for Sustainable Building Research. Their contributions are incorporated throughout their report and their input was critical to the success of this plan.

Ever-Green also utilized the expertise of MEP Associates for geo-energy exchange system evaluation. MEP is an industry leader in geo-energy exchange systems and has designed and implemented multiple geo-energy solutions around the Midwest.

About Report Author Ever-Green Energy

Ever-Green was secured by the City of Saint Paul to lead this phase of planning for the Ford Site's energy infrastructure. At Ever-Green, we take pride in being one of the country's premier district energy system experts, with decades of experience in developing, operating, and managing district energy systems. Our unique combination of technical expertise, business acumen, and operations experience has helped municipalities, colleges and universities, health care campuses, and government organizations advance the study, development, and operation of district energy systems. The Ever-Green team applies its depth of knowledge through every step of a system's development and implementation, finding sustainable solutions that are reliable and financially viable to secure a community's energy future.



1. Introduction	4
2. Approach	8
3. Building Design and Efficiency	10
4. Estimating Building Load	11
5. Source Energy Alternatives	14
6. Financial Model	19
7. Environmental and Greenhouse Gas Profile - Pathways to Net Zero	21
8. Innovation	25
9. Community Engagement	28
10. Organizational Structure Alternatives	29
11. Conclusion and Next Steps	
Appendices	32



1. Introduction

The 122-acre Ford Site has served as an important anchor to the City of Saint Paul (City) for multiple generations. The Ford plant operated in this corner of the city from 1925-2011 and upon its closure created both challenges and opportunities for the City and Ford Motor Company (Ford), who embraced the potential to transform this site into a "21st Century Community." Their vision included an emphasis on sustainability and resilience, with a goal of a net zero energy development that could serve as a demonstration project for smart and efficient design principles. This goal was developed through several years of analysis, community engagement, benchmarking of urban design successes, and rigorous technical studies. These efforts resulted in consecutive energy studies in 2015 and 2016 that identified key technologies that could be implemented on the site by the initial build-out year of 2025 and would position the site to meet the carbon neutrality objectives.

As Ford moved closer to selecting a developer, Ever-Green Energy (Ever-Green) was hired to develop an analysis of the financial and technical feasibility for implementation planning of a district energy system (DES). This plan is intended to help decision-makers prioritize the infrastructure and technology solutions for the development. An implementation plan focuses on the framework and action steps for financing, designing, building, and operating the DES. This implementation plan includes technical analysis, and focuses on the viability of the technologies that will most likely be implementation-ready considering the site development plan and schedule. This report touches on the technical and financial findings of the aforementioned foundational reports and the entirety of those documents can be found on the City's Ford Site website¹.

Implementation Plan Workgroup

To develop a comprehensive energy plan, the City and Ever-Green convened a multi-faceted Workgroup to explore the opportunities for this site, including the University of Minnesota Center for Sustainable Building Research (CSBR) and Xcel Energy. CSBR served as the plan's expert in smart building design. CSBR also prepared several site analyses in earlier phases of the work examining the potential for solar photovoltaic (PV) and high efficiency buildings. Xcel Energy has contributed to multiple phases of this site redevelopment planning and served a critical role in examining the infrastructure, building, and utility interfaces for this plan. All parties worked together to analyze what was implementable, financeable, and would still meet expectations for sustainability, resilience, and innovation.

¹ https://www.stpaul.gov/departments/planning-economic-development/planning/ford-site-21st-century-community



4

During the City's evaluation of best practices and best outcomes for the Ford Site redevelopment, they developed the following site objectives, which were reinforced by the Workgroup.

- Net zero by full build out (estimated 2030)
- Cost-competitive for the market (assuming a shifting market and value-add for sustainability)
- Implementable (technically and financially)
- Achieving goals through a phased approach

Overview of Past Analyses

For the City, the energy and sustainability goals were initially identified in the Ford Site Roadmap to Sustainability (2011).² This included the following principles:

- To maximize the use of renewable energy.
- To reduce operating energy use in all buildings and infrastructure.
- To maximize energy self-sufficiency.
- To meet minimum performance thresholds:
 - Per the Minnesota B3 Sustainable Building 2030 (SB 2030) policy. The SB 2030 program is a progressive energy conservation program that helps buildings identify a pathway to reduce energy and carbon consumption in buildings and help building owners and operators report on their progress against these goals.³
 - Per the City of Saint Paul Sustainable Building Policy.⁴ The City and the Saint Paul Housing and Redevelopment Authority adopted sustainable development policies for public and privately developed buildings receiving more than \$200,000 in public financing.
- Meet on-site energy needs with a fully integrated district energy system
- Use all feasible types of renewable energy on-site
- Reduce fossil fuel energy consumption by utilizing low-energy building technologies.

⁴ https://www.stpaul.gov/departments/planning-economic-development/economic-development/sustainable-building-policy



²https://www.stpaul.gov/sites/default/files/Media%20Root/Planning%20%26%20Economic%20Development/FINAL%20-Ford%20Site%20Sustainability%20Report%20%28low%20res%29%205-2-11.pdf

³ http://www.b3mn.org/2030energystandard/

- Reduce building energy load through building insulation and energy efficiency.
- Purchase carbon free energy, as available.
- Reduce public infrastructure energy use by using low-energy or self-powered technologies (Note: current energy modeling does not reflect electricity demands of public infrastructure streetlights, etc.).

When Ramboll analyzed the system in 2015, they narrowed these goals to focus on resilience, innovation, net zero, energy efficiency, and cost-effectiveness. As their engineering and project management team worked through the list of potential fuels and technologies, they used these key criteria to determine the viability for the site and recommended solutions. The outcome of this effort was a focus on the potential of aquifer thermal energy storage (ATES), which is a form of geothermal energy exchange that can be paired with a district energy network and building heat pumps to greatly reduce the carbon emissions of a development. Given this potential, the City hired Underground Energy to further analyze this application. This analysis included a close look at the aquifers directly beneath the Ford Site and their viability to serve the proposed low-temperature DES.



Figure 1. Aquifer thermal energy storage heating and cooling mode. Courtesy of Underground Energy.



Figure 2. District energy facility



Overall, the ATES evaluation was quite promising for cost-effectiveness and carbon reductions. These results are discussed further in Section 2 Approach and Section 5 Source Energy Alternatives.

Implementation Plan Objectives

Cities are currently playing a critical role in energy planning in the United States. Local leaders are driving development solutions that maximize energy efficiency, renewable integration, and financial stewardship, as part of a commitment to affordability and growth. Additionally, it is common to see progressive city planners advocate for the following:

- Adaptable infrastructure serving the city for today's needs, but creating flexibility for the next generation of technological advances, which are coming to market faster than ever.
- Smart design identifying savings or successes that can be achieved by starting out on the right foot, including site layout, making buildings solar-ready, and considering long-term needs such as increased electric vehicle (EV) parking.
- Resilience energy infrastructure has always emphasized reliability, but today's planners, businesses, and citizens are expecting the infrastructure to withstand everything from 200-year storms to major swings in commodity pricing or fuel/energy availability.



• Utility integration – with major infrastructure investments on the horizon, local government is getting more adept at looking at how major infrastructure can be integrated and save costs both upfront and over the life-cycle. This includes looking across energy, water, waste, and fiber/data networks.

2. Approach

At the onset of this Study, Ever-Green and the City initiated a project kickoff where the City shared its vision for a district energy system that would serve the Ford Site. CSBR and Xcel helped shape the focus and identify the challenges for the work ahead. It was important to outline issues early on that could pose technical, financial, or political challenges. From there, Ever-Green's engineering team began incorporating the major elements into an energy and cost-assessment model, with a primary objective of achieving net zero as it relates to the GHG profile of the energy systems of the site. In order to design a net zero development, the team looked at both building efficiency alternatives and energy source options.

The City approved a public realm and zoning plan for the site in fall 2017 that split the parcel into six districts, allowing for a mix of uses. More information about the zoning and development plans are available on the City website for the Ford Site⁵. The planning and development process also produced a buildout scenario with square footage assigned to different uses. This concept was used as the base information for estimating the potential building loads, DES distribution network, and energy source options (primarily used for geothermal, ATES, and solar PV analysis).

The previous technical evaluations were considered thorough and effective in narrowing plausible options for the site and were used as a basis for the financial modeling that was the focus of this phase. To validate the results for the financial modeling, some assumptions were updated to reflect market conditions, including current market pricing for construction (labor and equipment). One significant change from the 2015 report was updating the business as usual (BAU) scenario for heating ventilation and air conditioning (HVAC) equipment. In the previous report, it was assumed that boilers and chillers would be the market standard to heat and cool buildings. However, in the past five years, multi-family construction has shifted to heating and cooling through unitary systems that are not central to a building, most commonly a Packaged Terminal Air Conditioner (PTAC) unit. A wellknown product in this genre is Magic-Paks, which can be seen commonly in multi-family construction in Minnesota. This type of unitary system is considered the BAU for meeting code in this analysis and can be much less expensive than installing centralized heating and

⁵ Department of Planning and Economic Development, 2017. City of Saint Paul. https://www.stpaul.gov/departments/planning-economic-development/planning/ford-site-21st-centurycommunity/zoning



cooling through boilers, chillers, or other systems that require a water-based loop throughout the building.

Another significant element to assessing energy and carbon for the site is analyzing the building load profile, which estimates the buildings' heating and cooling energy needs based on an energy use intensity (EUI). EUI is a projection of a building's energy use that is developed with consideration to the building's size, its use (programming), the effectiveness of the building envelope (materials and insulation), and other factors. For the purposes of this Study, two different energy profiles (EUIs) were evaluated. The first profile would meet the State of Minnesota current energy code using the most common HVAC applications for multi-family and commercial construction. The second profile assumed higher efficiency building design and HVAC equipment to be utilized, which would meet Minnesota B3 Sustainable Building 2030 (SB 2030) Energy Standard. Of the two different energy profiles, Ever-Green concluded that the ATES was only economically feasible to serve higher efficiency buildings, so two energy scenarios were used throughout feasibility analysis. This feasibility conclusion was based on the additional costs of capital that would be involved for the ATES if building load was substantially higher. The reduced energy profile for SB2030 allows pipes, pumps, and other equipment and operating costs to be more competitive with alternatives.

Scenario 1 - BAU/Code: Scenario 1 assumes that the buildings for this site would be built to current market standards, using PTAC units to provide heating and cooling and with the building envelope and HVAC equipment designed to meet state building code. This scenario would assume traditional gas and electric service to the site, with no additional onsite renewables in the first phase of development. Buildings with this noncentralized HVAC approach would not be compatible with an ATES/district energy system, because they do not include a water loop in buildings to circulate hot water or chilled water. PTAC units would generally not meet the SB2030 requirements for the site without significant investment in other efficiencies and renewables, so this scenario is primarily for cost comparison with other approaches.

Scenario 2 – Heat Pumps Paired with ATES and District Energy: Scenario 2 assumes that the buildings for this site would be built to above average market standards, meeting the sustainability requirements for the Ford Site. To meet these standards in multi-family and commercial buildings, a temperate district energy water loop would draw and release energy from an onsite aquifer. At the building, energy would be exchanged from the district energy water to the building's loop. Heat pumps would then optimize this energy for use in the buildings to heat or cool. This scenario assumes limited to no gas service for the site, with increased electric service to accommodate heating and cooling through electricity (i.e. heat pumps).



These scenarios are reviewed throughout the remainder of the report to validate financial feasibility and alignment with City and State goals.

3. Building Design and Efficiency

Establishing Efficiency in Building Design and Construction

The energy profile of the future buildings is a critical component of determining what is technically and financially feasible. The most cost-effective

approach to reducing the energy profile and carbon emissions for the site is to design, construct, and operate high-efficiency buildings. To this end, the Workgroup benefited greatly from the depth of research and analysis previously developed by the CSBR team. The CSBR team's previous work on the Ford Site included an EUI analysis which was used to develop the building load profiles presented within this section.

To promote the most efficient approach for the Ford Site, it is recommended the City and the developer continue working with CSBR to identify potential building design assistance and implement best practices for building development. Xcel Energy and any other utility partners should also be involved in optimizing the building profile for the site's energy goals and The most costeffective approach to reducing the energy profile and carbon emissions for the site is to design, construct, and operate highefficiency buildings.

alternatives. High-performance buildings with a lower energy profile will provide an economically attractive environment where building owners save money through increased efficiency and lower energy bills. The implementation of improved building energy efficiency will be as important as the energy sources to achieving the community's low-carbon, resiliency goals. Considering demand-side management during development increases the opportunities for demonstration projects and resident, tenant, and commercial participation.

Evolving Design Considerations and Efficiency Implementation

With the expectation of public funding for the site development, the Workgroup assumed the application of the City of Saint Paul's Sustainable Building Policy, which will set the expectation that buildings meet SB 2030 design standards. The evaluation scenarios show the comparison between code and SB 2030 to clarify the potential energy, carbon, and cost variances between the approaches.

Looking forward, it will be important that the expectations for the building energy profile be identified early so utilities, practitioners, engineers, and the developer can maximize the potential opportunities for energy and cost savings. The efficiency of the buildings will ultimately determine the viability of renewable energy integration for the site.



4. Estimating Building Load

4.1 Introduction to Building Load Estimation and Assumptions

Estimation of building load profiles was completed by the Ever-Green engineering team. This analysis incorporated the team's experience with building design, building operation and performance, alternative source connections (PTAC or district energy), International Energy Conservation Code 2012 (IECC 2012 - current code), and the SB 2030 program. Based on the obligations of the City of Saint Paul Sustainable Building Policy, The 80% SB 2030 threshold takes effect in 2020 and would be applicable to the initial buildout. Buildings built and occupied between 2025 and 2030 would be expected to meet 90% progress to the SB 2030. In addition to the efficiency gains, SB 2030 also has several advantages as a framework for the building design.

- SB 2030 is designed and tailored for Minnesota buildings.
- SB 2030 is a performance based standard, providing guidance for the design of energy efficient buildings beyond prescriptive requirements, giving developers site-specific flexibility, however, prescriptive guidelines are available.
- It has building use based standards that cover all development types applicable to Ford: commercial, multi-family, and detached residential (requested by Ryan Companies in their October 2018 proposal to amend the Ford Site Zoning and Public Realm Master Plan).





As a comprehensive, performance-based energy standard, SB 2030 looks at all of the systems in a building and how they collectively impact the building's efficiency. Systems that are modeled or calculated under this standard are:

- Building envelope
- Equipment energy efficiency
- Lighting power density and controls
- Domestic hot water
- Mechanical systems
- Use of renewables

The building load estimate was derived from two sources: the building square footage extrapolated from the City's Ford Site Zoning and Public Realm Master Plan, and the EUI factors developed by CSBR for purposes of examining energy efficiency design principles and solar PV development for the site. The City plan assumes a breakdown of building-use



square footage shown in Table 1. A developer master plan for the site is anticipated in 2018 and this analysis will need to be revised based on the actual building square footage in that development plan.

Table 1. Ford Site Planning. Square footage by building type per the 2017 Ford Site Zoning and Public Realm Master Plan

Туре	SQFT
Low Density	812,481
Housing	
Med Density	1,679,580
Housing	
High Density	1,959,836
Housing	
Civic	135,324
Retail and Mixed	300,651
Use	
Office	455,702
Total	
	5,343,574

To develop total heating, cooling, and electric load profiles, the following assumptions were applied to the model:

- Business as usual load profile based on the EUI at current code IECC 2012, ASHRAE 2010
- SB2030 this higher efficiency alternative load profile is based on predictive SB 2030 EUI, which is 80% of the ultimate SB 2030 standards (approximately 35-50% more efficient than code).
- The code scenario in the model is based on current state codes. These codes are slated to be updated in 2020, but that update is not contemplated in this model.
- The model does not designate a shift in load based on site development phasing. The Workgroup assumed a phasing strategy and this should be applied to the model after the developer submits a plan to the City. A major shift in construction to the latter end of phasing or a site layout that does not optimize distribution, could be detrimental to the ATES strategy.



• The model does not currently include assumptions for increased EV usage onsite. This should be included in the next version of modeling after the master developer provides additional information on anticipated units, parking, and strategies for EV integration.

These scenarios provide a baseload profile for which the life-cycle cost analysis was developed. Additional load profile information for SB2030 80% is included in Appendix III.

Building HVAC Systems

The Ford Site development will include different building types, including commercial, multiuse with commercial and residential, health care/clinic, and both multi-family and singlefamily homes. Each of these building types would utilize a different approach for heating and cooling (HVAC) systems, depending on its programming and the energy scenario selected. In the case of the proposed ATES system, a pumping mechanism will draw water from the aquifer and transfer energy via a heat exchanger into a low-temperature district energy system. This is done without mixing the aquifer water and the district energy system water. The low-temperature district energy system then carries the energy to the end users at the building's service entry where water-source heat pumps installed in the buildings raise or lower the water temperature for heating or cooling purposes.

