The Science of TENs

HEET's LeGUp Research Consortium

Moderator: Mark Kleinginna / *Emergent Urban Concepts*

Panel: Isabel Varela / *HEET*

Eric Juma / *HEET*

Rebecca Brenneis / *HEET*

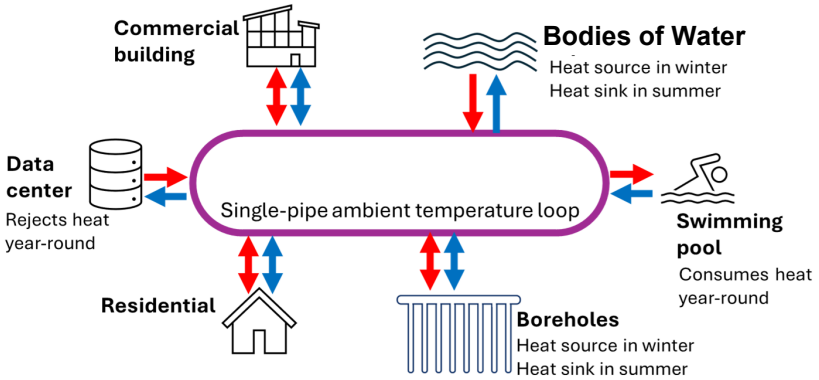
Learning from Geothermal Energy Networks (GENs)

Presented by Isabel Varela | Science Director at HEET | April 23, 2025

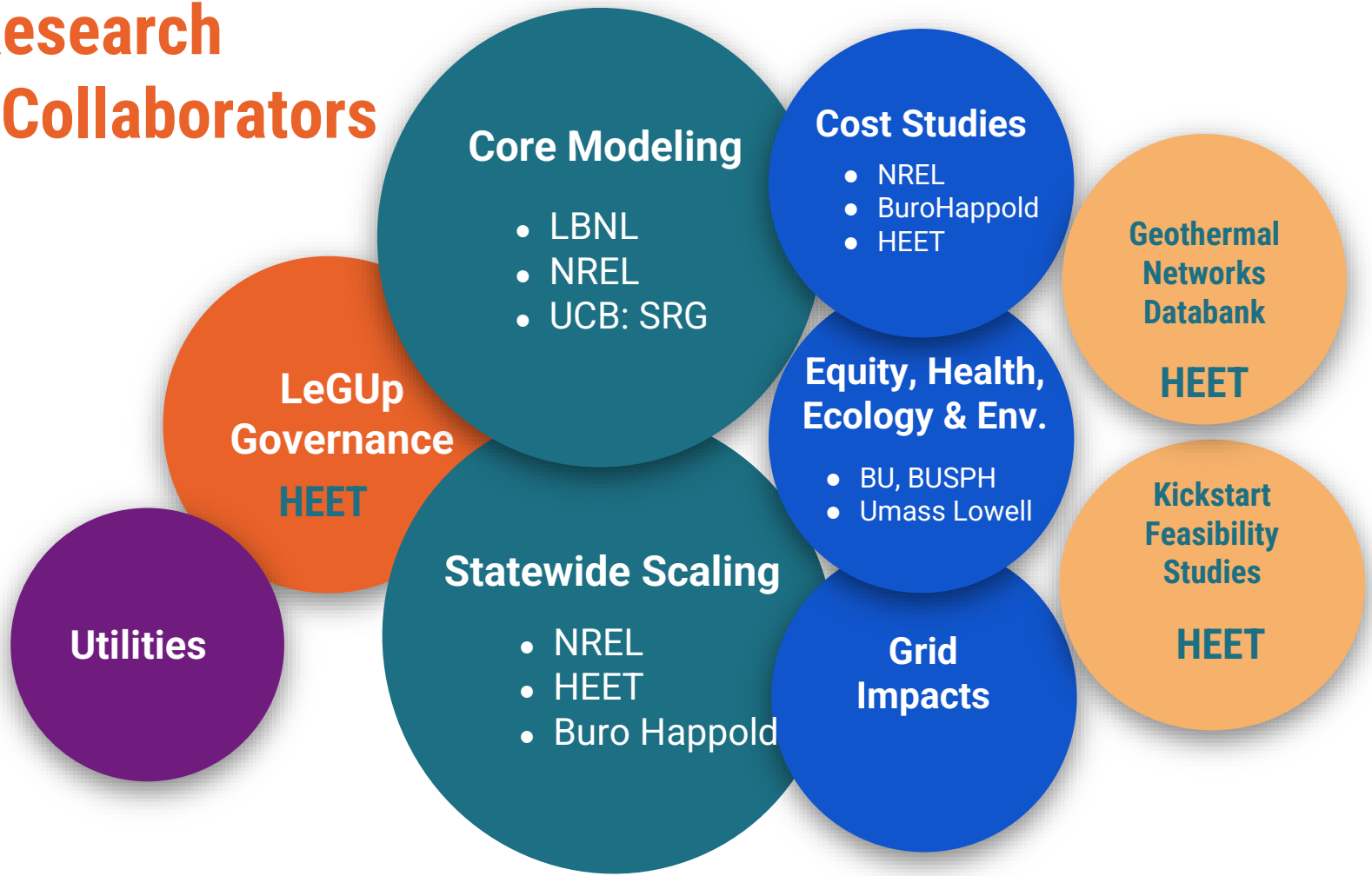
LeGUp - A Geothermal Energy Network (GEN) Research Consortium

