Leveraging Aquifers to Support Sustainable Energy Infrastructure

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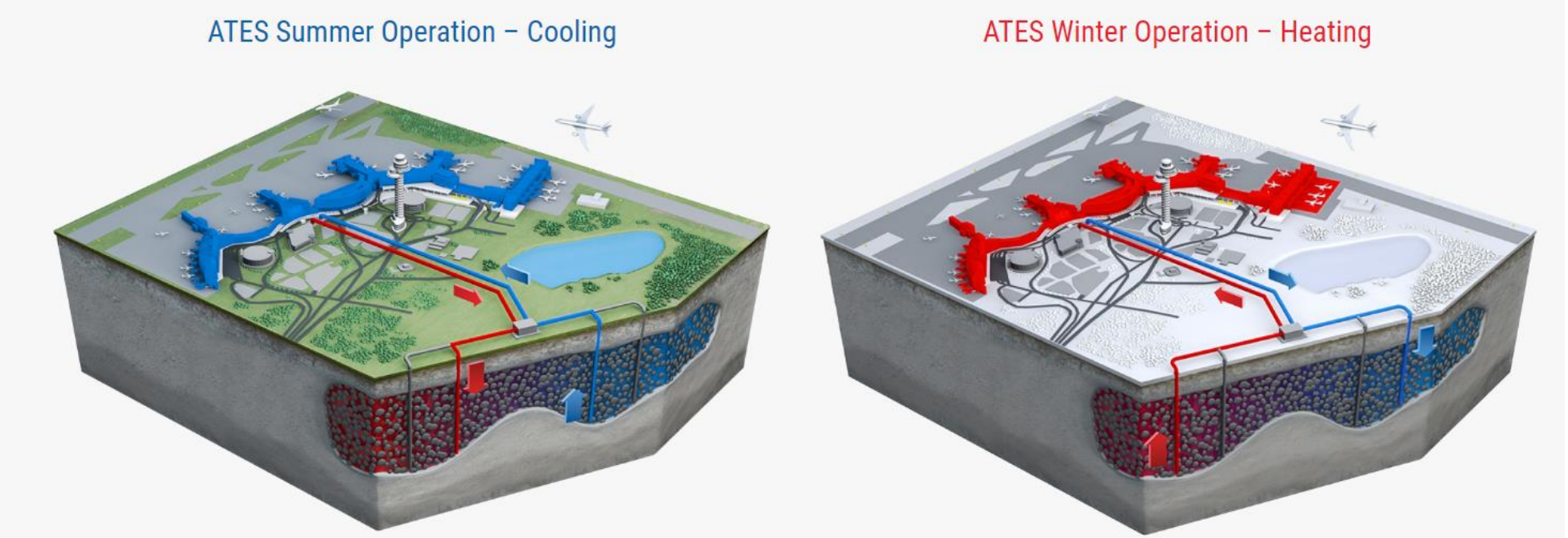
Aquifer Thermal Energy Storage (ATES)

- Aquifer technology has existed for about 25 years
- Well-established in the Netherlands – over 2,500 projects
- Optimal in climates with cold winters and hot summers
- Requires low groundwater velocity
- No groundwater consumed
- Balanced injection and withdrawal rates
- Heat stored in the aquifer in the summer
- Heat extracted from the aquifer in the winter

ATES – How it Works



- Open loop with separate warm and cold stores
- Seasonal reversal of warm and cold withdrawal/injection
- Hydraulically balanced

- Seasonal thermal energy storage enabled by:
  - High heat capacity of groundwater vs. aquifer skeleton
  - Dynamics of fluid flow in porous media
  - Low temperatures, low advection losses
  - Hydraulic modeling and management of aquifer

