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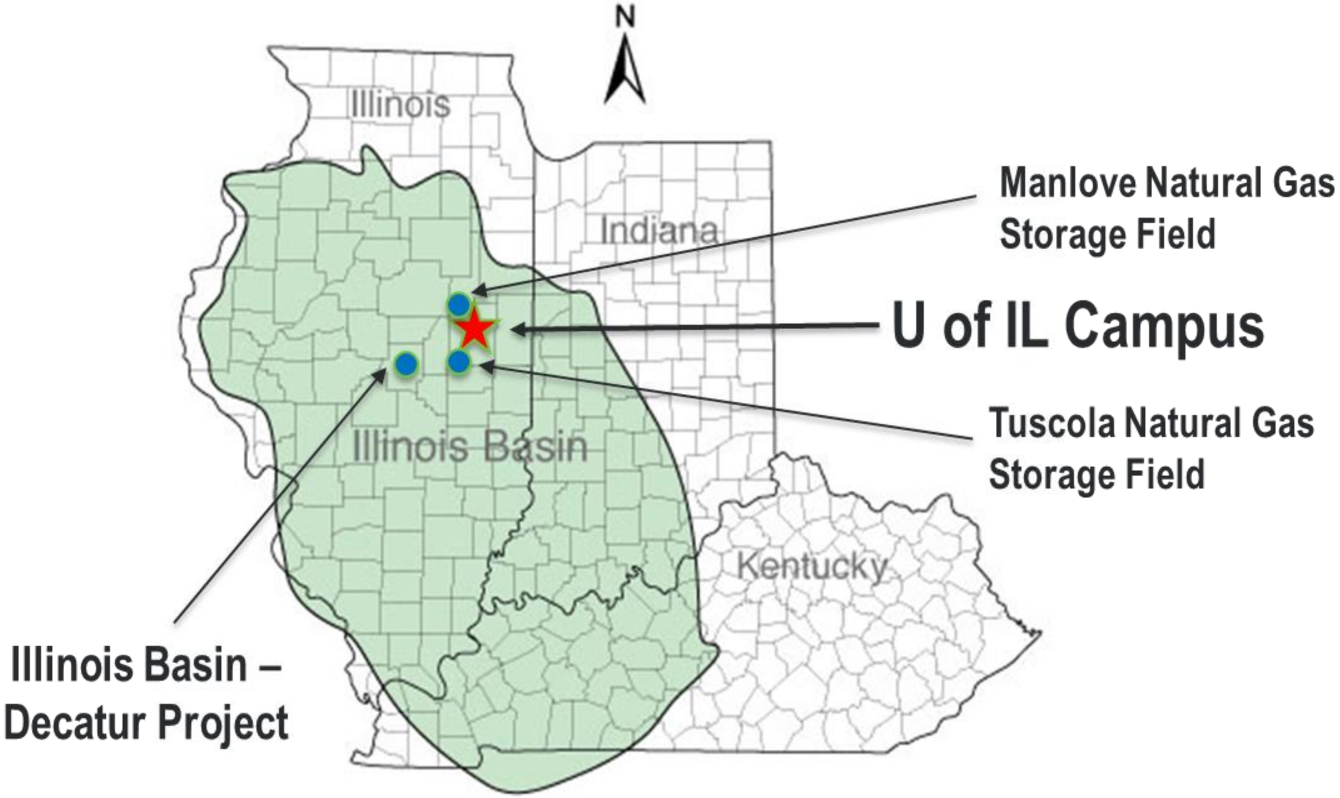

Feasibility of a Deep Direct-Use Geothermal System at the University of Illinois Urbana-Champaign

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Feasibility of a Deep Direct-Use Geothermal System at the University of Illinois Urbana-Champaign

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ABSTRACT

This study assesses the feasibility of using deep direct-use (DDU) geothermal energy in agricultural research facilities on the University of Illinois at Urbana-Champaign campus to exploit low-temperature sedimentary basins, such as the Illinois Basin. Subsurface components of the system include extraction and injection wells and downhole pumps. Surface equipment includes heat pumps/exchangers, and fluid transport and monitoring systems.

Two geologic formations in the region exhibit a potential as sources for geothermal energy, based on pre initial temperatures and flow rates of fluids. The St. Peter and Mt. Simon Sandstones lie at depths of 634 and 1,280 m, respectively. Geocellular modeling is used to characterize the reservoirs. A St. Peter Sandstone model was made for an area south of the campus. Petrophysical and geothermal properties used are based on data from the closest wells penetrating the formations. Characterization of the Mt. Simon Sandstone is in progress and is not discussed here.

Extraction and injection flows simulated with different wellbore configurations provide estimates of fluid flow out of and into the reservoir. The models are used to optimize flow rates, bottomhole pressure, and temperature of the produced fluid. Individual wellbore models simulate subsurface heat loss and gain, providing guidance on the optimal type and amount of insulation in the wellbore. Design of the surface facilities will address aspects of fluid delivery, heat exchange, capital operating costs, heat loss, and corrosion. Heat capacity and flow rates are assessed to estimate life-cycle costs and benefits, including the environmental benefits of reducing greenhouse gases and water use and increased energy efficiency. A preliminary analysis of surface configurations for the DDU system (including cascading applications) based on building heat loads is being conducted to identify multiple system designs that will maximize performance, energy efficiency, and cost recovery.

Main Objectives

- Investigate the feasibility of using deep direct-use (DDU) geothermal energy extracted from low-temperature geologic formations within the Illinois Basin to heat and cool agricultural research facilities located on the South Farms at the University of Illinois at Urbana-Champaign (U of IL).
- Design of cascading applications, such hot water heating and grain drying.
- Optimize workflows to assess project Levelized Cost of Heat (LCOH) on benchmarking models.
- Identify the challenges to commercialization of the DDU technology (including regulations, equipment, and economics) for analogous cascading applications at other installations in the Illinois Basin.
- Support early-stage research and development to strengthen the body of knowledge upon which the renewable energy industry can hasten the development and deployment of innovative geothermal energy technologies.

