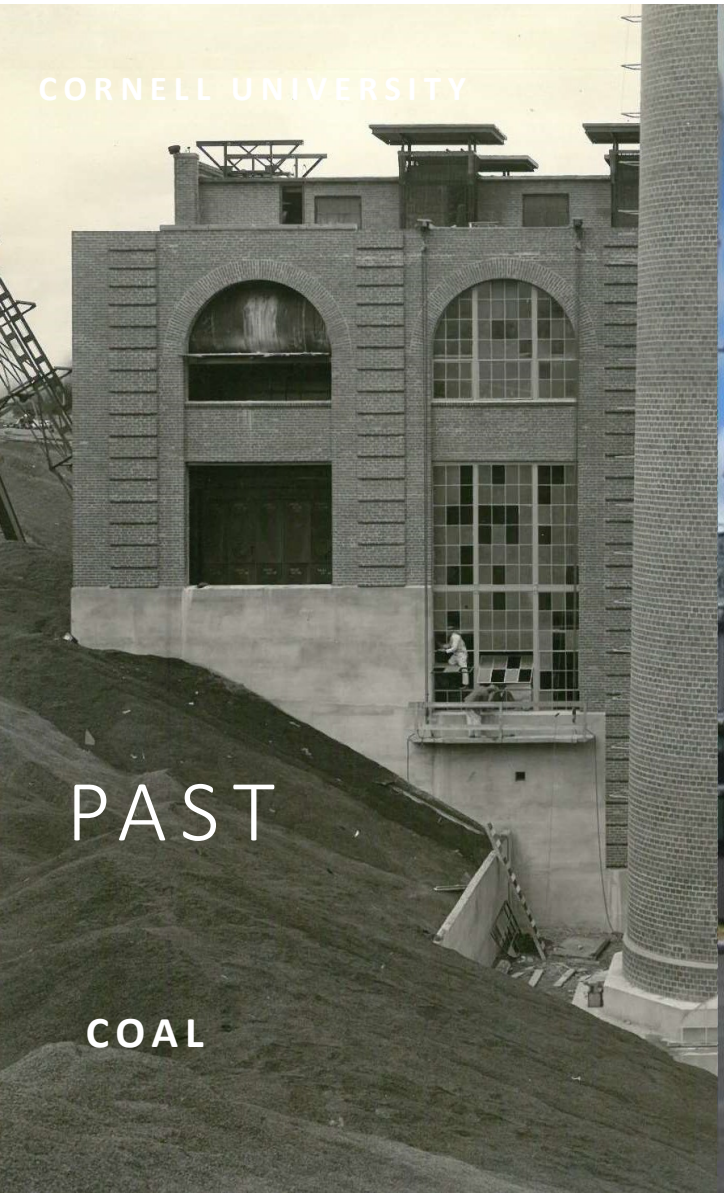
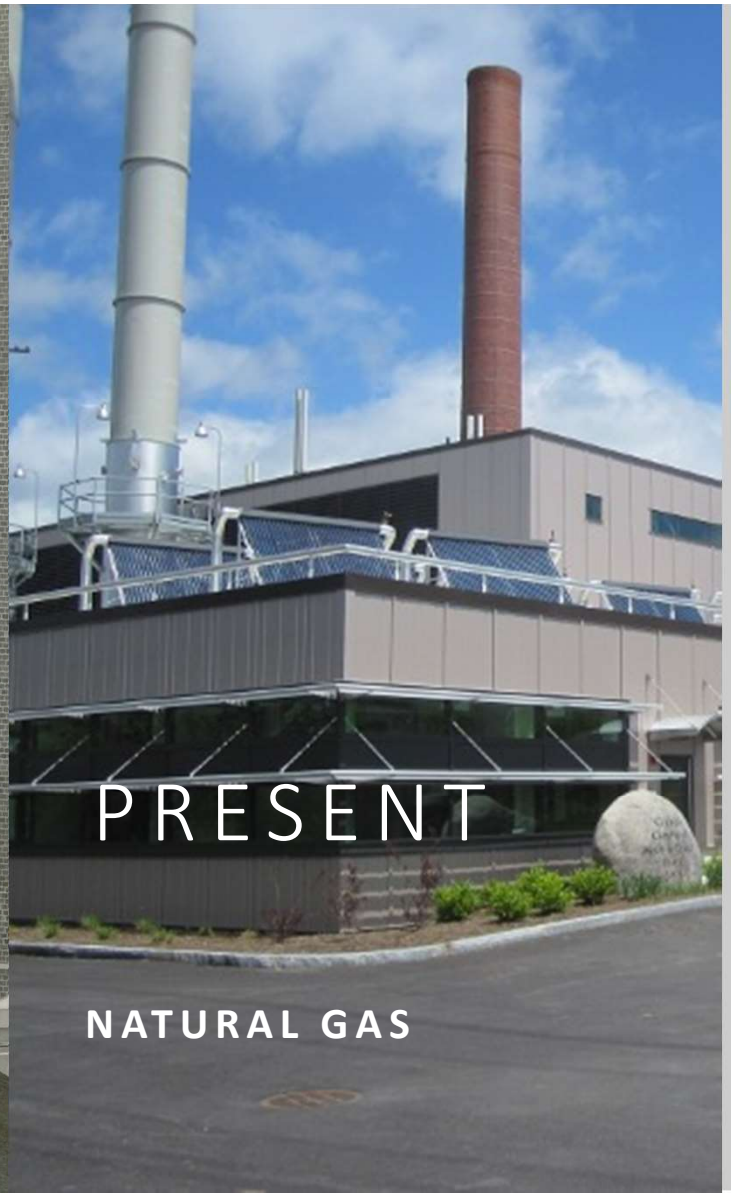
Cornell University Energy Future

CIBO Quarterly Meeting
September 2022

Cheryl Brown
Environment, Health & Safety


CORNELL UNIVERSITY
PAST
COAL


PRESENT
NATURAL GAS


FUTURE
CARBON NEUTRAL
RENEWABLES

Cornell University Fast Facts

Founded in 1865 by Ezra Cornell and Andrew Dickson White

Federal land grant institution of New York

1,600 faculty and staff (Ithaca campus only)

