Feasibility Study of Aquifer Thermal Energy Storage (ATES) Ford Site, St. Paul, Minnesota

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IF TECH

Outline

- Why seasonal thermal energy storage?
- Methodology for assessing ATES feasibility at the Ford Site
- ATES Feasibility at the Ford Site in St. Paul
  - Project History
  - Hydrogeology
  - Engineering
  - Regulatory & Permitting
  - ATES Benefits
  - Project Finances
  - Conclusions and Recommendations
- Overview of ATES suitability in the USA

Why seasonal storage?

- Steep reductions in GHG are not achievable without utilizing waste heat and low temperature renewable energy resources.

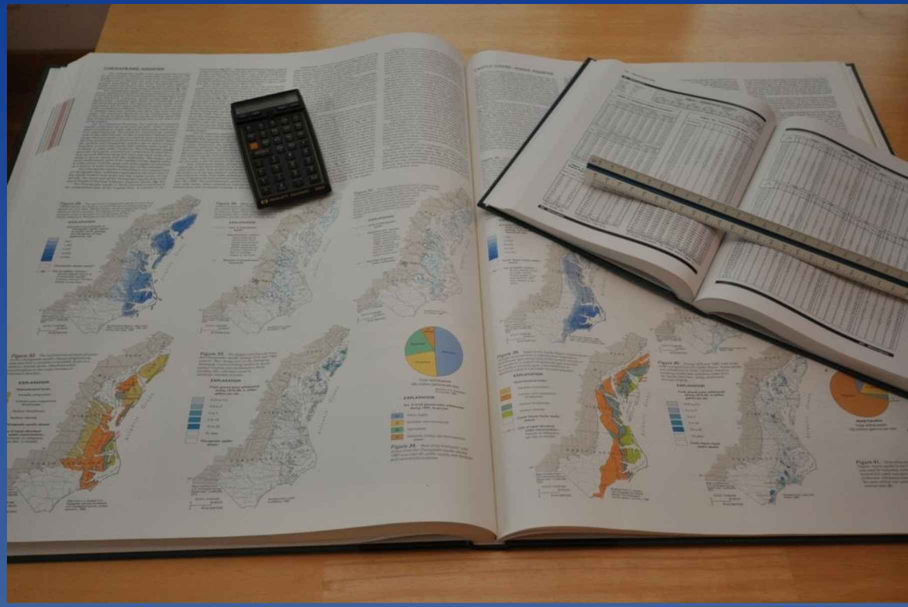
- Availability of zero-carbon heating resources is greater in summer when heat demand is low:
  - Solar
  - Reject heat from chiller systems.

- Availability of zero-carbon cooling resources is greatest in winter when cooling demand is low:
  - Cold winter air or cold surface water
  - Chilled water rejected from heat pumps

- Other no- or low-carbon heat resources may not correlate well with heating demand:
  - Industrial waste heat is tied to operating hours of the industrial facility, and may be subject to interruptions
  - Power production is generally more valuable during summer, leading to sub-optimized CHP design and operations.

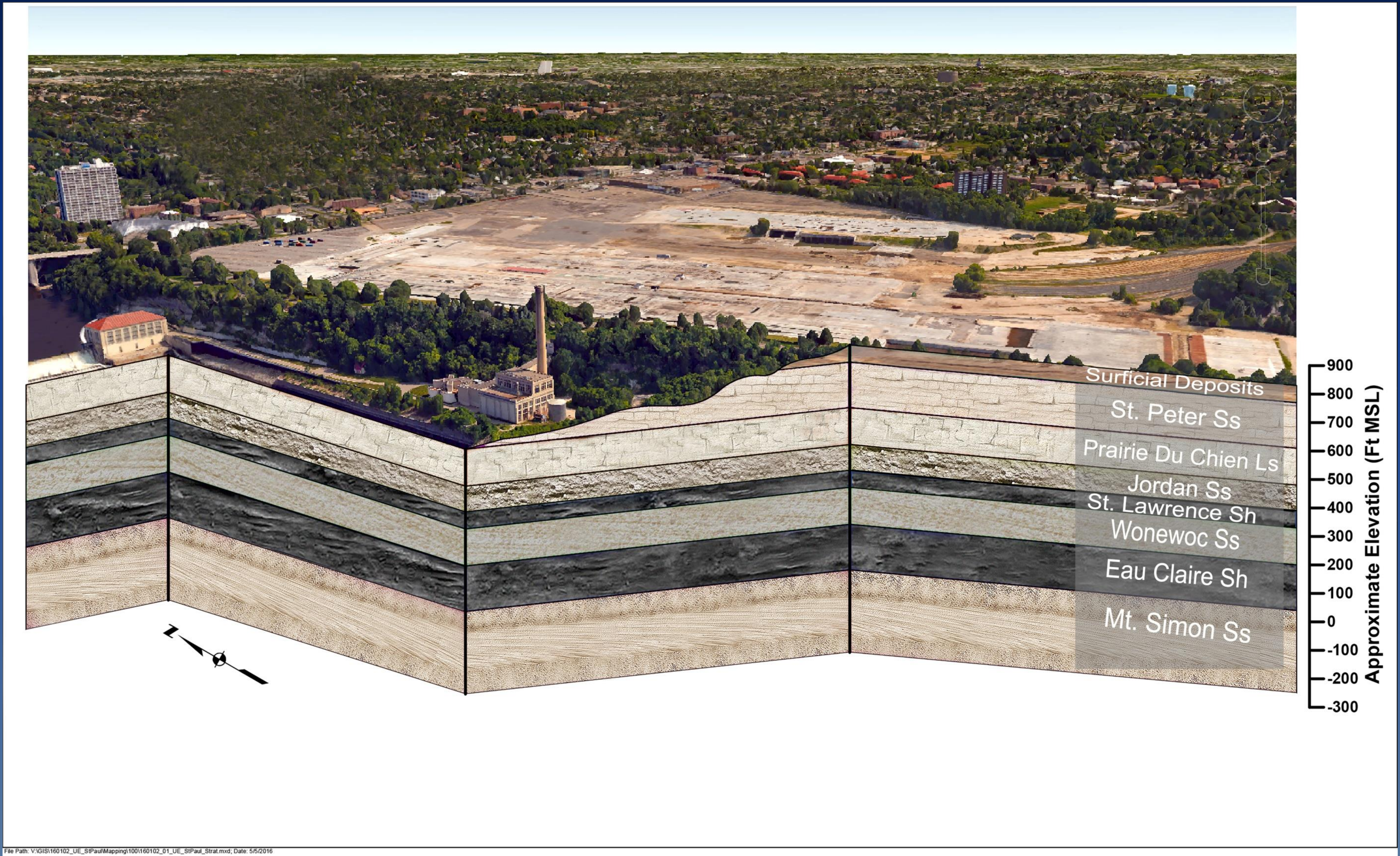
Seasonal Thermal Energy Storage Feasibility Study Components