Figure 4. Distributed heat pumps served by a low-temperature district energy loop in multi-family residential buildings



Another method that buildings can use with a low-temperature loop are fan coil units. A fan coil unit is a basic piece of equipment that can exchange heating or cooling within an HVAC



system through a fan and coil within the device. It is commonly used in residential and commercial buildings. A water-source heat pump serves the fan coil units from separate hot and chilled water distribution loops in the building, as shown in Figure 5. The hot water could also be used for radiant heating. The water-source heat pump is similar to an electric chiller and would be located in a mechanical room in the building. Domestic hot water can be generated through the heat recovery process and distributed and stored similarly to a central domestic hot water plant.



Figure 5. Water-to-water heat pump and four-pipe fan coil system

5. Source Energy Alternatives

Previous studies examined the options for source energy for this site at great length. The consensus from these efforts was that either ATES or traditional geothermal offered the most advantages to the project. This recommendation had been based on these technologies being implementable, cost-effective, and their potential to significantly reduce carbon. The primary exploration of this approach was first completed by Underground Energy in 2016 with a focus on ATES implementation.



What is ATES?

According to Underground Energy's Feasibility Study Report for the City of Saint Paul (2016), ATES is a sustainable geothermal heating and cooling technology that can yield significant, large-scale energy savings for buildings and energy districts that have large heating and cooling requirements and that overlie at least one productive aquifer. ATES is an open-loop, low-temperature geothermal technology that uses high-capacity wells for both withdrawal and injection of groundwater on a seasonal basis. ATES is well suited to application in low-temperature district energy systems, and the technology is well established in the Netherlands, where over 2,500 ATES projects have been commissioned.

Figure 6. Aquifer Thermal Energy Storage Cross-Section for Cooling Mode. Courtesy of Underground Energy.





Figure 7. Aquifer Thermal Energy Storage Cross-Section for Heating Mode. Courtesy of Underground Energy.



More simply put, an ATES system utilizes the low flow nature of the aquifer to reject heat into it during the summer and extract heat from it in the winter. In the summer, heat is extracted from customer buildings, and it is stored in the aquifer on one side of the site. Conversely, in the winter, heat is extracted from that aquifer water to heat customer buildings, and the cooled water is stored on another side of the site. Each building on the system will extract or input heat into the core water loop through heat pumps or heat recovery chillers.





Figure 8. Aquifer Cross-Section. Courtesy of Underground Energy.

Advantages

These types of systems are proven and reliable; having been in use for decades around the world. Energy cost reductions are a result of no natural gas being consumed with this system. A low-temperature district energy system also has a better opportunity to integrate renewable electricity through wind or solar photovoltaic generation. Integrating renewables into the electric source composition of an ATES system could enable buildings connected to the district energy system to be considered net zero carbon buildings.

Disadvantages

Currently, the ATES is proposed for the Prairie Du Chen Aquifer under the Ford Site parcel. To install this system, the Integrating renewables into the electric source composition of an ATES system could enable buildings connected to the district energy system to be considered netzero carbon buildings.

project developer or utility would need to secure a permit from the Minnesota Department of Health (MDH). The proposed approach (detailed in the full Underground Energy report), is



diligent about minimizing this risk by keeping any necessary water treatment isolated from the aquifer. Additional discussions and planning with MDH, as well as other state agencies will be critical to protecting the aquifer throughout the development process and operation of the ATES.

Viability

In order to enable the use of an ATES system for a larger site, district energy would be utilized as the distribution system and customer interface. District energy, in this approach, would deliver the energy from the ATES interface to the buildings within the site via a separated fresh water loop operating at temperatures of between 45°F and 65°F. Once it reaches the buildings, heat can be extracted or rejected dependent on mode. Today's high-efficiency, advanced heat pumps have a higher coefficient of performance, meaning they use less energy to add or subtract heat from the building, which has enabled more effective introduction of large-scale ATES installations.

The district energy system not only allows movement of energy to and from the ATES, it also helps balance the load across the site as some buildings may be rejecting heat at a time when other buildings can use it.

Overall, the ATES modeling yields a positive picture for advancing this solution.

- This aquifer can yield more than 1,000 gallons per minute (GPM) to water wells between about 220 and 490 feet deep.
- The well flow rate is 900 GPM per well (5,400 aggregate).
- The model estimated 12 ATES wells (6 warm/6 cold) with outputs of 53.6 MMBtu/hr peak (115,800 MMBtu annual) for heating. And output of 3,450 tons peak (66,900 MMBtu annual) for cooling. Assuming approximately 5.4 million square feet of conditioned space, this is enough energy to cover 75% of the heating and 100% of the cooling needs of the development. The system is scalable, and additional wells can be added to accommodate a future increase in building loads.

Traditional Geothermal

MEP Associates was consulted to examine traditional geothermal exchange, which would require significantly more wells and area for operations. MEP conducted a preliminary investigation of geothermal implementation feasibility with the purpose of establishing site geological conditions, available open land area, and whether financial feasibility supports installation of a geothermal heat exchanger. Their analysis found that to meet peak loads, the geothermal system would need between 15-23 acres using traditional U-bends. MEP did examine the potential of utilizing Rygan coaxial heat exchangers, as they require less area than traditional U-bends and would reduce geothermal space needs. However, the Rygan



grout is not acceptable in Minnesota, thus the Rygan coaxial heat exchangers could not be used. Given that this type of green space is not available at Ford, this option was not modeled within the scenarios.

Business as Usual (BAU) - PTAC Units, Boilers, and Chillers

Of the two scenarios, the first assumes a standard approach to multi-family residential and commercial buildings, which relies on PTAC or Magic-Pak units for the residential buildings and a combination of boilers and chillers for the commercial buildings.

Advantages

Individualized energy solutions, such as those suggested for the BAU scenario, allow for more individualized choice in energy/HVAC solutions. There may be some future tenants or business owners who prefer to not be connected to a larger thermal grid, although they will likely remain connected to a gas and electric grid for service. However, there are some energy customers who prefer to have more ownership of on-site production equipment, which may outweigh their valuation of environmental benefits and lower cost energy.

Disadvantages

Individualized units, such as the BAU options, may limit long-term flexibility for a building. For instance, it may be harder to add renewables or other decarbonizing solutions to the building energy profile with traditional HVAC equipment. Additionally, these units may create greater challenges with maintaining an efficient building envelope and long-term efficiency performance.

6. Financial Model

Ever-Green utilized the estimated capital costs presented in this report and the financial assumptions shown in the appendices to develop a life-cycle cost analysis (LCCA) for the proposed district energy system. The capital costs and estimated savings of the district energy system will be dependent upon the final development plan, distribution network, load profile, buildings connected to the district system, and other variables that have yet to be determined. The results of the LCCA analyses are summarized in the following tables.

Life-Cycle Costs Analyses Summary

A 30-year life-cycle cost analysis was completed for the two scenarios. This included analyzing upfront costs, financing costs, assumed energy and demand rates, operations and maintenance costs, and the costs of equipment and equipment replacement.

The upfront costs for building HVAC systems to meet current code were found to be approximately 10% lower than the upfront costs for those same buildings to meet SB 2030.



This could be prohibitive to developing the more sustainable system, however, when examined across a 30 year life-cycle, there are significant savings realized from the ATES/district energy approach. Primarily due to access to low-interest, long-term financing strategies and the savings of the ATES system compared to long-term gas prices and forecasting. These savings can be applied to overall sustainability investments, including HVAC equipment (heat pumps) through the long-term financing strategy for the district energy system (DES) business. However, if the site were to be developed only to current code standards, the additional costs shifted to the DES would make rates less competitive or create too much risk for the overall business structure. Due to the lack of cost-effectiveness, both upfront and life-cycle, it was determined that an ATES/district energy interface was only viable if the site stays on course to meet SB 2030 standards. This is represented in the two scenarios compared throughout the report.

Scenarios	30 Year Life-Cycle Cost
Scenario 1 - BAU - Code/PTAC	\$249,040,000
Scenario 2 - SB 2030/ATES/District Energy	\$242,560,000
Total Savings	\$6,480,000

Table 2. Life-Cycle Cost Analysis Summary

Life-Cycle Cost Factors

Overall financial results are affected by the following circumstances: interest rate increase, higher than expected construction bids, or fewer customers than anticipated connect to the system. There are also several opportunities to reduce cost and provide better savings that will need to be examined closer to the start of infrastructure development. These options include:

- Utilization of rebates for energy conservation. This will be dependent on future discussion related to fuel-switching, currently under evaluation by the Minnesota Division of Energy Resources.
- Availability of grants for demonstration projects and other integration of innovative technologies, efficiency measures, renewables, or carbon reduction strategies.
- Coordinating distribution piping construction with other site civil works could create the opportunity for cost sharing and reduced energy rates.



Project Financing

In order to support an ATES scenario, the financing would need to be publicly backed to mitigate the impact of a phased development schedule and non-rated system customers. This would offer access to long-term, low-interest financing, and lower overall energy-related costs.

If the ATES were to proceed, a non-profit business structure, with local stakeholder governance, would be optimal for the district energy system (DES) business. Additional models are noted in the report and could be considered in the next business planning phase, should this scenario move forward. An owner/operator for the DES is not defined.

7. Environmental and Greenhouse Gas Profile - Pathways to Net Zero

Achieving carbon neutrality and greater resilience are key tenets of the Ford Site vision for a 21st Century community. In reviewing the previous energy analyses for the site, it was clear that the immediate path forward needed to find a methodology that was implementable and financeable, while leading the development toward net zero. The SB 2030 building design approach coupled with the ATES district energy system, is the best-positioned approach for reaching these important goals for the site. To demonstrate the benefits of this approach, we conducted a GHG emissions analysis.

Greenhouse Gas Emissions Analysis

A GHG analysis was completed to compare the energy source alternatives. The report focused on SB 2030 as the standard for building efficiency. Buildings built to the SB2030 standard have a GHG profile that is 37% lower than buildings built to current code. When these high efficiency buildings are paired with ATES, the site can achieve 62% GHG savings in early phases. As Xcel continues to decarbonize the grid, the Ford energy system will also decarbonize, with an estimate of 75% savings beyond BAU in 2030. These savings are a combination of avoided energy use in high efficiency buildings, substituting natural gas service with low-temp district energy and ATES, and continued decarbonization of the electric grid. The ATES is key to enabling this beneficial electrification approach, meaning buildings energy consumption is primarily electric.

	Energy and GHG			
	MMBtu	kWh	GHG (Tons)	Percent Savings
BAU Code	145798	6584720	11430	6.2%
ATES SB2030	0	9928539	4373	0270

Table 3. 2020 GHG Emission Scenarios (electric grid - 881 lbs CO2/MWh)



Table 4. 2030 GHG Emission Scenarios (electric grid - 521 lbs CO2/MWH	Table 4.	2030	GHG Emission	Scenarios	(electric grid	- 521 lbs	CO2/MWH)
---	----------	------	--------------	-----------	----------------	-----------	----------

	Energy and GHG			
	MMBtu	kWh	GHG (Tons)	Percent Savings
BAU Code	145798	6584720	10244	750/
ATES SB2030	0	9928539	2586	/ 5%

Table 5. 2020-2030 GHG Scenario Comparison

Scenario	GHG- Tons
BAU Code	11430
ATES SB2030	4373
2030 BAU Code	10244
2030 ATES SB2030	2586

Figure 9. 2020-2030 GHG Scenario Comparison





Table 6. Thermal Load Shifting Scenarios Gas-Electric

Energy Comparison (MMBtu)			
	Gas load	Electric load	
BAU Code	145798	22450	
ATES SB2030	0	33851	

Figure 10. Thermal Load Shifting Scenarios Gas-Electric





Figure 11. Carbon Equivalent - Greenhouse Gas Savings 8,844 Metric Tons. According to the Environmental Protection Agency's Greenhouse Gas Equivalencies Calculator



Findings

Combining high efficiency building design and construction (SB 2030) with a lowtemperature district energy system ATES is an implementable path forward to achieve significant GHG reductions and should be pursued as the priority approach.

This approach will significantly reduce the carbon profile of the site, but does not completely eliminate the carbon footprint. As the plans with the master developer are refined, it will be important to spend additional time identifying the intermediary strategies that will supplement the high-performance buildings and ATES approach. These additional discussions should include the following:

- Offset programs these programs reinforce the commitment of the City and the master developer to carbon neutrality, while recognizing some of the limitations of the site and the phased approach of development.
- Solar PV and battery storage these are explored in Section 9 and are recommended to be a priority tactic to explore closer to development.



8. Innovation

The City's commitment to a 21st Century community sets the stage for the Ford Site to incorporate leading-edge technology. The plan for this site takes the long-term view for success, which creates the opportunity to get started with the solutions that are the best fit for the site objectives and are both technically and economically feasible for near-term infrastructure development. The Workgroup recommends continued evaluation of the preferred solution, which pursues the higher efficiency building profiles (SB 2030) and ATES district energy. Together, this approach helps the site achieve a 58% carbon reduction beyond the business as usual approach (standard building code with PTAC units). The district energy approach will also create a flexible infrastructure that will allow additional renewable and efficiency technologies to be integrated as they become market ready. It is also anticipated that the electric grid will continue to decarbonize (as noted in Section 8), allowing for the delivered electricity to the site to see significant carbon reductions by 2030.

In support of both the net zero carbon and innovation goals, the Workgroup identified several areas of potential for the site; 1) Near-term demonstration projects 2) Ongoing advancement opportunities (blue-sky alternatives) 3) Data and Energy Tracking

Near-Term Demonstration Projects

The Ford Site presents several opportunities to integrate advanced technology, renewable energy, and energy efficiency strategies. The following list represents opportunities that are expected to be implementable during site development and through the early years of building occupancy.

Tactic 1 - Beneficial Electrification

Over the past three years, there has been a significant push in the energy industry to accelerate electrification of all sectors; electricity, heating and cooling buildings, transportation, and industrial. This campaign has been motivated by the increasing decarbonization and flexibility in the modern electric grid and particularly the Xcel electric grid serving this region. By increasing electric service, the intention is to increase renewable options and decarbonize all sectors. The beneficial (or strategic) electrification approach, takes this into consideration, but also emphasizes customization to incorporate renewables and low-carbon solutions beyond electricity. For example – there are several sites in Minnesota considering an interface with sanitary sewer lines and groundwater to use them as a heat source and sink, similar to geothermal. When paired with heat pumps, the ATES approach shifts the Ford site load away from fossil fuels, but does not exclusively shift to electricity. The advantage of this approach is focusing the solution on efficiency and carbon savings, regardless of the energy source.



Applying this strategy for the Ford Site comes in the form of the ATES paired with lowtemperature district energy distribution. This approach allows for the Ford Site to minimize natural gas service to the site, instead using heat stored in the aquifer paired with heat pumps to displace natural gas heating. Implementation of this approach would put Saint Paul on the forefront of modern development strategies, balancing resilience goals with affordability. This infrastructure would make the Ford Site a destination for other communities planning major brownfield or greenfield redevelopment. That said, the site holds much more potential to integrate both small and large-scale solutions.

Tactic 2 - Advanced building design

The University of Minnesota Center for Sustainable Building Design Research has extensive information regarding best practices for building design to meet the SB 2030 design guidelines and operationalize best practices in building design and efficiency. Working with this team and other regional experts will provide the most financially viable and implementable pathways to smart building design that works for this site and its planned uses.

Tactic 3 - Solar PV paired with battery storage

The Workgroup agreed that solar PV and battery storage would be the two most likely technology advancements that could be market ready by 2023. The PV technology is already thoroughly demonstrated in Minnesota, but was not modeled during this phase of work because the costs for the development timeline are unknown. It is recommended that this solution be planned for in



the site infrastructure and thoroughly discussed with the master developer in the early stages of planning. This will give the utilities sufficient lead time to plan for any necessary changes to their infrastructure and service to the site. Within 12 months of major infrastructure implementation, these solutions should be thoroughly vetted and a cost analysis done with best available information about the market trajectory.

The ownership structure for these assets should be considered at a future date. Legislative changes and available programs should determine the most cost-efficient way to tie these resources into this localized grid.

Tactic 4 - Electric Vehicle (EV) stations

The carbon neutrality approach for this site should also consider reduction of car trips and optimization of EV infrastructure. EVs are the fastest growing automobile market segment,



with most major manufacturers expecting to have EV representing 50% of their market by 2030. Several European countries are contemplating bans of fossil-fuel vehicles as early as 2025. Access to EV charging and public transportation will be critical to both the carbon reductions attributed to the site, but also the marketability of the site to multigenerational tenants.

To remain competitive, the master developer should consider integration of Level 2 charging stations, which would require access to 240



volt (240V) service within their parking structures. The DCFC (Level 3) chargers are on the rise, however, they are more expensive and require a 480 volt connection. They are also targeted at charging on shorter timelines and may not be necessary for this application.

Finding

This infrastructure should be established to adapt to the market penetration of EVs. As a starting place, we recommend the master developer consider providing EV charging for 10% of its parking spaces during the initial phase of development, while ensuring that more stations can be added within this same parking infrastructure. Future phases should increase minimum requirements in line with market increases and best available technology.