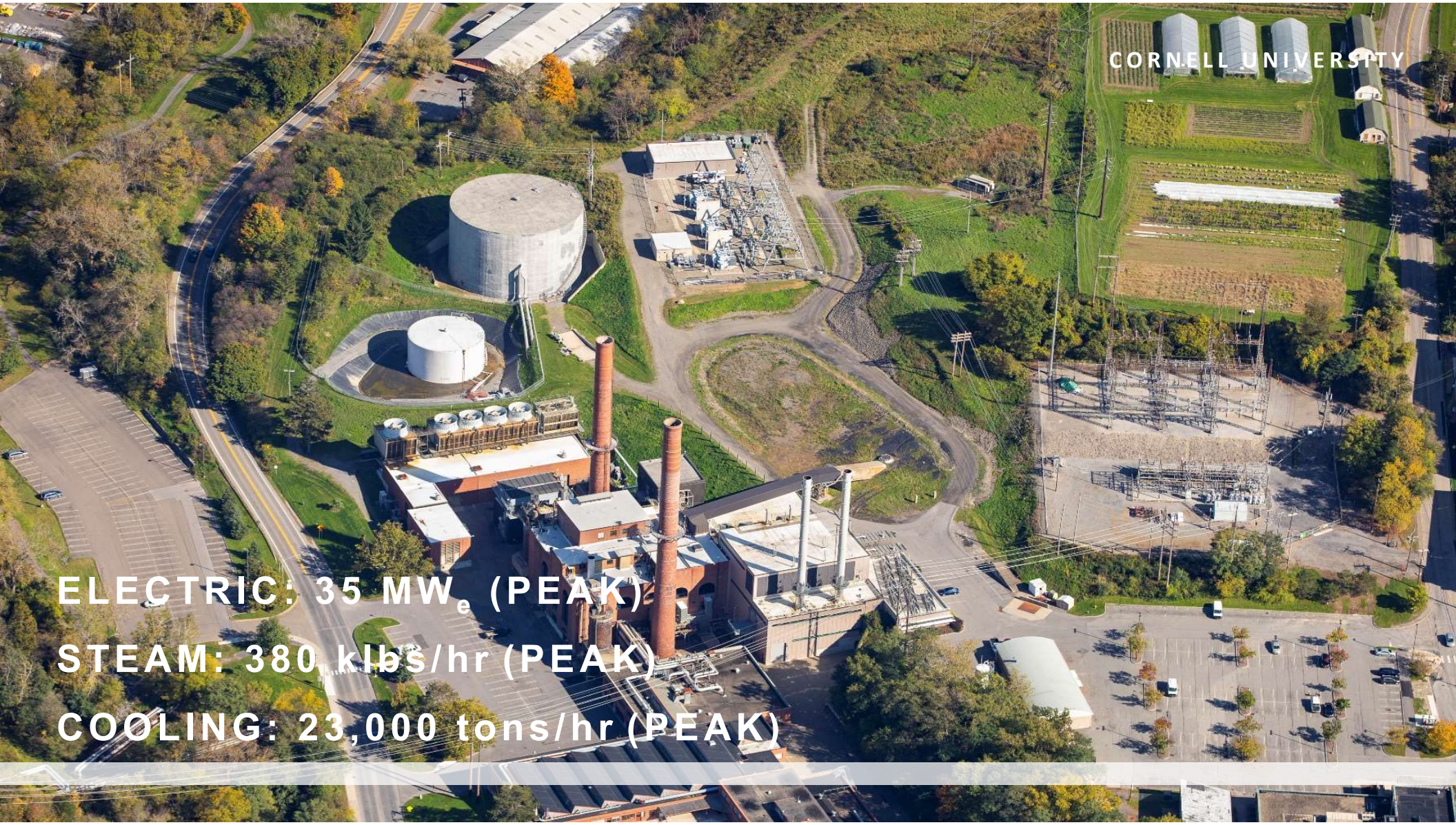
14,000 Undergraduates students

7,000 Graduate students

250 facilities @ 14.75 million sqft

$2.0 billion annual operating budget


CORNELL UNIVERSITY
CAMPUS SIZE: ~14,750,000 GSF


CORNELL UNIVERSITY
ELECTRIC: 35 MWe (PEAK)
STEAM: 380 klbs/hr (PEAK)
COOLING: 23,000 tons/hr (PEAK)

Cornell University District Energy

Enterprise Units

- Electric
  - 35 MW peak
  - 240 GWh/yr
- Steam
  - 380 kpph peak
  - 1,200,000 klbs/yr
- Chilled Water
  - 23,000 Tons peak
  - 40,000,000 ton-hrs/yr
- Water and Sewer

Boilers at Central Energy Plant

- Four Natural Gas/#2 Oil Boilers
- One Natural Gas Boiler

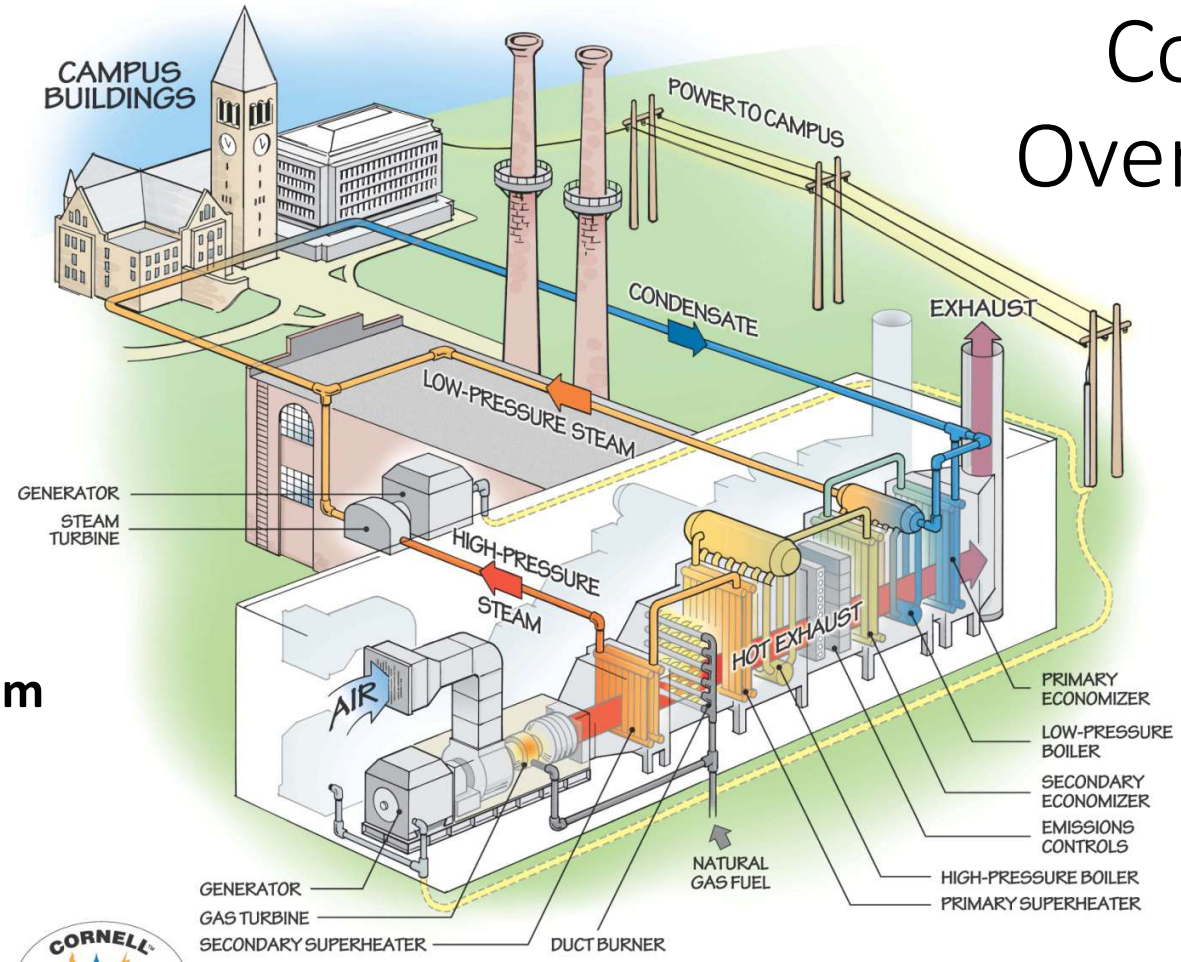
Combustion Turbines at Central Energy Plant

- Two 15 MW Combustion Turbines
- Heat Recovery Steam Generators with supplemental Duct Burners

Cornell Overview

Cornell CHP Plant

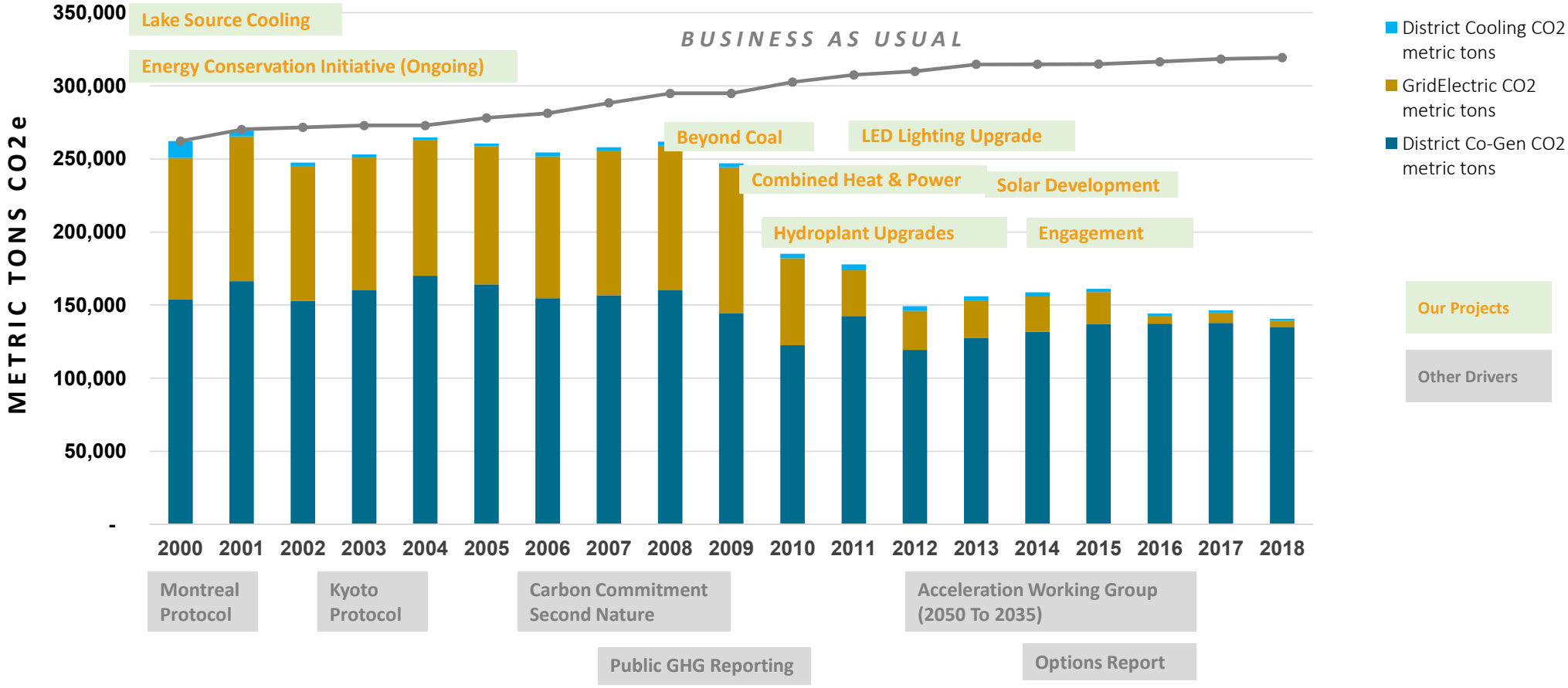
- **Two CTs**
- **Two Steam Turbines**
- **Steam Condenser Building allows us to condense excess steam**