Goals

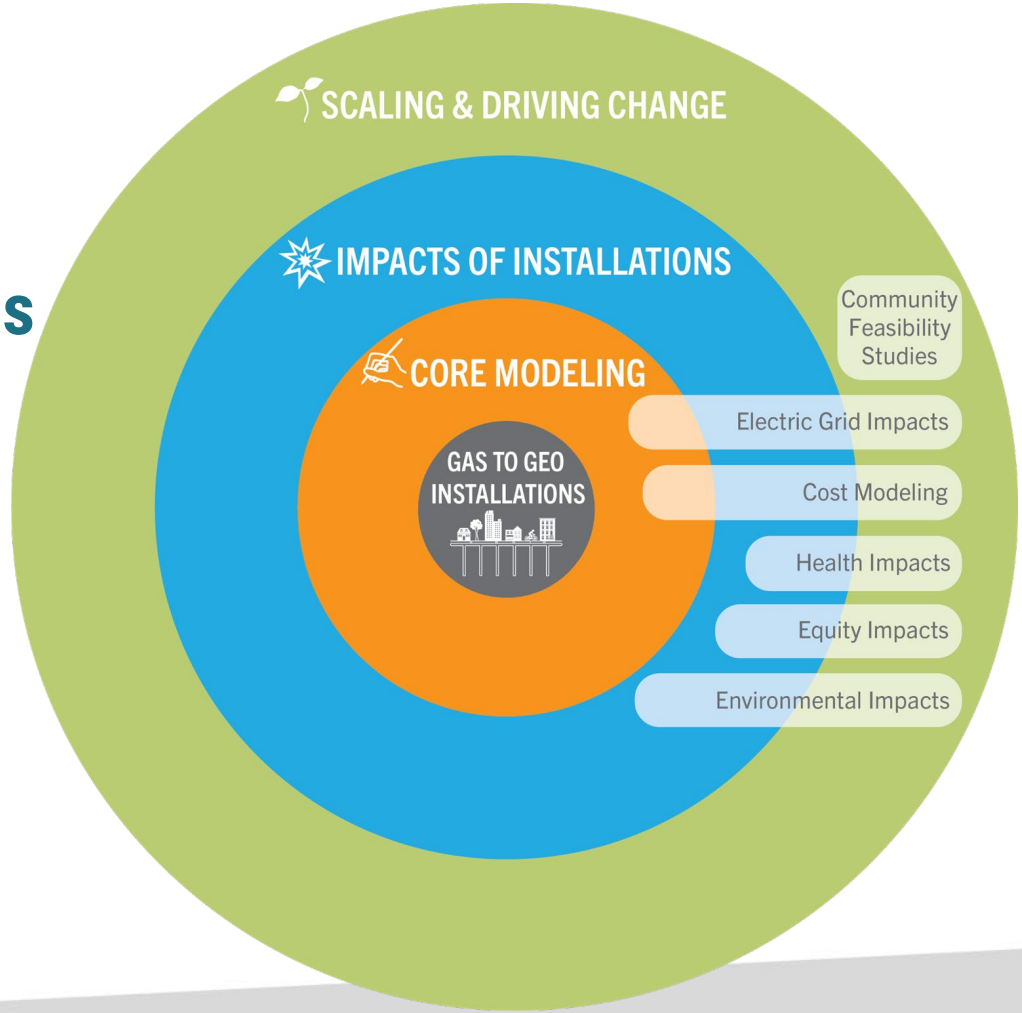
- Evaluate the potential of networked geothermal to deliver heating and cooling in Massachusetts
- Engage with and share findings with stakeholders (e.g., Department of Public Utilities, gas utilities, communities)
- Increase understanding and optimization of GENs



LeGUp Research Areas & Collaborators



LeGUp Project Connections



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LeGUp Data - Installations in MA

Motivation: MA Decarb Roadmap mandates net-zero emissions by 2050, 32% of emissions from building sector (MA)

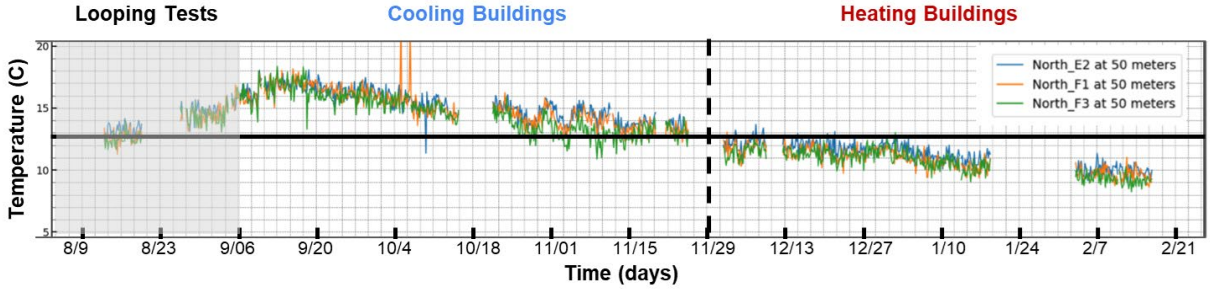
1. **Framingham** Eversource Gas
2. **Franklin Field** National Grid
3. **Framingham extension** Eversource Gas

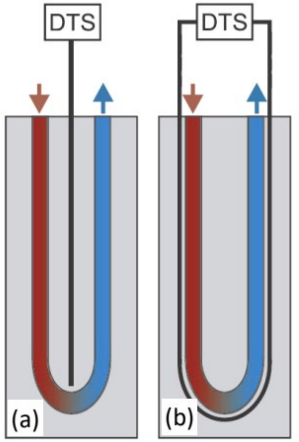
GAS TO GEO INSTALLATIONS

nationalgrid EVERSOURCE heet

Smart Ground - Monitoring Temperature In Boreholes

- Real-time monitoring of temperature along 14 boreholes at Framingham
- Monitor subsurface temperature drift & study thermal storage

