

CORNELL UNIVERSITY:
UTILITIES RELIABILITY AND ENERGY TRANSITION MASTER PLAN
EXECUTIVE SUMMARY

Jacobs

Project Scope and Key Findings

Cornell's Ithaca campus operates an efficient, adaptable district energy system that produces and distributes electricity, heating, and cooling through a campus-wide network. The reliability of these utility systems is essential to students, faculty and staff living and learning on campus as well as critical research that can be impacted by service interruptions. The Utilities Reliability and Energy Transition (UR&ET) master plan evaluates Cornell's current district energy system and proposes a transition strategy that complies with New York State's Climate Leadership and Community Protection Act (CLCPA) while preserving safe, reliable, and affordable utilities in support of Cornell's academic mission. The UR&ET master plan advances the goals of Cornell's Climate Action Plan and captures critical renewal and capacity needs.

A wide variety of solutions were methodically analyzed to identify an adaptable electrified campus heating solution. This solution, the "Recommended Scenario", uses geothermal energy and storage solutions combined with a full campus steam to hot water conversion and building efficiency improvements. It reduces long-term risk by avoiding over-reliance on any single technology or regulatory outcome, while preserving optionality through modular deployment and continued use of existing assets during the transition. It allows Cornell to decarbonize while controlling costs, preserving system reliability and retaining adaptability in the face of uncertain external conditions.

The following recommendations of the master planning process seek to set a long-term direction and execute on a logical starting portfolio of projects:

1. **Adopt the Recommended Scenario as the Utilities Reliability and Energy Transition Master Plan.** *A long-term vision, allowing the University to confidently make the best decisions today to work towards a future system.*
2. **Pursue a $93M 5-year capital program that addresses foundational projects and a key geothermal project.** *A strong, measured start that allows the University to tackle projects that remain viable and are compatible with any version of the future.*
3. **Revisit the master plan in 2028, check core assumptions, and reaffirm the direction.** *The master planning process maintains an up-to-date plan and is intentionally adaptable and responsive to changing conditions.*

Analysis Summary The study investigated multiple alternative cases, three of which were fully evaluated over a 40-year analysis period (2028-2067). The three scenarios include:

Recommended Scenario — uses Borehole Thermal Energy Storage (BTES) as the primary heating technology with conventional geoexchange and heat pumps balancing remaining thermal loads in both the heating and cooling systems. BTES is a serial array of tightly clustered shallow boreholes (500-900 ft depth) that are fitted with closed circulation

loops. Steam is fully replaced by hot water in both distribution piping and buildings. Energy conservation targets peak heating load reductions. Electricity is purchased from the New York State grid. Lake Source Cooling continues to provide the majority of campus cooling at unparalleled efficiency.

Baseline case — uses steam electrode boilers at the Central Energy Plant resulting in energy intensive electrified heat using electricity sourced from the New York State grid. Lowest capital option to achieve CLCPA compliance, but higher operating expenses.

Business as usual — continued operation of Cornell's existing Combined Heat and Power Plant with continued renewal. *This option is not compliant with New York State's CLCPA but provides a valuable financial comparison.*

Table 1: Recommended Scenario vs. Alternatives

Scenario		Recommended Scenario	Baseline	Business as Usual[1]
Description		Hot water distribution with shallow geothermal and demand reduction	Steam distribution with electrode boilers	Combined heat and power in perpetuity
40 Year Cumulative Cost (Nominal $)	Capital	$1,007 M	$894 M	$947 M
	O&M	$264 M	$383 M	$527 M
	Utility	$2,164 M	$3,014 M	$1,230 M
	Carbon Cost [3]	$87 M	$113 M	$461 M
	Total	**$3,522 M**	**$4,404 M**	**$3,165 M**
40 Year Net Present Cost (2025 $)	Capital Only	$603 M	$339 M	$328 M
	Total [2,3]	**$1,450 M**	**$1,411 M**	**$1,090 M**
Peak Campus Electrical Load (MW)		67	105	40
40 Year Cumulative GHG Emissions (MTCO2e) [4]		2,170,000	2,485,000	5,700,000