Combustion Turbine with Heat Recovery Steam Generator

DISTRICT ENERGY DECARBONIZATION

ELECTRIC, COOLING & HEATING



Solar Projects

- 6 Solar Farms
- 9 Solar/PV on campus buildings
- >20% annual campus electricity needs
  met by our solar farms

Cascadilla Solar Farm

Student, Faculty & Community Influences

- Students questioning refrigerants (HCFCs) and ozone layer impacts (1990s)
  - Cornell committed to the Kyoto Protocol and built Lake Source Cooling in 2000
- State DEC and Sierra Club's Campaign to stop coal
  - Cornell installed 2 new Combustion Turbines in 2009 that allowed us to stop firing coal sooner
  - Federal and State regulations would have likely driven us to retire coal eventually
- Faculty/Students questioning new building connections to our steam distribution system rather than the grid (thought to be greener) with latest campus dorm addition in 2018

Regulatory Influences

- **Changes State CO2 Regulations and Regional Greenhouse Gas Initiative (RGGI)**
  - Cornell's Central Energy Plant falls under the new regulations unless total export to grid is less than 10% of total generation
- **NY State Climate Leadership and Community Protection Act (CLCPA)**
  - State policy changes already implemented requiring review of installation need and assessment of carbon offsets in any future air permit changes
  - Electrification of buildings
- **City of Ithaca Energy Code**
  - Building codes may require Renewable Energy Credits (RECs) for new buildings and major renovations
- **Lake Source Cooling NY State SPDES discharge permit**
  - Requires Phosphorus offsets for new buildings connected to the cooling district

Cornell Sustainability Goals

- Cornell President signed Climate Commitment in 2007
- Developed a Climate Action Plan
- Set goals for carbon neutrality by 2050, then moved up to 2035

Climate Action Plan

Our commitment requires institutional and individual action to achieve carbon neutrality for the Ithaca campus by 2035

- Net zero combustion emissions from campus energy use, commuting, and business air travel
- Integrate climate literacy into curriculum and educational experience
- Expand research necessary to achieve carbon neutrality

Reduce Cornell's carbon emissions to net zero by 2035

Create a living laboratory for low-impact behaviors, climate education, and research

Lead by example on campus and exercise climate leadership beyond campus

Climate Action Plan Strategies & Key Actions

A living document for our living lab…

- Culture Change
  - Campus Climate Literacy
  - Improve Commuter Use of Alternative Transportation
  - Reduce Carbon Intensity of Air Travel
  - Optimize Use of Virtual Participation and Remote Work
- Green Development
  - Build and Maintain High-Performing Green Buildings and Spaces
  - Maximize Efficient Use of Existing Campus Buildings and Spaces
  - Improved Land Use
- Alternative Transportation
  - Improve Intracampus Transportation
  - Increase Efficiency of Cornell Fleet
  - Support Improvements to Regional Mass Transit
- Energy Conservation
  - Support Next-Generation Energy Conservation
- Renewable Energy
  - Steam to Low-Temperature Hot Water Conversion
  - Heat Campus with Renewable Energy: Develop Earth Source Heat
  - Power Campus with 100% Renewable Electricity
  - Optimize Campus Energy System for Renewable Heat and Power
- Mission-Linked Carbon Management Strategies
  - Leverage research, operations, and campus physical assets to offset unavoidable university emissions

Earth Source Heat vs Heat Pumps

- Earth Source Heat (ESH)
  - Low electric use, low/no refrigerant use
  - Potential for grant funding & attractive to external funding sources
  - Research and teaching opportunity for living lab
  - Game-changing, globally scalable solution
- Plan B: Ground Source Heat Pump system
  - 10,000 wells each 500 feet deep
  - 150 acres required for the well field
    - ~518 boreholes fit on A Lot
    - ~900 boreholes fit on B Lot
  - Significant electricity impact (double for Air Source Heat Pumps)
    - Doubles or triples peak electric demand in winter: ~25-40 MW higher
    - Increases annual electrical use by about 48%
    - Magnifies grid transition challenge facing NYS – Cornell is 1/1000 of NYS electric demand already
  - Heat pumps require significant building modifications for cooler water – more than ESH
  - Substantially more expensive
  - Refrigerants are among the most potent GHGs

All solutions require steam to hot water conversion: distribution system and building systems

Non-Feasible Heating Options

- Biomass gasification and combustion
  - Maximum sustainable yield on "local" Cornell lands (those potentially available for biomass within 25 miles of central campus) could only provide about 15 percent of the energy needed to heat the campus.
  - If produced regionally, biomass production could put significant strain on the ecological carrying capacity of our region, without net benefit on the surrounding community.
  - Biomass is considered potentially viable as a peaking or back-up fuel source
- Business as usual + carbon offsets (carbon capture?)
  - Does not meet the goals of our campus commitment
  - Significant financial risk to procure offsets
  - Counter to NYS strategy
- Business as usual + carbon capture
  - Not evaluated
  - Counter to NYS strategy

Quadruple Bottom Line Project Analysis

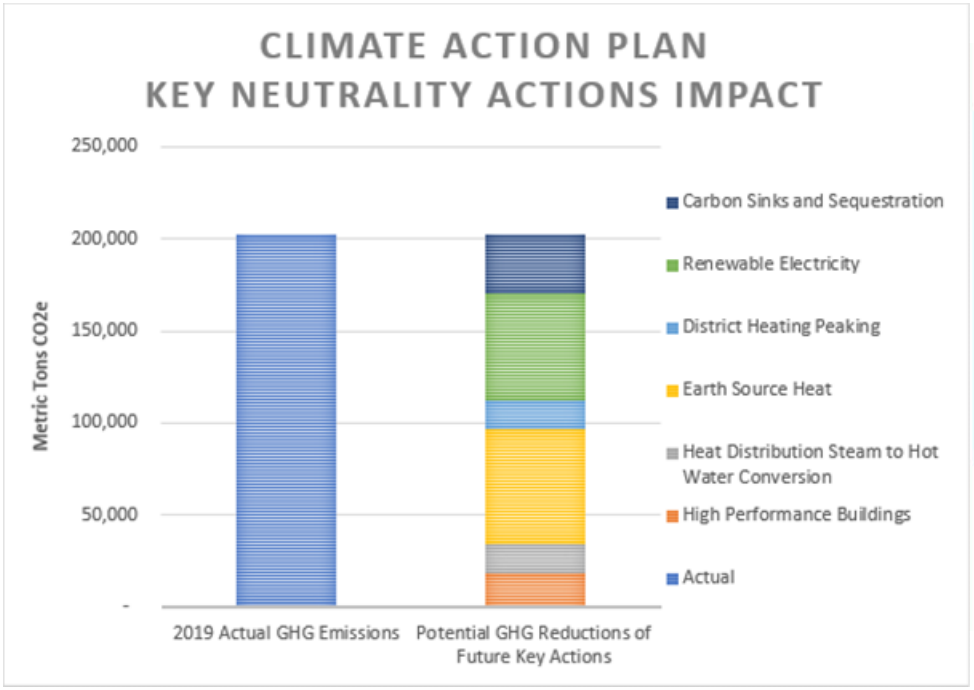
Options for a Climate Neutral Campus by 2035