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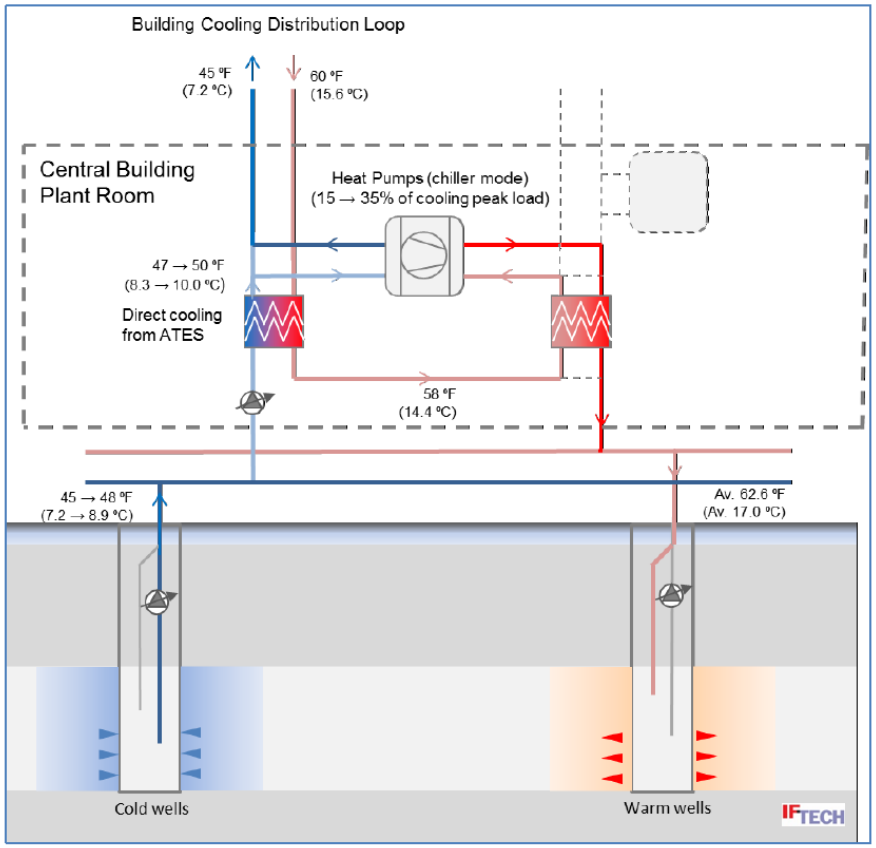
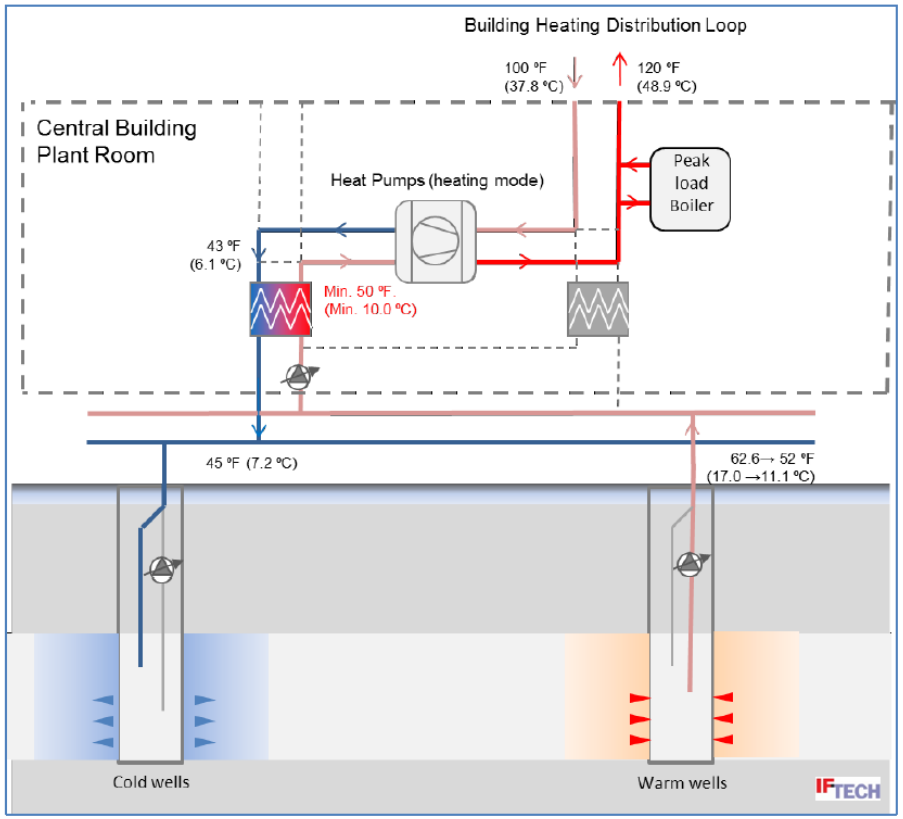
ATES Operating Modes