Metering and Data Management

Beyond carbon, it is important for this modern infrastructure approach to also emphasize data availability to energy consumers and building operators. To support this effort, Ever-Green recommends the following to be considered for this site:

- Sub-metering has the potential to lead to lower energy use since tenants directly see and pay for their energy use. Smart home appliances (e.g. Samsung)
- In-home network hubs, software and apps (e.g. SmartThings)
- Smart switches, plugs, and plug switching capabilities (e.g. Belkin WEMO)
- Connect light bulbs (e.g. Philips Hue)
- In-home energy storage/fuel cells and car-to-car charging (e.g. Honda's Home Energy Management System)
- In-home zoned temperature controls (e.g. Honeywell)

Ongoing Advancement Opportunities (Blue Sky Discussion)

There are several technologies and renewable applications that could be considered for the site at a future date in development. They are outlined here to serve as a reference to the discussions with the master developer.

- A microgrid does not appear to achieve high priority status for deployment to this site, based on the expectation that electricity production options are somewhat limited on-site and the current master plan does not identify critical functions for the site. As plans are refined, this could be revisited to maximize resilience planning and onsite options.
- Building integrated photovoltaic panel systems (e.g. BISEM)
- Photovoltaic or electrochromatic glass (e.g. Guardian Ecoguard glass)

9. Community Engagement

To-date there has been extensive outreach and engagement for the Ford Site as it has moved through phases of study, planning, remediation, and now the prospect of development on the horizon. The City of Saint Paul and regional stakeholders clearly care about the future of this site. The former Ford plant production, jobs, and role in the community created a connection that will follow the site as it establishes new purpose, develops innovative and resilient infrastructure, and sees new stewards implementing its next evolution.



Because of this high level of both tangible and intangible investment in this property, it is critically important that the next phase of energy discussions involve both the geographic community and the many stakeholders who are interested in what's next. These efforts will need to merge the interests of the City of Saint Paul, Ford, and the master developer to achieve the best outcomes. In an effort to facilitate this engagement, Ever-Green recommends consideration of the following activities:

- Development and sharing of community education materials, which could include web content, handouts, illustrations, animation, video, and other content that can help vested individuals and organizations understand the potential infrastructure and innovation being recommended. This should be seen as an opportunity to celebrate the innovation and possibilities that can be realized on the site and what sets it apart from other developments.
- Establish a series of public workshops to learn more about what the solution means to the community, how it will be experienced for those living and working on the site, and what the sustainability and financial benefits would be realized by the preferred approach. These sessions should be designed intentionally around the needs and interests of the stakeholder groups, so the level of technical discussion and opportunity to share questions and concerns is welcomed in the forum.
- Provide opportunities to organizations previously engaged or now engaged through Mayor Carter's administration to schedule sessions with the Project Team or other subject matter experts to discuss their interests.

10. Organizational Structure Alternatives

The determination of a system's organizational and financing model will have a lasting impact on the success of the system. The right business model depends upon a number of factors, including the project goals, the needs of the prospective customers, and the objectives of key stakeholders. Some options for potential structures include publicly owned, a private non-profit structure, a private for-profit structure, and a hybrid publicly-owned infrastructure operated as a private non-profit company.

Public business structures can be owned by a public entity like a city, county, or state. In this case, system financing could be based upon long-term customer contracts or it could be part of the public body's capital infrastructure budget and rates could be cost-based. A public system approach could provide access to low-cost financing and cost savings by implementing in parallel with other infrastructure projects. However, this approach may have challenges from blending private market development with the public sector model. Montpelier, Vermont has successfully implemented this model with District Heat Montpelier.



A private business model could be set up as a non-profit or a for-profit business. Both could be operated and managed by a third party, potentially utilizing a customer-represented board and third party operations and management partner, and would raise debt and equity based upon long-term customer contracts. The for-profit version may rely on the investors' balance sheets. The non-profit model would operate much like a cooperative, which may be more enticing for establishing long-term contracts. However, private financing of a non-profit model may be more challenging in certain markets. District Energy St. Paul has successfully used the non-profit model for nearly forty years. If developed as a private for-profit company, accelerated depreciation could allow the business to be more profitable in its early development. However, this approach may conflict with the community energy vision if it does not align with the interests of the system owner or stockholders.

There is also the option of a hybrid system with publicly-owned infrastructure and a private non-profit company. Under this scenario, a public body could invest in the infrastructure for the energy system, but a private non-profit entity could be formed for purposes of the energy business. Governance of this structure could be similar to the private, non-profit model, where the public body, customers, and local stakeholders cooperate in setting the strategic direction for the business. This hybrid model would leverage many of the benefits of each of the other business models. Energy Park Utility Company in Saint Paul, MN is one version of the hybrid model.

Organizational Development Recommendation

Given the existing local utility partnerships, the City should work with the Master Developer to review options and approaches. The Master Developer will likely have a preferred approach to business partnership and infrastructure development that will need to be integrated with the City's expectations, franchise agreements, financing approaches, and organizational readiness.

11. Conclusion and Next Steps

The following are the primary conclusions from the implementation planning:

- The ATES scenario is the best-positioned option to provide a cost competitive solution that meets sustainability objectives for the site.
- The developer costs for services from the ATES would be equal to the BAU alternative.
- To achieve net zero goals, gas service to the site should be limited to strategic placement for essential services or as density or development schedules necessitate.



- Energy efficiency (as outlined by SB 2030 building load scenarios) is key to meeting the carbon, energy savings, and cost savings objectives for the project.
- Ever-Green Energy also recommends a discussion with the Minnesota Housing Finance Agency about how these approaches fit into the affordability index and potential to promote affordable housing that works with sustainable solutions.

Effective implementation of an ATES system assumes the following:

- Credit enhancement of financing is available.
- Minnesota Department of Health (MDH) will permit the ATES interface.

Next Steps

Should the ATES be recommended to proceed by the City and master developer, the following would be the next steps:

- Engage MDH and other relevant state agencies to proceed with permitting activities
- Install test wells at the site to validate the aquifer water flow assumptions.
- Engage the master developer (and other stakeholders) in business planning.
- Finalize a site development timeline, which will dictate energy infrastructure next steps.
- Determine an education and outreach plan for community stakeholders.
- Discuss credit enhancement strategies with City/others as appropriate.
- Establish or identify a business to develop, own, and operate the DES.
- In order to achieve a net zero plan for development, solar PV and energy storage should be modeled closer to developer build out, leaving enough time for construction integration, financing, and utility integration. Modeling at this time will provide a more accurate market valuation and utilize best available technologies.

Summary

The opportunities at the Ford Site offer a viable and feasible pathway to carbon neutrality that will position this development as a national demonstration project for integrated energy efficiency, renewables, and beneficial electrification. An ATES district energy approach sets the stage for a phased approach for additional pilot projects and technology innovation, while also providing for reliable and effective energy to the many new residents and businesses who will be served by the system. As final planning proceeds with the master developer, the Workgroup will continue to serve as an important resource to refining the approach and helping the partners achieving the important objectives set forth by the City.



Appendices

Appendix I: Aquifer Thermal Energy Storage Feasibility Study Report - Underground Energy

Appendix II: Building Load Profiles

Appendix III: Life Cycle Cost Analysis Assumptions

Appendix IV: MEP Assessment of Geothermal for the Site

Appendix V: University of Minnesota Center for Sustainable Building Research Site Analysis



Executive Summary

Underground Energy, LLC performed a feasibility study of Aquifer Thermal Energy Storage (ATES) for heating and cooling of the proposed redevelopment of the Ford Site in Saint Paul, Minnesota. ATES is a sustainable geothermal heating and cooling technology that can yield significant, large-scale energy savings for buildings and energy districts that have large heating and cooling requirements and that overlie at least one productive aquifer. ATES is an open-loop, low-temperature geothermal technology that uses high-capacity wells for both withdrawal and injection of groundwater on a seasonal basis. ATES is well suited to application in low-temperature district energy systems, and the technology is well established in the Netherlands, where over 2,500 ATES projects have been commissioned.

The Twin Cities area has excellent climatic and hydrogeologic conditions for ATES; cold winters and large summer cooling demands are well suited to the application of seasonal thermal energy storage, and the area is underlain by multiple aquifers capable of providing high well yields. ATES systems are carefully designed and operated so that temperature is the only characteristic of the water that is modified; no chemicals or additives are injected into the aquifer. Balance is a key characteristic of ATES systems, the injection and withdrawal rates are balanced, the hydraulic conditions in the aquifer are seasonally balanced, and the systems are typically designed so that net thermal balance on the aquifer is maintained.

The preferred aquifer for ATES beneath the Ford Site is the Prairie du Chien-Jordan aquifer, which typically yields more than 1,000 gallons per minute (gpm) to water wells, and occurs at depths between about 220 and 490 feet at the Site. Deeper aquifers could also be utilized for ATES projects but with decreased well yields (more wells needed to meet a given thermal capacity) and higher drilling cost.

Underground Energy's conceptual design for an ATES system uses an estimated maximum ATES well flow rate of 900 gpm per well (5,500 gpm aggregate), a diversified heating load of 53.6 million British Thermal Units per hour (MMBtu/h) peak and 115,800 MMBtu of annual energy consumption (excluding domestic hot water production), a diversified cooling load of 3,450 Tons peak and 66,900 MMBtu of annual thermal energy consumption. These loads are based on approximately 6.5 million square feet of conditioned space. More than 75% of the annual cooling demand can be met with direct cooling enabled by seasonal thermal energy storage.

The conceptual design is based on boundary conditions that assume a low temperature heating system and a high temperature cooling system, with each building having its own centralized or individual domestic hot water system(s). Our conceptual design comprises a total of 12 ATES wells (6 warm and 6 cold wells) connected to a groundwater loop that connects heat pumps in individual buildings to the warm and cold ATES wellfields.

An estimated investment cost of \$27 million was calculated for both the ATES system and for the business-as-usual (BAU) scenario of a new, efficient four-pipe insulated district heating & cooling system with centralized gas boilers and electric chillers. Despite their comparable capital costs, the ATES system can provide savings on primary energy consumption of about 40% compared to the BAU scenario. Due to the greater energy efficiency of ATES, the estimated operating cost of an ATES system was calculated to be about 17% lower than for the BAU scenario.

While technical and financial measures of ATES feasibility at the Ford Site are strong, obtaining the necessary regulatory approvals will be an equally important component to development of an ATES project at the Ford Site. The salient regulatory issues lie within the jurisdiction of Minnesota Department of Health (MDH) under MR 4725.2050, which prohibits injection of any material into a well or boring in Minnesota. An exemption exists for smaller open-loop geothermal system (up to 50 gpm), but the only option for an ATES system, short of a change in law, is to seek a variance from the rule. There is precedent for a variance to that rule for an Aquifer Storage Recovery project, and MDH representatives have indicated a willingness to consider similar variances for ATES projects.

Underground Energy concludes that an ATES project is feasible at the Ford Site, where climate and aquifer conditions are ideal for this large-scale, sustainable heating and cooling technology. We recommend that pre-design activities include a phased, on-Site hydrogeologic study to confirm or modify the estimates of subsurface conditions that were the basis for our conceptual design, and to facilitate detailed design and financial analysis.

Table of Contents

Execu	tive Summary	1
Gener	al Report Disclaimer	i
Table	of Definitions and Acronyms	i
1.0	Introduction	3
1.1	GeoExchange and ATES	3
1.2	ATES Principle	4
2.0	Methodology	6
3.0	Site Hydrogeologic Evaluation	7
3.1	Data Compilation and Review	7
3	.1.1 Publically Available Hydrogeologic Data	7
3	.1.2 Site Specific Hydrogeologic Data	7
3.2	Conceptual Site Model	8
3	.2.1 Site and Regional Stratigraphy	8
3	.2.2 Aquifer Physical and Hydraulic Properties	12
3	.2.3 Aquifer Geochemical Properties	14
3.3	ATES Well Sizing	14
3.4	Proximity to Public Supply Wells	16
4.0	Building Information and Building Loads	18
4.1	Building Information	18
4.2	Building Loads	18
5.0	ATES System Conceptual Design	22
5.1	Configurations for ATES based DH&C Systems	22
5.2	Groundwater Distribution Options for ATES based DH&C Systems	23
5.3	ATES based DH&C Network for the Ford Site	26
5.4	Energy and Water Savings and Emissions Reduction Estimate	28
6.0	Initial ATES System Sizing	33
7.0	Financial Analysis	35
7.1	Investment Cost Estimate	35

7.2	Estimated Financial Benefit	. 37
8.0	Regulatory Evaluation	. 38
8.1	Underground Injection Control	. 38
8.2	Minnesota Pollution Control Agency	. 38
8.3	Minnesota Department of Natural Resources	. 38
8.4	Minnesota Department of Health	. 39
8	8.4.1 Prohibition of Underground Injection	. 39
8	8.4.1 Mt. Simon Aquifer Prohibition of New Appropriations	. 39
9.0	Conclusions	. 40
9.1	ATES Feasibility Summary	. 40
9.2	ATES Benefits	. 40
9.3	ATES Technical and Regulatory Feasibility	. 41
9.4	ATES Financial Feasibility	. 41
10.0	Recommendations	. 42
11.0	References	. 43

List of Tables

13
15
18
19
19
22
30
31
33
36
37
40
List of Figures

Figure 1 - Principle of ATES in heating (winter) and cooling (summer) mode	5
Figure 2 – Graphic depiction of bedrock aquifers beneath the Ford Site	8
Figure 3 - Paleozoic bedrock stratigraphy near the Ford Site	10
Figure 4 - Groundwater flow in the Prairie du Chien-Jordan aquifer	11
Figure 5 - Area Public Supply Wells	17
Figure 6 - Heating load duration curve for the Ford Site	20
Figure 7 - Cooling load duration curve for the Ford Site	20
Figure 8 - Distribution system selection flowchart	23
Figure 9 - Four-pipe groundwater distribution, passive building connections	24
Figure 10 - Two-pipe groundwater distribution, active building connections	24
Figure 11 - Active building connection	25
Figure 12 - Principle of ATES system in heating mode (winter operation)	26
Figure 13 - Principle of ATES system in cooling mode (summer operation)	27
Figure 14 - Energy flows ATES/HP system (without distribution losses)	29
Figure 15 - Conceptual Site Layout	34

Appendices

Appendix A – Minnesota Department of Health Variance Request Application

General Report Disclaimer

This report has been prepared by Underground Energy, LLC for the benefit of the Client to whom it is addressed. The information and data contained herein represent Underground Energy's best professional judgment in light of the knowledge and information available to Underground Energy at the time of preparation.

Cost estimates or estimates of profit or return on capital provided by Underground Energy to the Client as part of this study are subject to change and are contingent upon factors over which Underground Energy has no control. Underground Energy does not guarantee the accuracy of such estimates and cannot be held liable for any differences between such estimates and ultimate results.

Underground Energy denies any liability whatsoever to other parties who may obtain access to this report for any injury, loss or damage suffered by such parties arising from their use of, or reliance upon, this report or any of its contents without the express written consent of Underground Energy and the Client.

ASR	Aquifer Storage and Recovery
ATES	Aquifer Thermal Energy Storage
BAU	business as usual
bgs	Below ground surface
BTES	Borehole Thermal Energy Storage
СОР	Coefficient of Performance
CSM	Conceptual Site Model (hydrogeology)
CVOCs	Chlorinated Volatile Organic Compounds
CWI	County Well Index
DH&C	District Heating and Cooling
DHW	Domestic Hot Water
DNR	Minnesota Department of Natural Resources
EPA	Environmental Protection Agency
EUIs	Energy Use Intensities
GIS	Geographic Information System
HDPE	High Density Polyethylene

Table of Definitions and Acronyms

НР	Heat Pump
LDC	Load Duration Curve
MDH	Minnesota Department of Health
MFI	Membrane Filter Index
mg/L	Milligrams per liter
MGS	Minnesota Geological Survey
MMBtu	Million British Thermal Units
MMBtu/hr	Million British Thermal Units per Hour
MR	Minnesota Administrative Rules (regulations)
MSL	Mean Sea Level (reference datum)
MW	Megawatt
PCA	Minnesota Pollution Control Agency
PCBs	Polychlorinated Biphenyls
SDI	Silt Density Index
sf	Square feet
SPF	Seasonal Performance Factor (avg. COP over heating/cooling season)
АТ	Delta T, temperature difference (typically between supply and return
	temperatures)
UIC	Underground Injection Control
USGS	United States Geological Survey

1.0 Introduction

This Feasibility Study report has been prepared for the City of Saint Paul by Underground Energy, LLC. The objective of this ATES feasibility study has been to collect and analyze available data to assess the technical, regulatory and economic feasibility of Aquifer Thermal Energy Storage (ATES) for sustainable heating and cooling for the proposed redevelopment of the Ford Site in Saint Paul, Minnesota (the Site).

The Ford Site is 135-acres of land on the Mississippi River in Saint Paul, Minnesota for which a 21st Century Community is envisioned. Ford's former Twin Cities Assembly Plant will be redeveloped as a livable, mixed use neighborhood that looks to the future with clean technologies and high quality design for energy, buildings and infrastructure. A November 2015 Energy Study Report of the Ford Site by Ramboll and Krifcon Engineering identified ATES as a promising technology in a district energy concept that should be evaluated in more detail, which was the basis for Underground Energy's feasibility study.