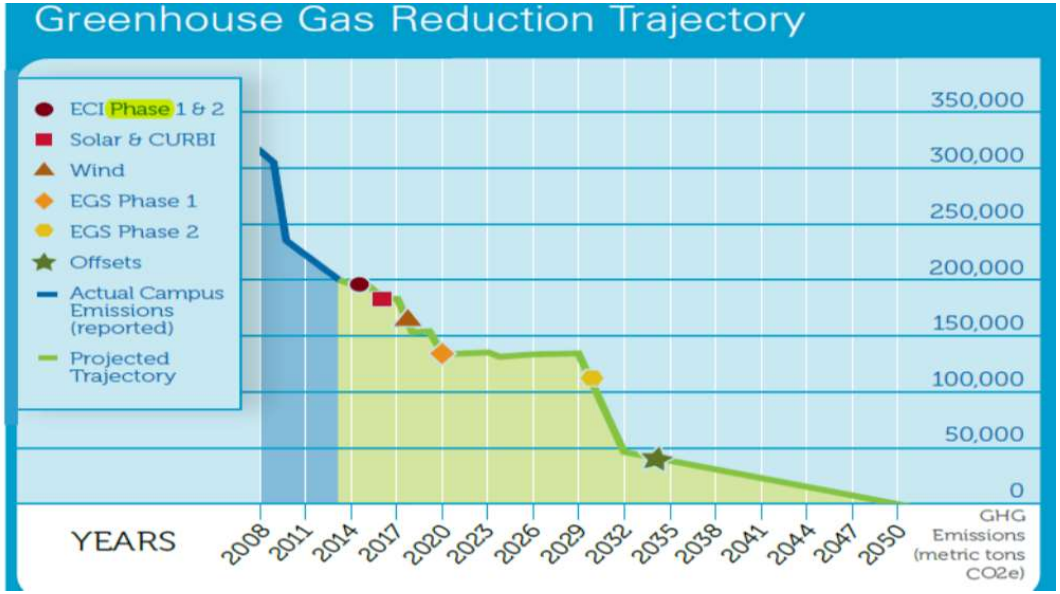
Heating & Powering Solutions	Purpose	Prosperity	People	Planet
	QBL Analysis			
Earth Source Heat + WWS + Biomass Gasification	🟢	🟡	🟡	🟢
Earth Source Heat + WWS	🟢	🟡	🟡	🟢
Air Source Heat Pumps + WWS	🟡	🔴	🟡	🟢
Ground Source Heat Pumps + WWS	🟢	🔴	🟡	🟢
Nuclear	🔴	🔴	🔴	🟡
Business as Usual + Carbon Offsets	🟡	🔴	🔴	🔴

Analysis clearly shows the "full benefit" to the institution in pursuing Earth Source Heat, and clear lack of institutional priority alignment in pursuing "business as usual" with offsets

WWS = Wind, Water, Solar

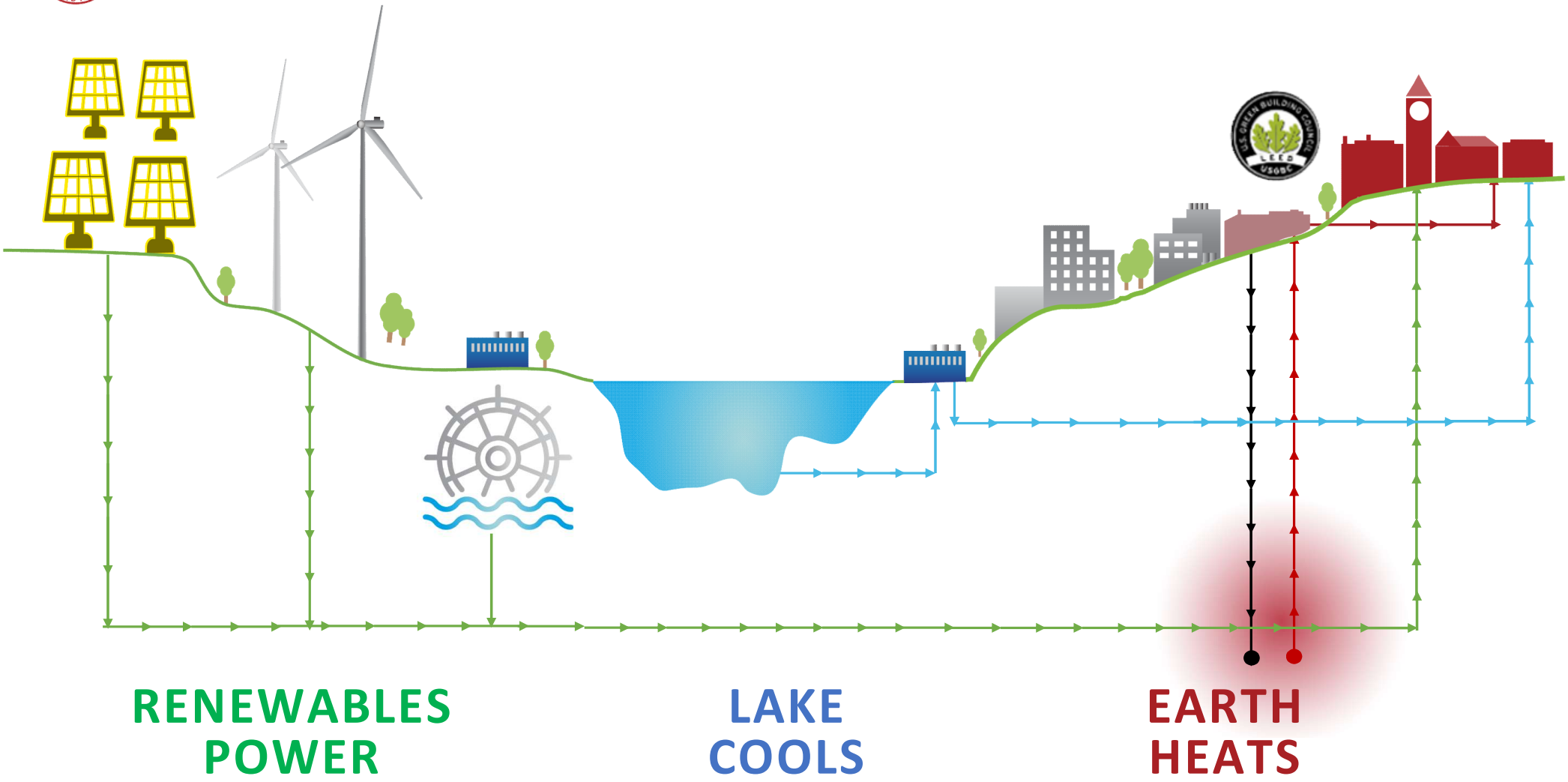
Carbon Neutrality Trajectory





CORNELL CARBON NEUTRAL DISTRICT ENERGY

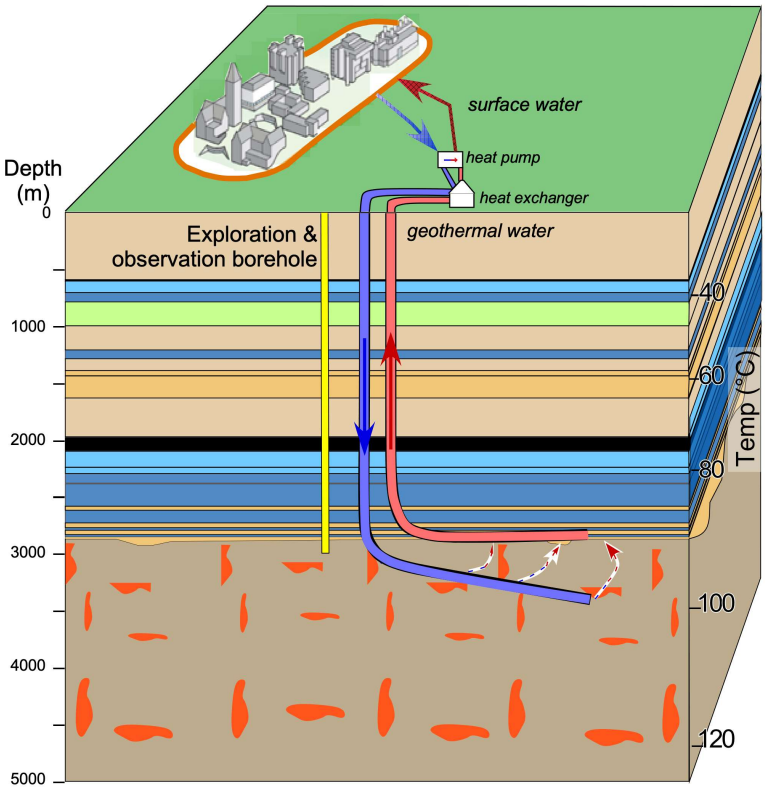
CURRENT & PLANNED



What is Earth Source Heat?