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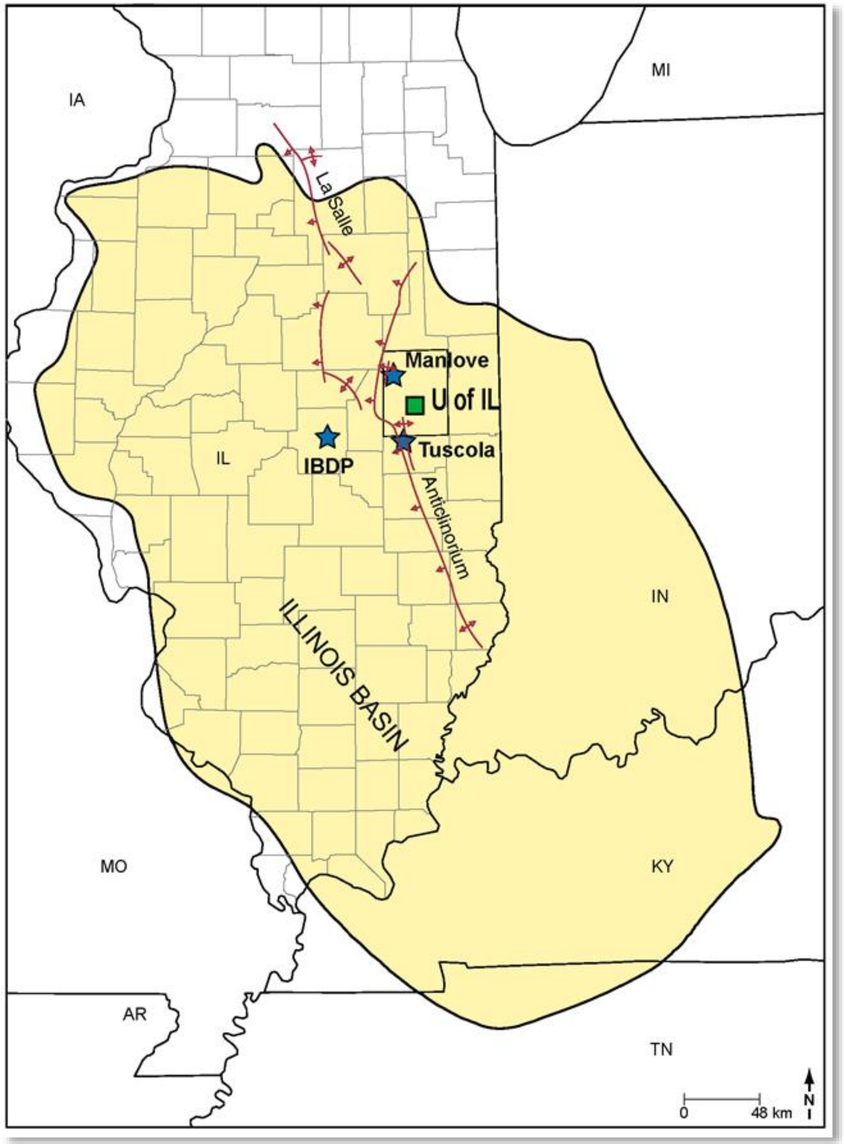
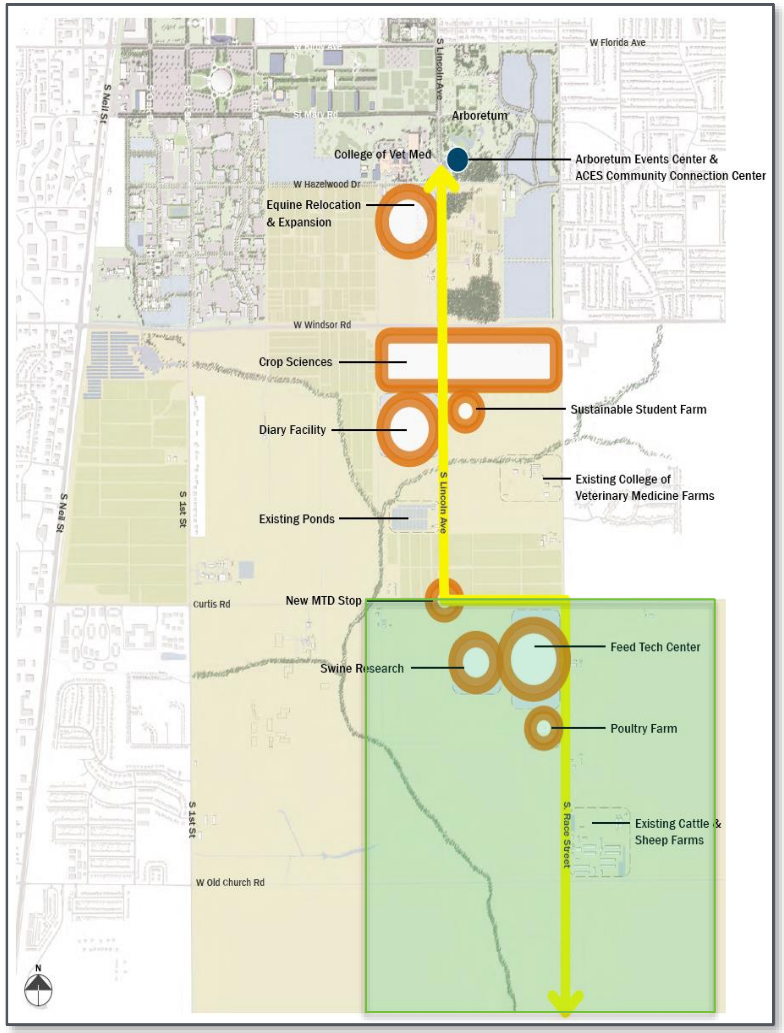
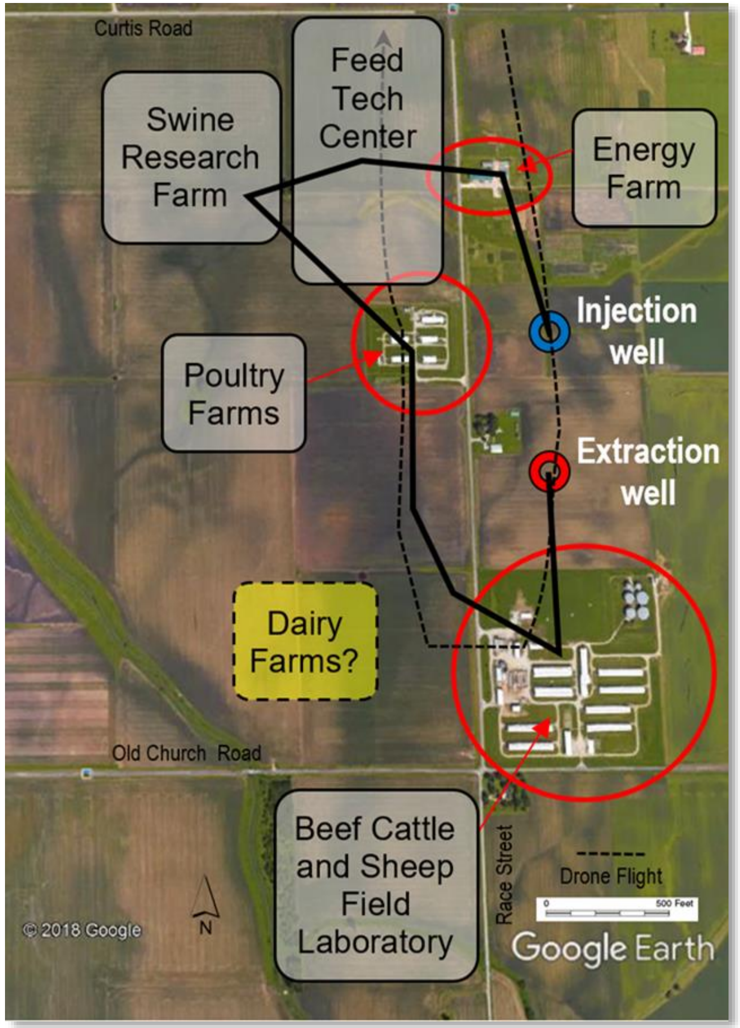
Study Area

- The assessment site is located in a 90 km^2 area around the U of IL campus in Champaign County, Illinois.
- The geology was characterized by using data from drilling records, wireline logs, and petrophysical analysis of core samples from the nearby Manlove and Tuscola gas storage fields and the CO2 injection well located at the Illinois Basin–Decatur Project (IBDP) site.
- The major geologic structure is the La Salle Anticlinorium, a belt of domes and anticlines that crosses the county along a trend oriented northwest.



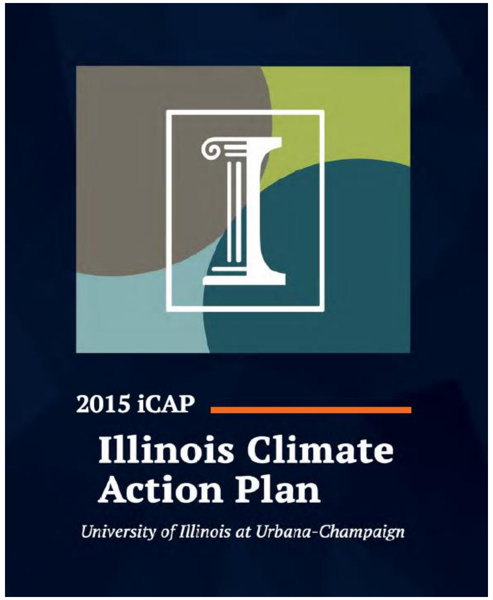
- The DDU system would deliver geothermal energy to agricultural research facilities on the South Farms.
- We are working closely with:
  1. Chancellors Office
  2. Office of the Vice Chancellor for Research
  3. Dean of the College of Agriculture, Consumer and Environment Studies (ACES)
  4. Facilities and Services
- The geothermal system would be located along the ACES Legacy Corridor that is being expanded within the next 10 years.





The deployment of DDU on U of IL campus:

- Contributes the Climate Leadership Commitment to be carbon neutral as soon as possible, or no later than 2050.
- Alternative to building costly steam or water lines from the main campus; this feasibility study will provide financial information.
- Reduce green-house gas (GHG) emissions from agricultural operations; ~7,320 tons of CO_2 equivalent/year, equaling 2.7% of GHG gases emitted for steam production on campus in FY14.