- Hydrogeologic Evaluation
  - Aquifer physical, hydraulic and geochemical properties
  - Identify nearby public water supply wells
  - size wells
- Engineering Evaluation
  - District Energy System Integration
  - Conceptual design
  - Calculate OPEX and emissions reductions
- Financial Evaluation
- Regulatory Evaluation



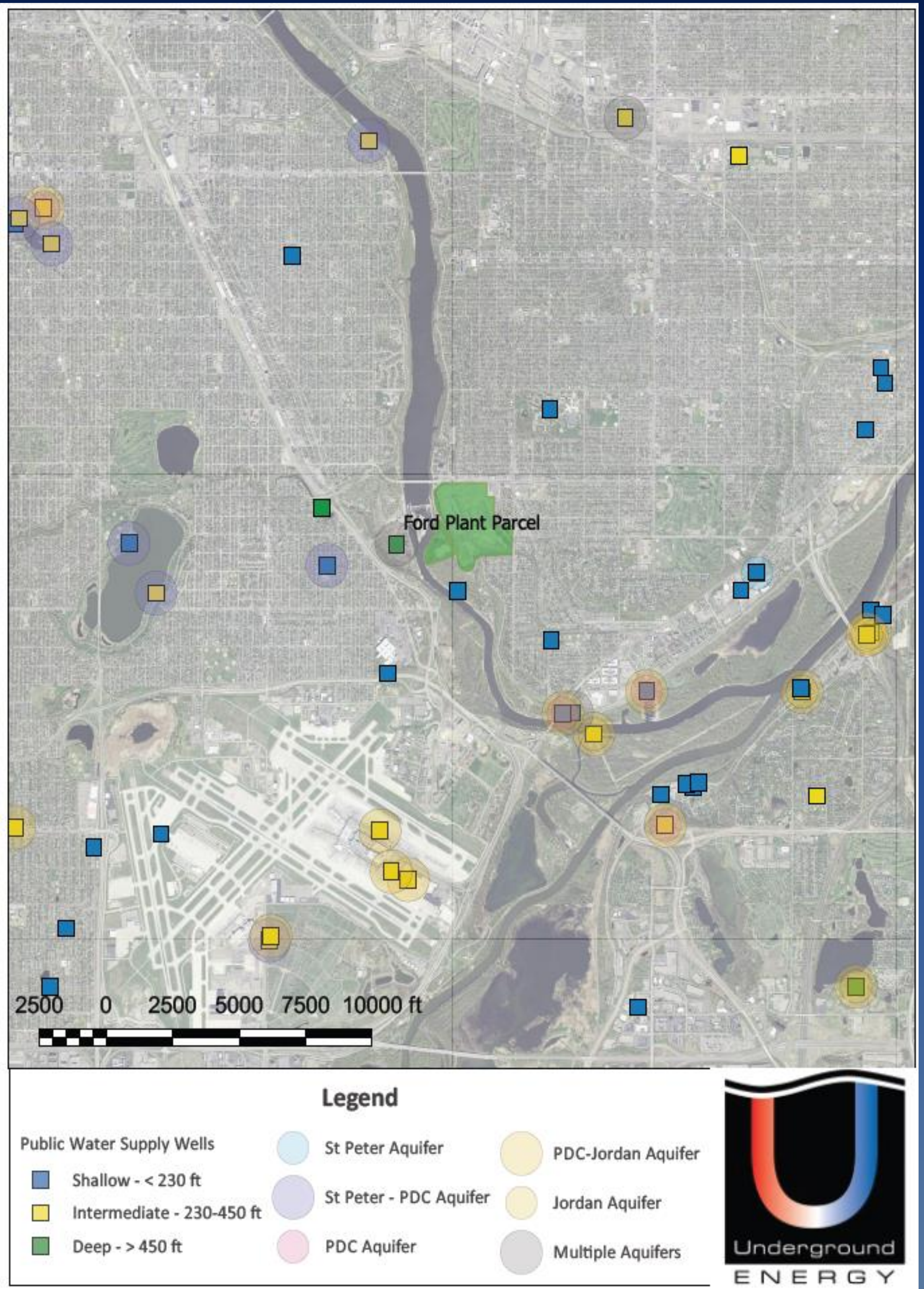
ATES Hydrogeologic Evaluation

Multiple Aquifers Underlie the Ford Site



ATES Hydrogeologic Evaluation

Public Supply Wells Proximal to the Ford Site



ATES Hydrogeologic Evaluation

ATES Well Sizing

	Aquifer System				
	St. Peter	**Prairie du Chien**	**Jordan**	**Wonewoc**	**Mt. Simon**
Well Depth	220 ft 67 m	350 ft 107 m	440 ft 134 m	700 ft 213 m	1100 ft 335 m
Well Screen Length	90 ft 27 m	130 ft 40 m	90 ft 27 m	130 ft 40 m	150 ft 46 m
Well Screen Depth Interval	130-220 ft 40-67 m	220-350 ft 67-107 m	350-440 ft 107-134 m	630-700 ft 192-213 m	950-1100 ft 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 Borehole Wall	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
Well Flow Rate	180-260 gpm 40-60 m^3/hr	255-760 gpm 60-170 m^3/hr	176-441 gpm 40-100m^3/hr	14-34 gpm 3-8 m^3/hr	73-370 gpm 15-85 m^3/hr
Maximum Injection Pressure	4 ft ags	13 ft ags	21 ft ags	38 ft ags	49 ft ags