(1) Not compliant with CLCPA regulations
(2) Represents construction, operations and maintenance, utility and carbon-related costs 2028-2067, discounted to 2025 using rate of 4.50%. Does not include financing costs or grants and incentives.
(3) New York Cap & Invest carbon cost assumptions are informed by NYSERDA cost projections.
(4) GHG Emissions are cumulative over the 40-year analysis period (2028-2067) and assumes a 70% reduction in grid emissions by 2035 and zero-emissions electric grid by 2043. Includes both scope 1 emissions from onsite combustion and scope 2 emissions from grid power generation.

Key Points

- The Recommended Scenario relies on lowering campus energy consumption and using efficient geothermal heating solutions to lower costs and emissions.
- Business as Usual is not a zero-cost option and does not comply with CLCPA. During the analysis period both system renewal and expansion are necessary.

- The Recommended Scenario is the lowest operation and maintenance cost (O&M) because of system renewal and highly efficient operations.
- The baseline scenario has 25% higher cumulative costs due to highest electrical demand; although discounting of future costs results in lower Net Present Cost (NPC) than the Recommended Scenario.
- Current and future incentives and grants have not been included in any scenario. The Recommended Scenario is most likely to capture the greatest volume of project related state and federal funds.

Master Planning Drivers and Goals

The purpose of the master planning process was to conduct long-term planning of the Ithaca Campus utility system considering several internal and external drivers.

The first driver is Cornell's goal of carbon neutrality by 2035.

The second driver is Cornell's existing need for renewal and capacity to ensure safe, reliable and efficient utilities critical to the continual operation of the Ithaca Campus.

The third driver entails regulatory compliance. The current interpretation of New York State's Climate Leadership and Community Protection Act (CLCPA) is that in 2040, fossil fuels shall not be combusted to produce electricity, and in 2050, fossil fuels shall not be combusted to produce heat. The existing law may limit operation of the Combined Heat and Power Plant starting in 2040, a system that produces all electricity and 85% of the heat on campus. Additionally, peak heating in the winter, above what is sourced using waste heat from the combustion turbines, may not be allowed to be met by the existing boiler fleet starting in 2050.

The Master Planning process was framed and directed with some specific goals:

- Maintain utilities resilience through redundancy, reliability and recoverability.
- Reduce Cornell's onsite carbon emissions (scope 1) without increasing grid emissions (scope 2).
- Consider existing asset remaining life and renewal possibilities in sequencing projects.
- Consider only commercially available technology.
- Consider constructability and minimize campus disturbances.
- Advance towards Cornell's Climate Action Plan voluntary carbon neutrality goals.
- Meet regulations including the legal milestones promulgated in the CLCPA.
- Consider Cornell's 2008 Campus Master Plan and account for possible campus growth.
- Develop living lab opportunities through demonstrating scalable low-carbon solutions on campus, advancing climate literacy and research initiatives, and accelerating impact through collaborative partnerships locally and globally.

Selecting the Recommended Scenario

For the UR&ET Energy Master Plan, a set of thirteen scenarios were developed that identified commercially available technologies and tailored them to meet campus thermal demands, the needs of existing infrastructure and operations, local resource constraints, campus growth projections and Cornell decarbonization goals.

All scenarios were quantitatively evaluated using the Cornell Quadruple Bottom Line (QBL) framework to consider impacts across the full spectrum of:

- Planet — *Does the solution support a sustainable planet?*
- Purpose — *Does the solution help Cornell fulfill its academic mission?*
- People — *Does the solution meet the needs of people on campus, in the community and in the world?*
- Prosperity — *Will the solution enhance overall prosperity for the campus and our region?*

Evaluated over a 40-year timeline (2028-2067), the scenario which had the highest overall rating using Cornell's quadruple bottom line (QBL) approach was selected as the Recommended Scenario. Ranking was conducted by a diverse committee of staff and faculty who had a comprehensive understanding of the multi-disciplinary implications of each scenario and the long-term impacts.