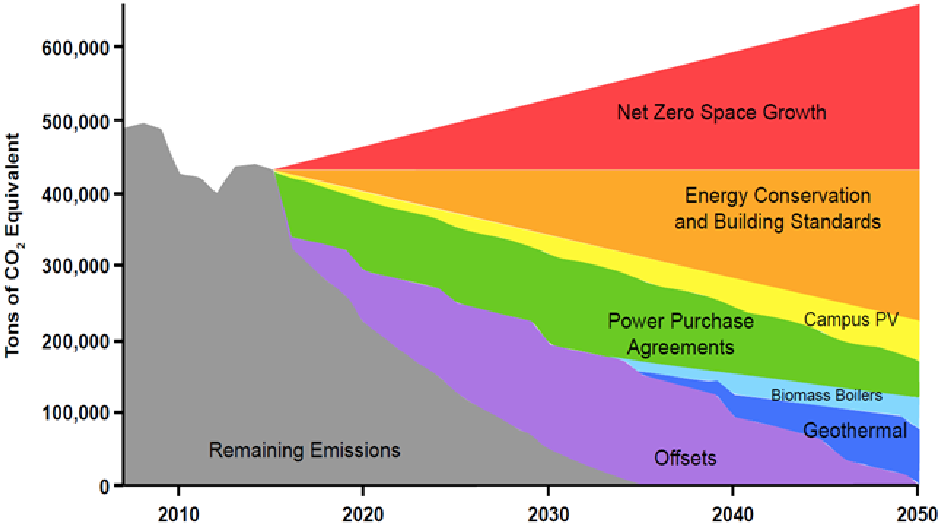
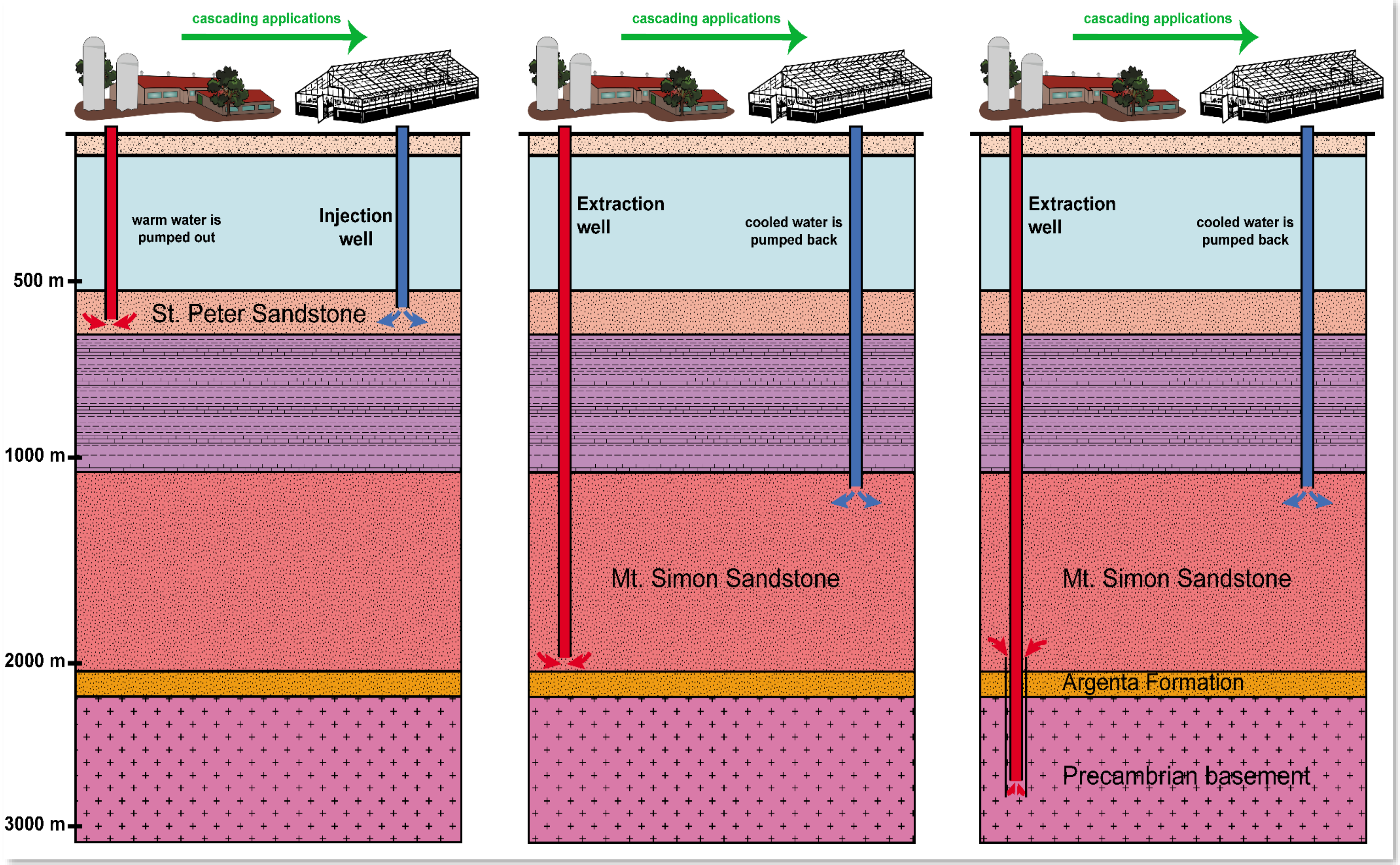


Figure 3: 2015 iCAP Wedge Diagram showing only energy emissions projected, with potential clean energy scenario

DDU geothermal system

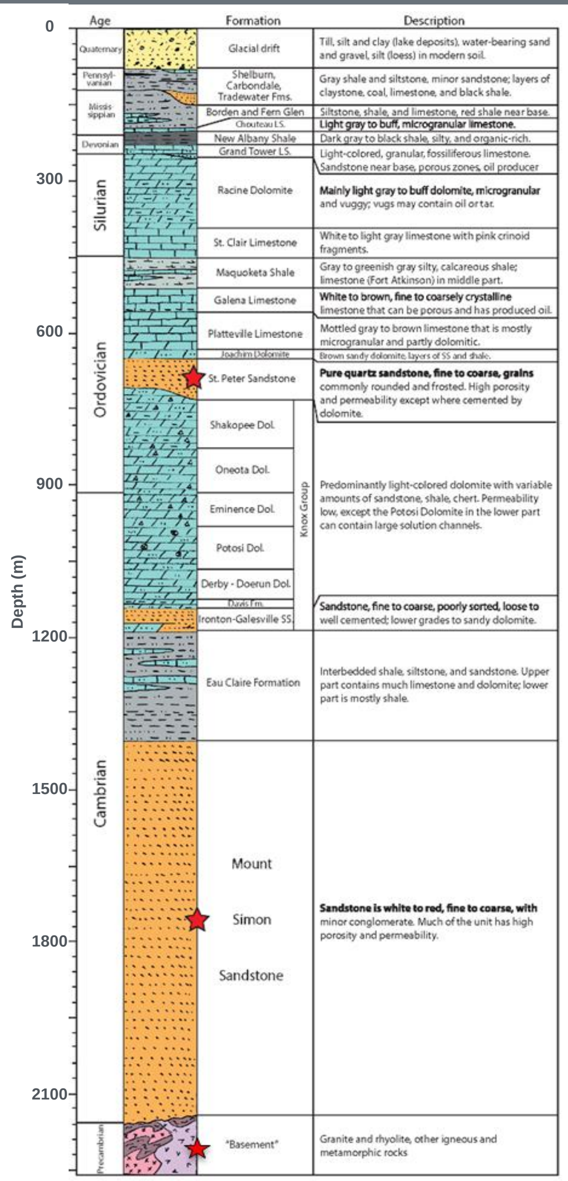
- A doublet system (production and injection wells).
- Geothermal resources are the St. Peter and Mt. Simon sandstones in the Illinois Basin.
- The system will be designed to operate as dual usage (heating and cooling and have cascading applications.
- Configuration will be specific to geothermal fluid conditions and energy end use to improve energy efficiency and reduce costs.