Saint Paul is unique from a historical energy perspective, where it was the site of some of the earliest ATES research and pilot testing ever performed during the 1980s. The earlier high-temperature (150 °C) ATES tests were not viable for long-term operation, but the research pointed the way to the technical and economic benefits of low-temperature ATES, which was subsequently developed and commercialized in Europe. The Ford Site offers a unique and exciting opportunity for Saint Paul to realize the benefits of ATES coupled with district heating and cooling and to lead the nation in the commercial development and sustainable operation of ATES systems.

1.1 GeoExchange and ATES

GeoExchange technologies all utilize the subsurface as a low-temperature heat source for heating or as a heat sink for cooling, typically using geothermal heat pumps in this heat exchange. The most common GeoExchange installations are closed-loop geothermal systems that circulate a glycol solution in a closed-loop high-density polyethylene (HDPE) piping network between borehole heat exchangers installed in borings and heat pumps. Open-loop geothermal systems typically withdraw water from an aquifer and pass the water through a heat pump after which the heated (in summer) or cooled (in winter) water from the heat pump is discharged either back into the aquifer, or to surface water, or even into a municipal water system. The common feature of closed loop and "once-through" open-loop geothermal heating and cooling systems is that they use the earth as a heat sink or as a heat source. The primary difference between ATES and other GeoExchange technologies is that ATES uses the earth not as a passive heat sink/source, but as a thermal battery, where warm and cold water is stored in separate portions of the aquifer. These warm and cold stores are charged and discharged seasonally, resulting in significant energy efficiency improvements over other GeoExchange applications. ATES is an open-loop geothermal technology that uses high-capacity wells for both withdrawal and injection of groundwater on a seasonal basis. ATES systems are optimized for thermal energy storage on a seasonal timeframe; it is possible to size an ATES system to meet (part of) the cooling demand with direct cooling, i.e. without running the heat pump. Normally, direct cooling can only be used by buildings on days when outside air temperatures are low, which, of course, is when cooling demand is low. ATES enables seasonal thermal energy storage, which allows chilled water injected and stored during winter to be recovered and used in summer for direct cooling. Because direct cooling with ATES is accomplished with circulation pumps rather than compression chillers, significant energy reductions can be realized, typically about 60% compared to conventional chillers. Similarly, warm return water in summer is injected to recharge the aquifer warm store, where it will be extracted the following winter. Because the warm store temperature is typically higher than ambient groundwater temperature, heat pumps operating in winter mode see a smaller "lift," the temperature difference between the heat source and the heating supply temperature. As the lift required of a heat pump decreases, its energy efficiency increases.

At present, there are over 2,500 ATES systems operating in Europe, most in the Netherlands, where climate and aquifer conditions are well suited for ATES.

1.2 ATES Principle

An ATES system is a large open-loop geothermal system optimized and operated to realize seasonal thermal energy storage by reversing extraction and injection wells seasonally. The basic principle is explained below for an application in which ATES is used for heating and cooling.

Figure 1 displays the basic principle of an ATES system that is used for both cooling and heating. In summer, groundwater is extracted from the cold well(s) and used for cooling purposes, depleting the cold store over the cooling season. The warmed return water is injected in the warm well(s) to recharge the warm store. In winter the process is reversed: water is pumped from the warm well(s) and applied as a low temperature heat source for a heat pump. After the exchange of heat the chilled water from the heat pump is injected into the cold well(s), recharging the cold store for use the following summer.



Figure 1 - Principle of ATES in heating (winter) and cooling (summer) mode

All the water extracted from the cold store is re-injected into the warm store. There is net extraction of groundwater, so despite the fact that ATES systems operate at high flow rates, there is no consumptive use of groundwater. ATES systems are carefully designed and operated so that temperature is the only characteristic of the water that is modified; no chemicals or additives are injected into the aquifer. Balance is a key characteristic of ATES systems, the injection and withdrawal rates are balanced, the hydraulic conditions in the aquifer are seasonally balanced, and the systems are typically designed so that net thermal balance on the aquifer is maintained.

ATES systems require a minimum distance between warm and cold wells, depending on site conditions and thermal capacity of the system. ATES systems require three primary site-specific physical characteristics: (1) an aquifer capable of yielding high flow rates to wells, (2) seasonally variable (and preferably, relatively balanced) heating and cooling requirements, and (3) large thermal loads, typically greater than 100,000 square feet (sf) of conditioned space. All three of these conditions exist at the Ford Site.

2.0 Methodology

This ATES Feasibility Study report for the Ford Site was prepared by a team that included <u>Underground Energy, LLC</u> and IF Tech USA LLP. Our team was supported by Ever-Green Energy, Inc. (Ever-Green), who provided estimated average heating and cooling loads and input on district energy system costs.

A hydrogeologic evaluation was performed using existing data, and potential yields of ATES wells were estimated. Estimated heating and cooling loads were provided by Ever-Green Energy, Inc. The well sizes and the loads are the design basis for a district-energy-based ATES system, for which a conceptual design was patterned after a conceptual layout prepared previously by Ramboll. A cost estimate was developed and the energy and economic benefits of ATES were compared to a district energy system with centralized gas-fired boilers and centrifugal chillers. Finally, a regulatory evaluation was performed, and Underground Energy participated in meetings with City of St. Paul staff and Minnesota regulatory officials.

3.0 Site Hydrogeologic Evaluation

3.1 Data Compilation and Review

3.1.1 Publically Available Hydrogeologic Data

The following sources of publically available information were useful in the development of a conceptual hydrogeologic model of the multi-aquifer setting of the Ford Site and of the Twin Cities region:

- Geologic Atlas of Ramsey County (1992),
- Metropolitan Council Twin Cities Regional Groundwater Flow Model V3 (2014),
- Minnesota Geological Survey (MGS) Report of Investigations 61 (2003),
- United States Geological Survey (USGS) Water Resources Investigations Reports, and
- County Well Index (CWI) database created and maintained by MGS.

A complete list of references reviewed is included in Section 11.0.

3.1.2 Site Specific Hydrogeologic Data

Site-specific hydrogeologic data were included in the Comprehensive Phase II Site Investigation Report that was prepared for Ford Motor Company by Arcadis U.S., Inc. (2015). The focus of the Phase II report was on soil and groundwater contamination at the Ford Site, which was primarily limited to the shallow portions of the unconsolidated glacial overburden at the Ford Site. The deepest bedrock unit investigated in the Phase II report was the St. Peter Sandstone, at the base of which is a confining unit that hydraulically separates the St. Peter Sandstone from the underlying aquifers considered for ATES in this feasibility study (Mossler, 1992).

Arcadis' Phase II report identified that some dissolved metals, diesel-range organics, cyanide and PCPs have been detected in the St. Peter sandstone aquifer at concentrations exceeding applicable regulatory screening values. However, these detections in St. Peter aquifer groundwater have been of low concentrations, isolated and not repeatable. (The source of the compounds had not been determined at the time of this report.) Chlorinated volatile organic compounds (CVOCs) are considered the contaminant of greatest concern to development of an ATES system because they are denser than water in their non-aqueous phase and tend to sink into deeper aquifers, because they are mobile and recalcitrant in groundwater, and because they pose significant human health risks and are difficult to remediate. No CVOCs have been detected in the St. Peter Sandstone beneath the Ford Site, and they are therefore unlikely to be detected in deeper aquifers. It is Underground Energy's opinion that the suitability for ATES of aquifers below the St. Peter sandstone historic land uses at the Ford Site.

3.2 Conceptual Site Model

A conceptual site model (CSM) has been developed in the following sections to facilitate interpretation of hydrogeologic conditions at the Ford Site in Saint Paul. The CSM is based on Underground Energy's review and interpretation of published hydrogeologic and subsurface data in the vicinity of the site.

3.2.1 Site and Regional Stratigraphy

The Twin Cities area is underlain by a mantle of Quaternary age glacial deposits that range in thickness from zero (exposed bedrock outcrop) atop Mississippi River bluffs to over 400 feet in buried bedrock valleys. These glacial deposits unconformably overlie more than 1,000 feet of nearly horizontal Paleozoic age sedimentary rocks. These bedrock formations comprise multiple sandstone and carbonate aquifers separated by shale confining layers. These units are laterally extensive on a scale of tens to hundreds of miles. The bedrock units tend to be more fractured within about 200 feet of the top-of-bedrock surface, and the limestone and dolomite (carbonate) units of the Prairie du Chien group exhibit dissolution enlargement of vertical and horizontal fractures and karstic behavior with respect to permeability and groundwater flow.

Figure 2 presents a graphic depiction of the bedrock aquifers and shale confining units that underlie the Ford Site.



Figure 2 - Graphic depiction of bedrock aquifers beneath the Ford Site

At the Ford Site, the unconsolidated glacial deposits range from zero to about 15 feet thick (Arcadis, 2015), and comprise both coarse-grained and fine-grained units. The glacial overburden deposits at the Ford Site are mapped as "stream sediment of Glacial River Warren" (Meyer et. Al, 1992). The overburden deposits may locally yield fairly large flow rates to properly constructed wells, but they are not considered suitable for ATES use at the Ford Site due to their thin nature and low transmissivity (which is the product of aquifer thickness and hydraulic conductivity). The surficial deposits overlie the uppermost late Ordovician bedrock formations at the Ford Site, either the Decorah Shale or the Platteville limestone/dolostone, which overlies the Glenwood shale. These upper bedrock units are not considered suitable for ATES use at the Ford Site due to low transmissivity. The Glenwood shale overlies the mid-late Ordovician St. Peter Sandstone, which can be a productive aquifer in southeastern Minnesota, however the St. Peter sandstone is not considered suitable for ATES at the Ford Site due to expected locally unconfined (phreatic) and unsaturated conditions and relatively low expected well yields. The base of the St. Peter sandstone in the Twin Cities area is comprised of shale and siltstone beds that are nearly continuous; these formations have a low permeability and are effective at confining the underlying Prairie du Chien aquifer and protecting it from contamination from above (Mossler, 1992).

The underlying bedrock aquifers and confining layers are described in more detail in the following subsections, in order of increasing depth and geologic age. Figure 3 (from Runkel et. al, 2003) depicts the stratigraphy and character of the Paleozoic formations near the Ford Site, including the higher degree of fracturing of the bedrock formations within 200 feet of the top of the bedrock surface and the dissolution features within the Prairie du Chien group.



Figure 3 - Paleozoic bedrock stratigraphy near the Ford Site

Prairie du Chien-Jordan Aquifer

The Prairie du Chien Group and Jordan Sandstone together form the most heavily used aquifer in Ramsey County. The aquifer is overlain and confined by the shaly basal part of the St. Peter Sandstone. The early Ordovician Prairie du Chien Group is composed predominantly of dolostone; groundwater flows mainly through fractures, joints, and solution cavities. The total thickness of the Prairie du Chien Group is about 120-130 feet. The Jordan Sandstone (70 to 100 feet thick) consists of highly permeable, fine- to coarse-grained quartzose sandstone, and, unlike the Prairie du Chien aquifer above, most groundwater flow is through intergranular spaces rather than along fractures. Despite their difference in rock type, the Prairie du Chien Group and Jordan Sandstone function as a single aquifer because no regional confining bed separates them. Locally, however, small water-level differences may exist, owing to relatively impermeable beds of shale of limited extent. The Prairie du Chien-Jordan aquifer is a confined aquifer at the Ford Site.

In general, groundwater in the Prairie du Chien-Jordan Aquifer flows from areas with the highest hydraulic head in northeastern Ramsey County toward the Mississippi River. This flow pattern indicates that the Prairie du Chien-Jordan aquifer discharges into the river. Figure 4, from the Twin Cities Metropolitan Area Groundwater Flow Model (Metropolitan Council, 2014), depicts piezometric surface contours and groundwater flow directions as determined from a calibrated groundwater flow model. The piezometric surface shown in Figure 4 shows a flattening of the hydraulic gradient near the Ford Site, probably attributable to the impounded area of the Mississippi River north of Lock and Dam No. 1(formerly the Ford Dam). A reduced hydraulic gradient is beneficial for ATES, as the lower groundwater velocity increases storage efficiency.



Figure 4 - Groundwater flow in the Prairie du Chien-Jordan aquifer

Wonewok Aquifer

The Wonewok aquifer (previously referred to in the literature as the Franconia-Ironton-Galesville aquifer) underlies all of Ramsey County. The aquifer has three parts: (1) the upper part is the Franconia Formation, which consists of about 115 to 160 feet of feldspathic and glauconitic sandstone with some shale and dolomite; (2) the middle part is the 15- to 20-foot-thick Ironton Sandstone, which contains minor shale partings; and (3) the basal part is the 30- to 40-foot-thick Galesville Sandstone. All three bedrock units are hydraulically connected, although small hydraulic head differences may be found locally.

Ground-water movement in this aquifer, like that in the overlying Prairie du Chien-Jordan aquifer, is from areas having the highest hydraulic head in northern Ramsey County toward the Mississippi River. The difference in water level between wells in the Prairie du Chien-Jordan and wells in the Wonewok aquifer, which ranges from 20 to 80 feet (Fig. 1), demonstrates the effectiveness of the St. Lawrence confining unit.

The Wonewok aquifer is little used in Ramsey County. In the northwestern part of the county the aquifer is used in a few multiple-aquifer wells drilled into the deeper Mt. Simon aquifer.

The Eau Claire Formation consists of siltstone, shale, and silty sandstone and is about 60-I 10 feet thick. It has low hydraulic conductivity and thus hydraulically separates the Wonewok aquifer from the Mt. Simon aquifer.

Mt. Simon Aquifer

The Mt. Simon aquifer underlies the Twin Cities area. It is composed of fine - to coarse-grained sandstone with many thin beds of siltstone and shale in the upper part, and ranges in thickness from 250 to 330 feet in Ramsey County. Nearly all high-capacity wells in the aquifer are located either in the south-central or the northwestern part of the county.

Data on ground-water movement are very limited, but the pattern of flow in the Mt. Simon aquifer apparently differs greatly from the pattern in the overlying aquifers. The general movement of ground water is from east to west toward the cone of depression formed by the major pumping centers in Hennepin County.

3.2.2 Aquifer Physical and Hydraulic Properties

Major aquifer physical and hydraulic characteristics are summarized in Table 1. This table was compiled by Underground Energy following review of the documents listed in Section 11.0. The assumed elevation at the Ford Site is 830 ft above mean sea level (MSL), and most of the depth and aquifer thicknesses data in Table 1 were obtained from a 1,070-foot-deep observation well (well #792118), approximately 1,000 feet south of the Ford Site. This well was completed to the base of the Mt. Simon aquifer and logged by MGS on behalf of the Minnesota Department of Natural Resources (DNR).

	Aquifer System					
Paramotor		Prairie du				
i arameter	St. Peter	Chien	Jordan	Wonewoc	Mt. Simon	
Ford Site Ground Elevation	830 ft	830 ft	830 ft	830 ft	830 ft	
Aquifer Top Elevation	770 ft	610 ft	480 ft	330 ft	40 ft	
Aquifer Bottom Elevation	610 ft	480 ft	390 ft	200 ft	-250 ft	
Saturated Thickness	160 ft	130 ft	70 ft	130 ft	290 ft	
Groundwater head in aquifer	690-710 ft	700 ft MSL	700 ft MSL	740 ft MSL	640 ft MSL	
Groundwater depth from ground surface	130 ft	130 ft	130 ft	90 ft	190 ft	
Aquifer depth	60-220 ft	220-350 ft	350-440 ft	630-700 ft	800-1100 ft	
	18-67 m	67-107 m	107-134 m	192-213 m	244-335 m	
K _h – Hydraulic	20-30 ft/day	20-60 ft/day	20-50 ft/day	2-5 ft/day	5-25 ft/day	
conductivity – horizontal	6-9 m/day	6-18 m/day	6-15 m/day	0.6-1.5	1.5-7.6	
				m/day	m/day	
K _v – Hydraulic conductivity	3 ft/day	1 ft/day	3 ft/day	0.07 ft/day	3 ft/day	
– vertical	1 m/day	0.3 m/day	0.8 m/day	0.02 m/day	1 m/day	
Aquifer transmissivity	3200-4800	2600-7800	1800-4500	250-650	1400-7300	
	ft²/day	ft²/day	ft²/day	ft²/day	ft²/day	
	300-450	240-730	170-420	24-60	130-670	
	m²/day	m²/day	m²/day	m²/day	m²/day	
Aquifer specific storage	4.5 x 10 ⁻⁶ 1/m	3.2 x 10 ⁻⁶ 1/m	1 x 10 ⁻⁶ 1/m	1 x 10 ⁻⁵ 1/m	2 x 10 ⁻⁵ 1/m	
Aquifer specific yield	0.2 %	0.2 %	0.2 %			
Hydraulic Gradient	1 x 10-2	2 x 10-3	2 x 10 ⁻³	1.4 x 10 ⁻³	6 x 10-4	
Aquifer Porosity	0.32	0.18	0.33	0.30	0.28	
Ambient Groundwater	47° F	49° F	49° F			
Temperature	8.2° C	9.3° C	9.3° C			
Groundwater flow velocity	0.6- 0.9	0.2-0.7	0.1-0.3	0.01-0.02	0.01-0.05	
	ft/day	ft/day	ft/day	ft/day	ft/day	
	0.2-0.3	0.07-0.2	0.04-0.09	0.003-0.007	0.003-0.02	
	m/day	m/day	m/day	m/day	m/day	

Table 1 - Estimates of bedrock aquifer properties at the Ford Site

3.2.3 Aquifer Geochemical Properties

As discussed in Section 3.1.2, it is Underground Energy's opinion that the suitability for ATES of aquifers below the St. Peter sandstone at the Ford Site has likely not been affected by anthropogenic contamination from historic land uses at the Ford Site.