Recommendations

The UR&ET Master Plan Study recommends immediately undertaking projects and living lab opportunities that are compatible with any version of the future. Cornell's decarbonization path is heavily influenced by external factors such as the rate that new clean energy sources are added to the New York electric grid relative to load growth, state and federal regulations and available technologies. Due to the risk and uncertainties identified, the initial recommendations are incremental in nature, maximize synergies with Cornell's academic mission, and build the foundation for the full transition to electrified heat and New York grid-supplied electricity. The initial projects reduce campus emissions.

Recommendation 1: Adopt the Recommended Scenario as the Utilities Reliability and Energy Transition Master Plan

Adopting the Recommended Scenario allows Cornell to set direction and create a shared vision of the future for the mission-critical utilities system.

Recommendation 2: Foundational Projects ($71M from 2028-2032)

The Foundational Projects represent the equipment renewal, energy conservation and expansion activities required to ensure reliable heating and cooling for campus. These projects are required in all of the scenarios. Prioritizing these projects allows the

University to make meaningful progress on the Master Plan while navigating uncertainty and preserving flexibility.

- Expansion and Renewal of Chilled Water ($22M)
  Install a heat pump at an expanded Chilled Water Plant 2 (renamed the "East Cornell Utility Building") to meet campus chilled water load growth while enhancing reliability for critical east campus cooling loads serving the College of Veterinary Medicine. This heat pump will also produce hot water for campus both during and after the transition to electrified heat.

  The existing chillers in Cornell's Chilled Water Plant 3 will be renewed to extend their life for another 15 years until new geothermal assets are in service.

- Distribution System Steam-to-Hot Water Conversion ($19M)
  Convert end-of-life steam distribution lines dating back to 1910 on North and Central Campus'. Complete the conversion on East Campus within the Center for Veterinary Medicine complex.

- Enhanced Energy Conservation and Building Hot Water Conversion ($34M)
  Energy conservation reduces both annual energy consumption and peak energy demand on the coldest and hottest days of the year. These projects immediately reduce operating costs and the required capacity of new electrified heating systems.

  In concert with distribution system steam to hot water conversions, buildings must be upgraded to receive hot water and to operate at lower temperatures. Where possible, these efforts will be combined with energy conservation to minimize the disruption to building occupants.

Recommendation 3: Pilot Borehole Thermal Energy System ($22M in 2029)
Borehole Thermal Energy Storage (BTES) is the primary heating technology in the master plan Recommended Scenario. This is leading edge technology and is an ideal solution for a heating-dominated system like Cornell's. A BTES system will be constructed on East Campus, the first of five BTES' laid out in the master plan. This project is important to complete in the first capital program for the following reasons:

- Cornell's existing system efficiency is improved immediately. The system will capture unutilized waste heat during the summer months, store it in the well-field, and put it to use in the winter to heat buildings on East Campus.
- Enables critical learning in design, construction and operations.
- Enables improved cost estimates and ramp-up of drilling contractors.
- Powerful living lab opportunities and technology demonstration for New York.
- Eligible for state and federal grants and tax incentives.

Recommendation 4: Revisit the Master Plan (2028)

The Master Plan will be reviewed in 2028 to ensure the critical inputs and assumptions are still valid. This process is intended to repeat at some regular frequency over the next 10 years. Uncertainty in NYS grid emissions reductions, regulations, and technology require revisiting the master plan regularly to ensure the direction is still congruent with state and University goals. Jacobs' Virtual Infrastructure (VI) software tool simulates the Cornell district energy system, enabling adjustments to the Recommended Scenario and measuring progress towards goals.