Geology

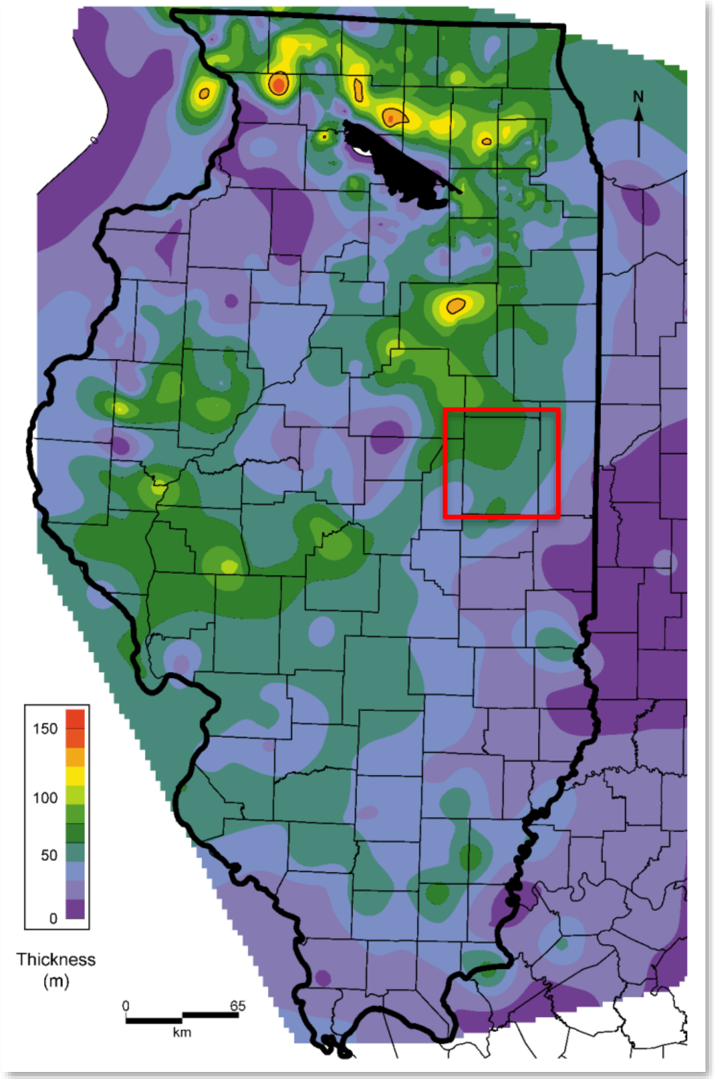
- St. Peter Sandstone is found at depths of 612 – 671 m.
- Mt. Simon Sandstone is at depths of 1,334 – 1887 m.
- Argenta Formation is a new unit; previously mapped to Mt. Simon Sandstone.
- Precambrian granites and rhyolite below 2,033 m.

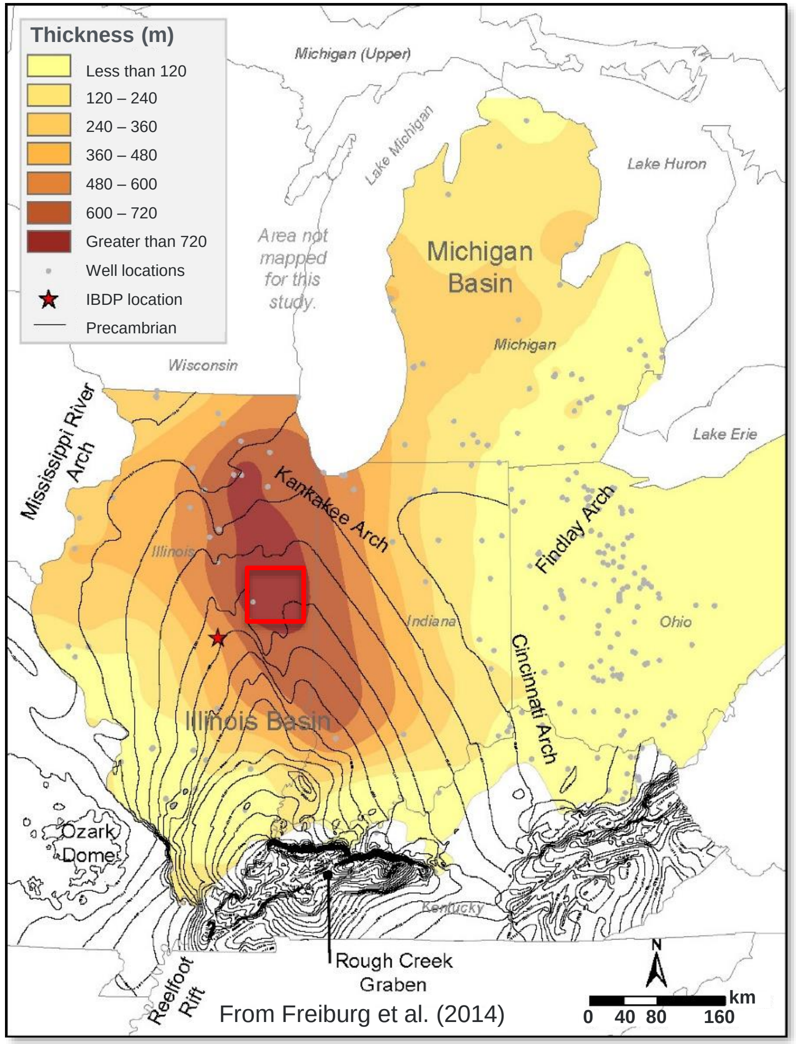
Formation	Thickness (m)	Top (m)	Description of Formation
Soil	2	0	Mollisol in loess and till
Quaternary (fine)	25	2	Till, fine outwash, lake sediment
Quaternary (coarse)	25	26	Outwash, mostly sand w/ gravel
Pennsylvanian	53	51	Shale, siltstone, sandstone, coal beds
Mississippian	78	104	Largely siltstone; Chouteau Limestone at base
New Albany	24	183	Dark colored, hard shale
GrandTower (Devonian)	24	207	Limestone, commonly sandstone at base
Silurian	180	231	Vuggy dolomite, lower part limestone; shows of oil likely
Maquoketa (Ordovician)	61	411	Shale; limestone in middle
Kimmswick	39	472	Limestone
Decorah and Platteville	82	510	Limestone, thin shale layers
Joachim	19	593	Dolomite and sandstone, shale layers
St. Peter	**59**	**612**	**Pure quartz sandstone, water bearing**
Knox Group	427	671	Dominantly dolomite, partly sandy and cherty
Ironton	53	1098	Pure quartz sandstone, water bearing
Eau Claire	183	1151	Shale, sandstone, and limestone; shale increasing downward
Mt. Simon (upper)	**139**	**1334**	**Sandstone with mudstones, arkose wacke to quartz arenite, well cemented, high porosity**
Mt. Simon (middle)	277	1473	Sandstone and conglomerate, quartz arenite to wacke with thin interbeds of mudstone and clay
Mt. Simon (lower)	**137**	**1750**	**Sandstone, subarkose to arkose wacke, water bearing, good reservoir**
Argenta	**146**	**1887**	**Sandstone, conglomerate, mudstone (marine)**
Precambrian	**>100**	**2033**	**Granite and rhyolite (basement)**



Geology

- Middle Ordovician St. Peter Sandstone and Upper Cambrian Mt. Simon Sandstone are pervasive through the entire ILB, extending into Indiana, Iowa, Michigan, and Kentucky.

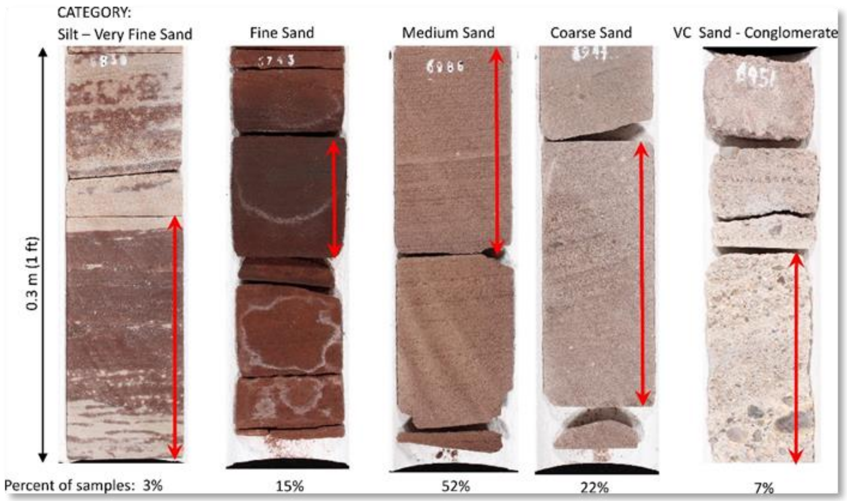




From Freiburg et al. (2014)