Earth Source Heat is Cornell's vision for a campus-wide geothermal heating system.
If successful, it will replace fossil fuels with renewable heat for our Ithaca campus.

How Does it Work?



- Uses campus **district energy system** with hot water
- **Two (or more) deep wells** are drilled to where rocks are hot
- **Hot water is pumped from one**, and cooled water is returned to the rocks in the other
- **Heat is extracted** from the geothermal water and transferred to surface water via the heat exchanger
- **The heated surface water circulates** through the pipes of the campus heating system

Usable Heat is Widely Available in the Earth

- 20% of the country's energy use occurs at **temperatures < 100°C.**
- Geothermal heat at 60-100°C is **accessible throughout the U.S.**, and its direct use would be **efficient and carbon-free.**
- Demonstrated success in a region like Upstate New York would effectively **expand the viability** of this energy source nationwide.

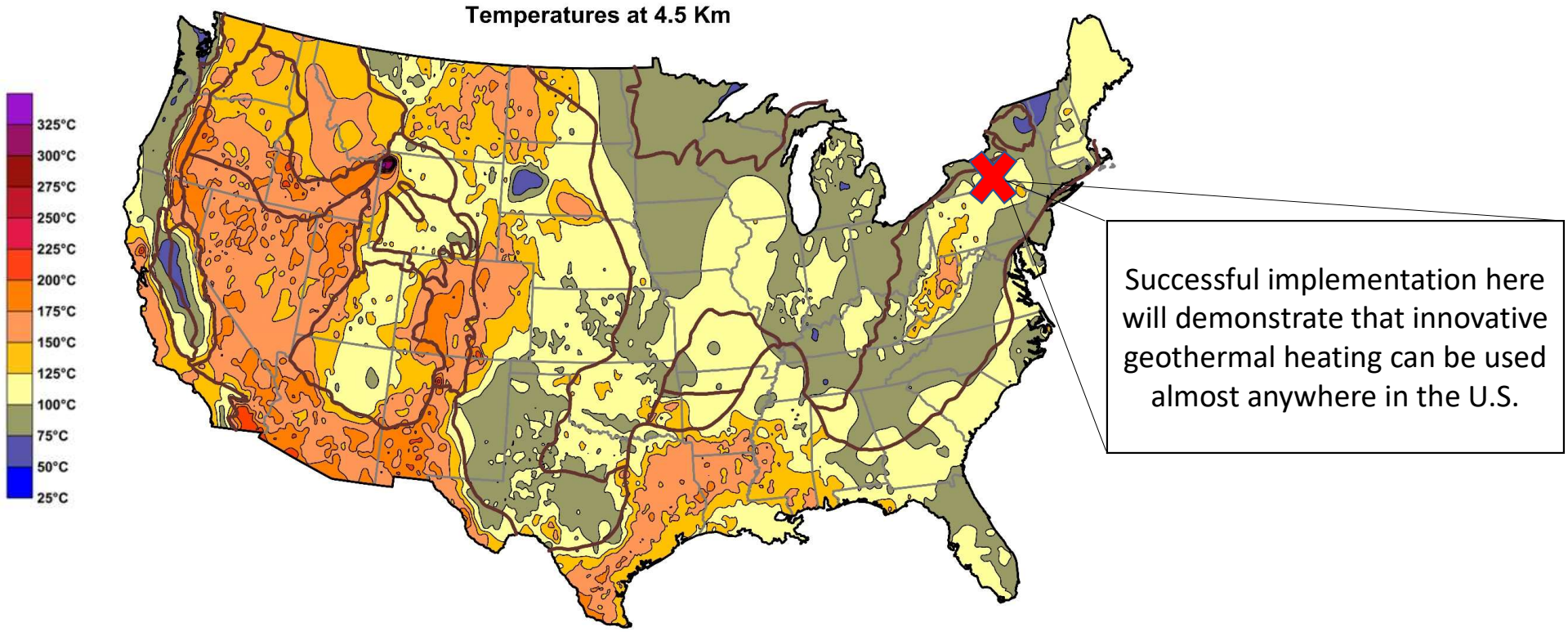
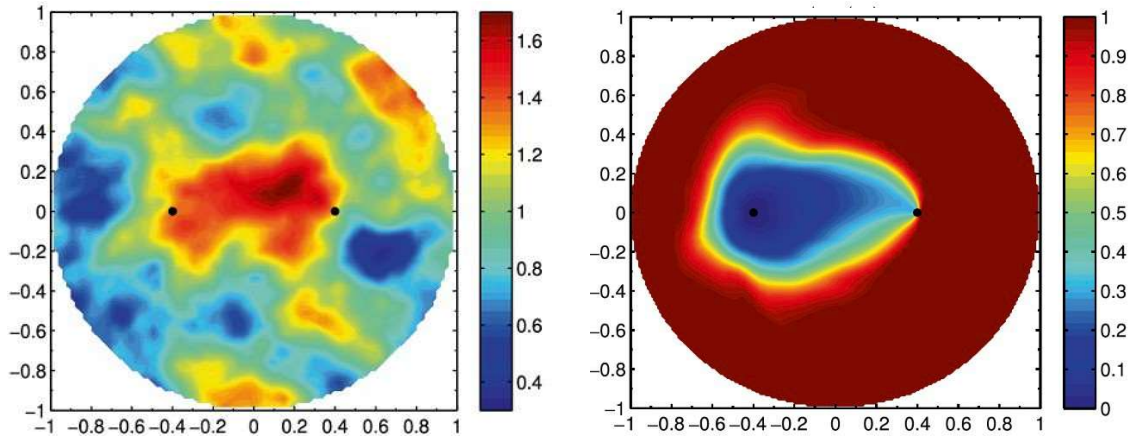


Image Source: SMU Geothermal Lab

Technology Innovations Reduce Risk

- Directional drilling means greater contact with target resources.
- Fiber optics installed in wells provide a window into subsurface conditions.
- Advanced subsurface imaging and micro-processing has eliminated guesswork.
- Smart tracers enable prediction of long-term reservoir performance.



Innovative tracers reveal the thermal profile within subsurface reservoirs.

Cornell Project Timeline: Staged to Mitigate Risks

DISCOVERY & DESIGN

- Data collection, including subsurface imaging, background seismic, and water monitoring
- DOE-funded borehole and subsurface analysis
- System design

DEMONSTRATE

- Create functioning well pair prototype
- Continued risk analysis
- Connect to district heating system

DEPLOY

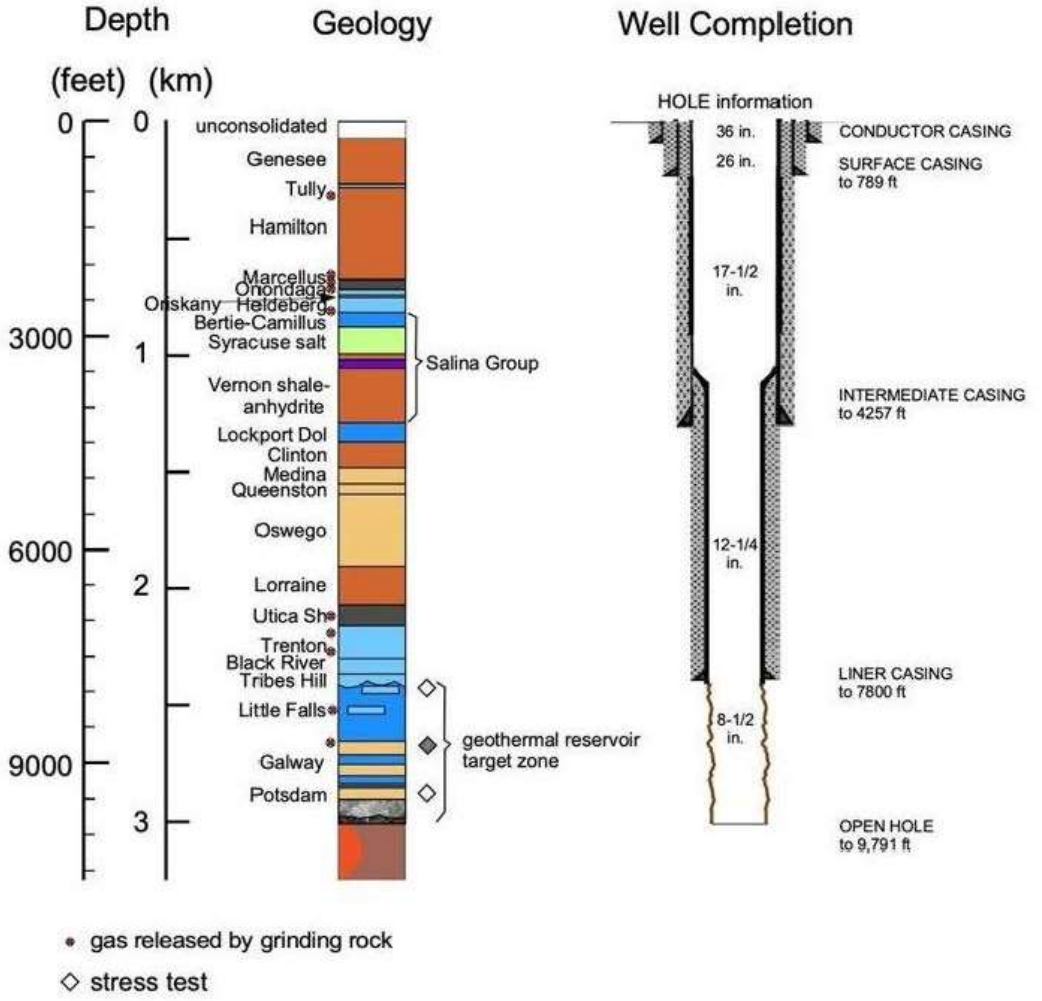
- Technology de-risked and fully deployable
- Private-sector deployment across the state at sites with existing district heating systems and appropriate geological subsurface

