Community Forum: Update on Earth Source Heat

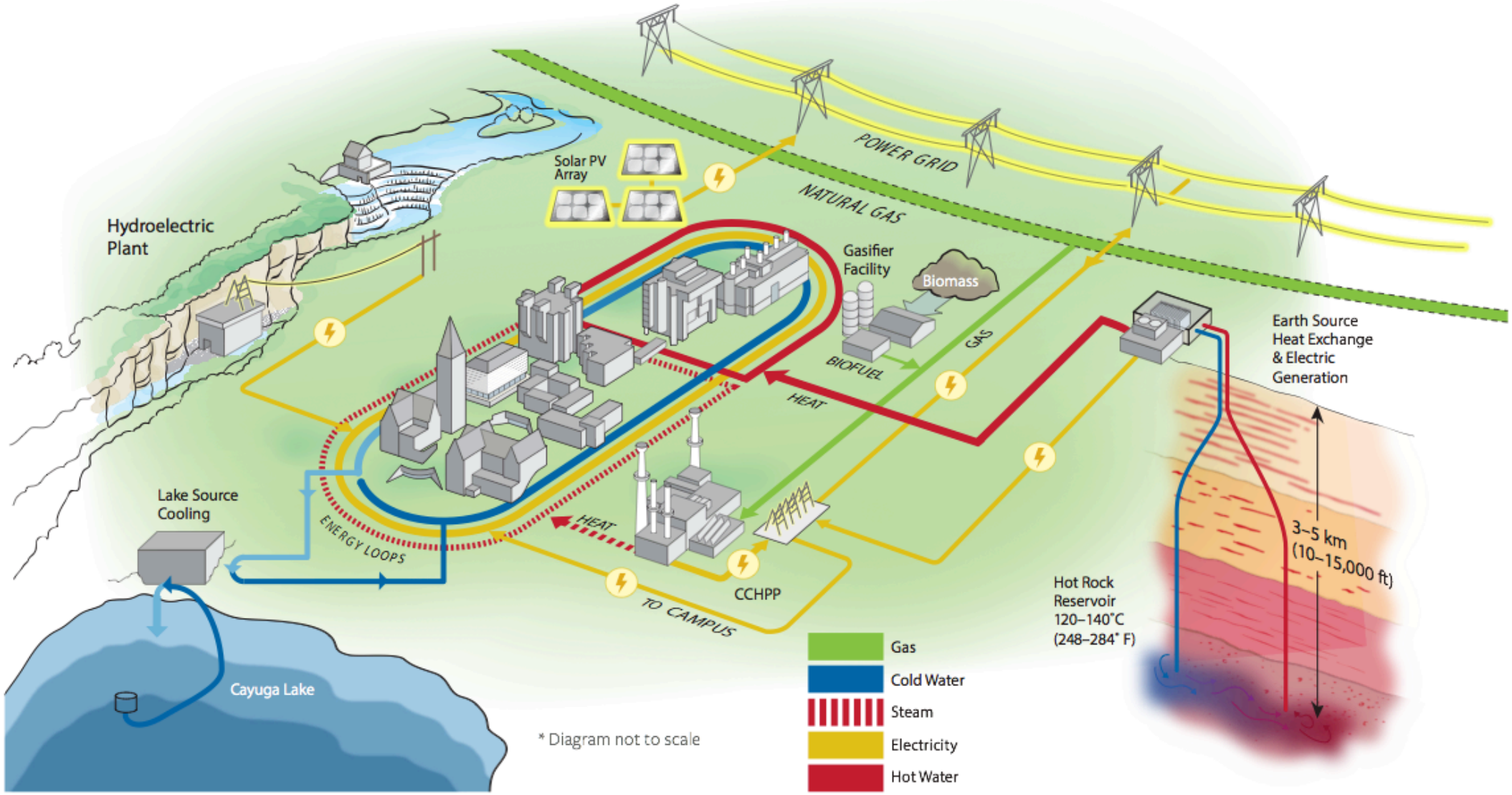
The Space at Green Star, Ithaca, NY

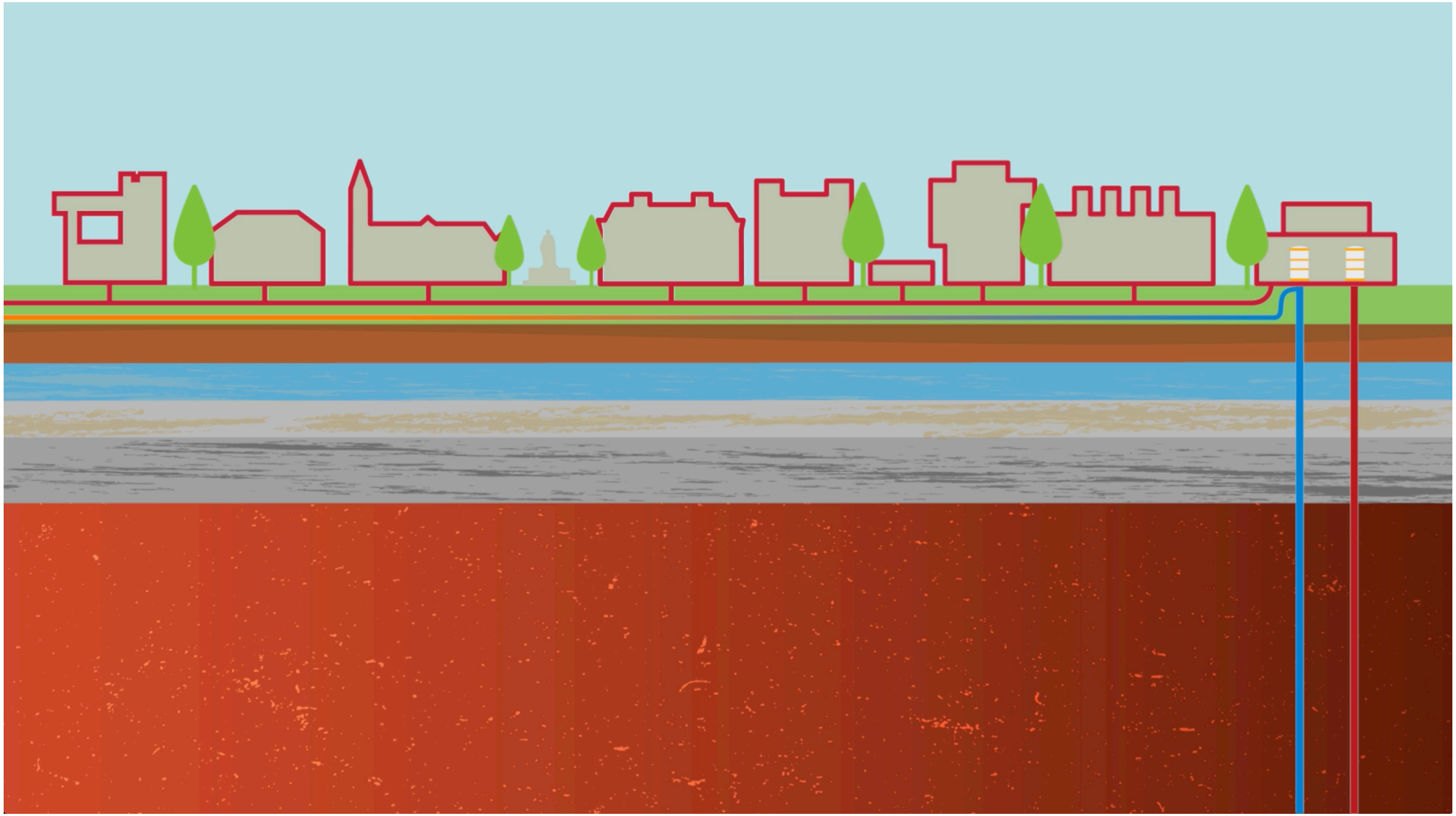
May 17, 2018

Cornell Panelists

- Lance Collins, Dean of Cornell Engineering
- Jefferson Tester, Chief Scientist for Earth Source Heat
- Rick Burgess, Vice President, Facilities and Campus Services
- Katie Keranen, Assistant Professor of Earth and Atmospheric Sciences
- Tony Ingraffea, Professor Emeritus of Civil and Environmental Engineering
- Todd Cowen, Professor of Civil and Environmental Engineering