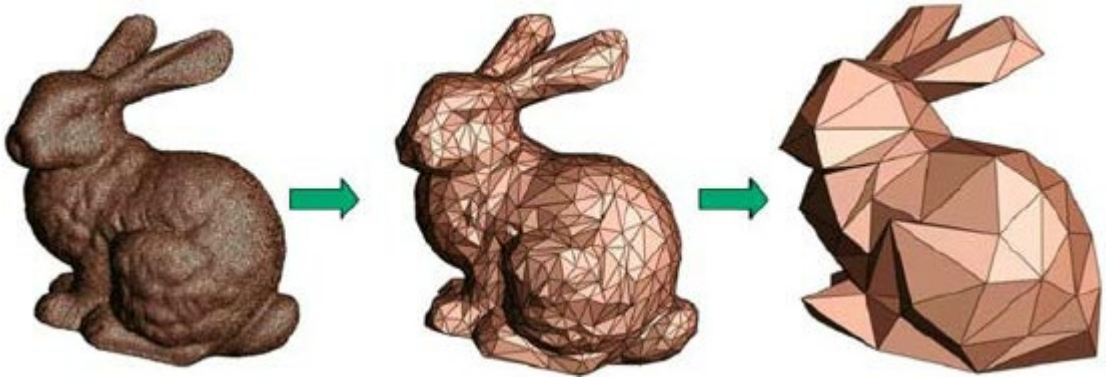




Fiber Optic Cable Configurations

LeGUp Develops GENs Modeling Tools

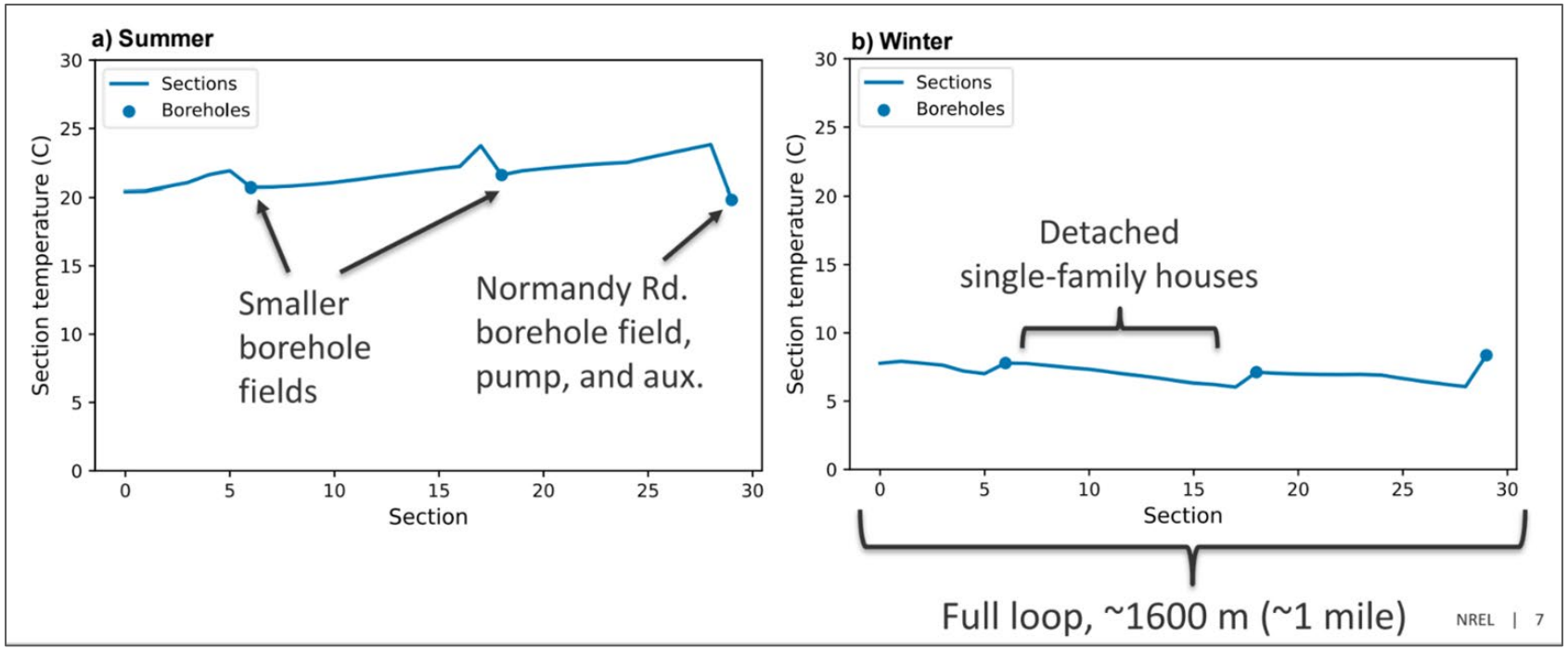
Develop **Full Physics** and **Reduced Order** models using data from the first few installations:



CORE MODELING

CORE MODELING

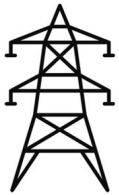
LeGUp Develops GENs Modeling Tools (NREL)



LeGUp Models and Monitors Impacts of GENs

Develop data-driven models and test predictions:

Emissions



Grid

Costs

Ecology

Health

Equity

IMPACT OF INSTALLATIONS

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Impact of GENs on Ecology

- 161 trees health assessment of crown and canopy, [0 dead, 5 excellent]
- Difference between 2023 and 2024 not significant (4.23 vs 4.29)
- After installation of GEN no negative nor positive impact on the overall health of the trees

Summer 2023 — **Construction of GEN started in Framingham**

Summer 2024 — **Construction of GEN completed in Framingham**

Summer 2025 — GEN partially operational for 1-year

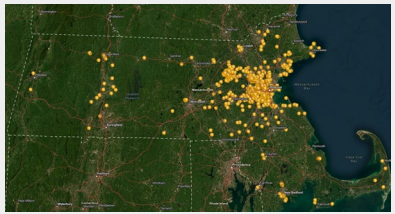
Summer 2026 — GEN fully operational for 2-years

BOSTON UNIVERSITY heet

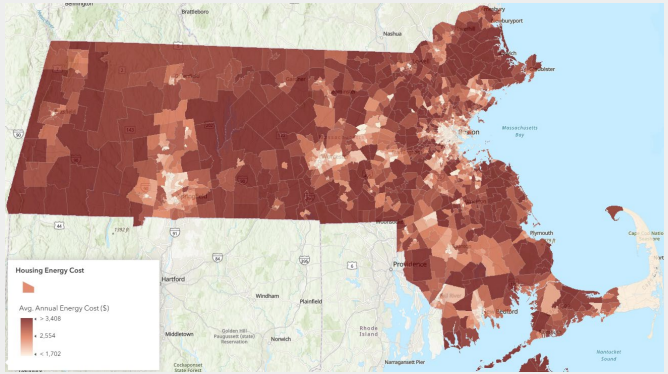
LeGUp Energy Systems Dashboard

- Population Data
- EJ Populations
- Household Income
- Energy Cost
- Justice40
- Natural Gas Infrastructure
- Utility Providers
- Housing Characteristics
- Gas Leaks
- Gas System Enhancement Program (GSEP)
- Parcel Information
- Asthma Health Data
- Non-Residential Buildings
- Interested in Geothermal Service