ATES Engineering Evaluation

Building Thermal Loads, Ford Site, St. Paul, MN

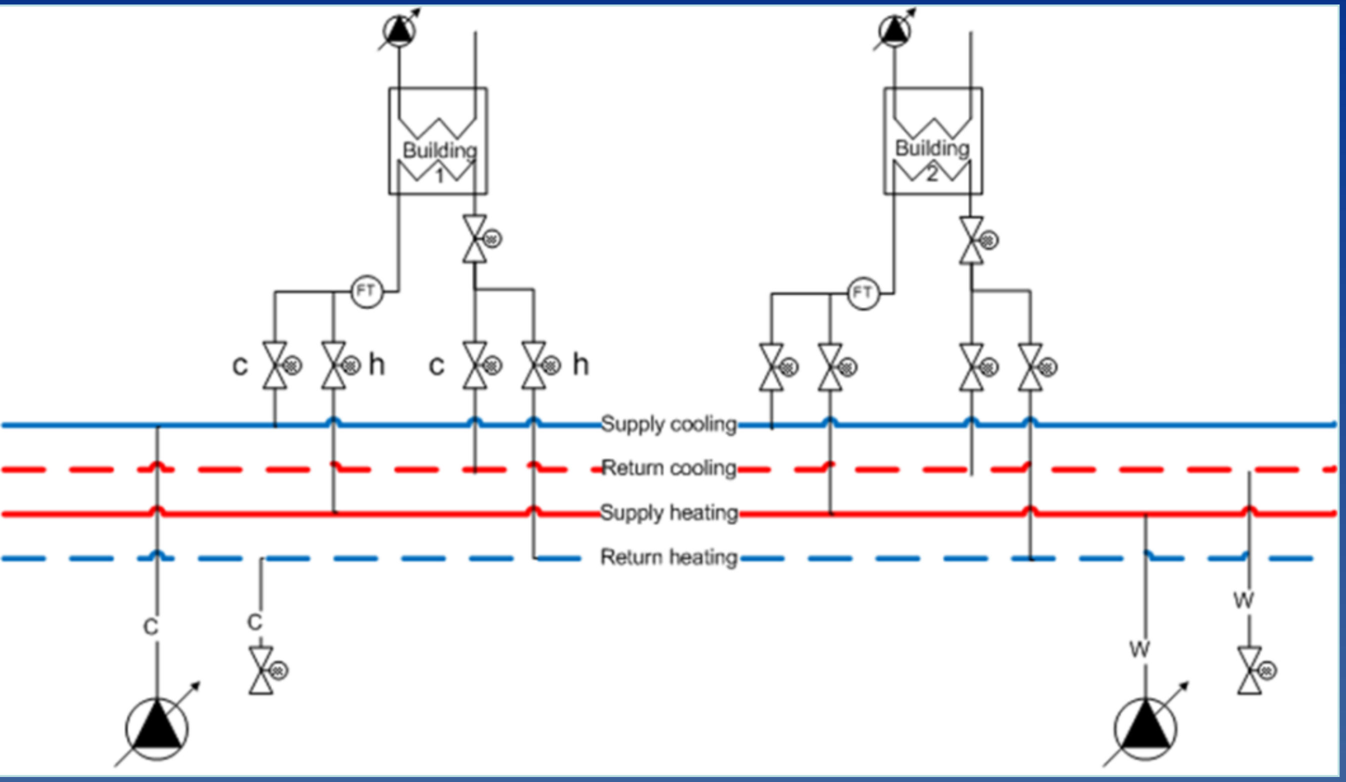
Building type	Conditioned floor area	
	sf	m²
Low density residential	890,000	83,000
Medium density residential	780,000	72,000
High density residential	3,450,000	320,000
Mixed use/retail	275,000	25,000
Retail	640,000	60,000
Civic buildings	300,000	28,000
Office buildings	235,000	22,000
Total	**6,570,000**	**610,000**

Building type	Heating demand		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**