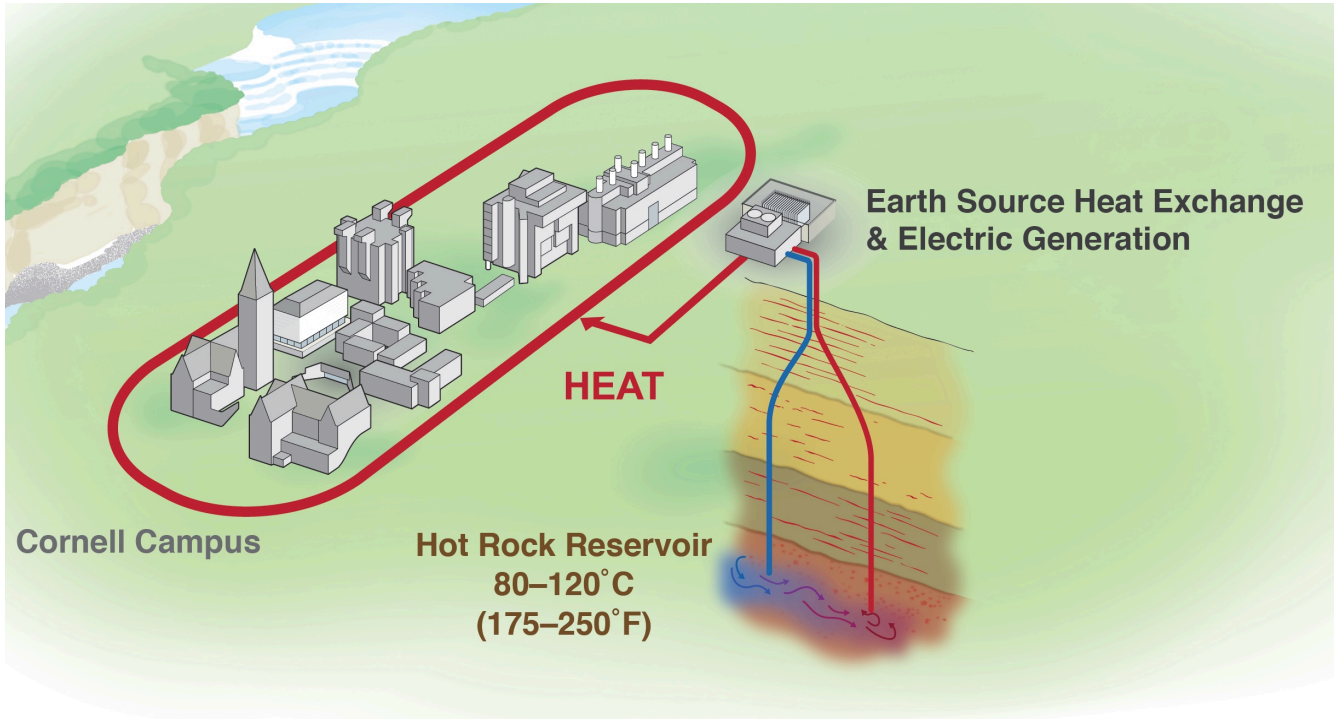
Campus Energy Systems



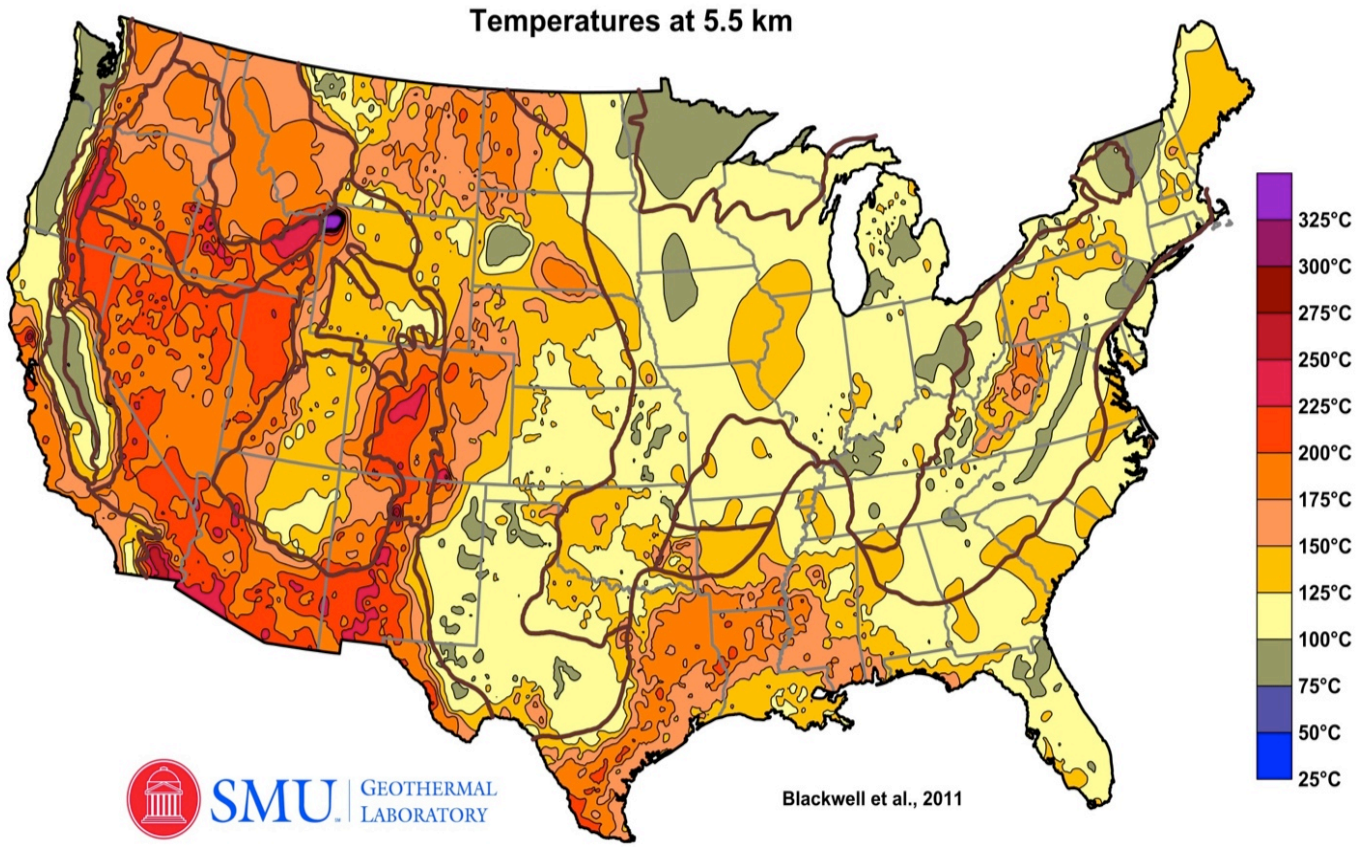


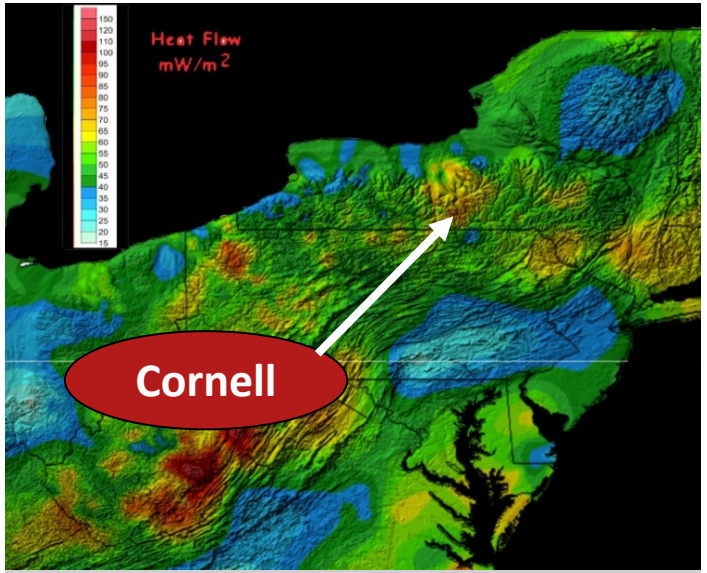
Common requirements for enhanced geothermal systems

- Accessible, sufficiently high temperature rock mass underground.
- Connected well system with ability for water to circulate through the rock mass to extract energy.
- Production of hot water at a sufficient rate and for long enough period of time to justify costs.
- Means of utilizing the thermal energy.