Mt. Simon Sandstone

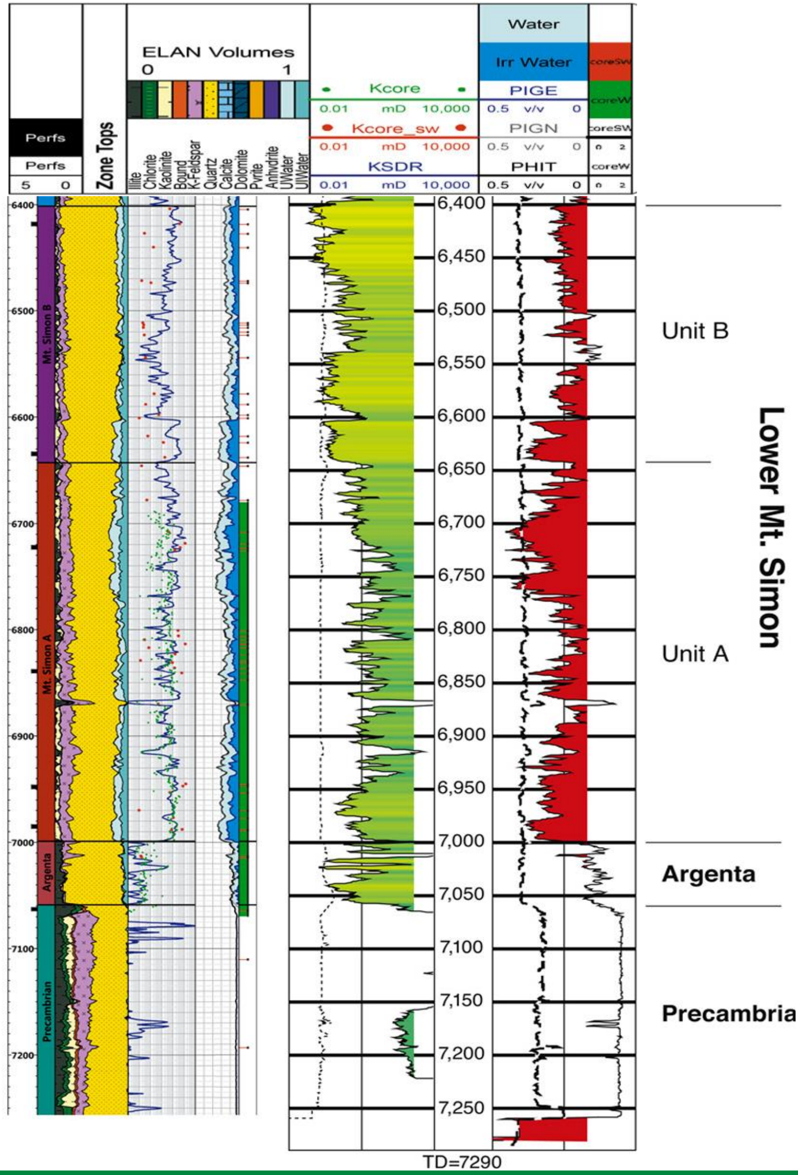
- The formation is dominated by quartz-rich quartzose sandstone.
- An arkosic zone at the base of the unit has exceptionally good reservoir qualities.
- Sandstone has very high porosity/permeability and is a reservoir for underground storage of natural gas in central Illinois



Lower Mt. Simon core at the Illinois Basin–Decatur Project.

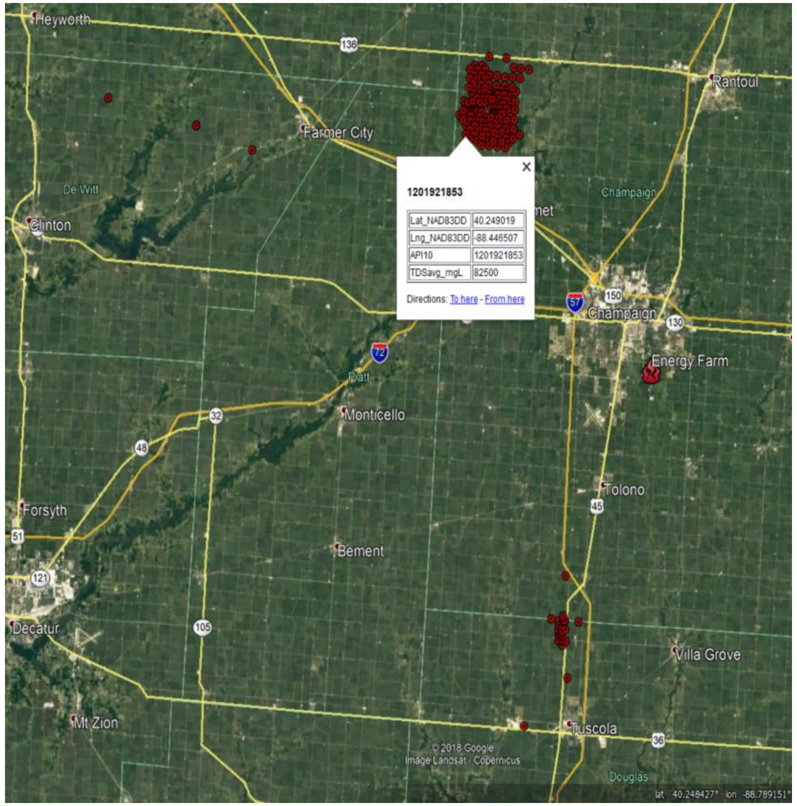
1) Very-fine-grained sandstone k_{hormax} = 0.2 mD, porosity = 9%.
2) Fine-grained sandstone, k_{hormax} = 50 mD, porosity = 23%.
3) Medium-grained sandstone, k_{hormax} = 151 mD, porosity = 21%.
4) Coarse-grained sandstone, k_{hormax} = 144 mD, porosity = 19%.
5) Conglomerate, k_{hormax} = 185 mD, porosity = 18%.

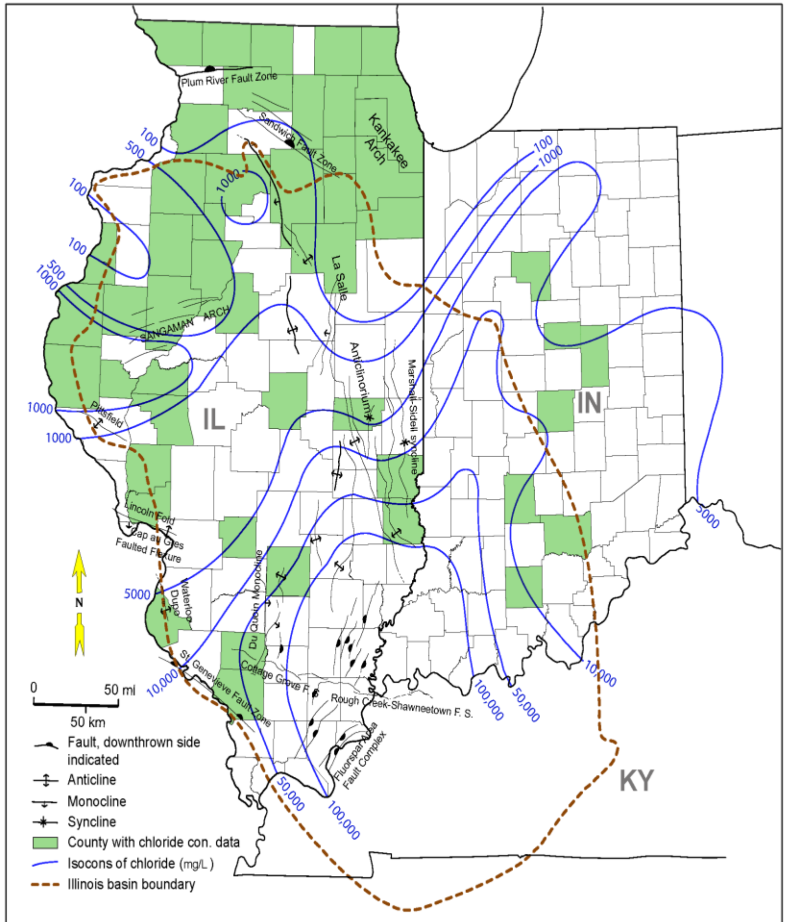
(From Ritzi et al. 2018)



Fluid (Brine) Chemistry

- Chemistry is based on regional studies of brine and spring water samples and borehole sampling.
- Salinity of St. Peter fluid ranges from 1,000 to 8,000 ppm.
- Salinity of Mt. Simon fluid ranges from 50,000 – >200,000 ppm.
- Removal of suspended solids, scale-forming species, and other contaminants is necessary to optimize desalination.
- Total suspended solids (TSS) are ~3,000 ppm.