- 2016 – Present
- **CUBO: Exploration & observation borehole in 2022**

- Subject to funding
- 2-3 years
- Rigorous risk analysis to determine system efficacy

- Subject to funding
- 3-5 years
- After successful demonstration, full deployment to campus and beyond

CUBO Project Plan



Seismic Monitoring

Borehole Site

Surface Seismometers

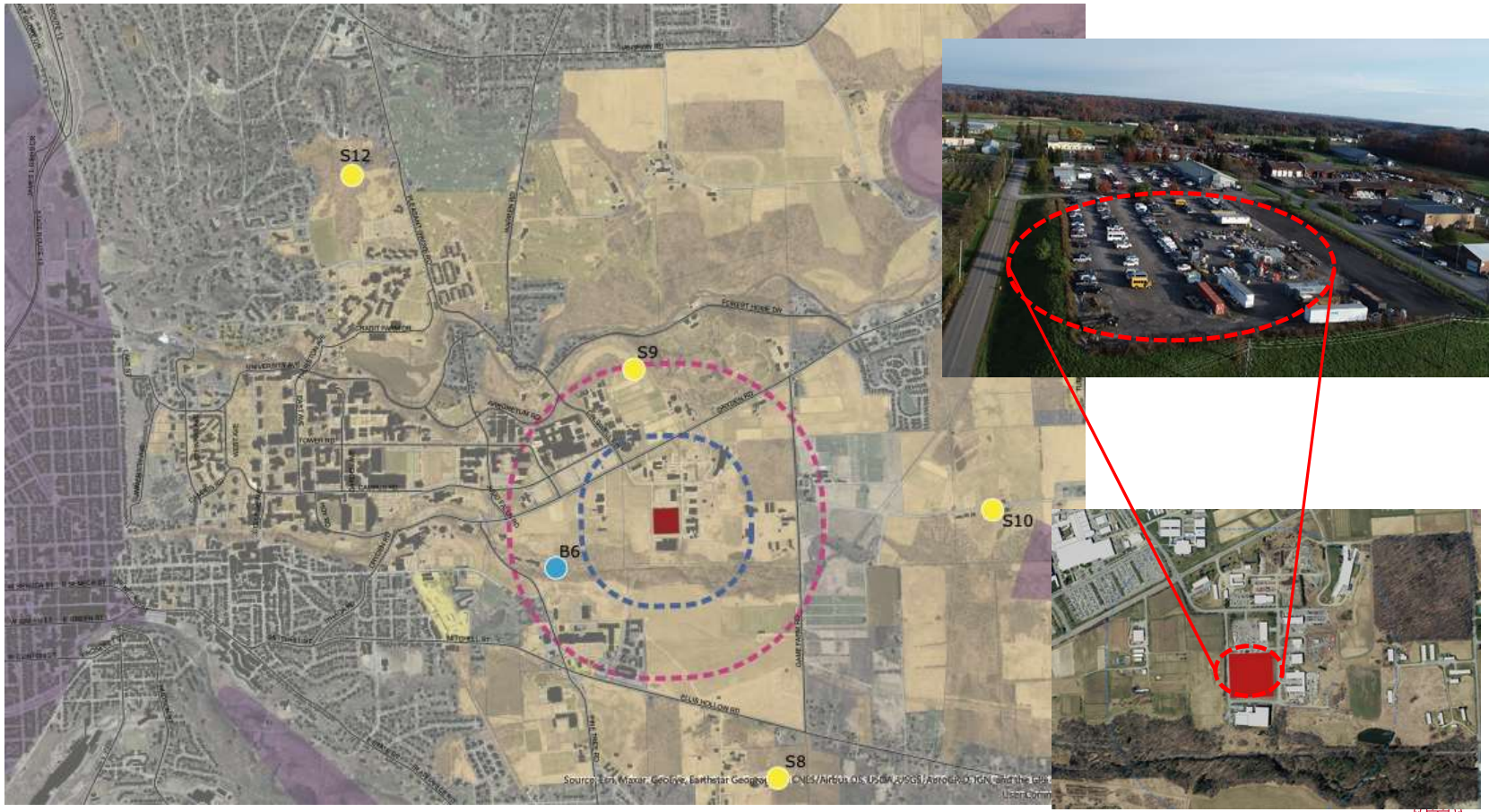
Borehole Seismometers

Cornell Land

Aquifer

½ mile radius

¼ mile radius

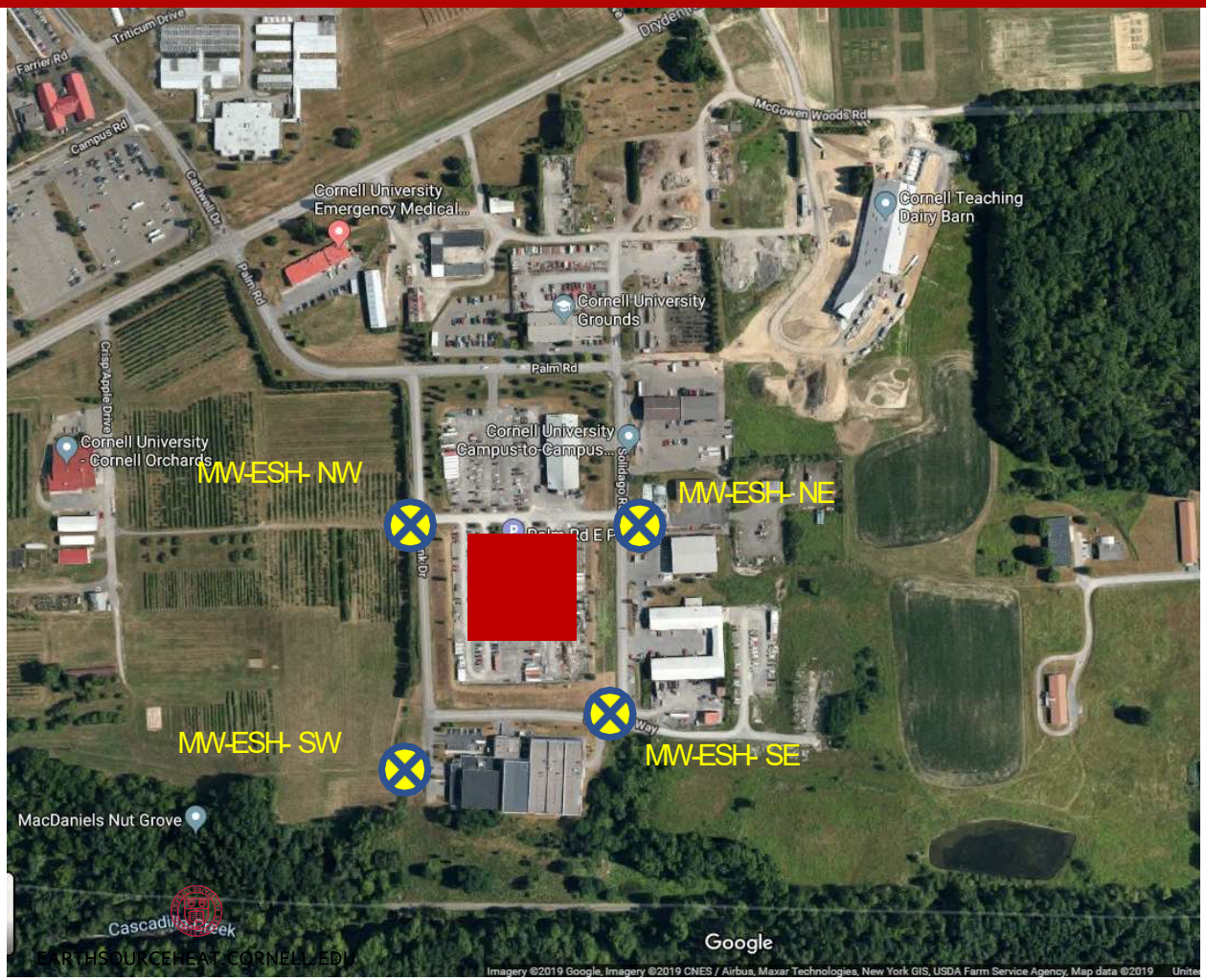


Water Monitoring

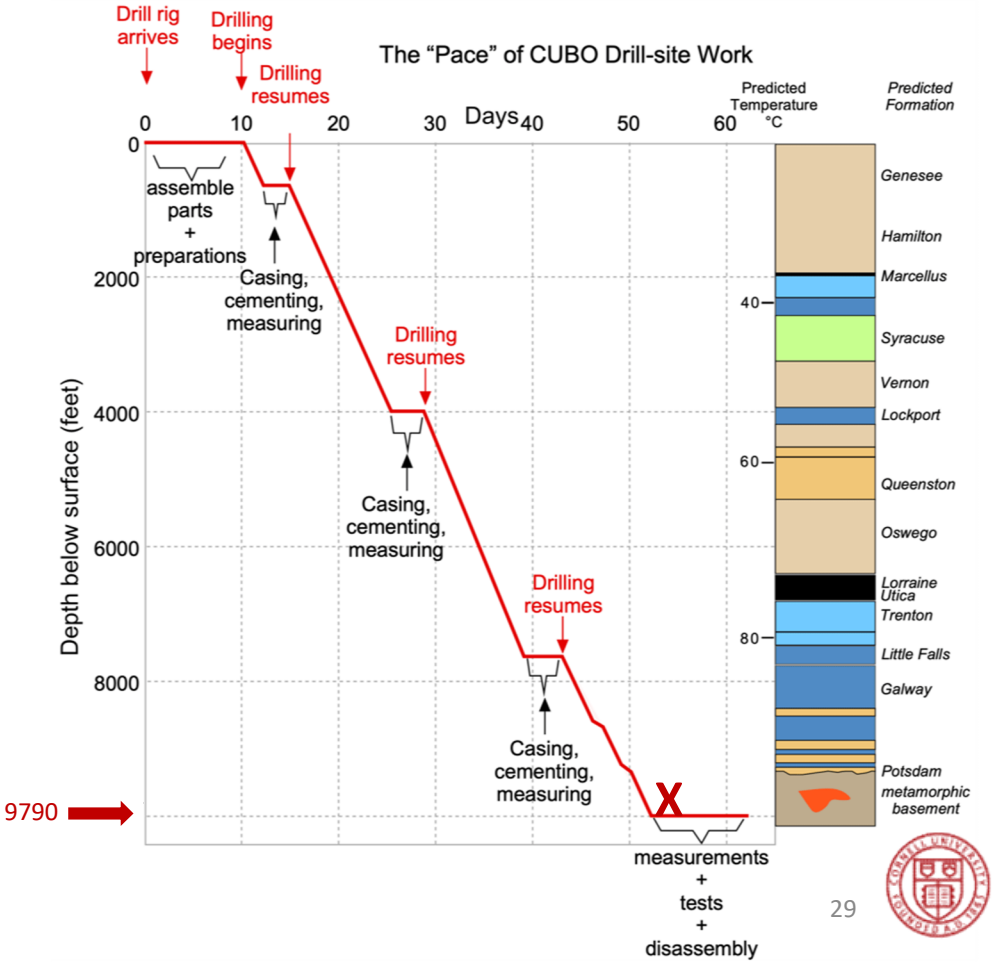
Location of new water monitoring wells near drill site

Monitoring well location