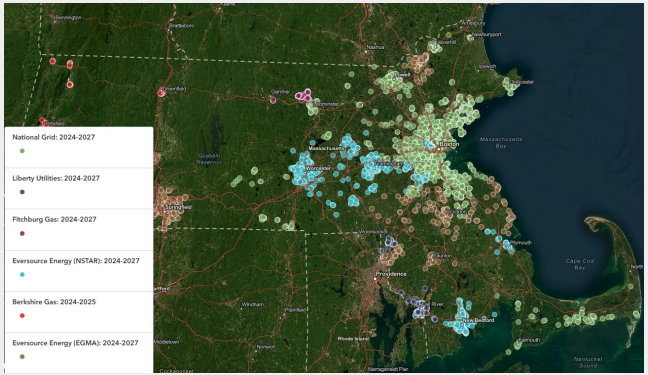
Interested in Geothermal Service



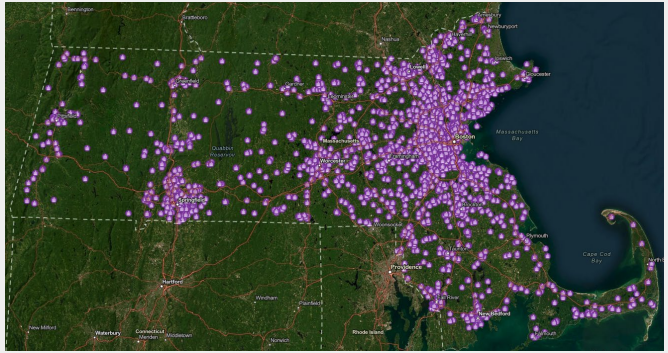
Energy Cost



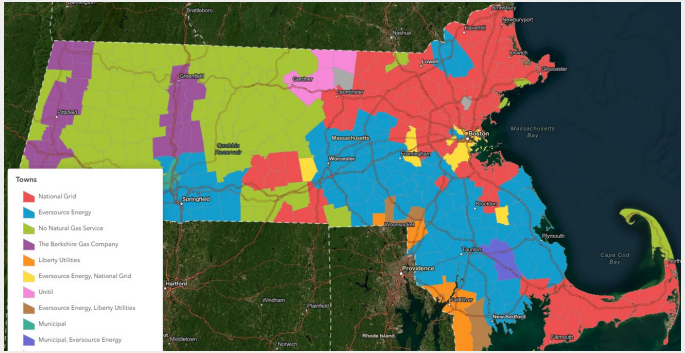
GSEP



Non-residential Buildings: Schools



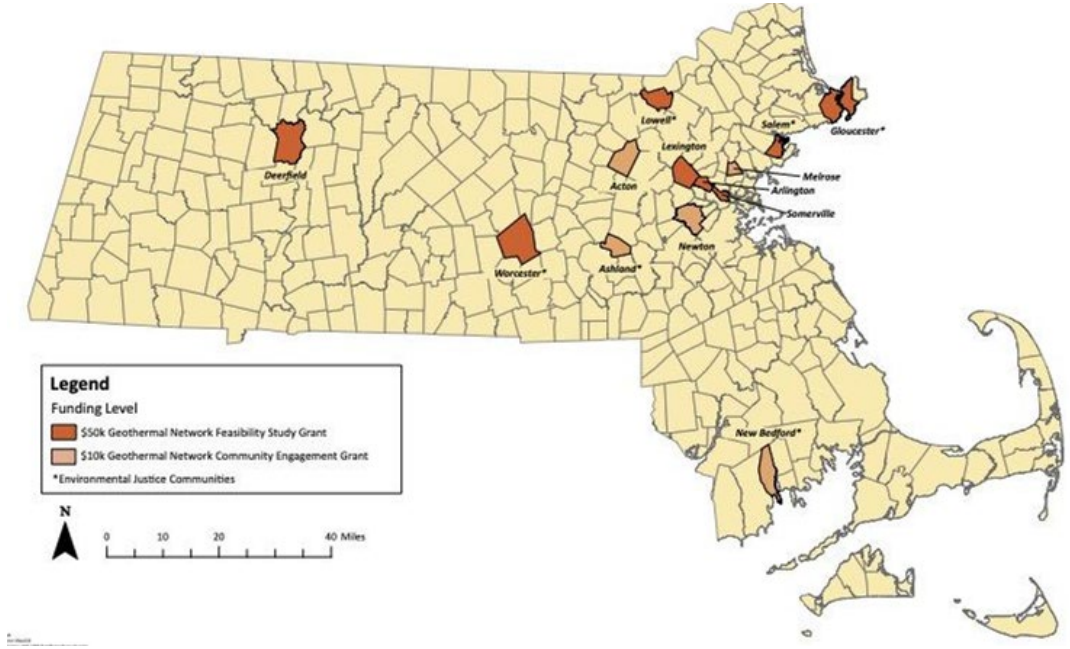
Utility Provider: Gas Service by Town



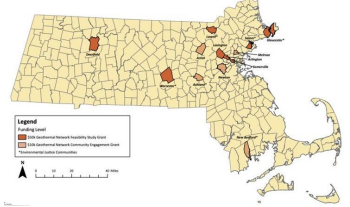
GEN Feasibility Projects in MA

8 communities received $50,000 for GENs **feasibility studies**

4 communities received $10,000 for GENs **community engagement**



MA GEN Feasibility Learnings



Policy & regulatory hurdles challenge non-geothermal experts

Community trust is foundational – early engagement with municipal leaders and residents significantly impacted project momentum.

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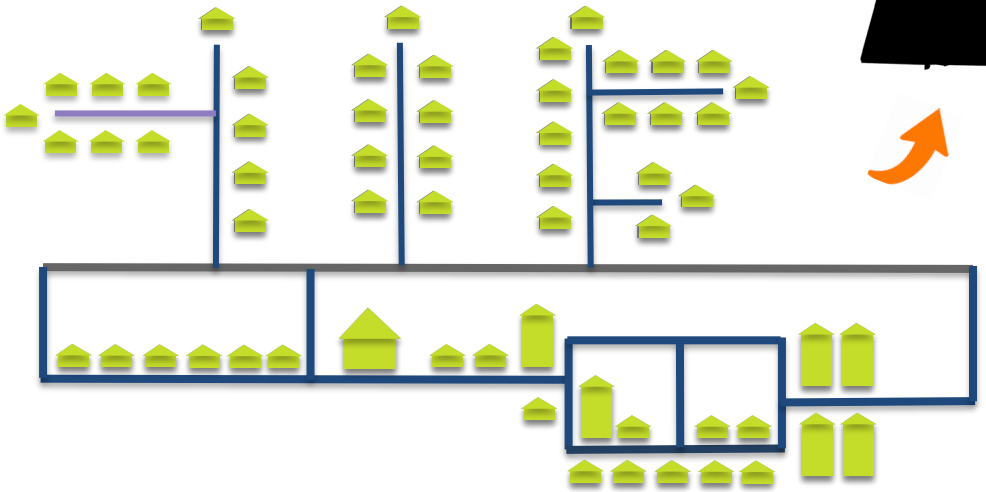
LeGUp Develops Regional Scaling Projections

- Develop scaling projections from the Core Models
- Measure and maximize impact



SCALING AND DRIVING CHANGE

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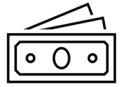
LeGUp Creates a Databank for GENs

Enable quantitative comparison

Contribute to prediction models

Inform planning & optimization of future systems



Record costs related to heating and cooling

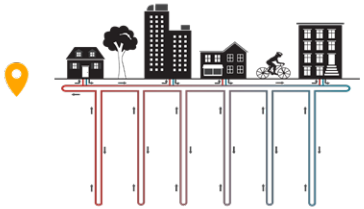
Identify costs and energy use by stages

Catalyze & derisk the adoption of these networks

Demonstrate impacts on emissions, environment and human health

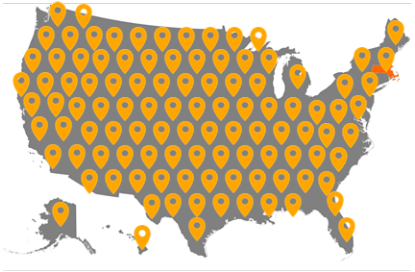
Support development of data-driven legislation & regulation

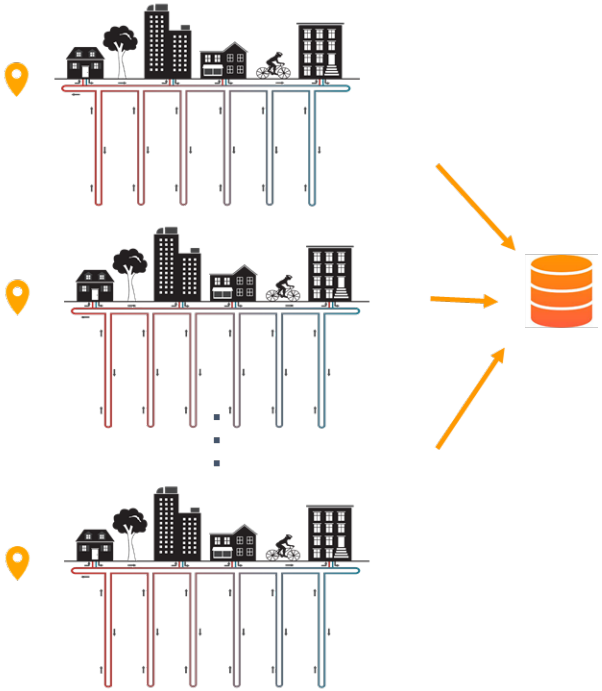
LeGUp Creates a Databank for GENs



- What? A **public data bank** of geothermal network installations
- Why? to **inform and facilitate** future developments, enabling societal-scale building decarbonization
- How? Interface with HEET website. Database saved in perpetuity in **Harvard Dataverse** . Open access.