Chloride Concentration in Wells Screened in the St. Peter Sandstone were Platted by County

From Panno et al. (2018)

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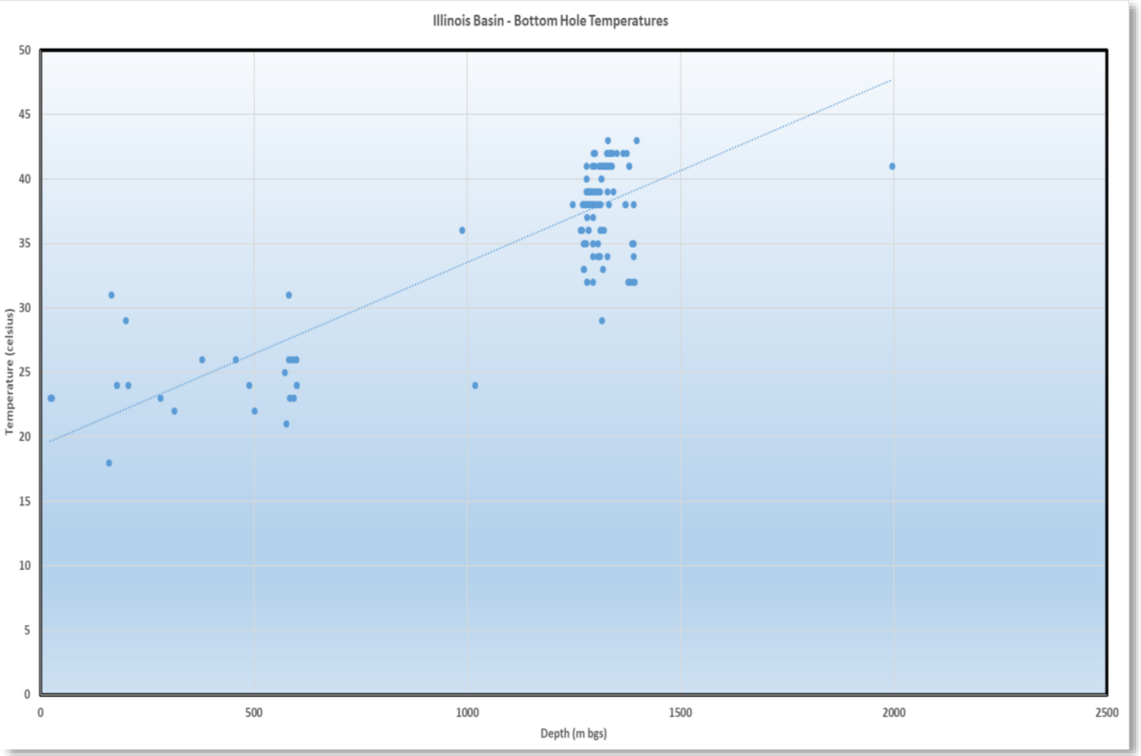
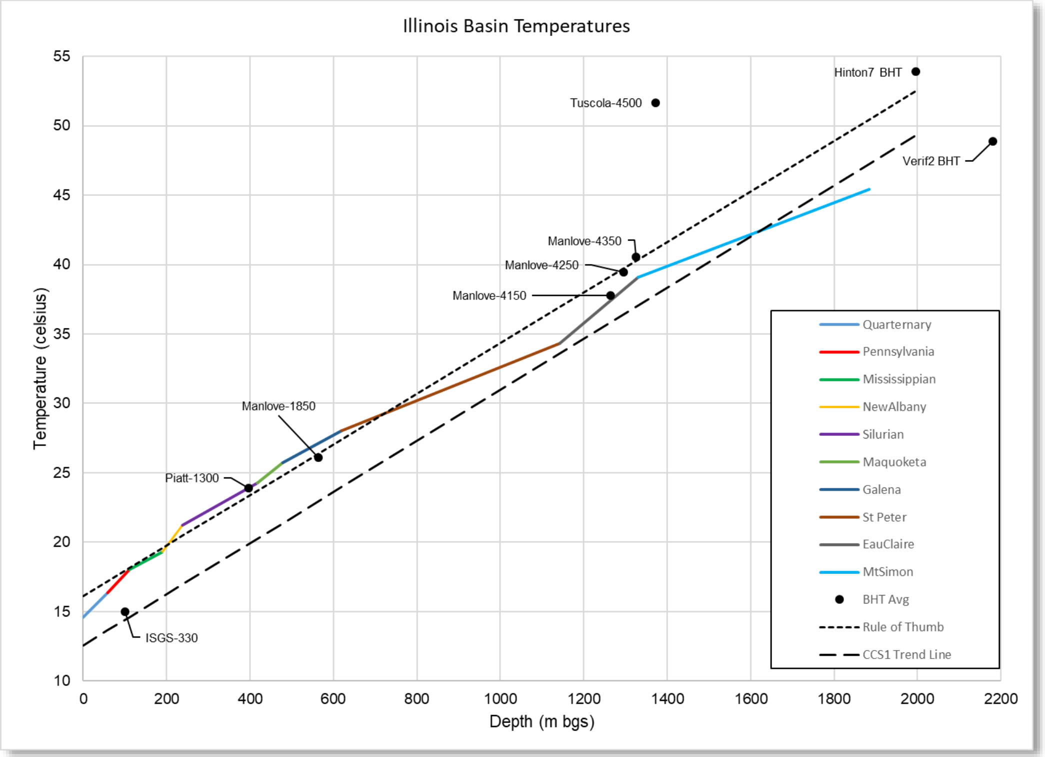
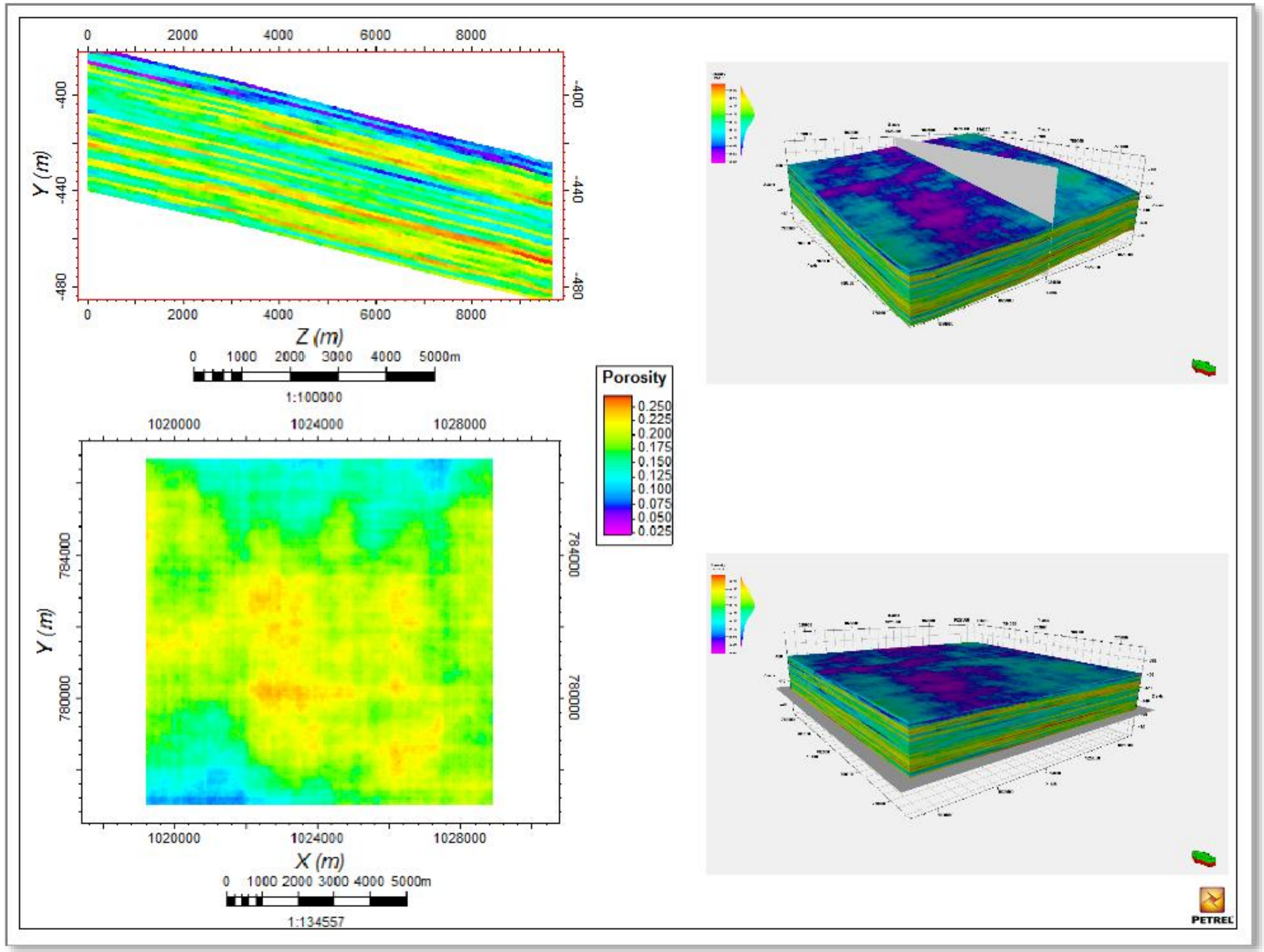
Subsurface temperatures

