Geothermal Technologies Office 2017 Peer Review

Deep Direct-Use Technical and Economic Working Group Kick-Off Meeting

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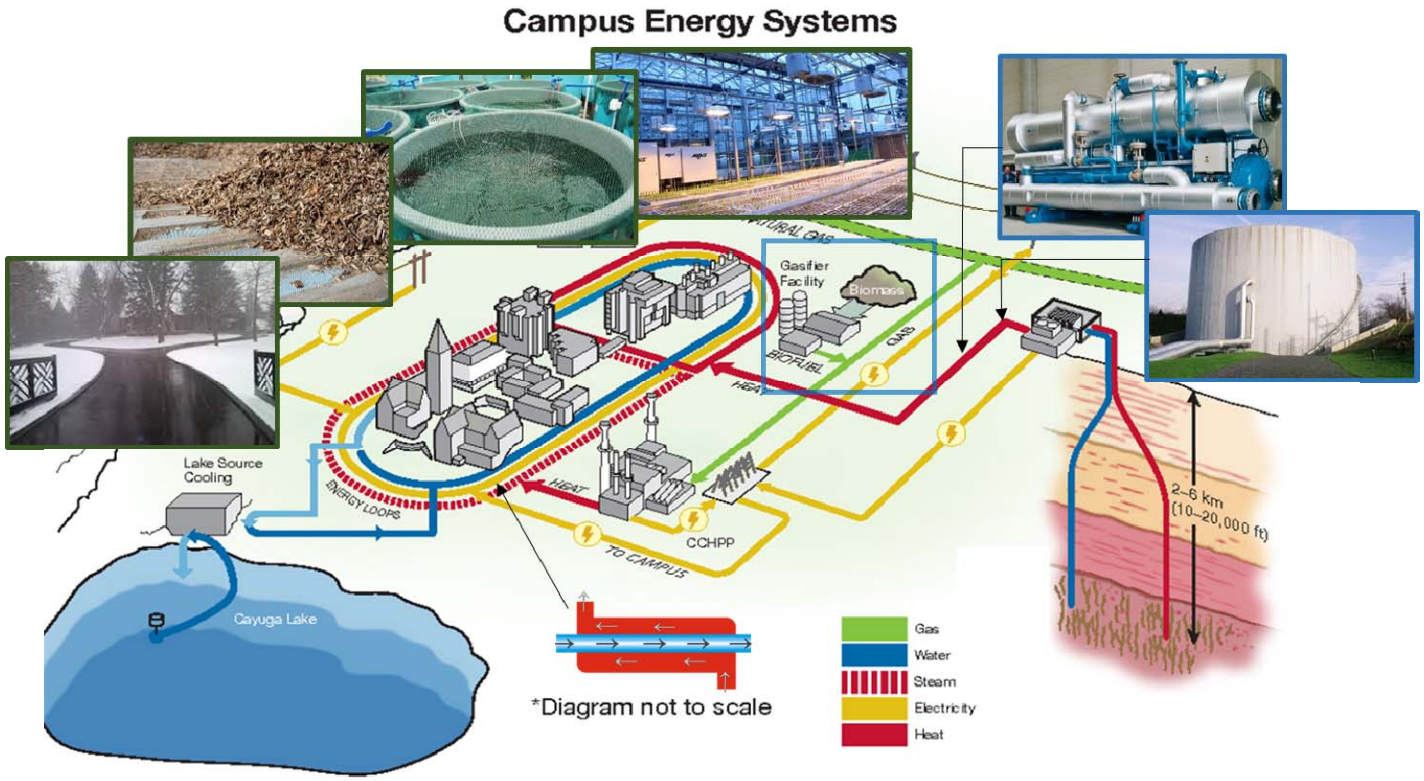

Earth Source Heat: Cascaded Systems Approach to DDU on the Cornell Campus

Project Officer: Arlene Anderson

Total Project Funding: $ 720,000

November 13, 2017

Principal Investigators: Jefferson Tester & Teresa Jordan

Project Technical Staff/Presenters: Steve Beyers & Ole Gustafson

Cornell University

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This presentation does not contain any proprietary confidential, or otherwise restricted information.

Relevance/Objectives (1 of 3)

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Project objectives:

- Determine the feasibility of DDU to improve district heating and cooling on the Cornell campus
- Document DDU cascading system efficiencies
- Model geothermal diversification of campus energy supply

This work is divided into three Tasks:

- **Task 1: Create and Document Framework to Evaluate Project Potential**
- **Task 2: Document Overall Site Resources & Heat Use Analysis**
- **Task 3: Analyze and Document LCOH for the Project**

Relevance/Objectives (2 of 3)

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Advancing the Science:

- Combine the analysis of available subsurface information with detailed energy use profiles → real-life site-specific annual heat use projections
- Estimate Levelized Costs of Heat (LCOH) for each DDU scenario selected
- Utilize an integrated systems approach to improve DDU value using cascading uses, “booster” heat pumps, and heat storage as inputs
- Generate framework for evaluating other potential DDU sites to help fill a gap in energy planning in the Eastern U.S.