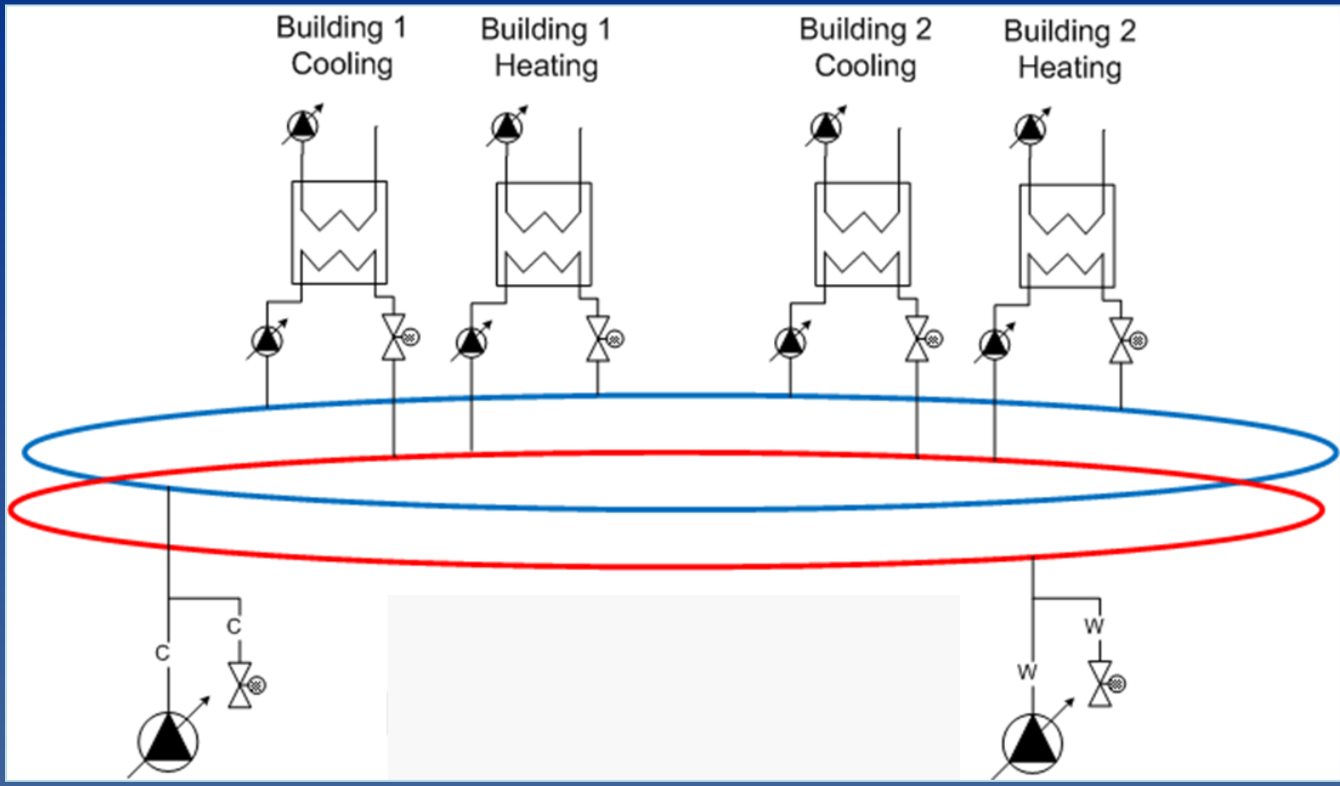
ATES Engineering Evaluation

District Energy Connection Options
Ford Site, St. Paul, MN

Four-pipe groundwater distribution, passive building connections



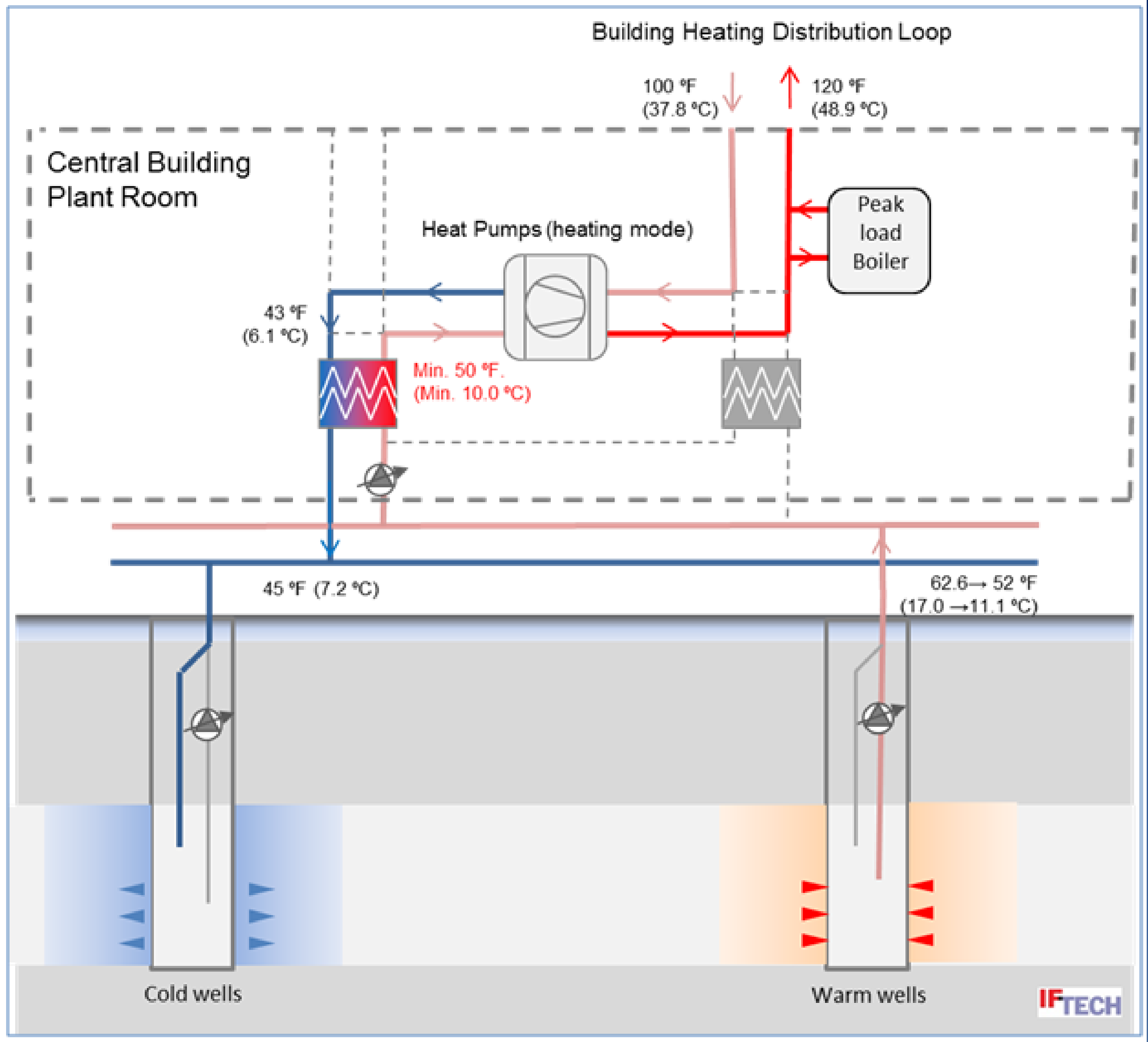
Two-pipe groundwater distribution, active building connections