Summer Mode



Winter Mode

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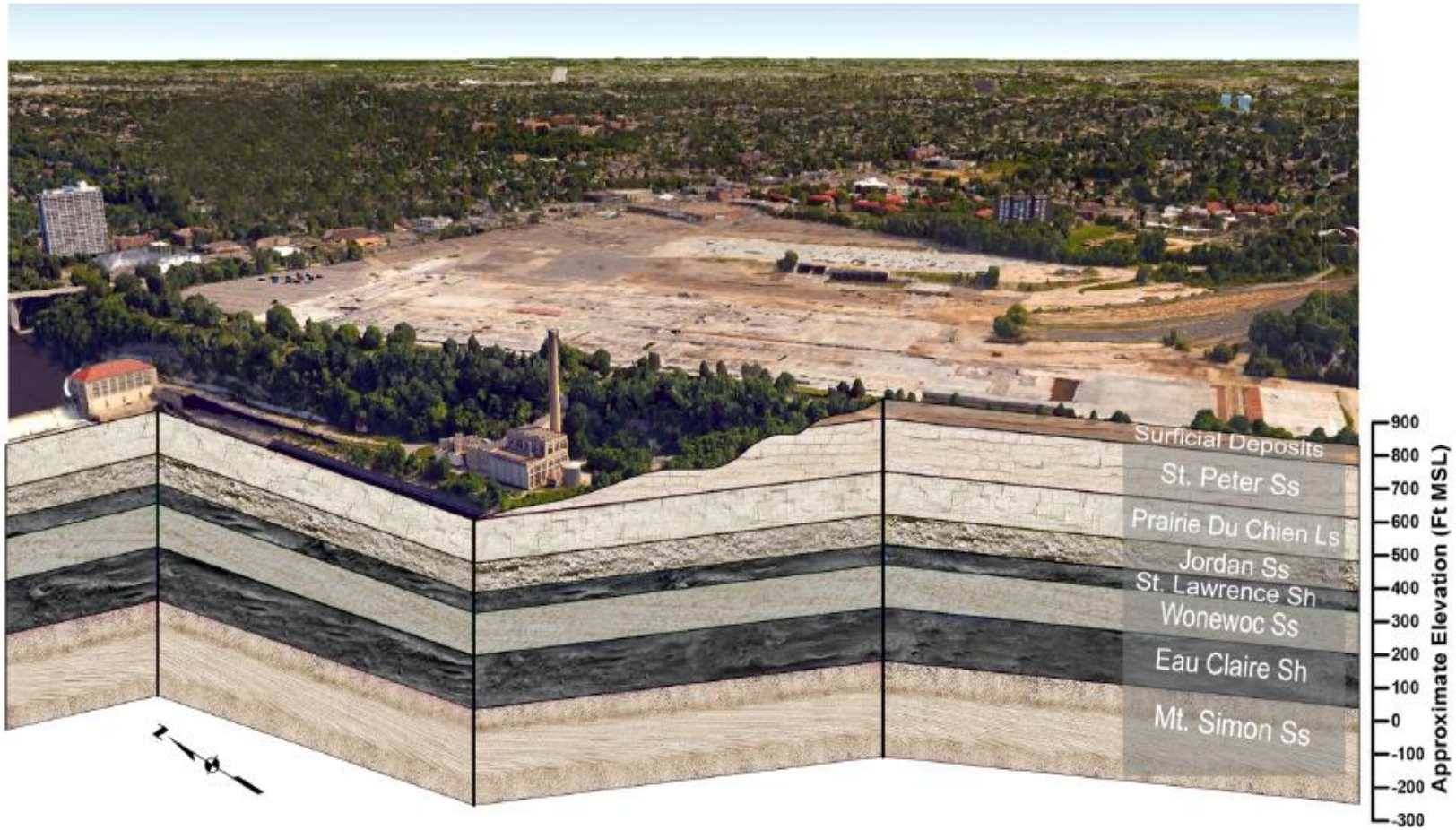
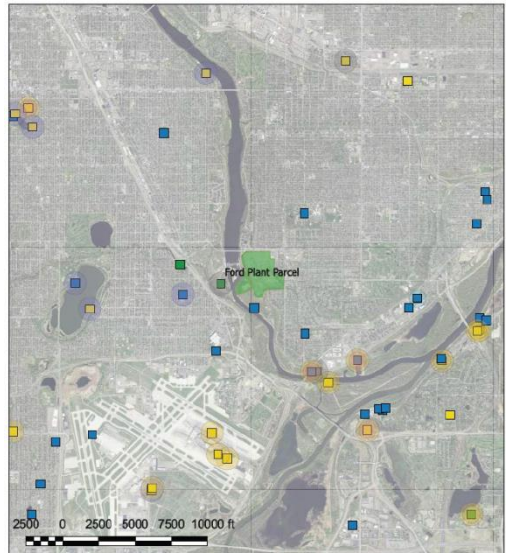
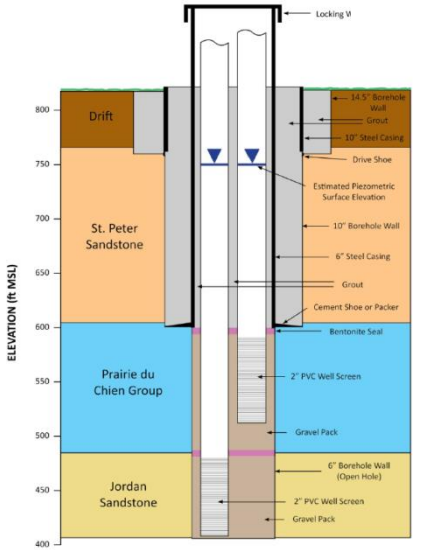
Hydrogeologic Due Diligence – Ford Site