U.S. Geothermal Resources



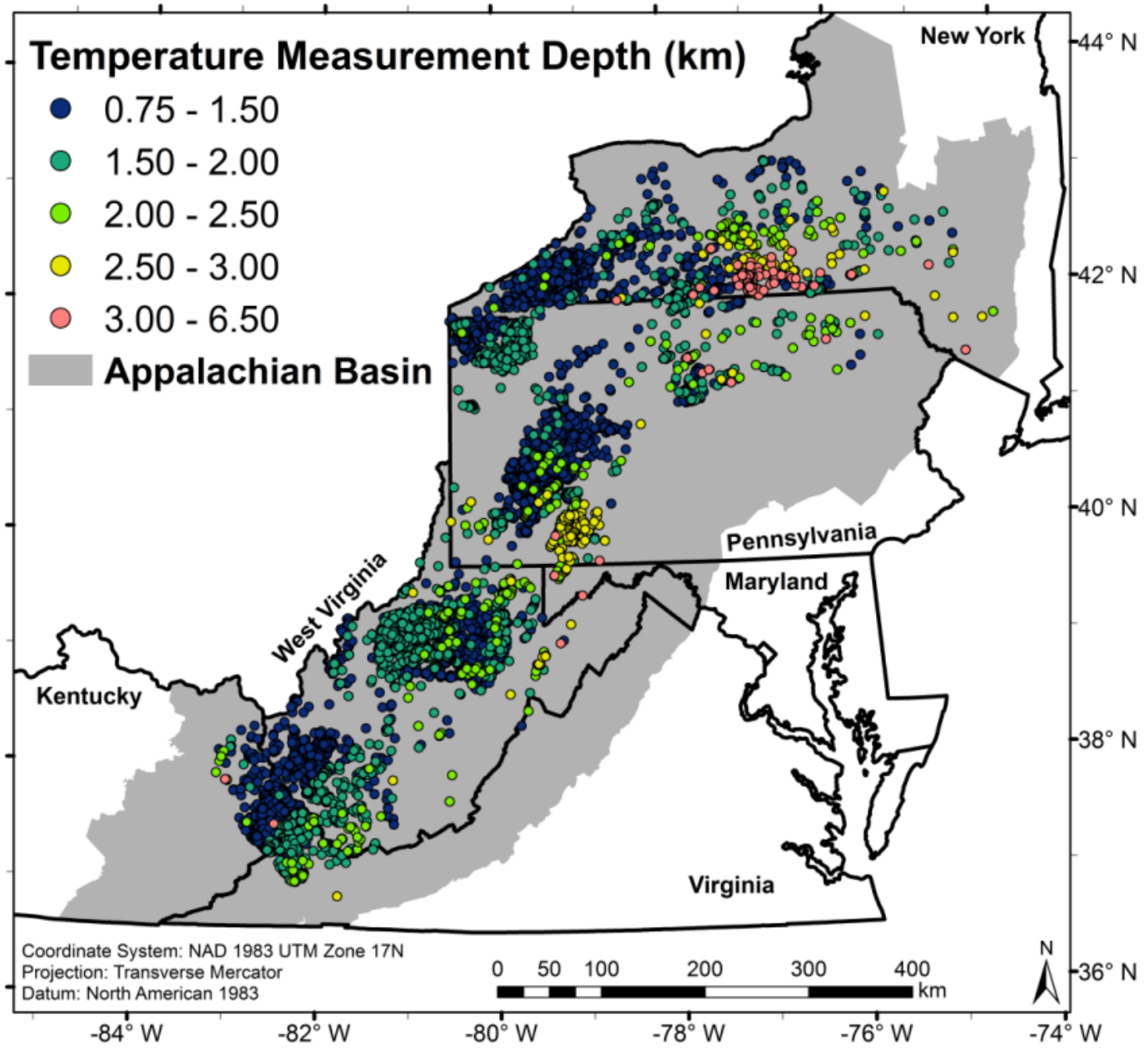


Cornell is located in a higher heat flow region for the Eastern U.S.

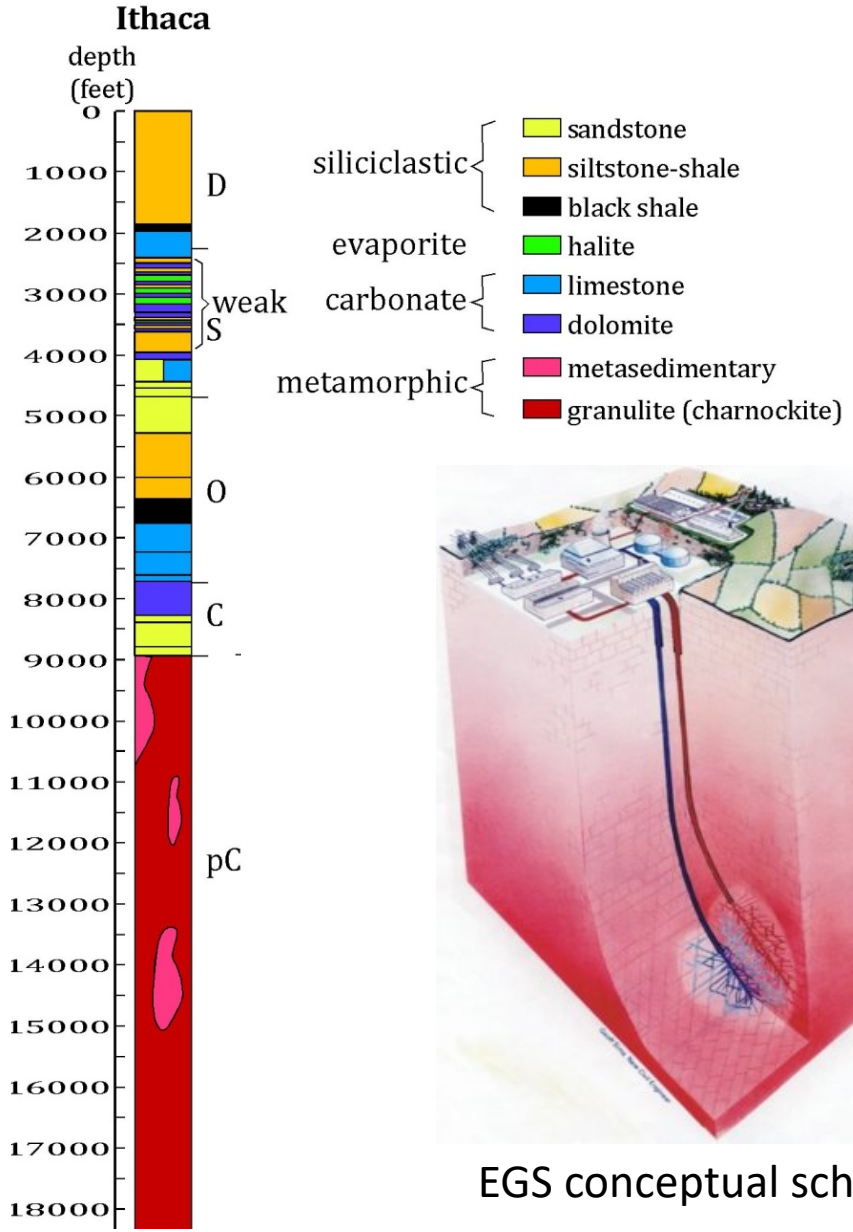
Southern tier region has above average temperature gradients

- Identified high heat flow and higher gradients by analyzing more than 8,000 wells in New York and Pennsylvania.

- The southern tier region of New York has many wells drilled to depths of 10,000 ft (3 km) of more.