LeGUp Creates a Databank for GENs





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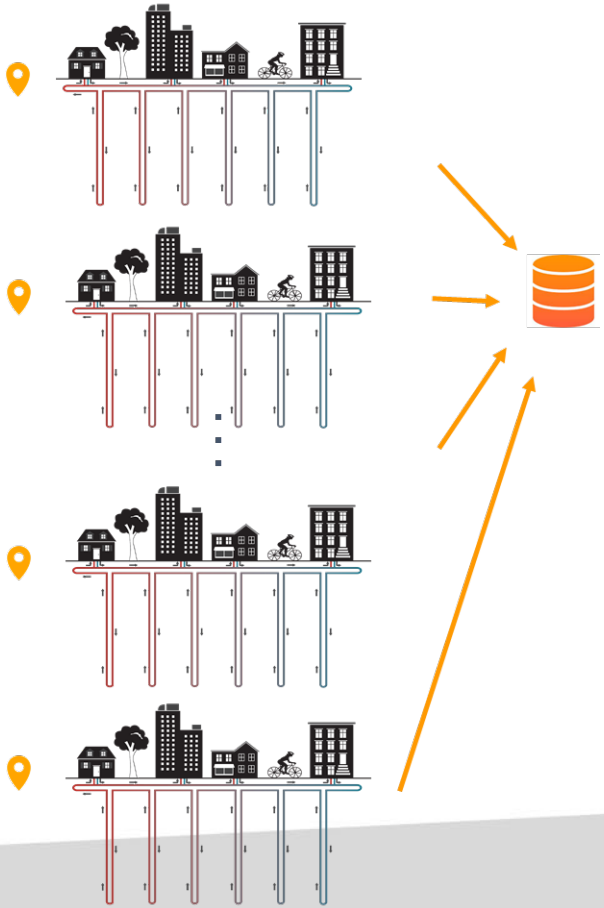

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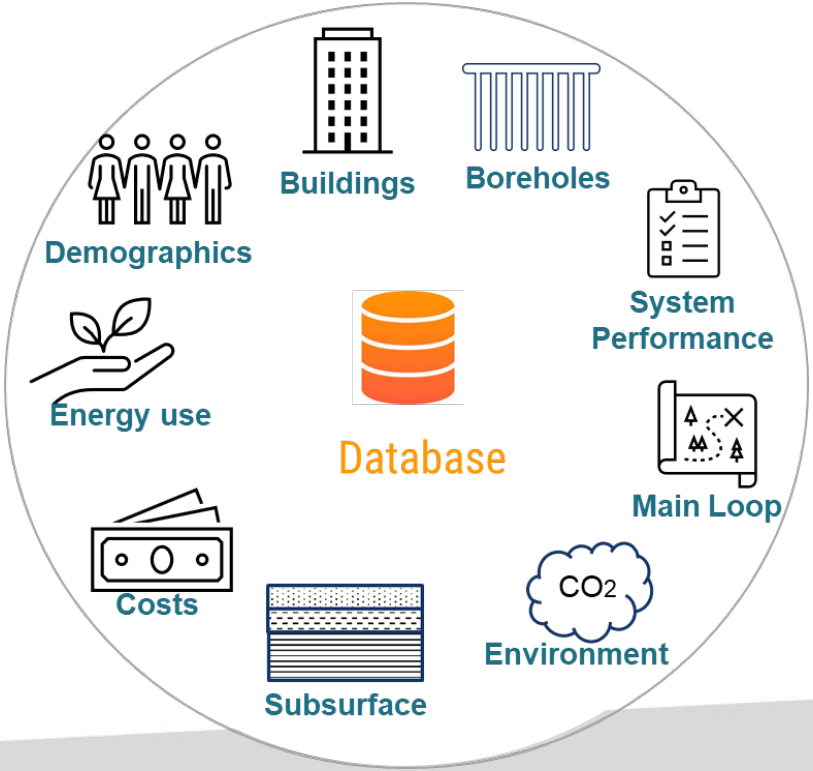
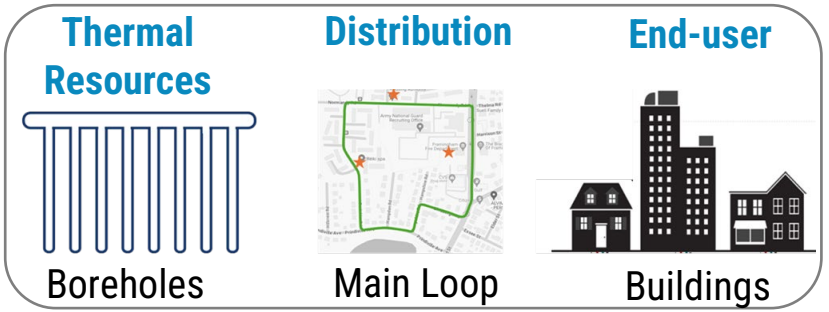
LeGUp Creates a Databank for GENs