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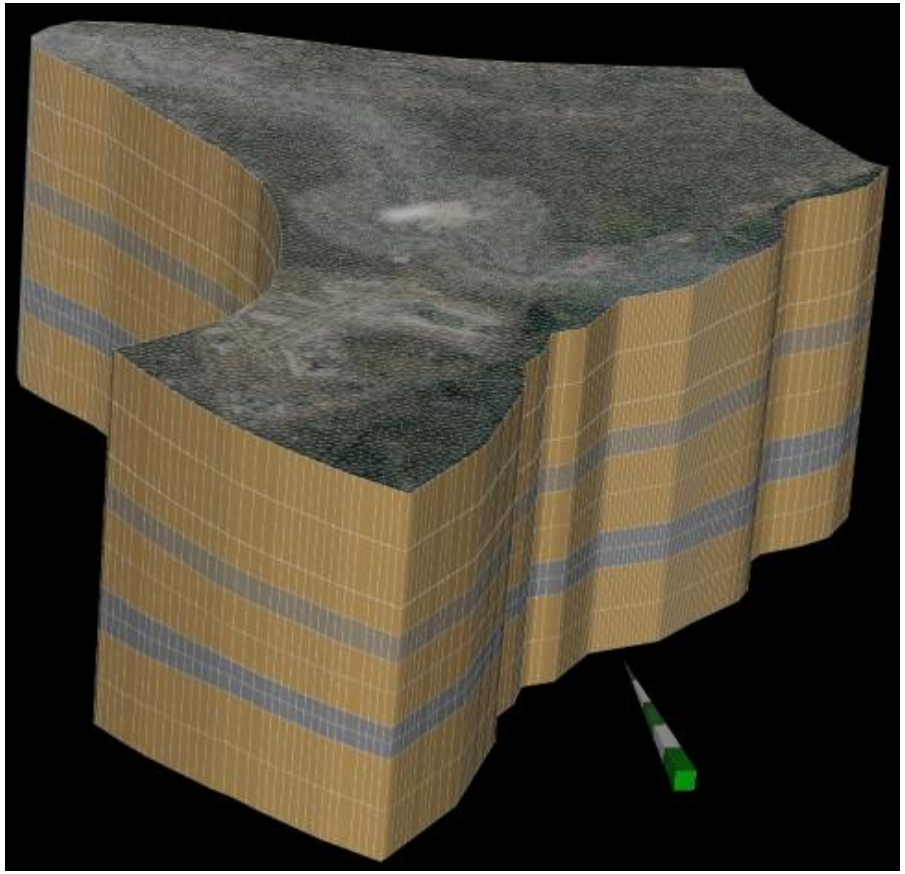
Hydrogeologic Due Diligence