Relevance/Objectives (3 of 3)

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Addressing challenges, barriers, and knowledge gaps:

- **Value of heating (vs. electricity) has not been adequately recognized:** Heat is major energy need for much of USA.
  - **Address potential for utilizing lower temperature geothermal heat** by evaluating several specific applications.
- **Depth of adequate resource is a cost barrier:** Recently deep drilling techniques have evolved to a level of economy and reliability suitable for new geothermal applications.
  - However, these techniques have also lowered the cost of natural gas, presenting a **challenge to the cost-competitiveness** of geothermal.

The Cornell project couples deep geothermal resources, an area of **promising thermal benefit,** with a site with **high heating demand representative of the region**

cascading uses → re-uses heat, "multiplying" its value

low-temperature design standards → limits drilling depths, reducing risks

Methods/Approach (1 of 2)

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Cornell's scientific/technical approach:

1) Thermal resource and site suitability
   - ✓ Results of past studies (including DOE-funded work)
   - ✓ Simple models of productivity from two reservoirs
   - ✓ Available borehole data and analog geology (Adirondacks)

2) Energy end use potential
   - ✓ Existing energy use data and profiles of campus energy use (hourly building-by-building data exists)
   - ✓ Consider cascading uses organized by temperature needs
   - ✓ Modeling analysis based on manufacturer's data (modular booster heat pump applications) and approved modeling tools
   - ✓ Incorporate thermal storage in modeling analysis

Methods/Approach (2 of 2)

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Scientific/technical approach: Cornell will use following approaches to resolve the listed technical need:

3) Technology

- ✓ Assume current drilling and casing technology
- ✓ Lower-temperature building design
- ✓ Flexible integration of modular heat pumps and storage systems

4) Methods for estimating project costs and benefits

- ✓ Extend past LCOE work (including DOE-funded work); all primary assumptions to be vetted with reviewers
- ✓ Update to current drilling and completion costs
- ✓ Use regional economic assessment methods to develop potential State government support based on economic return expectations
- ✓ Estimate benefits that extend beyond the region

Technical Objectives & Milestones (1/3)

- **Year 1, Task 1: Create and Document Framework to Evaluate Project Potential**
  - Subtask 1.1: Document Data Sources and Analytical Tools
  - Subtask 1.2: Establish Metrics and Success Criteria
  - Subtask 1.3: Document Heat Requirements of Site
  - Subtask 1.4: Develop Reservoir Models, Document Parameters
  - Subtask 1.5: Define Parameters of Surface Use Technology
  - Subtask 1.6: Present Assumptions and Criteria for Validation
  - Subtask 1.7: Document Approvals Strategy
- **Deliverable: Documentation of all of the above in a consolidated interim report**

Technical Objectives & Milestones (2/3)

- **Year 1, Task 2: Document Overall Site Resources & Heat Use Analysis.**
  - Subtask 2.1: Develop Analytical Tool Interfaces
  - Subtask 2.2: Analyze Potential DDU Resources
  - Subtask 2.3: Analyze Heat Requirements
  - Subtask 2.4: Document the Specific Analytical Processes (Models) to be Used to Evaluate Options
  - Subtask 2.5: Recommend Two Specific DDU Applications for Analysis
- **Deliverable: Documentation of all of Tasks 1 and 2 in a consolidated interim report**

Technical Objectives & Milestones (3/3)

- **Year 2, Task 3: Analyze and Document LCOH for the Project**
  - Subtask 3.1: Improve Analysis of Reservoir Productivity
  - Subtask 3.2: Refine Techno-Economic Model
  - Subtask 3.3: Analyze Alternatives Based on Refined Model
  - Subtask 3.4: Prepare and present Progress Report at 2018 annual GRC Conference.
- **Deliverable: Final Report and Presentation (PowerPoint).** Final Report will include documentation of all of the above and documentation of Tasks 1 and 2 as appendices

Future Activities

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- Cornell's project was initiated on October 2, 2017 and will include the following Milestones and Deliverables

Milestone/Deliverable	Expected Completion Date
Define Data Sources and Analytical Tools	Dec 2017
Establish Metrics and Success Criteria	Dec 2017
Document Heat Requirements of Site	Mar 2018
Develop Reservoir Models, Document Parameters	Mar 2018
Define Parameters of Surface Use Technology	Mar 2018
Document Approvals Strategy	Mar 2018
Project Framework Consolidated Report	Mar 2018
Characterize DDU Resources and Cascading Uses	Sep 2018
Recommend Two Specific Application Scenarios	Sep 2018
Interim Report of Recommendations	Sep 2018
Refine Models, Document LCOH, Final Report	Sep 2019

Proposed Metrics

Quantifiable metrics for techno-economic assessment of the project:

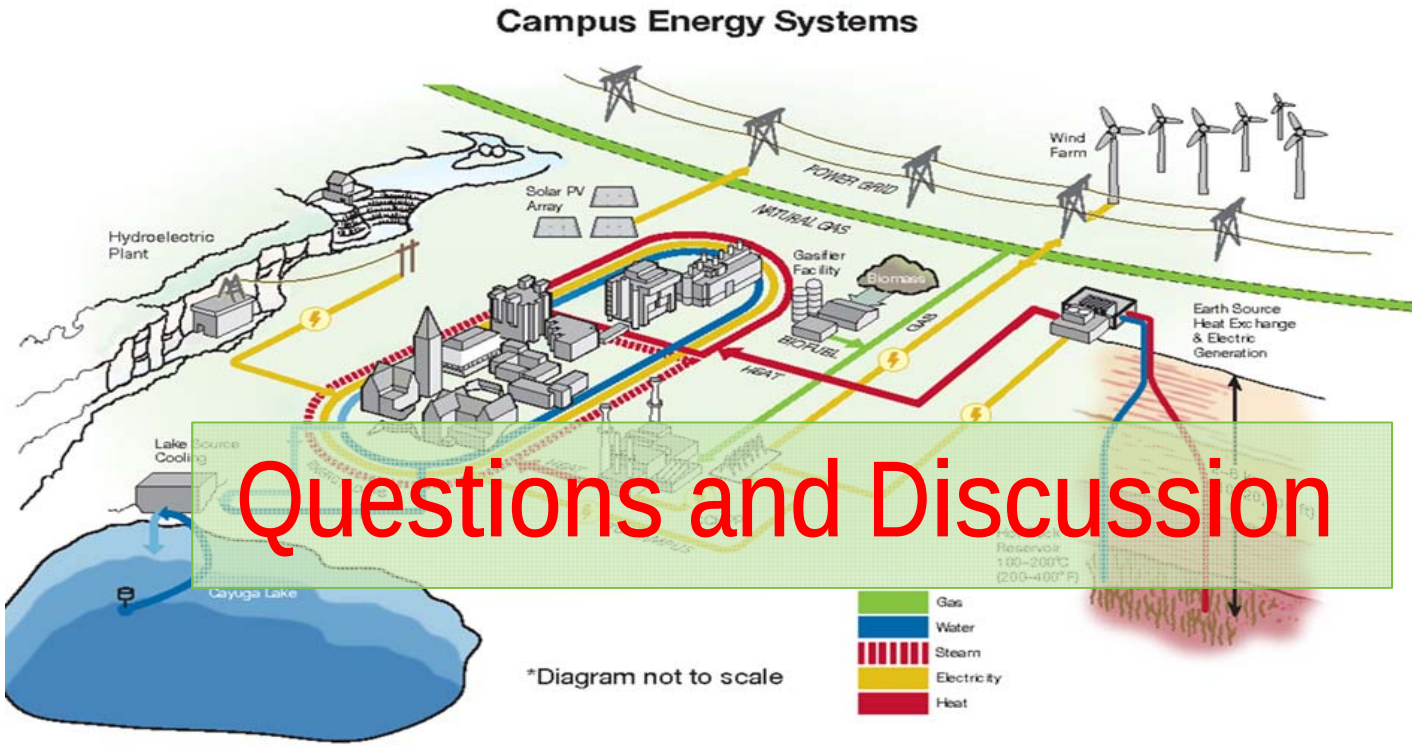
1) Thermal resource and site suitability: best available estimates of resource temperature(s) and potential geothermal flow rates (combined to create **available energy rates**) with estimated error bars
2) Drilling and completion **costs** with uncertainties
3) Energy end use potential: **energy use rates** for selected portions of existing (from energy metering) and proposed (from modeling) campus facilities
4) Technology: **Published values** for temperature-dependent Coefficients of Performance (COP) for modular booster heat pumps; high-insulated storage tank efficiencies
5) Methods for estimating **project costs and benefits**: LCOH based on approved metrics, incorporating economic and social benefits.

Collaboration Opportunities

- Project allows for **broad-based review** of assumptions, data sets, modeling tools, and decisions algorithms prior to implementation, with broad documentation, fostering common language and shared understanding of eventual results.
- Data and **results will be shared openly**
- Data Management Plan emphasizes **extensive use of the shared DOE data portal** to ensure access for third-party review and evaluation along the way
- Cornell's commitment to teaching, research, and outreach encourages **broad technology transfer**

Summary

- Cornell's study will estimate potential resources for two distinct DDU reservoirs
- We will identify uses that provide maximum economic value for a range of potential resources
- Flexible heat use options, including cascading uses and integrated storage and boosting (heat pump) systems, aim to optimize value of DDU resource for our "real world" demonstration site
- Methodology can be extended to other sites
- Consider both owner-specific and regional economic and environmental benefits to suggest appropriate financial approaches



Questions and Discussion

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