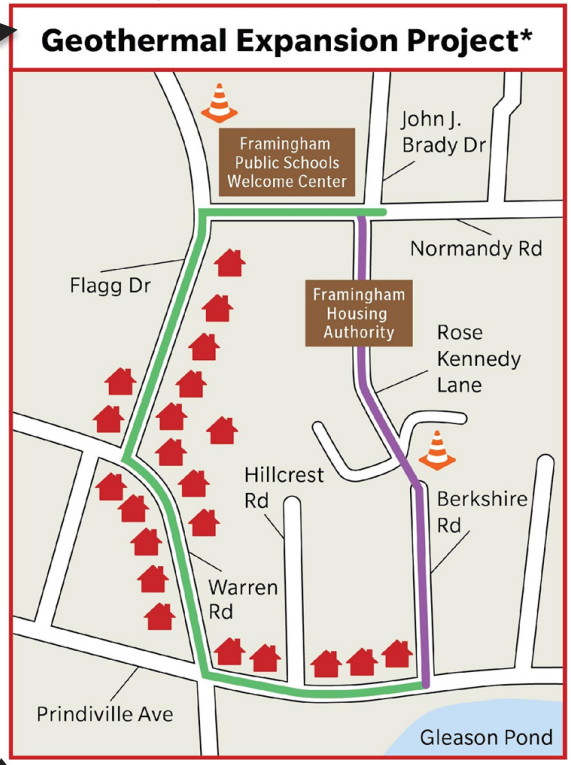
Categories



Stages



Framingham Project Selected by DOE Construction Grant



Proposed route

Existing Geothermal

Borefield drilling sites

Potential residential customers (representation only)

**Project is in the very preliminary stages and whether it goes forward will depend on the interest level of and support of the residents along the route.*

Partners: HEET, Eversource Energy, City of Framingham, Salas O'Brien.

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LeGUp Open Day

Findings from Geothermal Networks Research Consortium

April 28

Agenda & Register

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Distributed Fiber Optic Sensing in Geothermal Networks

NY GEO 2025

Presented by Eric Juma | HEET | April 23, 2025

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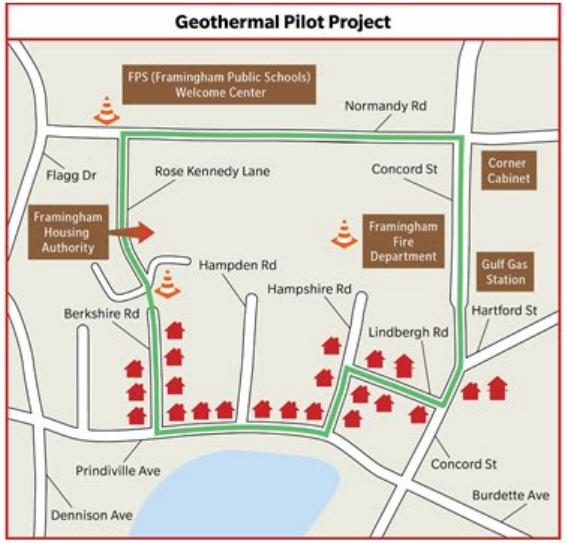
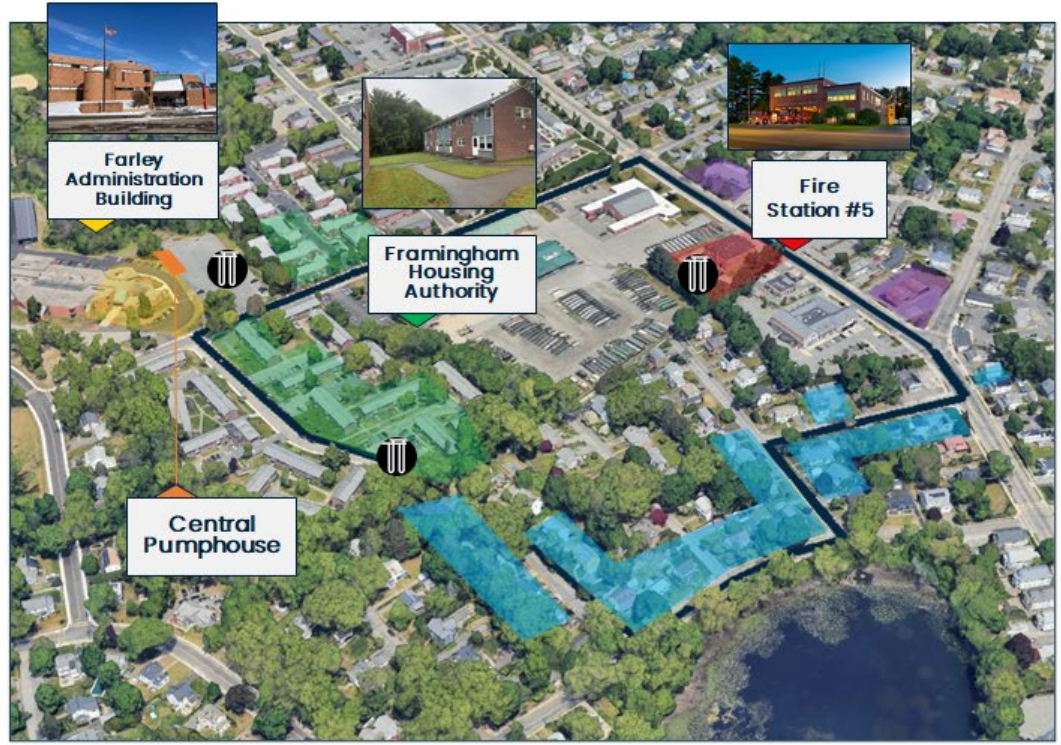
The Eversource Geothermal Pilot Project