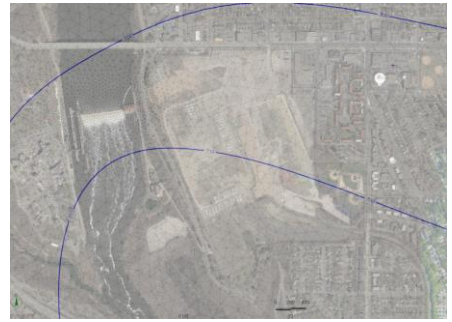
3D Groundwater Flow Model



Hydraulic Head

St. Peter Aquifer

Shakopee Aquifer



Jordan Aquifer

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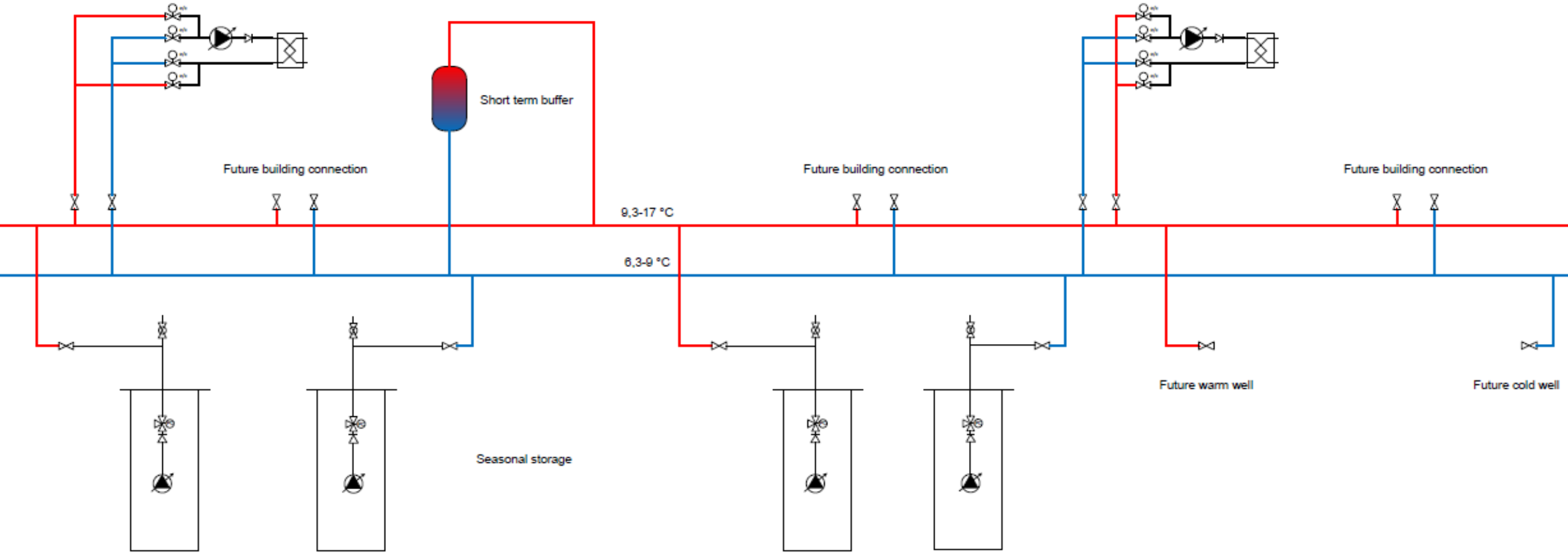
Regulatory Due Diligence