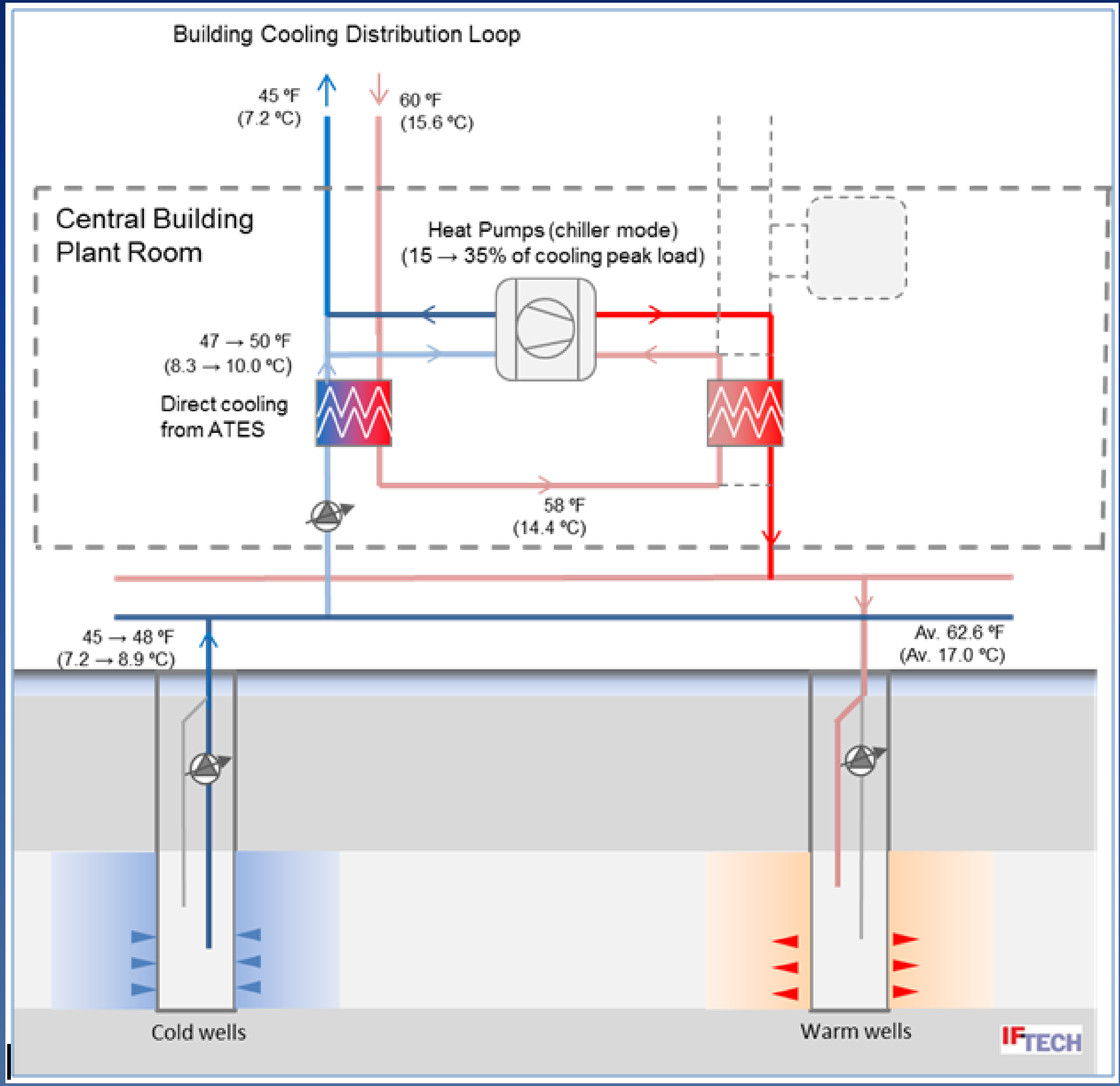
ATES Engineering Evaluation

ATES Heating and Cooling Modes, Ford Site, St. Paul, MN

ATES system in heating mode (winter operation)