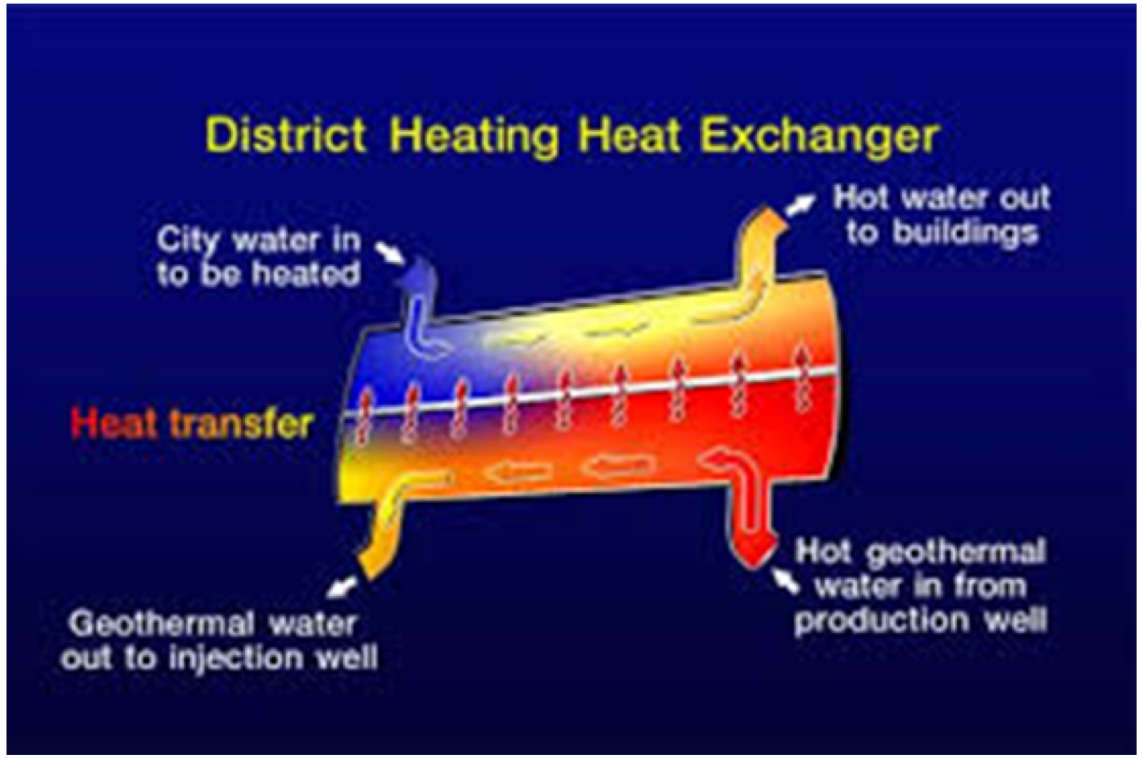


Details concerning proposed ESH system for Cornell



EGS conceptual schematic

To reach rock at 100 °C or higher well depths of 10,000 to 15,000 ft are needed.



Cornell is uniquely suited to explore ESH

- Committed to the goal of achieving carbon neutrality on our Ithaca campus.
- Longstanding tradition of innovating large-scale energy projects, including Lake Source Cooling.
- Deep faculty expertise in renewable energy production, seismicity, geology and the environment. Faculty-led research:
  - Establishing baseline and ground surface deformation
  - Seismic measurements
  - Gravity and magnetics
  - Groundwater and surface water
  - Reservoir thermal hydraulic performance

Cornell is uniquely suited to explore ESH

- Tompkins County has higher geothermal heat flows than in other Eastern sites.
- Potential EGS sites on Cornell property.
- Ability to utilize Cornell's existing district energy system infrastructure.
- Significant drilling experience in region to 2.5+ miles (~ 4+ km).
- Scalable to other communities in N.Y. and U.S. northern tier states.
- Deploying new energy development at scale provides a living laboratory for students and a teaching laboratory for workforce development.

Phases of Work

Preparatory Phase: Planning, research and design, permits and community engagement.

- Risk Management: Stage-gates that must be met in order for the project to continue.

Test Well: Single well, no integration with campus.

- Risk Management: Stage-gates that must be met in order for the project to continue.

Demonstration Well: One operating well-set, tie-in for use for limited portion of campus.

- Risk Management: Stage-gates that must be met in order for the project to continue.

Full Deployment: Multiple well-sets that would allow us to sustainably heat our entire campus.

Goals of Seismic Measurements

Geological Characterization

- Active imaging

Establishment of a Baseline (done)

- Passive listening for microseismicity establishes a local baseline
- Baseline surface measurements

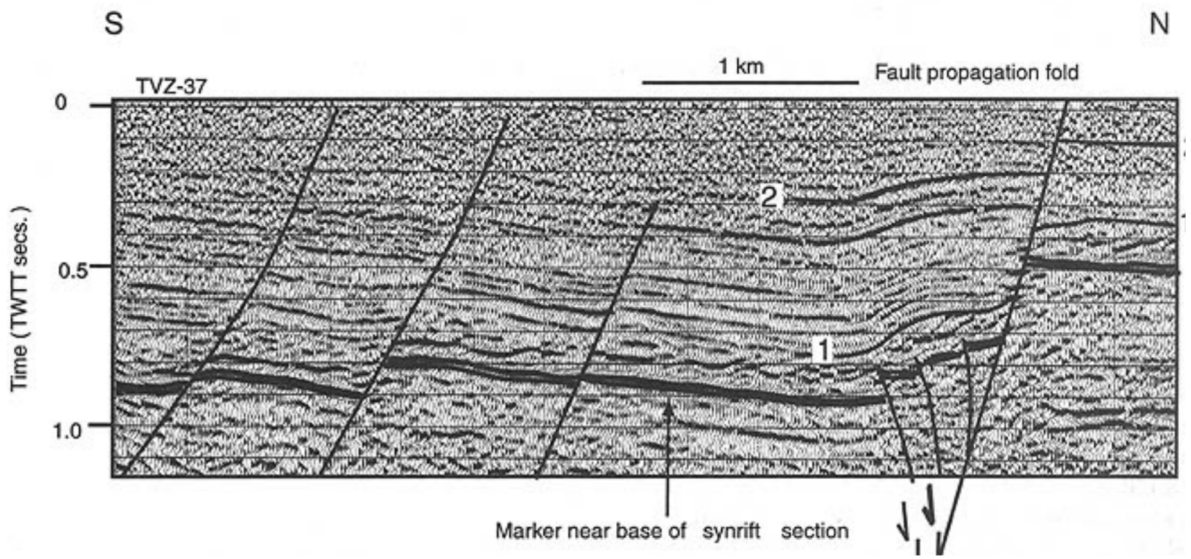
Baseline establishment is supported by the Atkinson Center at Cornell University