Master Plan Long Term Vision

The Recommended Scenario fundamentally reshapes campus energy infrastructure:

- Electricity is purchased from the New York State grid and no longer produced on-site.
- Steam piping is replaced across campus with hot water: a safer, simpler and more efficient distribution medium.
- Campus peak electrical loads increase by nearly 100% on a peak day. Electrical infrastructure expansion is required.
- In the context of the New York State grid, Cornell is currently invisible on a peak day. When electricity is at its most expensive and produces the highest emissions, Cornell imports zero electricity and can handle the entire load without becoming a burden to the grid. This will fundamentally change, with Cornell presenting a 67MW load to the grid at peak.
- Construction of three (3) Cornell Utility Buildings (CUBs) across campus to house production assets, such as heat pumps, to produce hot water and chilled water.
- Installation of ~1,800 boreholes that, when coupled to heat pumps, will provide efficient heating. Solar thermal collection panels will be installed on top of BTES well-fields allowing for thermal recharge during the summer.
- Continued use and renewal of Lake Source Cooling as the primary and most efficient cooling asset.
- Retention of existing Cornell Combined Heat and Power Plant (CCHPP) as emergency backup (as allowed under the CLCPA) with the option for natural gas, renewable natural gas, diesel or biodiesel fuel firing depending on fuel availability.

A transformation of this scale requires a significant capital outlay, exceeding $1Billion ($1,007Million), over the next 24 years. The full suite of projects required to complete the program can be grouped into three general categories:

1) **CONSUMPTION ($169M)** Conversion required to heat building with 150 to 160 deg F hot water and enhanced energy conservation which results in deep thermal demand reductions and builds on the great success of the existing energy conservation program. Energy conservation projects have been evaluated on both simple payback (capital cost versus operational savings) and future capital avoidance.

2) **DISTRIBUTION ($216M)** Conversion from steam distribution and heating to hot water is needed to enable geothermal system efficiency and allows for the best flexibility for future heating technologies. As the system is transitioned, it immediately results in a safer system with improved efficiency.

3) **PRODUCTION ($612M)** Three primary technologies will be employed to allow fossil fuel free district heating and cooling.
    a. Simultaneous heating and cooling heat pumps allow Cornell to leverage the campus' need for both cooling and heating throughout the year. Instead of the heat being captured or rejected from the different heating and cooling loops, the heat pumps serve as a mechanism to transfer the energy between the two loops maximizing the value of every unit of energy.

    b. Borehole Thermal Energy Storage (BTES) is an efficient geothermal heating technology that increases the operating coefficient of performance (COP) for district heating, maximizes operation of Lake Source Cooling, and reduces land use requirements relative to conventional geo-exchange. BTES is a serial array of tightly clustered shallow boreholes (500-900 ft depth) that are fitted with closed circulation loops and charged with nearby waste heat or renewable solar thermal energy during the cooling season and dispatched during the heating season. Storage temperatures can vary between 90-180F throughout the year and are supplemented with heat pumps to provide district heating. BTES can be installed in discrete modules (150 - 200 boreholes per module) and developed in multiple phases.

    c. Conventional geo-exchange is a complementary technology that uses the stable, moderate temperature of the earth as a heat source in the winter and a heat sink in the summer to move heat between the ground and the district energy system. The operating temperatures vary between 40-70F throughout the year and are supplemented with heat pumps to provide district heating and cooling.

Implementation Strategy

The UR&ET Energy Master Plan is a phased transition to an electrified hot water-based district energy system anchored by three distributed utility production hubs (North, East, South). However, the scenario is intentionally programmatic and adaptive rather than a lump-funded, fixed buildout. To maximize near-term emissions reductions and efficiency gains while preserving flexibility, the execution plan includes the following:

- Phased deployment aligned with asset renewal cycles
- Early prioritization of foundational projects to mitigate regulatory uncertainty and boost efficiency
- Decision gates along the implementation timeline to allow for changing conditions (e.g. updated costs, new technologies, electricity emissions progress, regulations).

- Modular design and execution that can scale or pause. All assets can be placed in service as they are built.

This approach reduces long-term risk by avoiding over-reliance on any single technology or regulatory outcome, while preserving optionality through modular deployment and continued use of existing assets during the transition.