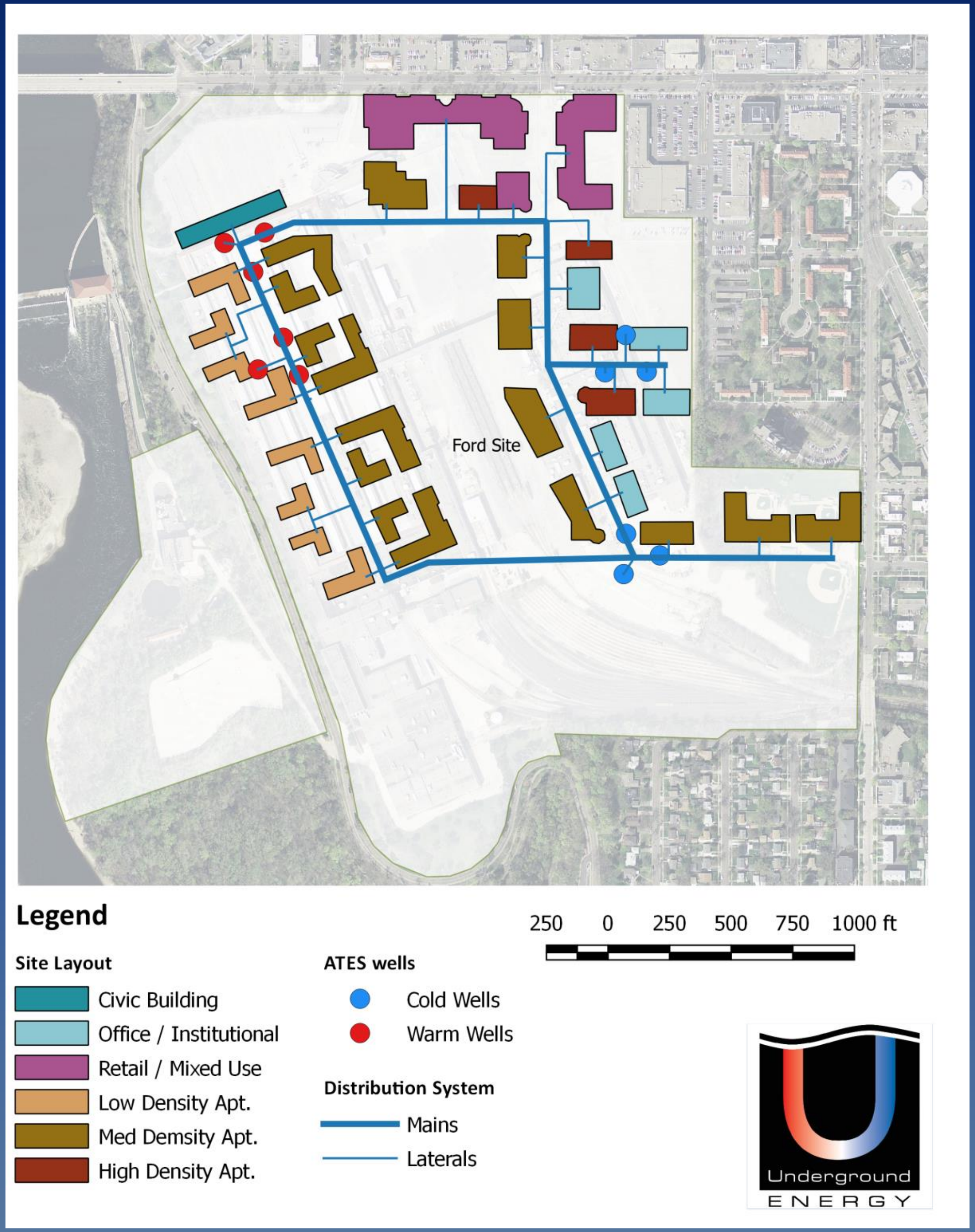
ATES system in cooling mode (summer operation)



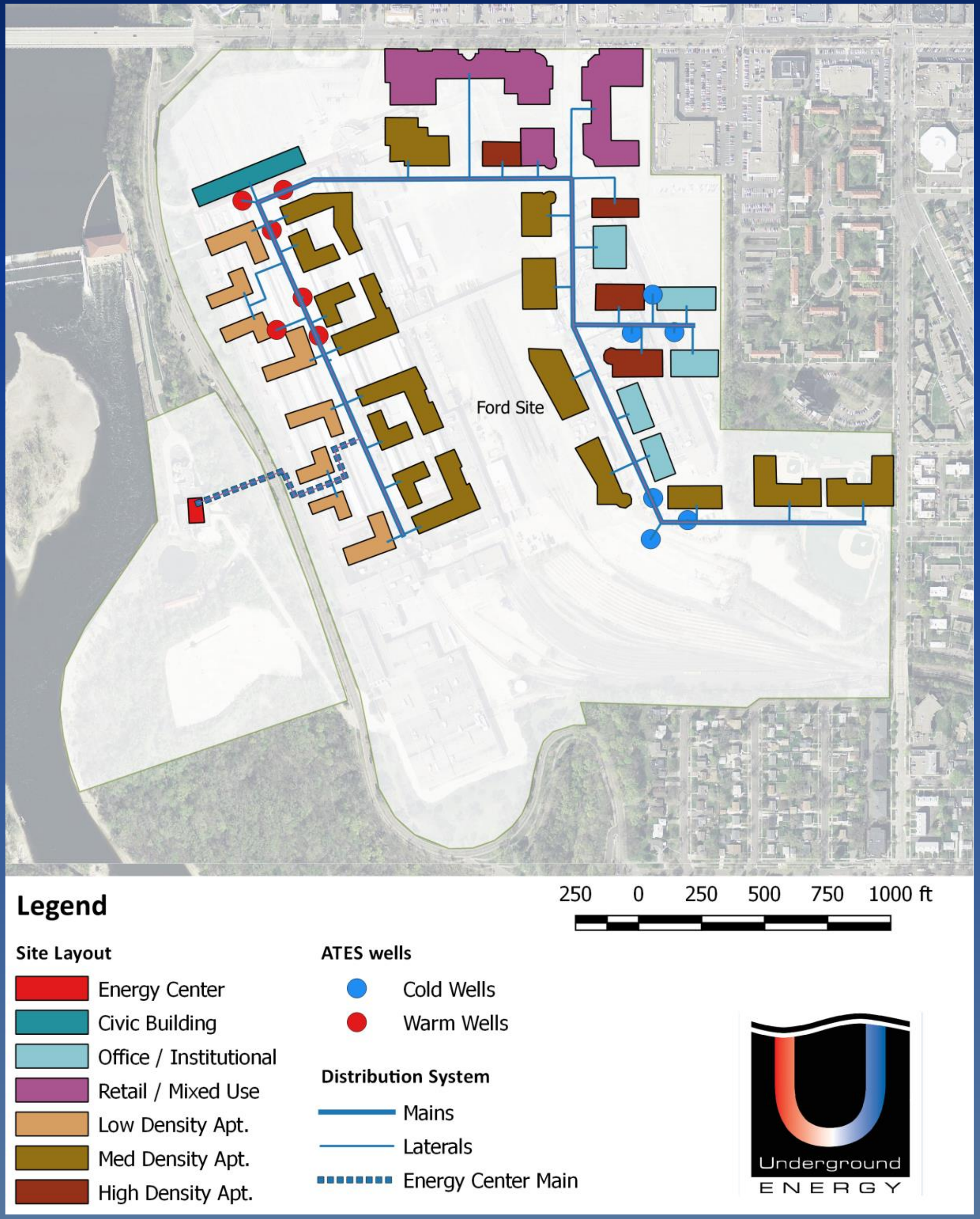
ATES Engineering Evaluation

ATES System Conceptual Layout, Ford Site, St. Paul, MN

Two-Pipe (uninsulated) DE system



Four-Pipe (insulated DE system



ATES Engineering Evaluation

Initial ATES System Sizing
Ford Site, St. Paul, MN

	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	m³/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	m³/h
Ambient groundwater temperature	49	°F	9.3	°C
ATES storage and abstraction temperatures 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