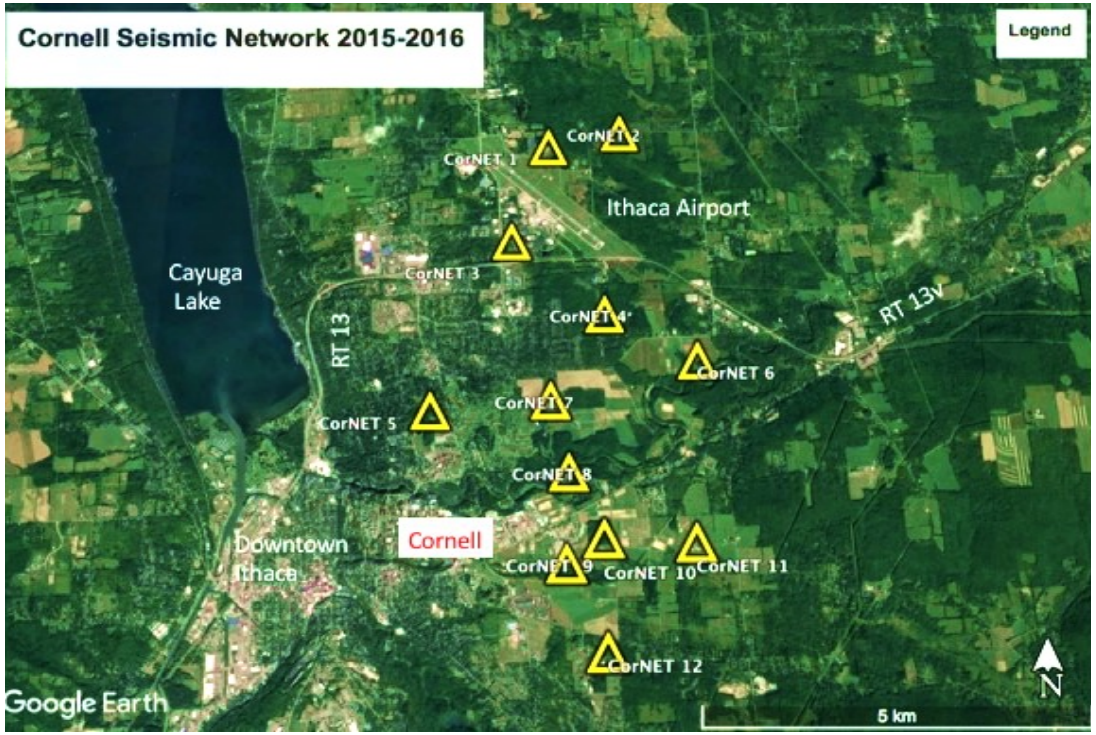
Active Seismic Testing:
One vibroseis truck planned for current work

Photos from R. Allmendinger from seismic testing in Ithaca on Warren Road in 2007

Outcomes Expected

- Geological characterization to identify possible subsurface fault structures.
- Establishment of a seismic (done) and ground surface baseline.
- Longer term related research goal: Image fractures and permeability pathways.





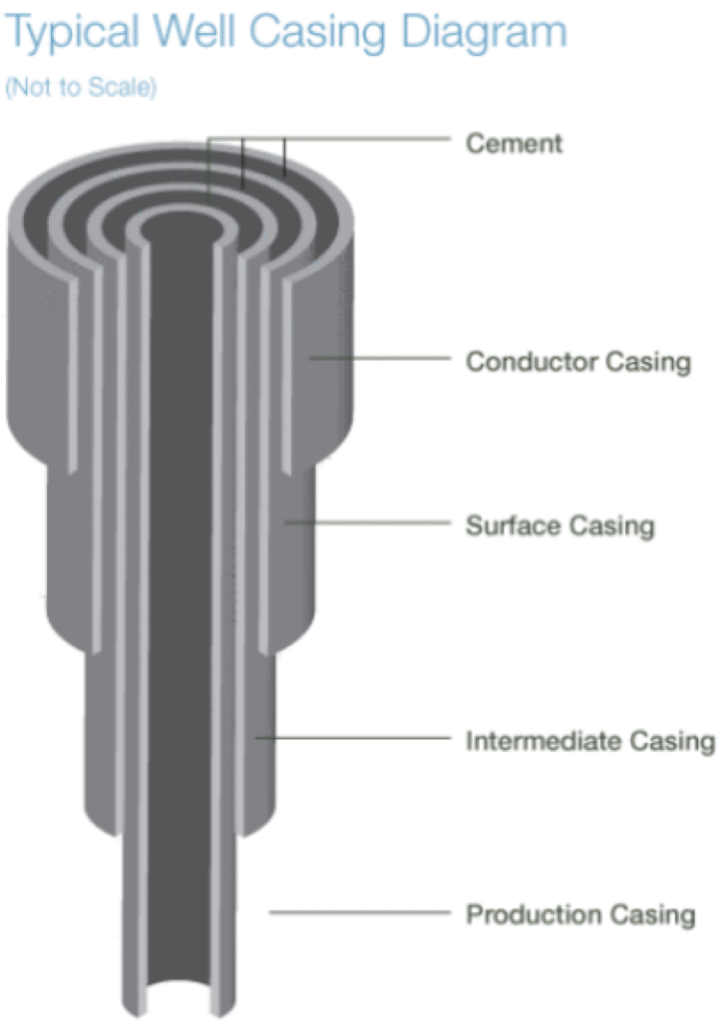
Seismic example from Morley, AAPG, 2002

Similarities and Differences

	Earth Source Heat	Shale Gas
Pre-Production Investigations: Seismic Testing	Passive background-level natural seismic measurements. Active seismic testing to characterize deep geology and identify faulting.	Seismic testing to identify faulting and gas-bearing zones.
Pre-Production Investigations: Exploratory Wells	One exploration well to measure temperatures, physical properties, and natural fractures.	May drill dozens of exploration wells to test productivity.
Pad Siting	Non-invasive; on Cornell owned land only; NYS requires a minimum of 500 feet from residential property, Cornell is looking at greater distances from residential properties	Invasive; within 300-500 feet of residential/school property
Pad Development	One; 5-10 acres; up to 12 wells eventually	Many clustered pads; 10-40 acres each; 20 wells or more on each