- Estimates based on bottom-hole temperatures, and DTS log from the Illinois Basin–Decatur Project.
- Temperature of formation water in St. Peter Sandstone is from 23.1 – 25.9 °C.
- Temperature of formation water in the lower Mt. Simon Sandstone ranges from 43.9 – 47.2 °C.

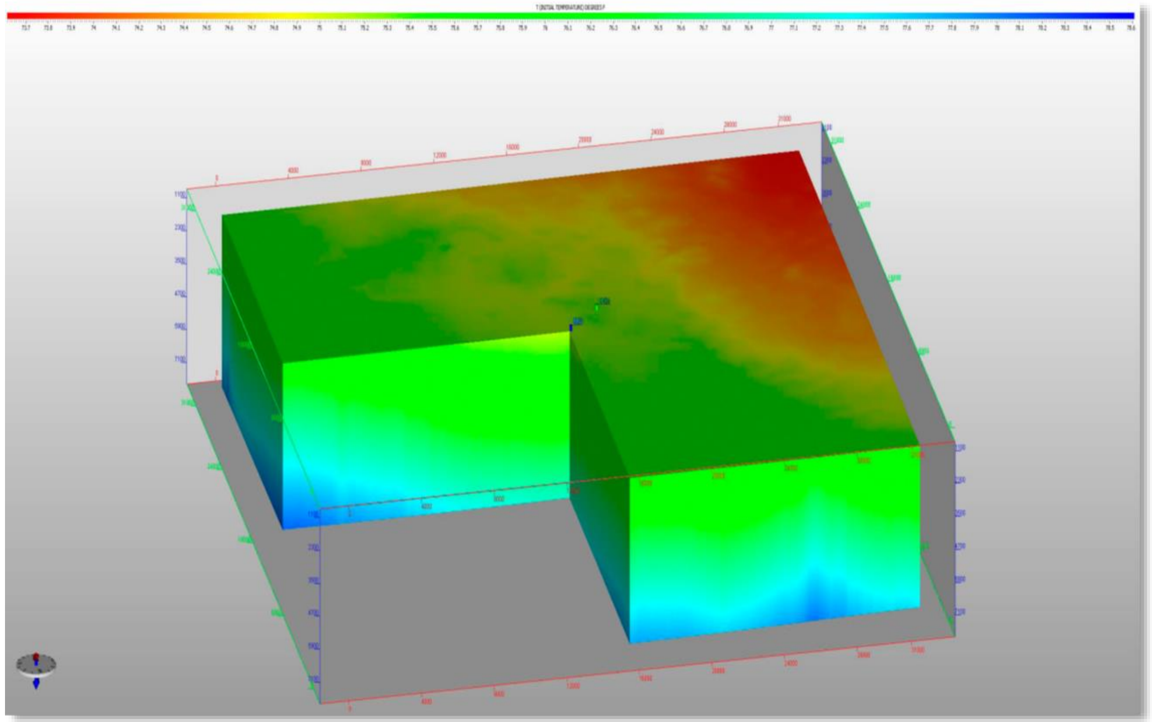




Geocellular modeling



Geothermal modeling



Wellbore modeling

- Possible to reduce temperature loss (<0.5 ºC) by increasing flow rate or insulating the production well.

Potential insulation methods:

1. Brine fluid (0.38 – 0.038 W/mK)
2. Silicate foam coating inside tube (0.03 W/mK)
3. Vacuum insulating tubing (0.008 – ~0.06 W/mK)
4. Using air or nitrogen (0.025 – ~0.032 W/mK) for annulus space

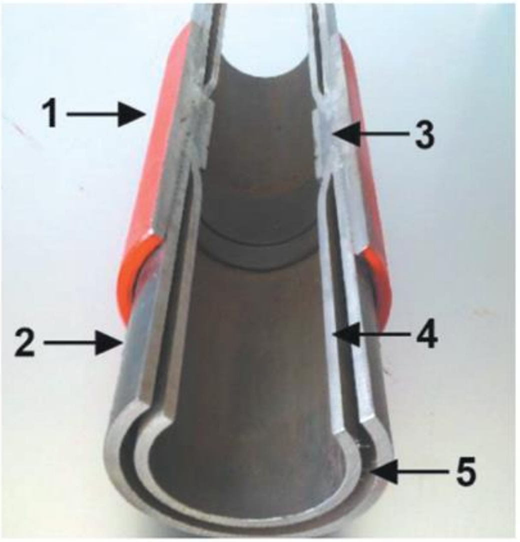
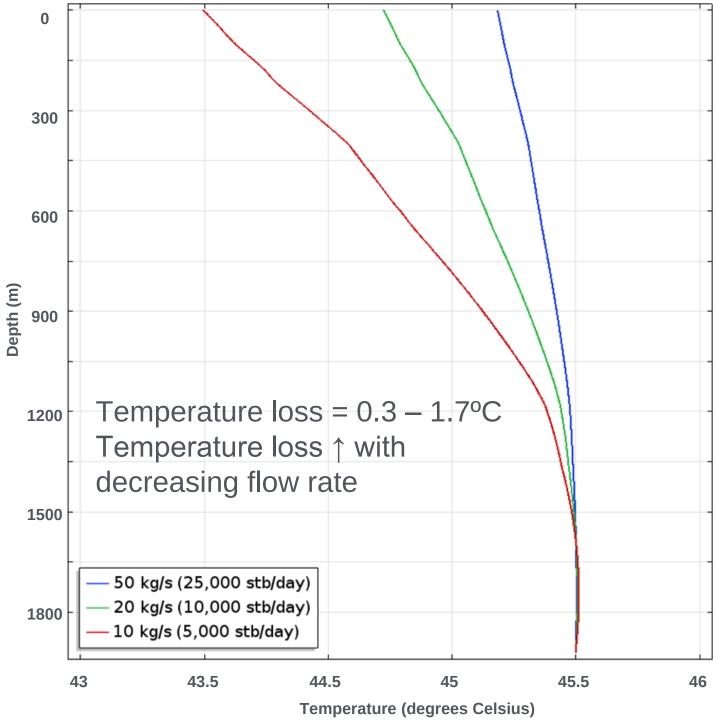
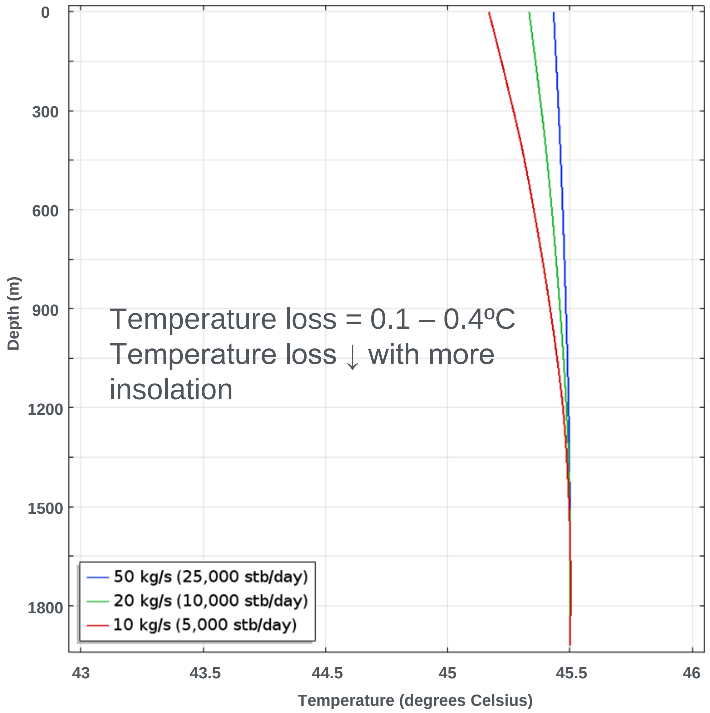