Ford Site, Saint Paul, MN

- **ENVIRONMENTAL:** Aquifers below the St. Peter sandstone are unlikely to have been affected by anthropogenic contamination from historic land uses at the Ford Site.
- **FEDERAL - Underground Injection Control:** ATES wells are Class V injection wells under the UIC program administered by the US EPA. EPA retains primacy over the UIC program in Minnesota.
- **STATE - MDNR Appropriation Permit:** Groundwater withdrawals > 10,000 gpd require an appropriation permit from the DNR, even for nonconsumptive use.
- **STATE - MDH Groundwater Thermal Exchange Device and Well Permits:**
  - Minnesota Statute 103I.621 – ATES system can be developed; MDH permit required
  - Minnesota Administrative Rules Ch 4725 - Wells and Borings

District Aquifer Thermal Energy Storage (DATES)

Distributed submersible well pumps allow reduced pipe size and cost



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Ford Site Redevelopment

Saint Paul

- 135 acre site
- Roughly 5 million square feet of commercial, retail, and residential
- Net-zero carbon goals
- Coordinated discussions between City, land owner, developer, and local utilities

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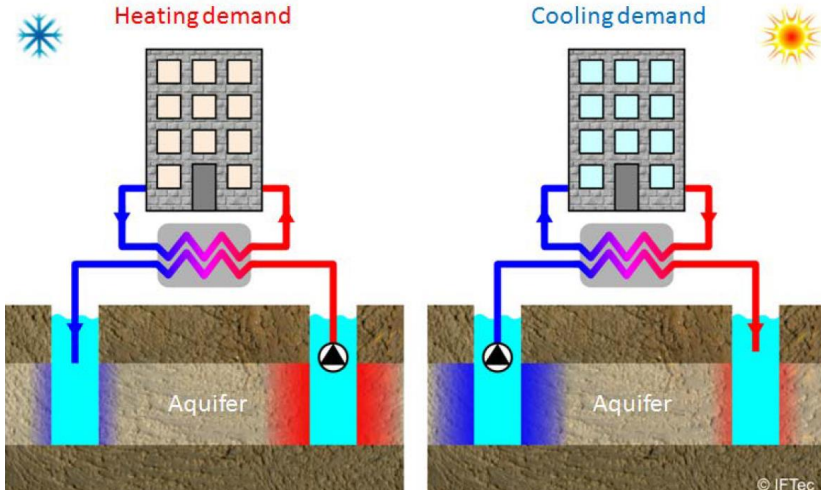
Proposed District Energy System

- About 5,000 GPM aggregate flow
- Heating and cooling site buildings
- Fresh water district energy loop serves the buildings
- Focus on commercial and multi-family residential
- Potential of adding single-family homes
- Phased approach to coincide with site development
- Sets the foundation for net-zero carbon development



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Financial Benefits

- Third-party financed – 100% debt financing
- Equivalent first-installed costs for developers
- Lower life-cycle costs for building owners
- Reduced maintenance
- Reduced labor costs
- Smaller building footprint
- Simpler mechanical systems
- Lower tenant energy costs

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Environmental Benefits

Xcel Current Profile - 881 lbs CO2/MWh

Scenario	*EUI Basis*	*Tons of CO2*	*% Savings*
Business as Usual	Code	9,261	37%
ATES	SB2030 - 80%	5,852	