Similarities and Differences

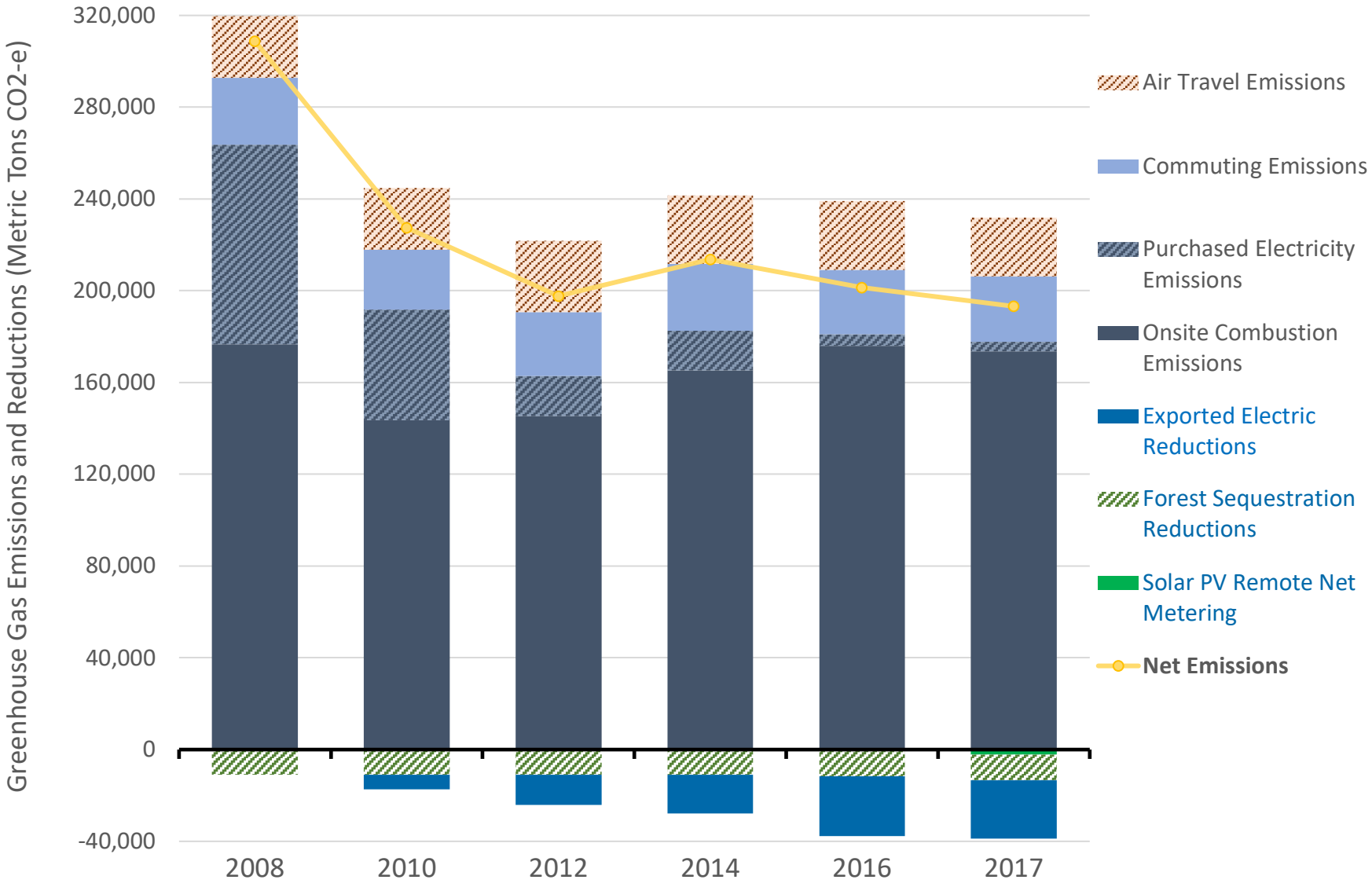
	Earth Source Heat	Shale Gas
Drilling	Vertical, directional; non-gas- bearing zone at 10,000 feet or more	Vertical and lateral always; gas-bearing zones at < 10,000 feet
Casing/Cementing	Multiple layers; isolate all gas-bearing zones; produce hot water from larger diameter production casing	Multiple layers; produce gas and NGL's from multiple zones
Stimulation	Might need hydraulic fracturing; tens of thousands of gallons; water and corrosion inhibitor; no additional chemical additives, no proppant	Always uses hydraulic fracturing; tens of millions of gallons; water and chemical mix; thousands of tons of proppant



Similarities and Differences

	Earth Source Heat	Shale Gas
Stimulation (Continued)	No flowback; no liquid waste disposal; no flaring/combusting/ venting of gases	Millions of gallons of flowback and liquid waste disposal from each well; flaring or combusting and/or venting of gases
Production	Hot water from non-gas-bearing zone at 10,000 feet or more	Gas and NGL's from gas-bearing zones at < 10,000 feet
Wellbore Integrity	Low number of wells, lower risk; farther from private water wells; venting not permitted	Very large number of wells, higher risk; close to private water wells; venting permitted
Methane and VOC Emissions	No hydrocarbon production, no flowback, no tank storage, no compressors, only water pipeline.	Methane and VOC production from flowback, tank storage, compressors, pipelines, end-uses

Cornell University GHG Inventory, Ithaca Campus



Travel
FY17 23%

Energy
FY17 77%

Claimed Reductions

Options for Achieving Carbon Neutrality

- Cornell's Climate Action (CAP) plan was first published in 2009.