Reducing (anaerobic) groundwater conditions, favorable for ATES, are expected in the confined Prairie du Chien-Jordan, Wonewok and Mt. Simon aquifers.

Based on water quality analyses from the Prairie du Chien-Jordan aquifer reported in Ruhl, et al. (1983), the groundwater from this aquifer system is predominantly of a calcium magnesium bicarbonate type. A relatively low dissolved solids concentration of about 100-300 mg/l is expected from this aquifer at the Ford Site. Average iron and manganese concentrations in the Prairie du Chien-Jordan aquifer are 0.65 and 0.2 mg/L, respectively.

Based on water quality analyses from the Wonewok aquifer reported in Ruhl, et al. (1982), the groundwater from this aquifer system is predominantly of a calcium magnesium bicarbonate type. A relatively low dissolved solids concentration of about 200-300 mg/l is expected from the Wonewok aquifer at the Ford Site. Average iron and manganese concentrations in the Wonewok aquifer are 1.3 and 0.1 mg/L, respectively.

Based on water quality analyses from the Mt. Simon aquifer reported in Wolf, et al. (1983), the groundwater from this aquifer system is predominantly of a calcium magnesium bicarbonate type. A relatively low dissolved solids concentration of about 200-300 mg/l is expected from the Mt. Simon aquifer at the Ford Site. Average iron and manganese concentrations in the Mt. Simon aquifer are 0.9 and 0.01 mg/L, respectively.

3.3 ATES Well Sizing

ATES wells differ from conventional water-supply wells because they are designed to operate as withdrawal wells during heating or cooling season and as injection wells during the opposite season. Because injection wells are subject to plugging from fines, colloids and mineral precipitates in the recharge water, typical practice in the United States has been to double the well screen length, if possible, or operate them at one half or less of the maximum flow rate of a similarly constructed groundwater withdrawal well (Driscoll, 1986). To size ATES wells operating in withdrawal mode, Dutch ATES practioners utilize a maximum approach velocity at the borehole wall, V_{b, max}, developed by IF Technology (2001). To calculate maximum infiltration flow rate from ATES wells, the calculations require measurement of Membrane Filter Index (MFI), a technique developed in the Netherlands that is used to predict the plugging performance of ATES wells. It is similar, but not identical, to the Silt Density Index (SDI) method. The Dutch practice is to size ATES wells based on the lower of the two calculated well flow rates. Because MFI data are collected by testing a production well, no MFI data are available for the aquifers beneath the Ford

Site, although the consolidated Paleozoic-age aquifers at the Ford Site suggest that MFI values will be low compared to similar values from unconsolidated aquifers. Therefore, the preliminary ATES well sizing used in this feasibility study was based on the IF Technology approach velocity method.

For production (withdrawal) mode, the maximum approach velocity at the borehole wall is used to estimate maximum ATES well flow rate, Q_{max} , using the following equations:

$$v_{b,max} = K/12$$
$$Q_{max} = A_b v_{b,max}$$
$$A_b = \pi D_b L_s$$

where: $v_{b,max}$ = maximum production flow velocity on the borehole wall (m/hour);

K = formation hydraulic conductivity (average over the screened interval; m/day); and

 A_b = area of the borehole along the screen length (m²); and

 D_b = diameter of the borehole (m); and

 L_s = length of the screened interval (m).

Table 2 presents the data used to calculate Q_{max} , for the aquifers that underlie the Ford Site. From Table 2, the combined calculated flow rates for the Prairie du Chien and Jordan aquifers ranges from 430 to 1,200 gallons per minute (gpm). A maximum ATES well yield value of 900 gpm from the Prairie du Chien-Jordan aquifer was used in the conceptual design.

	Aquifer System					
		Prairie du				
	St. Peter	Chien	Jordan	Wonewoc	Mt. Simon	
Well Depth	220 ft	350 ft	440 ft	700 ft	1100 ft	
	67 m	107 m	134 m	213 m	335 m	
Well Screen Length	90 ft	130 ft	90 ft	130 ft	150 ft	
	27 m	40 m	27 m	40 m	46 m	
Well Screen Depth Interval	130-220 ft	220-350 ft	350-440 ft	630-700 ft	950-1100 ft	
	40-67 m	67-107 m	107-134 m	192-213 m	290-335 m	
Borehole Diameter	36 in	36 in	36 in	36 in	36 in	
Well Casing Diameter	20 in	20 in	20 in	20 in	20 in	
Max. Approach Velocity on	0.5-0.8 m/hr	0.5-1.5 m/hr	0.5-1.3 m/hr	0.05-0.1 m/hr	0.1-0.6 m/hr	
Borehole Wall						
Well Flow Rate	180-260 gpm	255-760 gpm	176-441 gpm	14-34 gpm	73-370 gpm	
	40-60 m ³ /hr	60-170 m ³ /hr	40-100m ³ /hr	3-8 m ³ /hr	15-85 m ³ /hr	
Maximum Injection Pressure	4 ft ags	13 ft ags	21 ft ags	38 ft ags	49 ft ags	

3.4 **Proximity to Public Supply Wells**

Underground Energy obtained public supply water well information from the County Well Index (CWI) database maintained by the MGS. The CWI well data were analyzed using Geographic Information System (GIS) software to identify nearby public supply wells by their use codes, which are:

- PC Community Supply
- PN Public Supply/non community-transient
- PP Public Supply/non-community-non-transient
- *PS Public Supply/non-community*
- MU Municipal
- LN Licensed Non-Public Water Supply

Figure 5 depicts public supply wells within about two mile of the Ford Site, labeled according to their completion depth and by the reported aquifer from which they withdraw groundwater. The nearest public supply well that obtains water from the Prairie du Chien-Jordan aquifer is at the Minnesota Veterans Home approximately 1,200 feet west of the Ford Site. This is a deep well and obtains water from multiple aquifers. The next nearest public supply wells that obtain water from the Prairie du Chien-Jordan aquifer are located approximately 1.5 miles to the southeast of the Ford Site. All of the nearest public supply wells are located at distances from the Ford Site that are significantly greater than the maximum isolation distance of 300 feet for water supply wells as set forth in Minnesota Rules 4725.4450-4500.



Figure 5 - Area Public Supply Wells

Building Information and Building Loads 4.0

4.1 **Building Information**

The Ford Site Draft 1 Conceptual Development Plan, prepared by the City of Saint Paul for the purpose of technical analyses and studies of potential redevelopment needs, impacts and costs, shows about 6,570,000 sf (610,000 m²) building conditioned floor area, mainly consisting of medium-high density residential buildings. The approximate floor space per building type is presented in Table 3 below.

able 3 - Building information				
Building type	Conditioned floor a			
	sf	m ²		
Low density residential	890,000	83,000		
Medium density residential	780,000	72,000		
High density residential	3,450,000	320,000		
Mixed use/retail	275,000	25,000		
Retail	640,000	60,000		
Civic buildings	300,000	28,000		
Office buildings	235,000	22.000		

Tab

С

Total

Source: E-mail from Ever-Green Energy dated March 11, 2016.

4.2 **Building Loads**

In order to develop a concept for a District Heating & Cooling (DH&C) network including ATES and to evaluate the feasibility of this concept, the peak demand and annual energy use of the future buildings on the Ford site has to be estimated. To predict the loads at this level of analysis, Energy Use Intensities (EUI's) have been used by Ever-Green Energy for both cooling and heating. EUI's are defined as thermal peak demand or annual energy per unit floor area. It has been assumed that all buildings meet the energy efficiency standards according to the Minnesota Sustainable Building Code 2030.

6,570,000

610,000

The heating and cooling loads were developed based on the building areas given in Table 1. The diversified heating load for the Ford site is estimated to be 53.6 MMBtu/hr peak and 115,800 MMBtu of annual energy consumption (excluding domestic hot water production). The diversified cooling load for the Ford site is estimated to be 3,450 Tons peak and 66,900 MMBtu of annual energy consumption. The estimated energy loads for the various building types are summarized in Table 4.

Building type	Heating de	emand	DHW demand		Cooling demand	
	MMBtu/y	MWh/y	MMBtu/y	MWh/y	MMBtu/y	MWh/y
Low density residential	13,600	3,980	0	0	6,800	1,990
Medium density residential	15,800	4,640	3,960	1,160	7,900	2,320
High density residential	70,600	20,700	17,650	5,180	35,300	10,350
Mixed use/retail	4,300	1,250	430	120	4,200	1,250
Retail	7,400	2,170	740	220	7,400	2,170
Civic buildings	2,400	700	130	35	3,500	1,020
Office buildings	1,700	510	290	85	1,800	510
Total	115,800	33,950	23,200	6,800	66,900	19,610

Table 4 - Building thermal energy demands

Source: E-mail Ever-Green Energy dated March 11, 2016.

Table 5 indicates the total peak loads and the diversified total peak loads. The latter loads take into account that the peak loads of all homes, apartments and buildings do not coincide. This implies that the peak load of the overall system will be lower than the sum of the peak loads of the individual thermal energy consumers. For this study a diversity factor of 0.75 has been assumed.

Table 5 - Building thermal peak loads

Building type	Heating peak load		DHW peak load		Cooling peak load	
	MMBtu/h	MW	MMBtu/h	MW	Tons	MW
Low density residential	8.49	2.49	0	0	514	1.81
Medium density residential	9.90	2.90	1.13	0.33	600	2.11
High density residential	44.12	12.93	5.04	1.48	2,674	9.42
Mixed use/retail	2.36	0.69	0.13	0.04	295	1.04
Retail	4.11	1.20	0.09	0.03	121	0.43
Civic buildings	1.33	0.39	0.04	0.01	290	1.02
Office buildings	1.16	0.34	0.09	0.03	132	0.47
Total	71.5	20.9	6.5	1.9	4,600	16.3
Total diversified load	53.6	15.7	4.9	1.4	3,450	12.2

Figure 6 and Figure 7 below show the assumed load-duration curve (LDC) for the estimated heating and cooling loads, respectively. These curves are estimates and included only for explanatory reasons. A LDC indicates, on an annual basis, the time that loads are less and/or greater than a given value in a typical year. LDC's are useful tools for visualizing a load profile throughout the year; they show, amongst other things, that peak demand only occurs for a very short time.

LDCs also assist with sizing energy source options and estimating the energy that each source would contribute on an annual basis. The area under the load duration curve represents the energy demand from the buildings. For example, an energy source with a higher capital cost but a lower operating cost would be sized at typically 35-50% of the peak load but supplies 80% or more of the annual energy for the system. The remaining energy could be provided by an energy source with a lower capital cost and a higher fuel cost, as it is used very little and is required for backup in any event (see Section 6.0 on ATES system sizing).

Placeholder - Load Duration Curve

Figure 6 - Heating load duration curve for the Ford Site

Placeholder - Load Duration Curve

Figure 7 - Cooling load duration curve for the Ford Site

In order to be able to apply an ATES system combined with heat pumps for heating and cooling of the buildings on the Ford site, there are some boundary conditions that have to be taken into account. This study is based on the assumption that the following boundary conditions are met:

- The buildings, homes and apartments have a low temperature heating system, enabling the application of heat pumps. Assumed heating supply and return temperature under design conditions 120-100 °F (48.9-37.8 °C).
- The buildings, homes and apartments have a high temperature cooling system, enabling the application direct ATES cooling in combination with heat pumps. Assumed cooling supply and return temperature under design conditions 45-60 °F (7.2-15.6 °C).
- The homes and apartments have a centralized domestic hot water (DHW) system per residential building or individual DHW production with a booster heat pump using the ventilation air or the heating/cooling return.

5.0 ATES System Conceptual Design

5.1 **Configurations for ATES based DH&C Systems.**

Utility scale ATES projects consist of a well field with several groundwater withdrawal and recharge wells (open-loop system), groundwater transport/distribution piping, heat pumps as well as warm and chilled water distribution piping. The system is providing heating or cooling, or simultaneous heating and cooling to several buildings. The groundwater circuit is hydraulically separated from the heating and cooling circuits inside the buildings by plate heat exchangers.

From the thermal energy distribution perspective, several system configurations can be distinguished (Table 6).

Heat pump location	Distribution System	Distribution System
	Groundwater	Chilled and Warm Water
1. In centralized plant room for	Between well field and central	Supply and return piping for
all buildings together.	plant room. Single, uninsulated	warm and chilled water between
	piping (water is flowing either	central plant room and buildings,
	from warm to cold wells or from	and inside buildings.
	cold to warm wells).	Four-pipe system, insulated.
		Remark: DHW supply requires
		special attention.
2. In central plant room per	Between well field and buildings.	Supply and return piping for
building (also group of	Two- or four-pipe system, piping	warm and chilled water inside
houses/apartment block).	not insulated.	buildings. Four-pipe system,
Remark: Best suited for aquifer		insulated.
seasonal thermal energy storage		Remark: DHW make-up might be
application.		integrated in building plant
		room.
3. Distributed heat pumps in the	Between well field and buildings.	Two-pipe system (supply and
buildings.	Two pipe system (supply and	return) inside buildings between
Remark: Central heat exchanger	return), piping not insulated.	heat exchanger and distributed
per building is recommended for		heat pumps. Piping insulated.
hydraulic separation.		Supply and return piping for
		warm and chilled water after
		heat pumps. Two- or four-pipe
		system.

Table 6 - Distribution system configurations

The majority of the utility scale ATES projects in Europe provide heating and cooling. Most of the utility scale ATES projects are providing heating and cooling applying the distribution configuration according to #2 in Table 6. This configuration will be discussed in more detail hereafter. Although this paragraph is focusing on ATES based systems, the approach is not limited

to this type of system. Especially utility scale systems based on borehole thermal energy storage (BTES) will have similar issues when selecting the distribution system configuration.

5.2 **Groundwater Distribution Options for ATES based DH&C Systems.**

In the case of an ATES based utility scale DH&C system with a mechanical room in each of the buildings (configuration #2 in Table 6), the selection of the distribution system between the wells and the building plant rooms is summarized as a flowchart in Figure 8. If there is no simultaneous demand for heating and cooling (all buildings are either demanding cooling or heating), a two-pipe groundwater system (supply and return) will suffice. The two-pipe system provides either warm water or chilled water to the building plant rooms.



Figure 8 - Distribution system selection flowchart

In the case of simultaneous heating and cooling demand, which is the most common situation for ATES-based systems, both a two-pipe and a four-pipe groundwater distribution layout are possible.

Figure 9 and Figure 10 show a schematic representation for the four-pipe and two-pipe configurations.



Figure 9 - Four-pipe groundwater distribution, passive building connections



Figure 10 - Two-pipe groundwater distribution, active building connections

In both the four-pipe system and the two-pipe system the flow of the groundwater in the ATES system is driven by the well pumps. In the four-pipe system, these well pumps also provide the pressure drop over the heat exchangers in the central building plant rooms. This is realized by maintaining a constant pressure difference between supply and return pipes of the groundwater loop. This building connection is defined as a passive building connection, see also Figure 9. By

opening/closing valves, the building is connected to either warm water supply and return or chilled water supply and return. A separate control valve in the building connection controls the flow over the building heat exchanger by maintaining a pre-set return temperature or temperature difference between supply and return.

In the two-pipe system, the well pumps in combination with the valves in the discharge wells maintain an equal pressure in the warm and chilled water loop. Each building has its own pump to take water from the chilled water loop and return it to the warm water loop and vice versa (active building connection). The flow rates of the building connection pumps are controlled by the temperature of the return water, see Figure 11. In this example schematic the building is taking water from the chilled water pipe and returning it to the warm water pipe at a minimum temperature of 15 °C (59 °F). It is important that this pre-set temperature condition is met, because a neighboring building might be taking water from the warm water pipe at the same time and the minimum supply temperature has to be guaranteed by the energy supply entity.



Figure 11 - Active building connection

The two-pipe configuration is more complex regarding building connections and controls. The piping cost, however, is significantly lower than for the four-pipe distribution system. Because the piping cost increases with the overall capacity of an ATES based district heating and cooling system (larger distances, larger diameters), the two-pipe system tends to be the preferred option for the larger scale ATES applications (ATES capacity > 5.0 MW, 1,500 tons) with a limited number of building connections. In this ATES feasibility study, the two-pipe system is analyzed in more detail.

5.3 ATES based DH&C Network for the Ford Site

Figure 12 and Figure 13 depict the conceptual design of an ATES system integrated with new building systems and with a new local District Heating and Cooling loop. This configuration uses a two-pipe groundwater loop with active building connections (configuration #2 in Table 6).