Xcel 2030 Profile - 521 lbs CO2/MWh

Scenario	*EUI Basis*	*Tons of CO2*	*% Savings*
Business as Usual	Code	8,543	59%
ATES	SB2030 - 80%	3,461	

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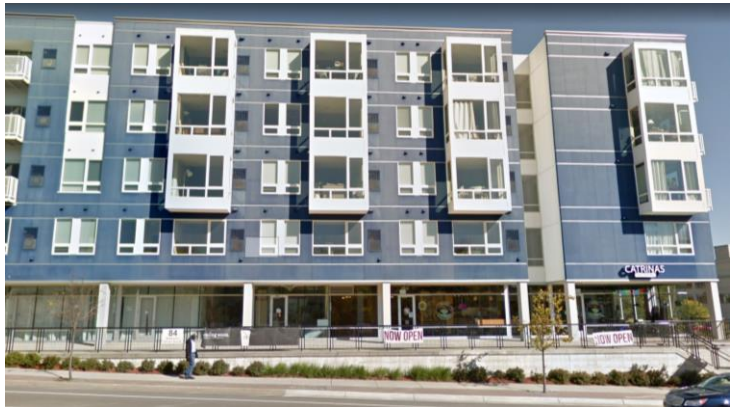
Environmental Benefits

- Differing financial timelines (8-year vs 30-year)
- More complicated cost allocation
- Competing site priorities (affordable housing, infrastructure investment)
- Uncertainty of a new technology
- Inexperienced engineers, architects, and contractors
- Complicating the Developer's program
- Submetering



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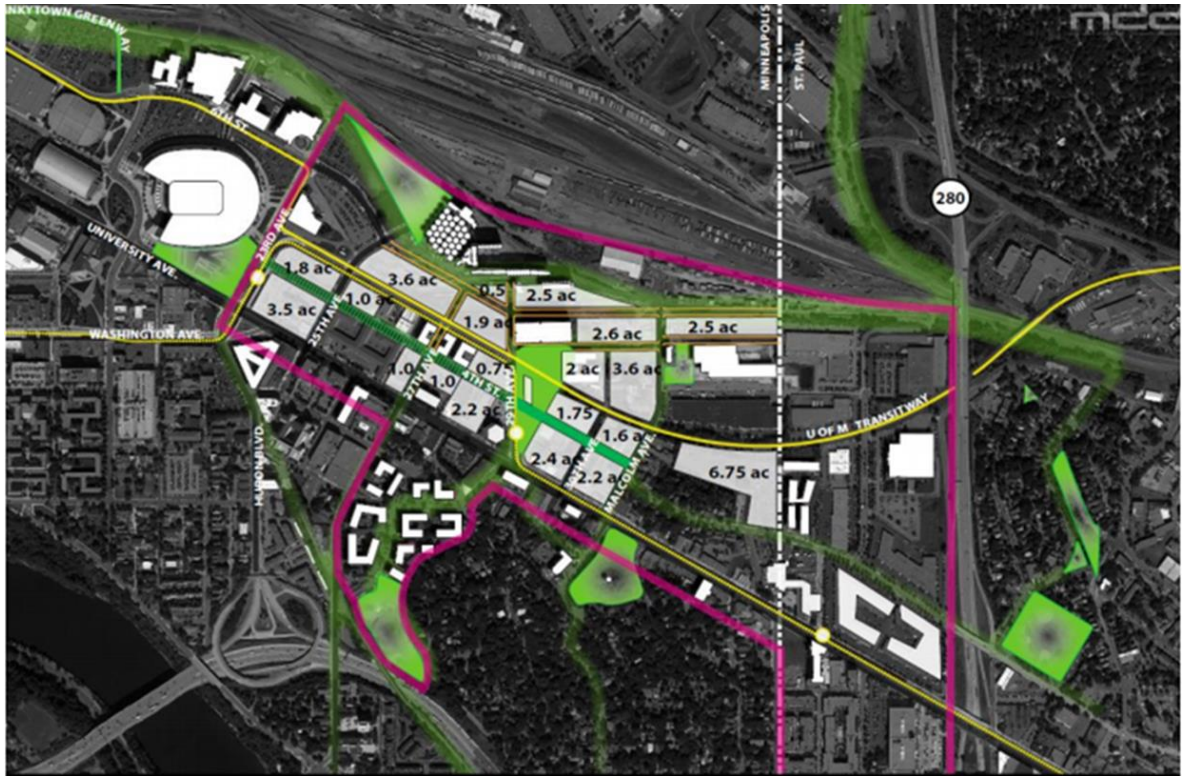
Opportunities for Improvement