- "Options for Achieving Carbon Neutrality by 2035" report provided a thorough review of feasible options and associated costs, including:
  - Biomass
  - Heat pumps
  - Geothermal Direct Use – Earth Source Heat (ESH)

- All options were carefully considered in the context of the University's need to advance its full academic mission and the creation of new knowledge that advances society and serves the citizens of New York state.

Heat Alternative: Biomass Combustion

Land and transportation resources needed to support biomass combustion are not practical.

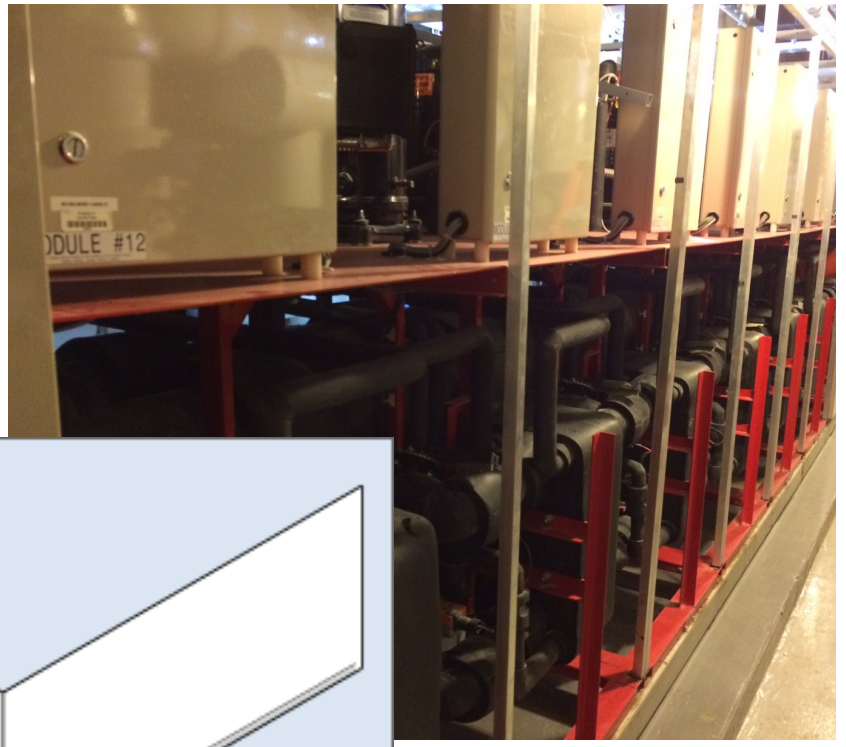
Managed forest: 140,000 acres = ~220 square miles

- 115,000 tons green wood chips
- 5,800 truck loads per year
    - 22 truck trips per day, 5 days per week
- Sustainably managed forest

Energy crops: 20,000 acres = ~32 square miles

- 160,000 tons chopped willow or switchgrass
- 8,000 truck loads per year
    - 30 truck trips per day, 5 days per week

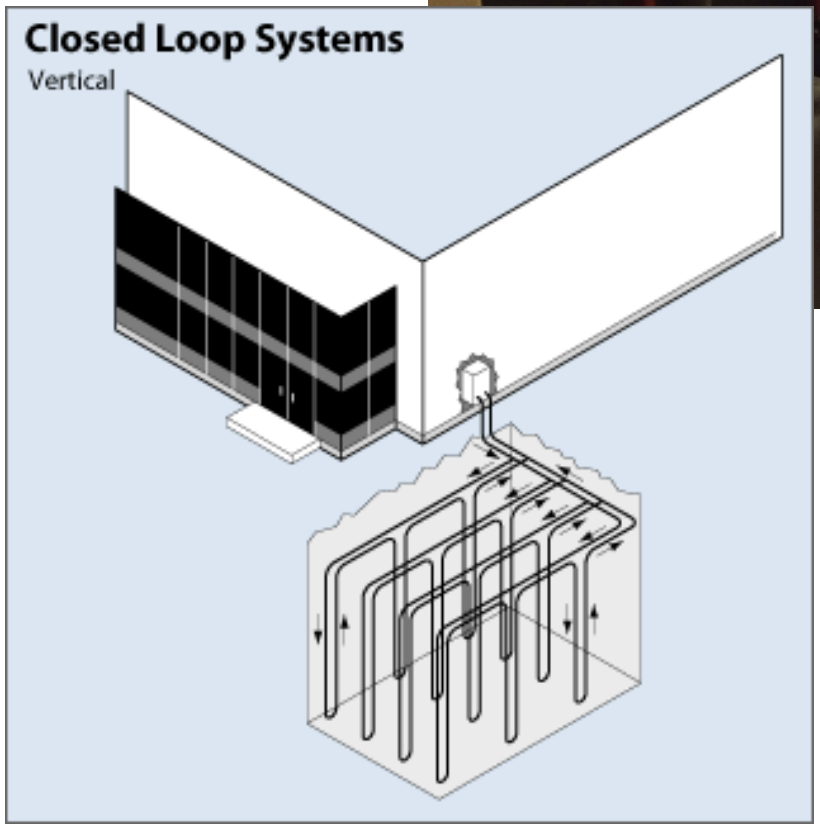
Heat Alternatives: Heat Pumps



Ground Source Heat Pumps

Ground source heat pumps are not practical at a scale needed to meet Cornell's heating load.

- 15,000 wells each 500 feet deep.
- Over 150 acres required for the well field.
- Needs 50% more electricity as current campus use. Double the peak load.



Air Source Heat Pumps

- Needs twice the electricity as current campus use.
- Quadruples peak electric winter load.

Benefits Beyond Campus

- Potential for a research-driven solution that could lead to a new sustainable, scalable solution to heating challenges throughout New York state and across the globe.

Thank you.

For more information, please visit:

earthsourceheat.cornell.edu