The principle of operation for a building in winter mode and the ATES system in winter mode (ATES system heating mode and charging operation for the cold ATES well field) is displayed in Figure 12.



Figure 12 - Principle of ATES system in heating mode (winter operation)

In winter mode, groundwater is pumped from the warm wells to the cold wells and the warm water is used by heat pumps as a low temperature heat source. The water that is cooled down by the heat pumps is discharged into the cold wells. The heat pumps provide heating for the buildings in winter operation.

Note that with this winter mode configuration:

- Some buildings can still be in cooling mode while the remainder are in heating mode. In heating mode of the ATES system, the net flow in the groundwater loop will be from the warm wells into the cold wells.
- The warm well discharge temperature indicated in Figure 12 is resulting from the summer operation, see hereafter.

The principle of operation for a building in summer mode and the ATES system in summer mode (cooling operation) is displayed in Figure 13. In cooling mode (discharging operation for the cold ATES well field) groundwater is pumped from the cold wells to the warm wells. Direct cooling to a building in cooling mode is supplied by thermal energy exchange over a plate heat exchanger.



Figure 13 - Principle of ATES system in cooling mode (summer operation)

At the start of the cooling season, when the cold wells are fully charged, the extraction temperature from the cold wells will be close to the charging temperature. As a result of the temperature drop over the plate heat exchanger (2.0 °F - 1.1 °C) both during charging and

discharging, the temperature supplied to the building distribution loop will be 47 °F (8.3 °C). During summer operation the extraction temperature from the ATES wells will gradually rise.

The heat pump(s) in the central building plant room are utilized in chiller mode for additional cooling in order to have a guaranteed cooling capacity and temperature. In the conceptual design according to Figure 13, the heat rejected into the aquifer in ATES cooling mode is about 70,300 MMBtu/y (20,600 MWh/y). If the full annual heating demand were provided by heat pumps, the heat pumps abstract about 104,400 MMBtu/y (30,600 MWh/y) from the aquifer. These energy figures are calculated using the efficiencies given in Table 4. In order to maintain a thermal energy balance for the aquifer and to avoid low abstraction temperatures in heating mode, part of the heating is not supplied by heat pumps but by peak load gas boilers. These gas boilers are located in the plant rooms of the buildings.

5.4 Energy and Water Savings and Emissions Reduction Estimate

An energy savings estimate for the application of the ATES/HP system described in Section 5.3, as compared to the reference system, has been made. Savings on energy also result in a reduction of CO2 emissions.

The reference system (or business as usual, BAU) for the energy savings estimate consists of a DH&C network with a central chiller and boiler plant with heating supply and return temperatures of 180-130 °F and cooling supply and return temperatures of 42-56 °F.

In the ATES/HP system, part of the heating is provided by the heat pumps and part by the gas boilers. Because the total heat pump capacity is about 38% of the diversified peak heating capacity (see Section 6 – Initial ATES System Sizing), the heat pumps will be able to provide about 75% of the annual heating demand (see Figure 6). In a similar way, part of the cooling is provided by direct ATES cooling and part by the heat pumps in chiller mode. Because the minimum direct cooling capacity is about 65% of the diversified peak cooling capacity (see Section 6), the ATES direct cooling will be able to provide well over 75% of the annual cooling demand (see Figure 7). The 75% contribution of heat pump heating and ATES direct cooling has been taken into account for the energy savings estimate.

A graphic presentation of the thermal energy flows in the ATES/HP system is shown in Figure 14.



Figure 14 - Energy flows ATES/HP system (without distribution losses)

To calculate the energy consumption of the ATES/HP system and of the reference system, an estimate has to be made for the annual (seasonal) efficiencies for the various system components. The values applied in this study for these efficiencies, also called Seasonal Performance Factor (SPF) or seasonal Coefficient of Performance (COP), are shown in **Error! Reference source not found.**

Table 7 - Estimated annual efficiencies

	Annual Ffficiency	Unit	Annual Ffficiency	Unit
	Linelency		Linelency	
Gas boiler (condensing)	0.95	MMBtu-out/	0.95	MWh-out/
		MMBtu-in		MWh-in
Centrifugal chiller, incl. pumps cooling	0.65	kWe/Ton	5.4	MWht/
tower, condenser and evaporator				MWhe
Screw heat pump-cooling operation, incl.	0.70	kWe/Ton	5.0	MWht/
pumps condenser and evaporator				MWhe
Screw heat pump-heating operation, incl.	0.25	kWe/kWt	4.0	MWht/
pumps condenser and evaporator	0.875	kWe/Ton		MWhe
Well pumps	0.0875	kWe/Ton	40	MWht/
				MWhe
Distribution pumps	0.05	kWe/Ton	70	MWht/
				MWhe
Distribution efficiency (loss)	0.95	MMBtu-out/	0.95	MWh-out/
groundwater loop		MMBtu-in		MWh-in
Distribution efficiency (loss) heating loop	0.90	MMBtu-out/	0.90	MWh-out/
		MMBtu-in		MWh-in
Distribution efficiency (loss) cooling loop	0.95	Ton-in/	0.95	MWh-out/
		Ton-out		MWh-in
Electrical power plant	0.40	MWhe/	0.40	MWhe/
		MWht		MWht

Table 8 below summarizes electricity, natural gas and water consumption as well as CO2 emissions for the ATES/HP system as well as the BAU scenario.

Table 8 - Annual energy savings and CO2 emissions reduction

Item	BAU		ATES/HP	
	Electricity	Gas	Electricity	Gas
Heating: gas boiler (condensing), incl. distribution losses		(47,180 MWh)		(10,730 MWh)
Heating: heat pump-heating operation, incl. pumps condenser and evaporator			(7,640 MWh)	
Distribution pumps/well pumps	(640 MWh)		(600 MWh)	
Cooling: chillers, incl. pumps cooling tower, condenser and evaporator and distribution losses.	(3,810 MWh)			
Cooling: ATES direct cooling, incl. distribution losses (well pumps only)			(530 MWh)	
Cooling: heat pump-cooling operation, incl. pumps condenser and evaporator			(980 MWh)	
Distribution pumps	(290 MWh)			
Total	(4,740 MWh)	(47,180 MWh)	(9,750 MWh)	(10,730 MWh)
Total primary energy consumption		(59,030 MWh)		(35,100 MWh)
Total CO2 emissions	12,400 (metric tons per year)		7,900 (metric tons per year)	
Total water consumption	60,300 (metric tons per year)		0	

From Table 8 it can be concluded that the ATES/HP system provides savings on primary energy consumption of about 40 % as compared to the BAU scenario.

The annual reduction of CO2 emissions of about 35% is based on an average emission of 1290 pounds (lbs) of carbon dioxide (CO2) per MWh or 586 metric ton CO2/MWh electricity for the grid electricity sources in Minnesota. Natural gas sources consist of 132 pounds (lbs) of carbon dioxide (CO2) per MMBtu fuel or 0.204 metric ton CO2/MWh fuel (Ramboll, 2015, Table 27).

An ATES/HP installation will also reduce the water usage because no evaporative cooling towers will be installed. For water savings we have assessed the total make up water for evaporative cooling towers to 2.3 gal/TR-hr (consisting of 1.8 gal/TR-hr for evaporation+drift and 0.5 gal/TR-hr for blow down).

6.0 Initial ATES System Sizing

An important factor for the sizing of an ATES system is the achievable well yield for extraction and injection of groundwater. The maximum well yield depends on local hydrogeology and well dimensions (depth and diameter). Based on the available information on hydrogeology (Section 3.0) it is currently considered that 900 gpm (200 m³/h) is about the maximum sustainable yield that can be obtained from an ATES well completed in the combined Prairie du Chien-Jordan aquifer.

The initial sizing of the ATES/HP system is presented below in Table 9.

Table 9 - Initial ATES/HP system sizing

	Value	Unit	Value	Unit
System heating capacity, incl. DHW	58.5	MMBtu/h	17.1	MWh
System cooling capacity	3,450	Tons	12.2	MWc
Depth wells	440	ft	135	m
Screened section	165	ft	50	m
Maximum well yield	900	gpm	200	m ³ /h
Number of doublets (pair of wells)	6	-	6	-
Minimum distance between warm and cold well clusters	650	ft	200	m
Maximum flow rate groundwater system	5,500	gpm	1,250	m ³ /h
Ambient groundwater temperature	49	°F	9.3	°C
ATES storage and abstraction temp- eratures in winter and summer operation	Figure 7 and 8	°F	Figure 7 and 8	°C
ATES/HP heating capacity	22.2	MMBtu/h	6.5	MWh
Total boiler capacity	36.3	MMBtu/h	10.6	MWh
Annual heating demand supplied by ATES/HP system	75	%	75	%
Annual heating demand supplied by boilers	25	%	25	%
ATES direct cooling capacity	2,230	Tons	Min. 7.9	MWc
Total HP cooling capacity	1,220	Tons	4.3	MWc
Distribution system length, mains	1,650	ft	503	m
Distribution system length, laterals	1,340	ft	408	m

In principle, the wells can be located everywhere along the district loop, taking into account sufficient distance between the wells. It is assumed that the well field consists of two clusters of 3 warm wells each and two clusters of 3 cold wells each. There is a minimum distance required between a cluster of cold wells and a cluster of warm wells to avoid thermal breakthrough between the wells. To have some preliminary insight on the required well distance a simple calculation has been performed, according to which the distance between the clusters should be at least 200 m.

Figure 15 shows the routing of the district loop and proposed location of the wells, along with conceptual building configurations from Figure 6 of Ramboll (2015).



Figure 15 - Conceptual Site Layout

7.0 Financial Analysis

7.1 Investment Cost Estimate

The following assumptions and limitations have been used in the cost estimate:

- All costs are considered pre-feasibility study level given the scope of work assigned.
- All costs are 2016, 1st quarter, US Dollars and exclusive of taxes.
- General contractor OH&P, bonding, permitting, insurance and construction management & supervision are allowed for at 10%.
- Engineering, testing and commissioning are allowed for at 10%.
- The scope of this feasibility study did not allow for an investigation of well locations and routing of the groundwater piping. The well locations and piping routing assumed for the investment cost estimate are as shown in Figure 14.
- The wells will be drilled with cable tool or reverse flow rotary drilling equipment to minimize aquifer clogging due to drilling fluid.
- The well cvaults will be partly underground and partly above ground (about 2 ft).
- For each of the well clusters, power for the well pumps is available from one of the building plant rooms nearby. Power and control cabling is in the piping trench.
- Trenching is assumed to be in green field. Trench depth allows for 2 3 feet of cover to the top of the pipes.
- Given the temperatures of the groundwater in the ATES distribution piping, the "cold" piping is HDPE piping with insulation, the "warm" piping is uninsulated HDPE piping. Piping for the BAU scenario is insulated steel and PEX piping for hot water and insulated HDPE piping for chilled water.
- The costs for ground and plant rooms (including external utilities) are not included in the estimate. The central plant room (BAU) and building plant rooms (ATES/HP) are on ground floor and/or basement level.
- The site wide heating and cooling capacity and demand are more or less equally divided over the 38 building connections.
- Redundancy for main components (chillers, boilers, heat pumps and wells) is N+1.
- The cost for the gas distribution network to the central plant room (BAU scenario) and the building plant rooms is not included.
• Distribution of thermal energy from the Energy Transfer Station (ETS) or central plant room in the building to the individual consumers is not included.

A breakdown of the estimated investment cost is shown in Table 1 below. The investment cost for the ATES/HP option turns out to be almost equal to the investment cost for the BAU option.

	BAU	ATES/HP
Site investigation incl. test well (first borehole) and	\$ 0	\$ 600,000
three monitoring wells, analysis of results, EIA		
Thirteen additional boreholes 36"diameter, 440 ft	\$ 0	\$ 4,200,000
depth, incl. development and tests		
Well housings and well M+E equipment, incl.	\$ 0	\$ 900,000
installation		
Piping incl. trenching DH&C distribution and piping and	\$ 5,200,000	\$ 1,800,000
cabling incl. trenching groundwater distribution	(1)	
respectively		
M+E equipment central plant room and 38 building	\$ 9,200,000	\$ 13,300,000
plant rooms respectively, incl. controls and installation	(1)	
Energy transfer stations 38 buildings	\$ 6,600,000	\$ 0
	(1)	
Subtotal BAU and ATES/HP system	\$21,000,000	\$ 20,800,000
Engineering, main contractor overhead, bonding,	\$ 4,200,000	\$ 4,000,000
insurance 20% (excluding site investigation)		
Contingency 10% (including site investigation)	\$ 2,100,000	\$ 2,100,000
Total BAU or ATES/HP system	\$27,300,000	\$26,900,000

Table 10 - Estimated investment costs (excluding taxes)

(1) Source: Ever-Green Energy, June 3th, 2016

7.2 Estimated Financial Benefit

Because of the fact that the investment cost for both options is almost the same, the financial comparison is reduced to the comparison of the operating cost of the BAU scenario and the ATES/HP scenario. This comparison is presented in Table zz. The assumptions made to develop this Table are the following:

Variable operating costs:

- The utility electricity rate applied is \$55.00/MWh. This is the weighted average of the on peak and off peak rate (Ramboll, 2015, Section 5.7).
- The utility gas rate applied is \$16.5/MWh (Ramboll, 2015, Table 21).
- The water rate applied is \$4.0/1,000 gal (\$1.1/metric ton). Costs for chemicals and disposal to sewer have not been included.
- No economic value has been assigned to the reduction of carbon dioxide, although it is likely that some form of greenhouse gas regulation will be implemented in the coming years.

Fixed operating costs:

• Operation and Maintenance (O&M) cost of 3% of the investment for M+E equipment and wells and 1% of the investment for buried piping and cabling.

Table 11 - Estimated operating costs per year (excluding taxes)

	BAU	ATES/HP
Electricity consumption	\$ 260,700	\$ 536,300
Natural gas consumption	\$ 778,500	\$ 177,000
Water consumption	\$ 66,300	\$ 0
Operating and maintenance cost	\$ 615,000	\$ 720,000
Total BAU or ATES/HP system	\$ 1,720,500	\$ 1,433,300

Table 11 shows a 17% saving on operating cost for the ATES/HP system as compared to the BAU scenario, to a large extent a result of savings on energy and water consumption when applying an ATES/HP system.

8.0 Regulatory Evaluation

While technical and financial measures of ATES feasibility at the Ford Site are strong, it is Underground Energy's opinion that obtaining the necessary regulatory approvals is an equally important consideration to development of an ATES project at the Ford Site. A draft of this regulatory evaluation was provided by the City of St. Paul Department of Planning and Economic Development to members of the Minnesota Environment Quality Board (EQB) and of the Minnesota Department of Health (MDH) for their review in advance of meetings about regulatory feasibility of ATES at the Ford Site on 23 May and May 31, 2016, respectively. The salient regulatory issues lie within the jurisdiction of MDH, as discussed in Section 8.4.

8.1 Underground Injection Control

The primary federal regulation that applies to an ATES system is the Underground Injection Control (UIC) program administered by the US Environmental Protection Agency, Underground Injection Control Program (USEPA-UIC). ATES wells are Class V injection wells under the UIC program. An ATES system that discharges non-contact heating and cooling water without chemical additives must register with USEPA-UIC. ATES systems are designed and operated in such a manner that temperature is the only regulated parameter that is modified from ambient groundwater conditions. The discharge must meet all drinking water and other health-based standards. The US EPA has primacy in Minnesota over the Underground Injection Control program and a Class V geothermal well registration is a relatively simple process.

8.2 Minnesota Pollution Control Agency

As discussed in Section 3.1.2, it is Underground Energy's opinion that the suitability for ATES of aquifers below the St. Peter sandstone at the Ford Site is unlikely to have been affected by anthropogenic contamination from historic land uses at the Ford Site. Underground Energy therefore assumes that ATES project development will not be burdened by groundwater contamination issues. As such, Minnesota Pollution Control Agency (PCA) regulations or other regulations related to oil and hazardous material in the environment are excluded from consideration in this feasibility study.

8.3 Minnesota Department of Natural Resources

An appropriation permit for a groundwater withdrawal exceeding 10,000 gallons per day or one million gallons per year is required from the Minnesota Department of Natural Resources (DNR).

Because an ATES system withdraws groundwater concurrently with injection, the net flow rate in the aquifer is zero and there is no consumptive use of the groundwater resource. In this situation, many other state agencies have indicated they would waive a similar permit requirement. However, in Minnesota the DNR permits required by law are for appropriation, not consumption.

8.4 Minnesota Department of Health

8.4.1 Prohibition of Underground Injection

The Minnesota Department of Health (MDH) regulates Wells and Borings under Minnesota Administrative Rules Chapter (MR 4725), which were adopted according to and must be read in conjunction with Minnesota Statutes, chapter 103I, relating to wells, borings, and underground uses. Under MR 4725.2050, injection of any material into a well or boring in Minnesota is prohibited.

One exception is contained in Minnesota Statutes, section 103.621, which establishes a permit system for groundwater thermal exchange devices, which are defined as heating and cooling systems that withdraw groundwater from a well and inject into the same aquifer. These permits are limited to a maximum flow rate of 50 gpm, which is too low a threshold for an ATES system. The only option for an ATES system, short of a change in law, is to seek a variance from the rule pursuant to MR 4725.0400.