ATES Engineering Evaluation

Energy Savings, Ford Site, St. Paul, MN

- ATES Savings vs BAU:
  - 40% savings in primary energy consumption
  - 35% reduction in CO_2 emissions
  - 100% reduction in cooling water consumption

ATES Financial Evaluation

Ford Site CAPEX Summary

	BAU	ATES/HP
Site investigation incl. test well (first borehole) and three monitoring wells, analysis of results, EIA	$ 0	$ 600,000
Thirteen additional boreholes 36”diameter, 440 ft depth, incl. development and tests	$ 0	$ 4,200,000
Well housings and well M+E equipment, incl. installation	$ 0	$ 900,000
Piping incl. trenching DH&C distribution and piping and cabling incl. trenching groundwater distribution respectively	$ 5,200,000	$ 1,800,000
M+E equipment central plant room and 38 building plant rooms respectively, incl. controls and installation	$ 9.200,000	$ 13,300,000
Energy transfer stations 38 buildings	$ 6.600,000	$ 0
Subtotal BAU and ATES/HP system	***$ 21,000,000***	***$ 20,800,000***
Engineering, main contractor overhead, bonding, insurance 20% (excluding site investigation)	$ 4,200,000	$ 4,000,000
Contingency 10% (including site investigation)	$ 2,100,000	$ 2,100,000
Total BAU or ATES/HP system	***$ 27,300,000***	***$ 26,900,000***

ATES Financial Evaluation

Ford Site, St. Paul, MN

	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***

ATES system yields 17% OPEX savings vs. BAU

ATES Regulatory Evaluation

- The federal regulation that applies to an ATES system is the Underground Injection Control (UIC) program administered by the US EPA. ATES wells are Class V injection wells under the UIC program. The EPA retains primacy over the UIC program in Minnesota.

- 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.

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

- Under MR 4725.2050, injection of any material into a well or boring in Minnesota is prohibited. 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. Precedent exists for issuance of such variances.

ATES Feasibility Study Conclusions

- ATES is feasible at the Ford Site in St. Paul. The climate, hydrogeology and large, relatively balanced loads are well suited for ATES. More than 75% of the annual cooling demand can be met with direct cooling enabled by seasonal thermal energy storage.

- The ATES system can provide savings on primary energy consumption of about 40% compared to the BAU scenario of centralized gas boilers and electric chillers with a 4-pipe DH&C system.

- Our conceptual design utilizes 12 ATES wells (6 warm, 6 cold) of ~900 gpm capacity (5,500 gpm total max flow) to provide a heating capacity of 59 MMBtu/h (17 MW) and a cooling capacity of 3,450 tons (12 MW).

- The ATES project can be completed in phases as the Ford Site redevelopment is built out.

- Other than localized thermal impacts in the aquifer and temporary construction impacts, an ATES project will have minimal adverse environmental impact.

ATES Feasibility Study Conclusions
(continued)

- The regulatory scheme in Minnesota prohibits underground injection for large open-loop systems, however, there is precedent for a variance to the rule.

- Other than localized thermal impacts in the aquifer and temporary construction impacts, an ATES project will have minimal adverse environmental impact.

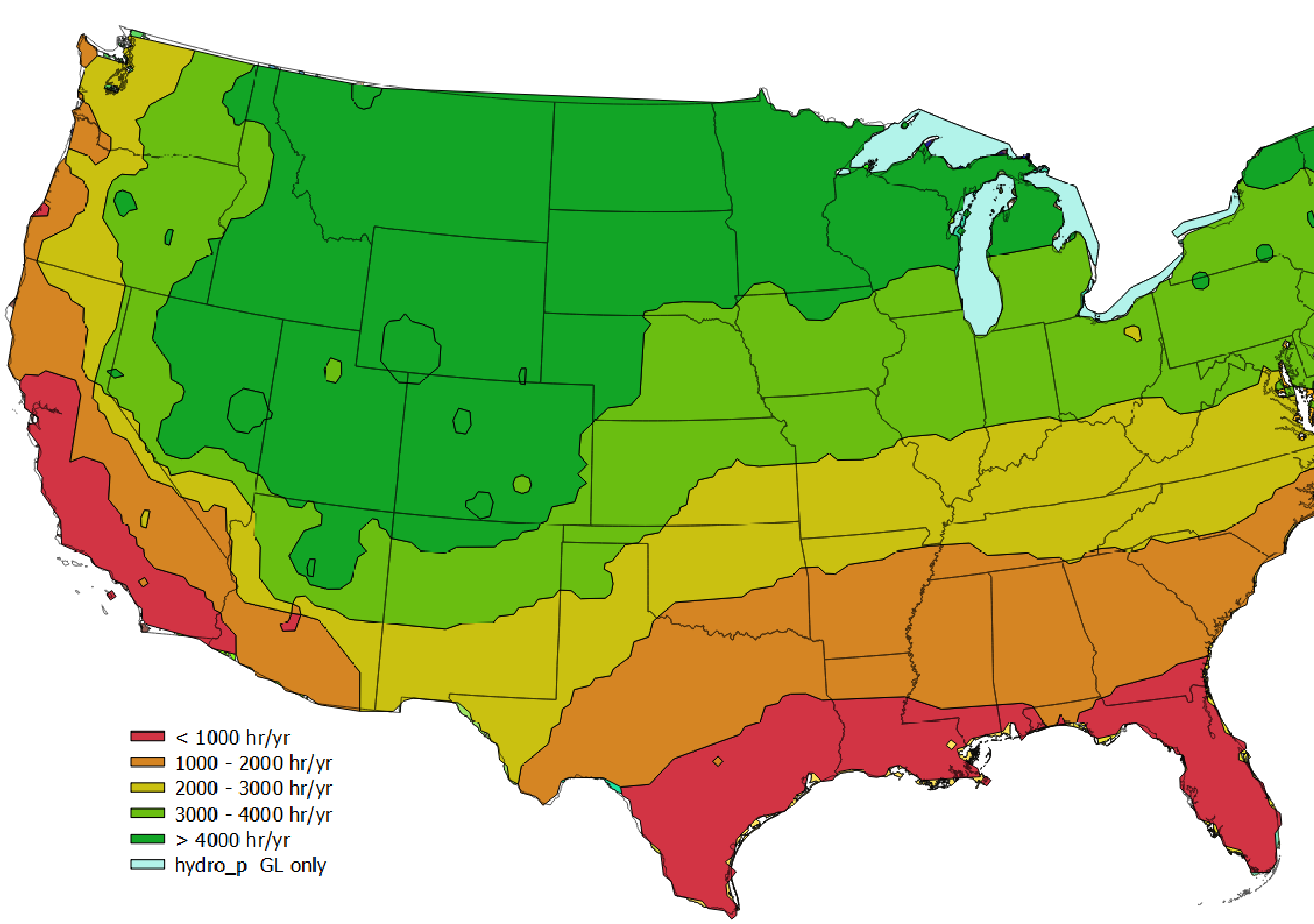
- Compared to BAU, ATES yields a 17% reduction of operating expenses at a similar capital cost.