Fig. 8. Components of Vacuum Insulating Tubing:
1 – coupling, 2 – outer steel pipe (e.g. L80), 3 – internal coupling insulator and weld, 4 – inner steel pipe (e.g. 13CR85), 5 – vacuum with getter material [17]

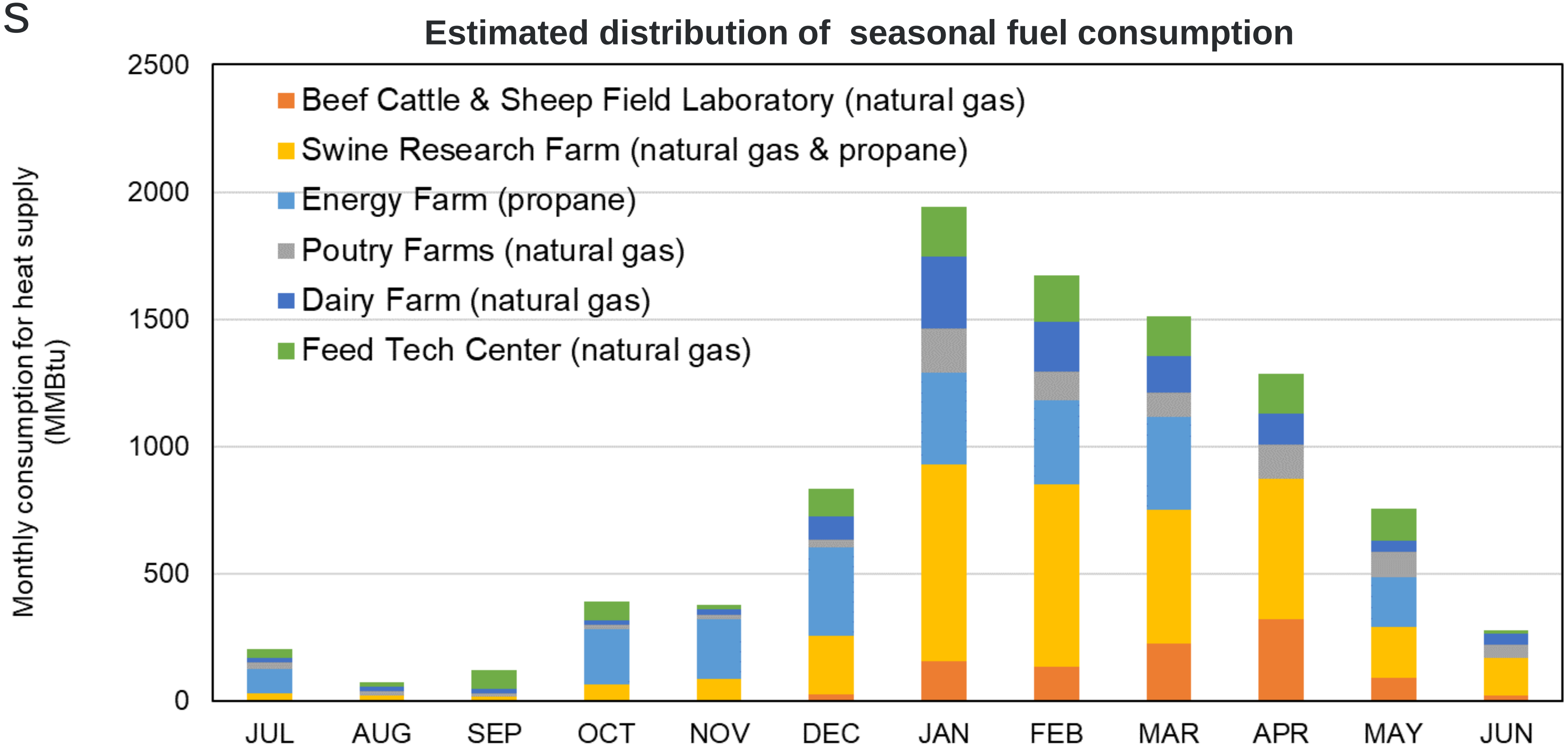
Temperature profile along center line of production well (normal Insulation)



Temperature profile along center line of production well (good insulation)

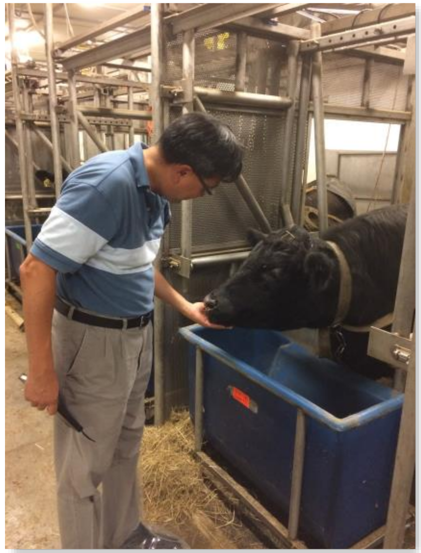


Heating and Cooling Demand Analysis



Energy Farm data for period March 2015 to February 2016; all other data period July 2016 to June 2017
Data source: UIUC Facilities & Services Energy Billing System accessed 2018-08-06

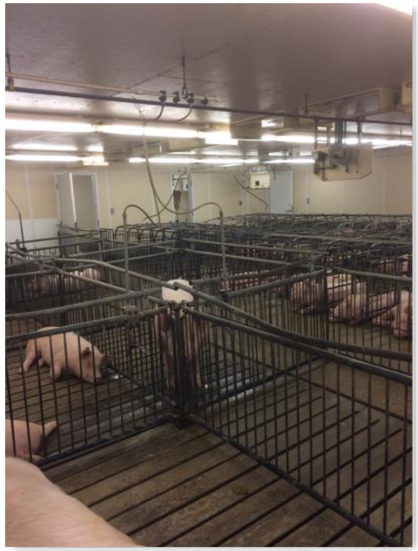
***Target fluid temperature at surface: 43°C**
****Target extraction temperature: 54°C**



Dairy Farm:
- 77°C for washing in milking parlor building
- 3.3°C for milk tank refrigeration
- 16°C plate cooler to cool hot milk
- Cows like to be at 4.4°C

Feed Tech Center:
- Grain dryer (batch drying at air temperature of 60°C).

Poultry Farms:
- Walk in incubator at 37.5°C (3-week hatchery)
- Hatching egg cooler at 16°C
- Grower building from April to September at 32°C
- Egg cooler ≤7.2°C year round



Swine Research Farm:
- Breeding, gestation, farrowing, grower, finishing at 23 – 24°C
- Nursing pigs: 1st week at 32°C; afterwards decrease 0.3°C/day to 24°C

Greenhouse temperature at 27 – 29°C
Normal heating and cooling of buildings at 24°C
Hot water for showers and laundry facilities at 41°C

Techno-Economic Simulation

- A preliminary economic analysis was conducted that included application of the simulation software tool GEOPHIRES© v2.0.
- A large number of parameters were varied, including, but not limited to:
  (1) Energy use at the facilities
  (2) Cost of constructing the extraction and injection wells
  (3) Amount of heat available from reservoirs
  (4) Cost of propane fuel replaced by geothermal resource.
- This analysis will potentially be beneficial for developing DDU geothermal systems at similar facilities (e.g., military installations) in the Illinois Basin.

Thank you!!

Questions??