MDH can issue variances and has done so for an Aquifer Storage and Recovery (ASR) project. In that case, the applicant was a public water supplier, and the water will be ultimately withdrawn and used for potable purposes. The purpose of the ASR request was to maximize water treatment capacity, not for thermal energy storage or space heating and cooling. While there will be differences for an ATES project, many of the MDH concerns and requirements would be the same including the quality of the injected water, potential to mobilize contaminants, contaminant plume impacts, and potential effects on drinking water supplies.

The fee for processing a variance is currently \$235, and a variance will typically be subject to conditions such as hydraulic and geochemical monitoring. A variance request application is provided in Appendix A. Underground Energy has reviewed three variances issued by the MDH and it is our opinion that any such conditions would probably be consistent with the monitoring we would normally recommend for an ATES project.

In summary, MR 4725.2050 is a regulatory obstacle to an ATES project in Minnesota, but there is precedent for a variance to that rule and regulators have indicated to Underground Energy a willingness to consider similar variances for ATES projects.

8.4.1 Mt. Simon Aquifer Prohibition of New Appropriations

Minnesota Statutes Section 103G.271 4(a) prohibits new permits for appropriation and use of water from the Mt. Simon aquifer. At present this is not considered an obstacle to ATES development due to the high cost of installing ATES wells in this deepest aquifer beneath the Ford Site. Underground Energy notes that, given the nonconsumptive nature of ATES and the potential to utilize ATES wells also as ASR wells, an opportunity may exist to develop ATES/ASR projects that could beneficially restore lowered groundwater elevations in the Mt. Simon aquifer that were the basis for this prohibition.

9.0 Conclusions

9.1 ATES Feasibility Summary

It is Underground Energy's opinion that ATES is feasible at the Ford Site, and that an ATES system with a two-pipe District Heating and Cooling system can meet the City of St. Paul's objectives for redevelopment of the Ford Site, provide a significant, large-scale energy and financial benefit, long-term operational flexibility and a hedge against future fuel cost increases.

The overall feasibility of an ATES project has several facets, the most important of which is usually, and often arguably, financial. Underground Energy's opinion on the multi-faceted feasibility of ATES at the Ford Site is summarized below in Table 12, where one to three check marks are assigned to criteria depending on how well each criterion is suited for an ATES project.

Feasibility	Feasibility Criteria	Summary
$\checkmark \checkmark \checkmark$	Financial	Similar investment cost to BAU, 17% operating cost
		reduction
\checkmark	Regulatory	Underground injection prohibited by rule, variance required
$\checkmark \checkmark \checkmark$	Climate	Cold winters/hot summers well suited for seasonal energy
		storage
$\checkmark \checkmark \checkmark$	Hydrogeology	High well yields, multiple aquifers, low groundwater velocity
$\checkmark \checkmark \checkmark$	Geochemistry	Contamination unlikely, low dissolved solids, good redox
		conditions
$\checkmark\checkmark\checkmark$	Facilities	Master planning and new construction best suited for ATES
	Integration	

Table 12 - ATES Feasibility Summary

9.2 ATES Benefits

The advantages and benefits of an ATES system design at the Ford Site include:

- Compared to a new, efficient four-pipe district energy system with a central plant, ATES can achieve annual savings of
 - 24,000 MWh per year of primary energy (41% reduction);
 - 4,500 metric tons CO2 per year (36% reduction); and
 - 60,000 metric tons (15.9 million gallons) of cooling water (100% reduction).

- An ATES system can be powered by renewable electricity, displacing the combustion of fossil fuels for heating and for grid electricity, and potentially facilitating net-zero development.
- An ATES system would provide a hedge against future fuel cost increases.
- An ATES system can be completed in phases as the Ford Site is redeveloped, allowing developers and tenants to develop a high level of confidence in the technology as the project is built out.
- Undertaking an ATES project at the Ford Site can accelerate the rate of adaptation of ATES elsewhere in Minnesota and in the US marketplace, with resulting large CO2 reduction and resiliency benefits.

9.3 ATES Technical and Regulatory Feasibility

ATES is feasible at the Ford Site from a technical perspective. Multiple transmissive aquifers lie beneath the Ford Site, thermal loads are fairly well balanced, and ATES can meet approximately half of the cooling demand for approximately 6.5 million square feet of conditioned space with direct cooling from seasonally stored chilled water. The Prairie du Chien-Jordan aquifer has high transmissivity and can provide good well yields, but the karstic conditions in the Prairie Du Chien carbonate aquifer may result in high natural groundwater flow velocity unacceptable for ATES.

Obtaining the necessary regulatory approvals will be required for development of an ATES project at the Ford Site. The salient regulatory issues lie within the jurisdiction of Minnesota Department of Health (MDH) under MR 4725.2050, which prohibits injection of any material into a well or boring in Minnesota. An exemption exists for smaller open-loop geothermal system (up to 50 gpm), but the only option for an ATES system, short of a change in law, is to seek a variance from the rule. There is precedent for a variance to that rule for an Aquifer Storage Recovery project, and MDH representatives have indicated a willingness to consider similar variances for ATES projects.

If the full energy, economic and environmental benefits of ATES are to be realized in Minnesota, where climate and aquifer conditions are ideal for this large-scale, sustainable heating and cooling technology, consideration should be given by Minnesota's policy makers how best to responsibly embrace this technology, as the Dutch have done so successfully.

9.4 ATES Financial Feasibility

ATES is feasible at the Ford Site from a financial perspective. The estimated investment cost for an ATES system of \$26.9 million is similar to the estimated cost of a 4-pipe district heating and cooling system of \$27.3 million. The more efficient ATES system would reduce operating expenses by an estimated additional 17% compared to the BAU scenario.

10.0 Recommendations

Given the favorable findings regarding ATES feasibility at the Ford Site, Underground Energy recommends that a phased hydrogeologic investigation be performed at the Ford Site to confirm or modify the estimates of subsurface conditions that were the basis for our conceptual design, and to facilitate detailed design and financial analysis. Underground Energy recommends that the design of a hydrogeologic testing program consider the following elements:

- Borings and (smaller diameter) monitoring wells are needed for hydraulic and geochemical testing.
 - Three wells are needed in an aquifer in order to measure groundwater elevations and estimate the piezometric surface (3 points define a plane, which is a first approximation of the piezometric surface). This allows calculation of hydraulic gradient, groundwater velocity and flow direction.
 - Because groundwater flow in the Prairie du Chien aquifer is through karstic dissolution-opened fractures while groundwater flow in the Jordan is through porous media, it will be important to evaluate groundwater velocity separately in the Prairie du Chien and Jordan aquifers. This would require a minimum of six wells, three in the Prairie du Chien aquifer and 3 in the Jordan aquifer.
- A larger diameter boring/well will be needed for aquifer pump testing to size and design the ATES wells.
 - An evaluation of the vertical distribution of hydraulic conductivity down from the top of the Prairie du Chien group to the base of the Jordan. Underground Energy recommends packer tests in a moderate-sized boring to accomplish this task. The boring could be completed as a well and used later for a combined Prairie du Chien-Jordan aquifer pumping test while monitoring hydraulic effects separately in these two formations with the six observations wells.
- Geochemical testing is needed, with the scope to be determined pending discussion with regulators.
- Hydraulic testing is needed, and initial efforts can focus on the smaller-diameter monitoring wells.

The City of Saint Paul and project proponents should continue the productive dialogue that was begun with the EQB and MDH in meetings in May 2016. We recommend that work plans for any subsurface investigation activities be coordinated with experts at the Minnesota Geologic Survey and MDH.

11.0 References

Arcadis U.S., Inc., December 2015, Comprehensive Phase II Site Investigation Report, Twin Cities Assembly Plant, St. Paul, Minnesota, prepared for Ford Motor Company, Ref. DE000372.0003.

County Well Index, 2016, Database created and maintained by the Minnesota Geological Survey, a department of the University of Minnesota, with the assistance of the Minnesota Department of Health.

Driscoll, F.G., 1986, *Groundwater and Wells (2nd ed.)*, Johnson Filtration Systems, Inc., St. Paul, Minnesota, 1089p.

Engineering Weather Data, 1999, National Climatic Data Center - Climate Services Division, Asheville NC.

Meyer, G.N.; Swanson, L., 1992, C-07 Geologic atlas of Ramsey County, Minnesota. Minnesota Geological Survey. Retrieved from the University of Minnesota Digital Conservancy, http://purl.umn.edu/58233.

Metropolitan Council, 2014, Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3.0. Prepared by Barr Engineering. Metropolitan Council: Saint Paul, MN.

Minnesota Department of Natural Resources, Water Appropriations Permit Program, <u>http://www.dnr.state.mn.us/waters/watermgmt_section/appropriations/index.html</u>, accessed May 2016.

Minnesota Department of Health, MR 4275, Wells and Borings, <u>https://www.revisor.mn.gov/rules/?id=4725</u>, accessed May 2016.

Mossler, J.H., 1992, Basal Confining Units of the St. Peter Sandstone, in Meyer, G.N.; Swanson, L., 1992, C-07, Plate 4 Geologic atlas of Ramsey County, Minnesota. Minnesota Geological Survey.

Mossler, J.H., 2008, Paleozoic stratigraphic nomenclature for Minnesota: Minnesota Geological Survey Report of Investigations 65, 76 p., 1 pl.

Ramboll Inc., October 2015, Ford Site Energy Study – Financial Analysis, 38p.

Ruhl, J.F., Wolf, R.J., and Adolphson, D.G., 1982, Hydrogeologic and water-quality characteristics of the Ironton-Galesville aquifer, southeast Minnesota: <u>U.S. Geological Survey Water-Resources</u> <u>Investigations Report 82-4080</u>, 2 sheets. Ruhl, J.F., Wolf, R.J., and Adolphson, D.G., 1983, Hydrogeologic and water-quality characteristics of the Prairie du Chien-Jordan aquifer, southeast Minnesota: <u>U.S. Geological Survey Water-Resources</u> <u>Investigations Report 83-4045</u>, 2 sheets.

Runkel, A.C., Tipping, R.G., Alexander, E.C., Jr., Green, J.A., Mossler, J.H., and Alexander, S.C., 2003, Hydrogeology of the Paleozoic bedrock in southeastern Minnesota: Minnesota Geological Survey Report of Investigations 61, 105 p., 2 pls.

Sanocki, C.A., Langer, S.K., and Menard, J.C. 2008, Potentiometric surfaces and changes in groundwater levels in selected bedrock aquifers in the Twin Cities Metropolitan Area, March-August 2008 and 1988–2008: <u>U.S. Geological Survey Scientific Investigations Report 2009–5226</u>, 67 p. with appendices.

Schoenberg, M.E., 1984, Water levels and water-level changes in the Prairie du Chien-Jordan and Mount Simon-Hinckley aquifers, Twin Cities metropolitan area, Minnesota, 1971-80: <u>U.S.</u> <u>Geological Survey Water-Resources Investigations Report 83-4237</u>, 23 p.

Schoenberg, M.E., 1990, Effects of present and projected ground-water withdrawals on the Twin Cities aquifer system, Minnesota: <u>U.S. Geological Survey Water-Resources Investigations Report</u> <u>90-4001</u>, 165 p.

US Energy Information Administration (EIA), Annual Energy Outlook 2015.

Walton, M., Eisenreich, S.J., Holm, N.L., Holm, T.R., Kanivetsky, R., Jirsa, M.A., Lee, H.C., Lauer, J.L., Miller, R.T., Norton, J.L., and Runkel, H., 1991, The University of Minnesota Aquifer Thermal Energy Storage (ATES) field test facility-system description, aquifer characterization, and results of shortterm test cycles: Pacific Northwest Laboratory Report PNL-7220, UC-202, 295 p.

Wolf, R.J, J.F. Ruhl and D.G. Adolphson, 1983, Hydrogeologic and water-quality characteristics of the Mount Simon-Hinckley aquifer, southeast Minnesota, <u>USGS Water-Resources Investigations</u> <u>Report 83-4031</u>.

Appendix Building Load Profiles for SB2030 80%

Heating Load Profile – Space Heating and Domestic Hot Water

	SB 2030 80%
Building Type	MMBtu
Low Density Housing	16,655.86
Med Density Housing	34,431.39
High Density Housing	43,116.39
Civic	1,420.90
Retail and Mixed Use	2,926.84
Office	4,944.37
Total	103,495.75

Cooling Load Profile – Space Heating and Domestic Hot Water

	SB 2030 80%
Building Type	Ton-Hours
Low Density Housing	555,195
Med Density Housing	1,147,713
High Density Housing	1,437,213
Civic	101,493
Retail and Mixed Use	221,730
Office	353,169
Total	3,816,513

Electricity Load Profile

	SB 2030 80%
Building Type	Kwh
Low Density Housing	2,928,932
Med Density Housing	6,054,758
High Density Housing	7,582,015
Civic	416,443
Retail and Mixed Use	961,784
Office	1,449,111
Total	19,393,043

Appendix III Life-Cycle Cost Analysis Assumptions

		SB2030-	
Energy and Demand Rates	BAU	80%	
Summer Electricity Rate (\$/kWh)	0.1	22	
Winter Electricity Rate (\$/kWh)	0.089		
Electric Service Charge per Residential Unit Annually	0.0	00	
Sales Tax (In Rate)	0.0	0%	
Natural Gas Rate (\$/MMBtu)	9.5	59	Plus St. Paul Franchise Fee
Natural Gas Service Charge per Residential Unit Annually	154	.20	Plus St. Paul Franchise Fee
Escalation Rates			
Location Factor	104	.3%	RS Means 2017 Total for Fire Suppression, Plumbing, and HVAC
Inflation Rate	2.5	0% 0%	
Cost of Capital Developer	10.	0%	
Cost of Capital - City	20.	070	City backed tax exempt bands
Payment Periods	21	n	City backed, tax exempt bonds
Fauinment Efficiency	20		
			BALLASHRAF ON 1 SB2030 ASHRAF
Through the Wall Air Conditioning (SEER)	11.1	12.0	189.1
Through the Wall Air Conditioning (EER)	10.0	11.0	
Through the Wall Air Conditioning COP	2.93	3.23	
Through the Wall Air Conditioning kW/ton	1.20	1.09	
Furnace	80%	90%	BAU ASHRAE 90.1, SB2030 ASHRAE 189.1
Heat Pump Cooling FER	13	14	BAU ASHRAE 90.1, SB2030 ASHRAE
WS Heat Pump Cooling	3.81	4.10	
	0.01		BAU ASHRAF 90.1. SB2030 ASHRAF
WS Heat Pump Heating	4.30	4.30	189.1
WS Heat Pump Cooling kW/ton	1.07	1.01	
			BAU ASHRAE 90.1, SB2030 ASHRAE
WS Heat Pump Cooling - Ground Water EER	18	18	189.1
WS Heat Pump Cooling - Ground Water COP	5.28	5.28	
WS Heat Pump Cooling - Ground Water			
kW/ton	0.72	0.72	
W/S Heat Ruma Heating Crowd Water COD	27	27	BAU ASHRAE 90.1, SB2030 ASHRAE
WS neat Pump Heating - Ground Water COP	3./	3./	189.1
HP CITCUIATION PUMP KW/IVIIVIBTU	4.17	4.17	
ws near rump building rumping kW/ton	0.05	0.05	

Life-Cycle Cost Analysis Assumptions

WS Heat Pump CT and Pumping Power			
kW/ton	0.10	0.10	
RTU Gas Efficiency	80%	80%	
			BAU ASHRAE 90.1, SB2030 ASHRAE
RTU Cooling kW/ton	1.20	1.09	189.1
4-Pipe and HP Boiler Efficiency	80%	89%	BAU ASHRAE 90.1, SB2030 ASHRAE 189.1
4-Pipe Chiller Efficiency (kW/Ton)	0.71	0.65	BAU ASHRAE 90.1, SB2030 ASHRAE 189.1
DHW Boiler Efficiency	80%	80%	BAU ASHRAE 90.1, SB2030 ASHRAE
Terminal Equipment Unit Costs	0070	0570	109.1
Through the Wall Unit (80% AFUE)	\$8 344	\$9.178	-
Heat Dump Water to Air + Electric Desictance	<i>\$6,511</i>	<i>93,170</i>	-
Backup	\$10	221	
	\$10, \$26	075	
	, JZU,	,075	Annualized From RSMeans 2017 Eacilities
Through the Wall PM Per Unit Annually	\$5	95	Maintenance
			Annualized From RSMeans 2017 Facilities
Heat Pump PM Per Unit Annually	\$4	22	Maintenance
	4		Annualized From RSMeans 2017 Facilities
RTU (Gas fired and DX)	\$1,439		Maintenance
Operation and Maintenance			-
Building Production Equipment			
Building Boiler \$/MW	\$1,0	043	
Building Cooling Tower \$/ton	\$1	13	
Central Plant Equipment			
ATES (% of Capital)	1%		-
Expected Unit Life Expectancy			-
Through the Wall Unit	15 Y	'ears	
RTU (Gas fired and DX or HP)	15 Y	'ears	
Heat Pump	19 Y	'ears	-
Build, Rebuild and Replace Production			
Equipment			_
Building Production Redundancy	150	0%	-
Boiler Plant (\$/MMBtu/hr)	\$80,000		
Boiler Repair (\$/MMBtu/hr)	\$3,500		
Boiler Replacement (\$/MMBtu/hr)	\$33,	,000	
New Building Cooling Tower \$/ton	\$4	10	160 ton tower, RSMeans 2017
New Building Cooling Tower Pumps	\$50,	,000	Two 300 GPM pumps
CT Repair \$/ton	\$3	30	Every 10 Years
CT Replace \$/ton	\$1	65	Every 20 Years
New Building DHW Boiler \$/MMBtu/hr	\$73,	,010	

Life-Cycle Cost Analysis Assumptions

DHW Boiler Repair \$/MMBtu/hr	\$1,043	
DHW Boiler Replace S/MMBtu/hr	\$49.908	1,150 GPH Gas Water Heater. RSMeans 2017
Through the Wall Unit Replace	\$3,651	
RTU Replace (Gas and DX or HP)	\$15,645	
Heat Pump Replace	\$3,129	1-2 ton
District Energy System Capital Costs		
ATES Plant	\$9,120,000	
Backup Production Equipment	\$362,019	
Distribution Pipe	\$2,880,000	
Indirect Energy Transfer Stations	\$1,750,000	
Organization and Financing	\$1,854,303	



MEMORANDUM

To:Ryan JohnsonFrom:Lucas Dahlingc:Jeff Urlaub

November 9, 2017 Geothermal Implementation Feasibility – Ford St. Paul

MEP Associates conducted a preliminary investigation of geothermal implementation feasibility for a potential project site located in St. Paul, MN. The purpose of the investigation was to establish if site geological conditions, available green space, and financial feasibility supports installation of a geothermal heat exchanger.