Recommendations

- Evaluate ATES for cooling and/or heating in the Twin Cities area and other US locations where there are:
  - Large heating and cooling loads, and
  - Seasonably variable climate, and
  - An aquifer exists!

Where is the climate suitable for ATES?

Annual water-side economizer (free cooling) hours



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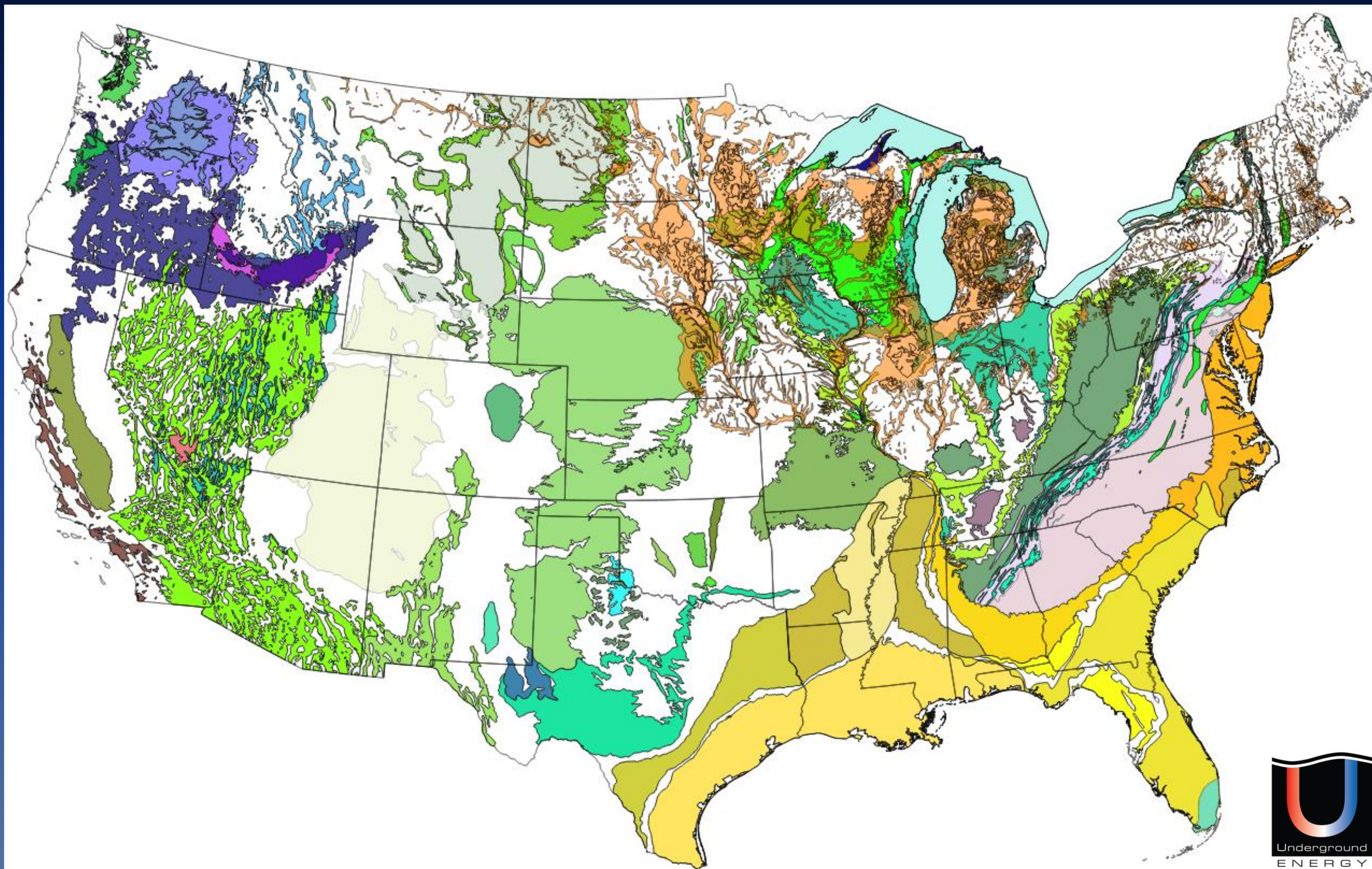
Where are the aquifers?



Thank You!