- More detailed educational materials before the developer is engaged
- Simplified financial models and financing plans
- Eliminate uncertainty
- Match the traditional utilities' rate structures and billing strategies
- Quickest path to the second system:
  - Install the first

The Silver Lining

Towerside District Energy (Minneapolis, MN)



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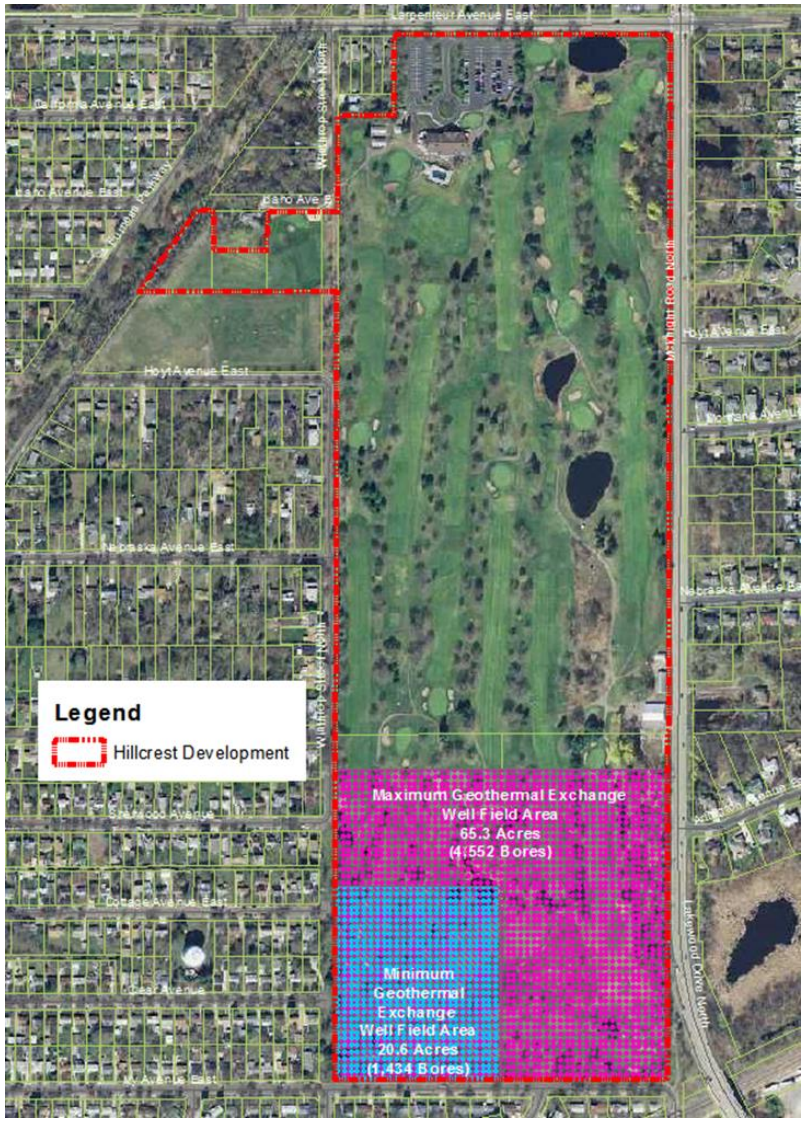
The Silver Lining

Hillcrest Redevelopment (Saint Paul, MN)



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Thank You

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