Results of the investigation have been summarized in the following paragraphs with supporting documentation provided as attachments.

Site Geological Conditions & Green Space:

The existing site includes a variety of small and large parcels available for installation of vertical bores including one large green space parcels at the corner of Montreal Ave and Cleveland Ave. The total area available for vertical bore installation is roughly 8 acres.

MEP researched municipal and private well logs to establish both drilling and thermal performance conditions of the St. Paul site. There were two 450' wells drilled in the 1950's showing soapstone down to 50', limestone from 50' to 100', sandstone from 100' to 250', dolomite from 250' to 375', and sandstone from 375' to 450'. Drilling logs for both wells and a site map showing location to project site have been included as attachments to this document.

Based on the well logs, MEP estimates that the ground has an average thermal conductivity of 1.4 Btu/hr*ft*°F and an average thermal diffusivity of 1.2 ft²/day.

Analysis:

Evergreen Energy provided two load profiles based on two energy codes. One energy code is at SB2030-80%, while the other is at the current Minnesota Code (2012 IECC). Using the SB2030-80% code resulted in peak cooling and heating requirements of 2,770 tons and 38,320 Mbh, respectively. Using the 2012 IECC code resulted in much higher peak cooling and heating requirements of 4,340 tons and 58,600 Mbh, respectively.

Page 1 of 2



MEP performed GLD analysis for both energy codes using $1-\frac{1}{4}$ " U-bend bores. The results of the analyses are shown below.

- Using SB2030-80% load profile, the geothermal heat exchanger would require:
 - 1,650 bores at a depth of 500'
 - Spaced 20' on center
 - Minimum requirement of 15.1 acres of green space
- Using IECC 2012 load profile, the geothermal heat exchanger would require:
 - 2,500 bores at a depth of 500'
 - Spaced 20' on center
 - o Minimum requirement of 23.2 acres of green space

When compared to the total green space available on the St. Paul site, there is not enough space to install a geothermal heat exchanger using traditional U-bends. MEP looked into utilizing Rygan coaxial heat exchangers, as they require less area than traditional U-bends. However, the Rygan grout is not acceptable in Minnesota, thus the Rygan coaxial heat exchangers could not be used.

An opportunity to reduce the required green space would be to utilize a hybrid geothermal system. In a hybrid system, the geothermal well field covers a portion of the heating and cooling loads, while conventional cooling and heating equipment (e.g. cooling tower, boiler, etc.) cover the remaining loads. While not as efficient as a full geothermal system, a hybrid system would reduce the required green space, as well as the upfront investment cost.

Preliminary Well Field Costs

To determine preliminary costs, the unitary costs for traditional U-Bend were assumed to be roughly \$17/lineal ft of bore. The unitary costs include site excavation, drilling, piping material and installation, grouting material and installation, backfill, lateral piping to the pump house, vaults, and site clean-up. In addition, approximately \$300,000 would be required for a pump house. With these assumptions, the cost of a traditional U-Bend well field would be \$14,325,000 using the SB2030-80% load profile, or \$21,550,000 using the 2012 IECC load profile.



St. Paul Ford Site: Twin Cities Assembly Plant to a 21st Century Community

- Opened in 1925, built in St. Paul on the promise of cheap hydropower.
- The Ford Dam, part of Lock and Dam No. 1, was completed in 1929 and provided 14.4 Mw of electricity.
- Glass was made from 1926 to 1959, and was produced from silica mined on site. The mining tunnels still exist below grade.
- Closure of the plant was announced in April of 2006, and the last vehicle was produced on December 16, 2011.



- Site clean up and environmental testing is ongoing to prepare the property for future development.
- St. Paul Mayor Chris Coleman has emphasized a desire for "net-zero" community that includes housing, commercial space, park space, and transportation options.



FORD SITE REDEVELOPMENT "NET ZERO" AS A BRIDGE FROM STANDARD TO REGENERATIVE DEVELOPMENT



FORD SITE REDEVELOPMENT "NET ZERO" AS A BRIDGE FROM STANDARD TO REGENERATIVE DEV

Code-Based Buildings - ASHRAE 90.1 2010 2015 Energy Grid

Total Energy Use: 60,984 MWh / year



FORD SITE REDEVELOPMENT

Code-Based Buildings - ASHRAE 90.1 2010 2030 Energy Grid

Total Energy Use: 60,984 MWh / year



FORD SITE REDEVELOPMENT





College of Design UNIVERSITY OF MINNESOTA

MINNESOTA SUSTAINABLE BUILDING 2030

CASE STUDY METRICS – www.casestudies.b3mn.org



Bear Head Lake State Park



Hennepin County 911 Facility



BSU Decker Hall Renovation



MnSCU Mankato Clinical Sciences Building



Hamline Station



Tettegouche Visitor Center and Rest Area



Western U Plaza



Kendall's Payne Avenue Hardware



Big Bog State Recreation Area



Minnesota National Guard Winona Armory Renovation



MSU Science Education Building



Camp Ripley COE Training Facility



NHCC Biosciences and Health **Careers Center**



NCC Academic Partnership

Center

Maplewood Mall Parking Structure



SCC Classroom Renovation and Addition



UMM Green Living and Learning Community



BSU Memorial Hall Renovation





Silver Creek Corner



PTC Entrepreneurship Center and Business Incubator



Washburn Center for Children



STCC Medium Heavy Truck and Auto Body



Duluth Entertainment and **Convention Center**













RESULTS – ENERGY (DESIGN/SB 2030 STANDARD)





IMPACT OF B3 PROGRAMS







B3 Guidelines

- 286 projects in B3 Guidelines (including SB 2030 projects)
 SB 2030 Program
- Over 70 projects in SB 2030 Program
- First 40 projects anticipated aggregate savings of:
 - 327 million kBtus/year
 - \$5.24 million/year

B3 Benchmarking

- Over 7,600 buildings representing over 315 million SF in program
- Identified over 3,000 buildings that are good candidates for improvement (42% of the population)
- Potential savings of 3,585 million kBtu per year
- Potential savings of 46.6 million dollars per year

Building Definition

Building Type		Gross Building SF			l	Location	
Office	Ŧ	176,865		ft²		Minneapolis	Ŧ
			_				
Space Asset Areas	+ Add Area	ی Scale All To Fit	🖽 Summ	hary			
		4 1					• •
Retail 1			Office				-
Type: Retail	Area: 26,865 ft² (1	5%) 💌	Type: Office	e		Area: 150,000 ft² (85%)	
Floors-1	Arrangement: Star	cked	Floors: 5			Arrangement: Stacked	
Construction Type: New			Constructio	n Type: New			
1	Edit					Edit	

Exterior Lighting











Energy Standard (kstu/#*/yr)

Target (based on 70% reduction)	1
Carbon Dioxide (Ibs CO2/ff?/yr)	



Organization	CSBR
Location	Minneapolis

Space Asset Areas

Retail 1	Office				
Type: Retail	Type: Office				
Area: 26,865 ft² (15%)	Area: 150,000 ft ² (85%)				
Floors:1	Floors: 4				
Arrangement: Hosted	Arrangement: Adjacent				
Construction Type: New	Construction Type: Renovated				
Cooling: Not District	Cooling: Not District				
Heating: Not District	Heating: Not District				

Exterior Lighting

Parking Area Illuminated	0	Number of Main Entrances	0
Number of Secondary Entrances	0	Exterior Wall Area Illuminated	0

Estimated Site Energy Utilization Intensity (EUI) for different new building types in climate zone 6A (St. Paul) using different energ codes or certification systems.

Current MN Energy



COMPARATIVE SITE EUI

kBtu/ft²/yr		Code									\square	
Code Building Type	Prototype Floor Area (sf)	ASHRAE 90.1-2004	2012 IECC / ASHRAE 90.1-2010	2015 IECC / ASHRAE 90.1-2013	SB 2030 (2010) -60%	SB 2030 (2015) -70%	SB 2030 (2020) -80%	SB 2030 (2025) -90%	German Passive House System	Danish Building Code BR 2010	Danish Building Code Class 2015	Danish Building Code Class 2020
Small office	5,502	53.7	41.8	37.2	63.0	47.3	31.5	15.8	14.3	37.1	25.8	18.7
Medium office	53,628	62.2	46.2	42.8	62.0	46.5	31.0	15.5	14.3	36.1	25.2	18.7
Large office	498,588	99.7	84.8	83.5	60.0	45.0	30.0	15.0	14.3	36.1	25.1	18.7
Stand-alone retail	24,692	107.2	71.9	61.9	59.0	44.3	29.5	14.8	14.3	36.3	25.2	18.7
Strip mall retail	22,500	118.3	85.4	77.9	60.0	45.0	30.0	15.0	14.3	36.3	25.3	18.7
Supermarket	n/a	208.0	145.0	128.7	119.0	89.3	59.5	29.8	14.3	36.0	25.1	18.7
Primary school	73,959	100.1	75.1	67.8	70.0	52.5	35.0	17.5	14.3	36.1	25.1	18.7
Secondary school	210,887	98.4	64.7	56.2	60.0	45.0	30.0	15.0	14.3	36.1	25.1	18.7
Hospital	241,501	179.9	138.5	130.5	79.0	59.3	39.5	19.8	14.3	36.1	25.1	18.7
Outpatient health care	40,946	161.5	123.3	118.8	52.0	39.0	26.0	13.0	14.3	36.2	25.2	18.7
Full-service restaurant	5,502	570.2	470.9	450.8	90.0	67.5	45.0	22.5	14.3	37.1	25.8	18.7
Quick-service restaurant	2,501	781.9	723.0	689.6	98.0	73.5	49.0	24.5	14.3	38.3	26.6	18.7
Small hotel	43,202	87.4	75.8	71.5	50.0	37.5	25.0	12.5	14.3	28.5	19.6	15.0
Large hotel	122,120	151.8	119.1	109.4	63.0	47.3	31.5	15.8	14.3	28.5	19.5	15.0
Warehouse	52,045	35.3	25.2	23.6	42.0	31.5	21.0	10.5	14.3	36.2	25.2	18.7
Mid-rise apartment	33,741	68.0	60.4	57.3	82.0	61.5	41.0	20.5	14.3	28.6	19.6	15.0
High-rise apartment	84,360	72.1	65.8	61.2	88.0	66.0	44.0	22.0	14.3	28.5	19.5	15.0

© 2010-2014 Krifcon Engineering PC



Design Strategies

program. 26,865 square feet of retail



HUMAN POWERED LIVING: Open and attractive stair encourages occupants to use stairs instead of electricity-driven elevators. 50% reduction in elevators trips can save 6,701 kWh per

yeat, equivalent to 4.6 metric tans of CO2

HUMAN POWERED LIVING: Dense neighborhood with frequent pedestrian and bicycle paths encourages residents and building users to leave cars behind.







HVAC: Ground source heat pump tied into aquifer thermal energy storage. Provides heating and cooling using deep underground aquifer.



INTERNAL LOADS: Lighting power densities are limited to 0.4 watts / ft2. Equipment power densities limited to 0.8 watts / ft2.

Equipment power densities limited to 0.8 watts / ft2. 44% reduction in lighting watts / ft2 from code. 20% reduction in equipment watts / ft2 from typical buildine



two-way solar array that maximizes production potential.

RAINWATER CAPTURE: Collect rainwater from roof, treat

Collect and treat grey wat

sinks and use it to flush toilets and urinals. Excess grey

48,500 gallons of rain water collected each month

and store in cistern for use in building.

72% of demand for potable water met.

1.394.650kWh produced yearly

92% of electicity demand met 962 metric tons CO2 saved

SOLAR ARRAY: Renewable energy generated on site using PROGRAM: Mixed use Residential and Retail



HUMAN POWERED LIVING: Centrally-located stairs provide views of surrounding neighborhood and encourage users to use stairs rather than elevator.



HUMAN POWERED UVING: Dense neighborhood with frequent pedestrian and bicycle paths encourages residents and building users to leave cars behind.



BUILDING ENVELOPE: Increased insulation in exterior walls (R60) and roof (R80) and improved glazing (U-0.24) reduce energy demands throughout the year.

HVAC: Ground source heat pump system uses year-round average underground temperature to cool or warm interior spaces.



INTERNAL LOADS: Reduction in lighting power densities and equipment power densities by 20% reduces EUI by 3 kBtu/st/yr.



SOLAR ARRAIT: Photovoltaic panels covering the roof area 24) generate 18% of the building's energy demand.



RAINWATER CAPTURE: Rooftop rainwater collection to treat and used to meet 35% of monthly potable water demand



GREYWARTER REUSE: Basement cisterns collect greywater from within building to reuse for toilets and urinals. Able to provide for 100% of greywater demand.





FORD SITE REDEVELOPMENT

Office Prototype

IMPROVED CASE - BY THE NUMBERS Office and Retail



BUILDING DETAILS

176,865 Total SF 26,865 Retail SF on 1st Floor 30,000 Office SF on 2nd-6th Floor 30,000 Roof SF

ENERGY PERFORMANCE 22.5 kBtu/sf/yr EUI

610,837 kW Photovoltaic Array

WATER USE

72% of Potable Water Demand met by Rainfall 6.3 Gallon Demand per Person per Day

VALUE

\$000 / SF Baseline \$000 / SF Net Zero Energy \$000 / SF Net Zero Water \$000 / SF Living Building Challenge

MAJOR DESIGN STRATEGIES

88% Potable Water Demand Reduction Rainwater capture & Greywater reuse Increased R Values for Walls & Roof Improved Glazing Performance Improved HVAC system and efficiency Lighting Power Densities reduced 50% Equipment Power Density Reduced 40%

IMPROVED CASE - ENERGY USE

Office And Retail



EUI = Energy Use Intensity measured in kBtu/sf/yr

FORD SITE REDEVELOPMENT

Total Energy Use: SB2030 80% Better Buildings 26,121 MWh / year 2030 Energy Grid 57% Reduction Built Up Area: Low Density Housing -534,000 ft2 Natural Gas Imported 1,296,000 ft2 Med Density Housing -9,142,392 kWh / year 570,000 ft2 High Density Housing -Civic -50,000 ft2 35% of Total Energy Retail and Mixed Use -375,000 ft2 Institutional -194,000 ft2 Total -3,019,000 ft2 Electricity Imported 16,978,730 kWh / year 65% of Total Energy Wind Generated - 25% Hydro Generated - 2% Biomass Generated - 0% Nuclear Generated - 28% Natural Gas Generated - 22% Coal Generated - 15% Solar Generated - 8%

FORD SITE REDEVELOPMENT



FORD SITE REDEVELOPMENT



FORD SITE REDEVELOPMENT



FORD SITE REDEVELOPMENT "NET ZERO" AS A BRIDGE FROM STANDARD TO REGENERATIVE DEVELOPMENT



MPCA GRANT PROTOTYPE TEST

- 1. SUPER INSULATED ENVELOPE
- 2. STORAGE OF ENERGY AND WATER
- 3. MAINTAIN CRITICAL SYSTEMS
- 4. MULTIPLE SOURCES OF ENERGY AND WATER SUPPLY
- **5. FOOD PRODUCTION**
- 6. DISTRIBUTED ENERGY PRODUCTION
- 7. RAINWATER CAPTURE

FORD SITE REDEVELOPMENT "NET ZERO" AS A BRIDGE FROM STANDARD TO REGENERATIVE DEVELOPMENT