Borehole site



CUBO Project Delivered



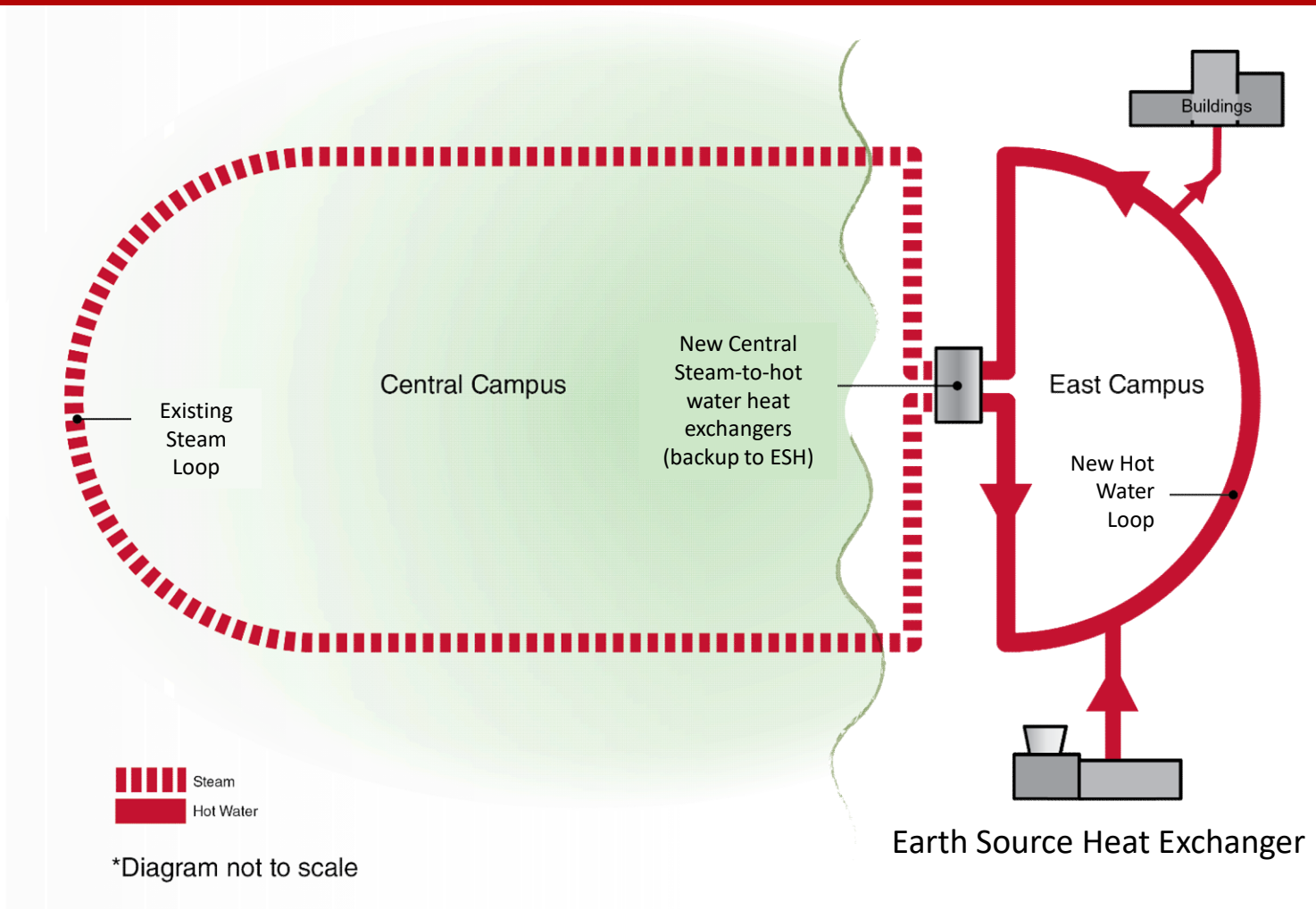
Summary Accomplishments

- Drilled ~3km from June 21 - August 15
  - Successfully drilled through geologic target formations
- Performed tests and collected samples from August 16 - 22
  - Confirmed fractures present
  - Confirmed usable temperatures of 170-190^{o}F
  - Currently compiling raw data for analysis
- Zero accidents and zero environmental incidents
  - No impacts detected via seismic and water quality monitoring network
- Consistently positive community engagement and feedback
  - Hosted 100's of guests at weekly "office hours"

Next Steps: Earth Source Heat

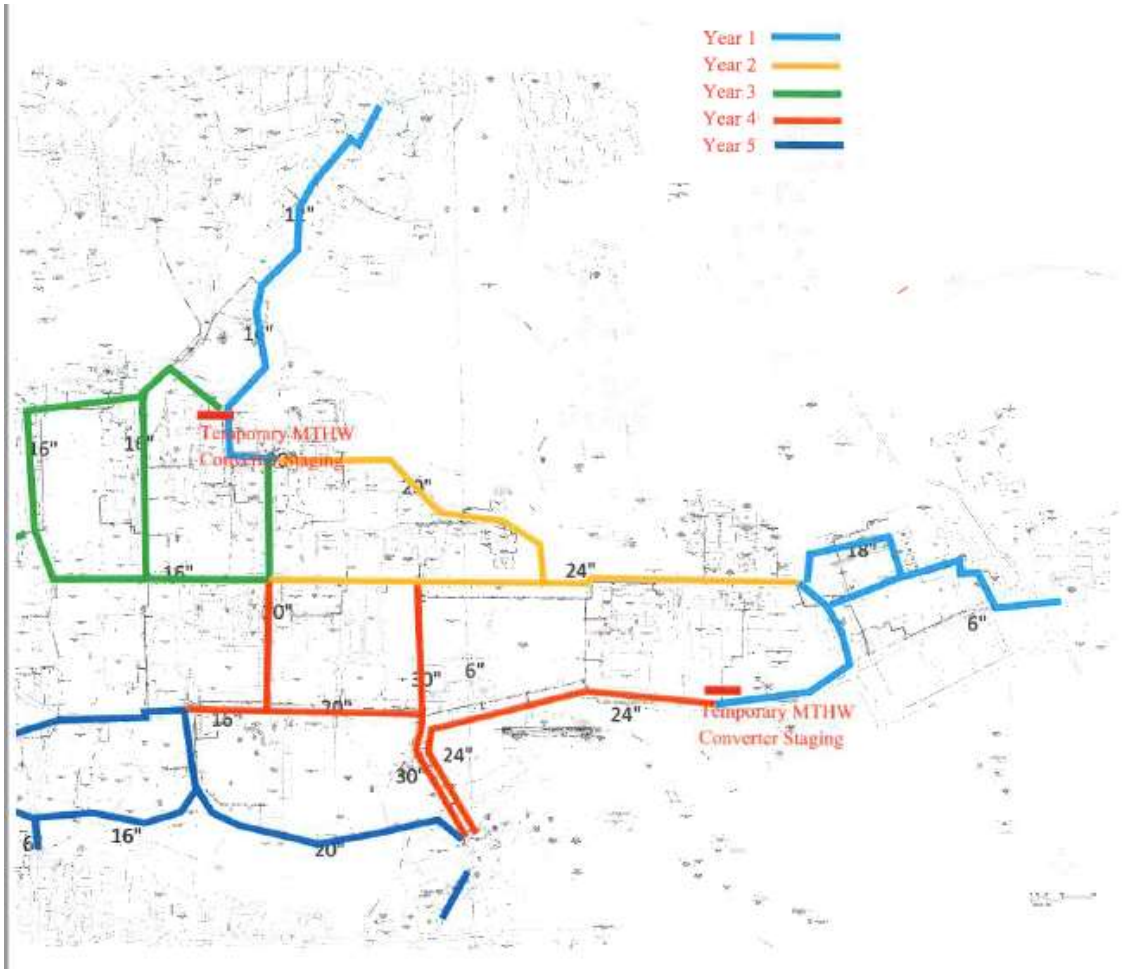
- Analyze CUBO data, calculate heat production capacity
- Seek grant from Department of Energy and raise matching funds as required
  - Create consortium with drilling and geothermal industry
- Continue academic/research collaboration
- Engineer a stimulation plan for developing the heat reservoir at depth with hydroshearing technology
- Design first well of demonstration well couplet

Steam to Hot Water Conversion: Essential Enabler



Campus Steam to Hot Water Conversion

- 17-year effort starting in 2018
- Start with new buildings and campus extremities first
- Steam system will still require maintenance
- Incorporate HW conversion into steam projects
  - Source to nodes
  - Nodes to point of use
  - Point of use building conversions

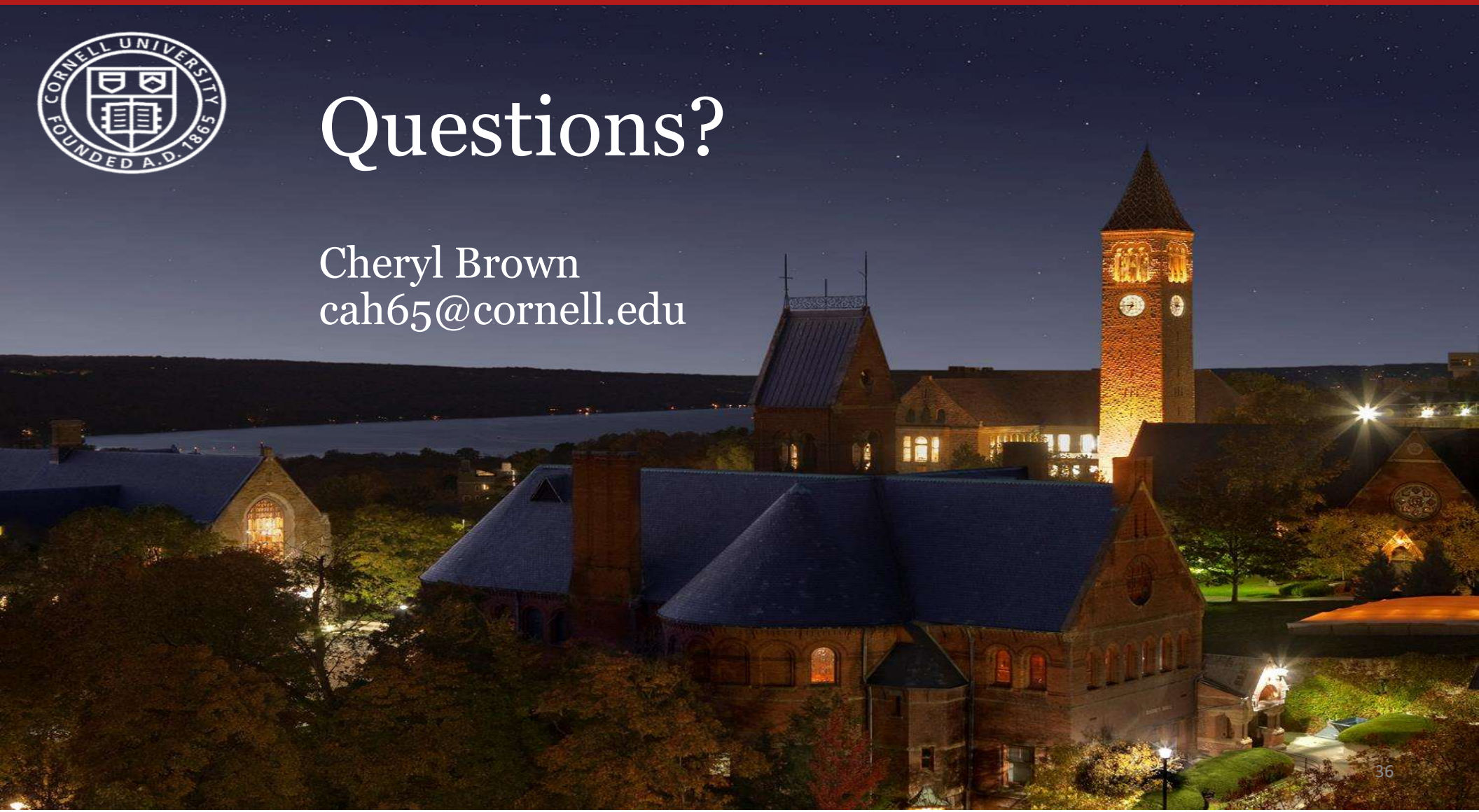


Low Temperature Hot Water

- All new buildings and major reconstructions require
  - Hot water system in building to be sized at 130 F
  - Hot water service to facilities should be sized at 170 deg F

Future Considerations

- Electricity
  - Backup / emergency power and heat
- Heat
  - Earth Source Heat – Looking to donors and outside money to help fund, such as grants, incentives, etc.
  - Distribution – Steam to Hot Water conversion timing and amount of construction needed and disturbance to campus will be significant (10x current normal for the next 12 years!)
- Continue Energy Conservation
  - Savings! Return on investment
- Campus-Based Carbon Sinks and Sequestration
  - Investments in living lab programs and Cornell lands (want to invest in our own land vs. purchasing external offsets)



Questions?

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