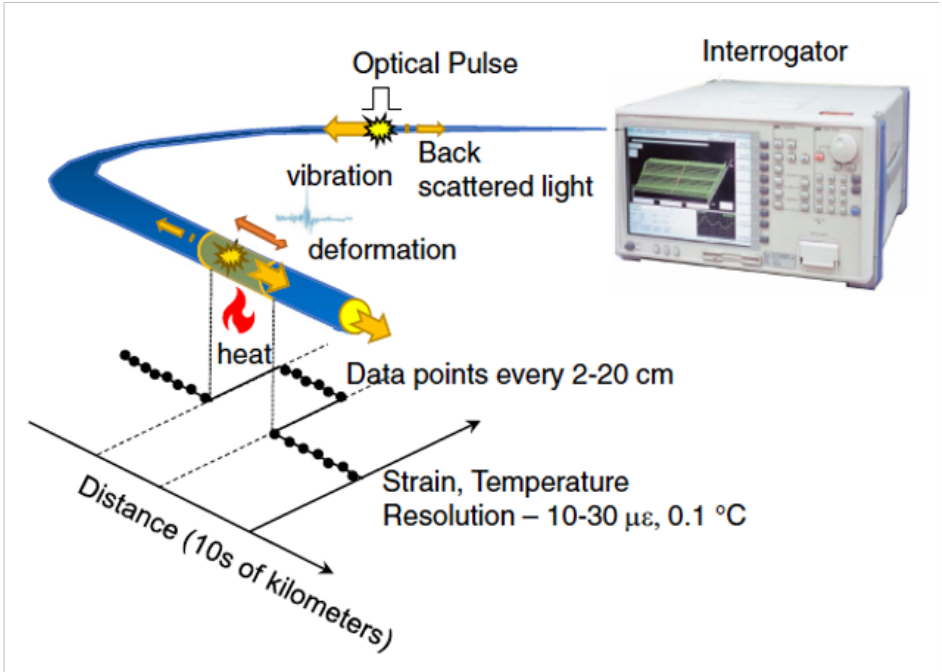
1 mile of main

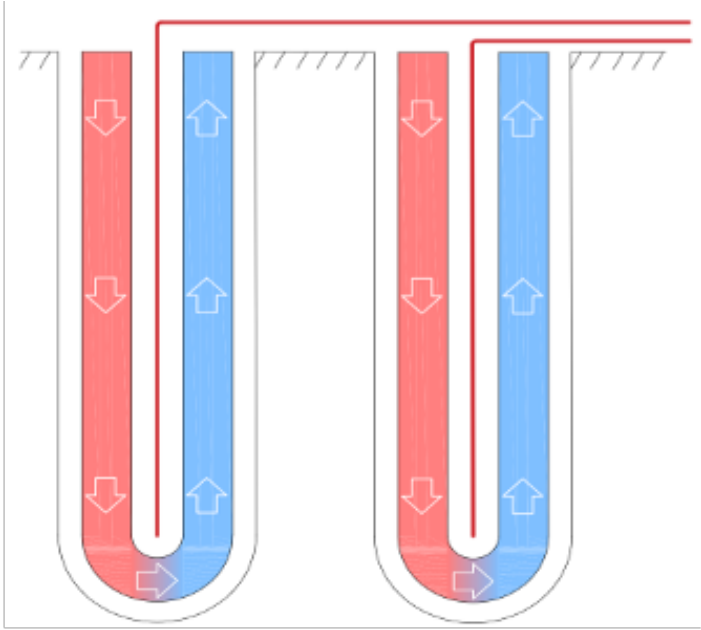
90 boreholes

375 tons of thermal load

36 buildings

What is DFOS? (Distributed Fiber Optic Sensing)

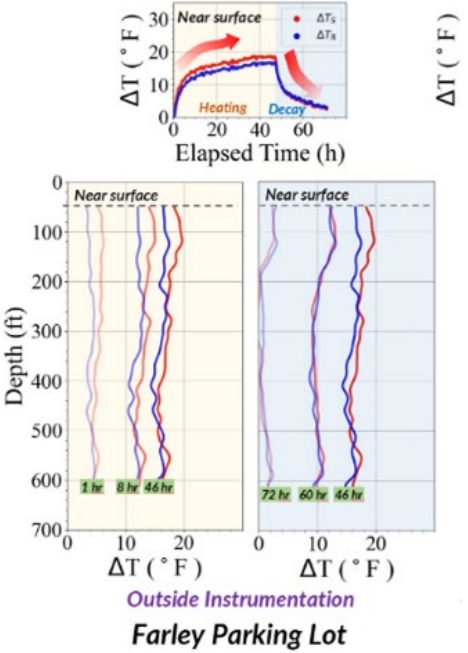




Schematic representation of DFOS technology (Mahmoud et al. 2021)

Why do DFOS?

- Typical monitoring = only input/output temps (ΔT)
- DFOS = **Actual borehole/subsurface conditions**
- Detects **thermal drift** & groundwater flows
- Measure **thermal storage**
- Helps **test models** and integrate with them
- Groundbreaking project - want to **learn** as much as we can



Our project

- 14 boreholes instrumented total
- 1 borehole instrumented during TRT at each borefield
- 2 boreholes instrumented, but not connected to loop

EVERSOURCE

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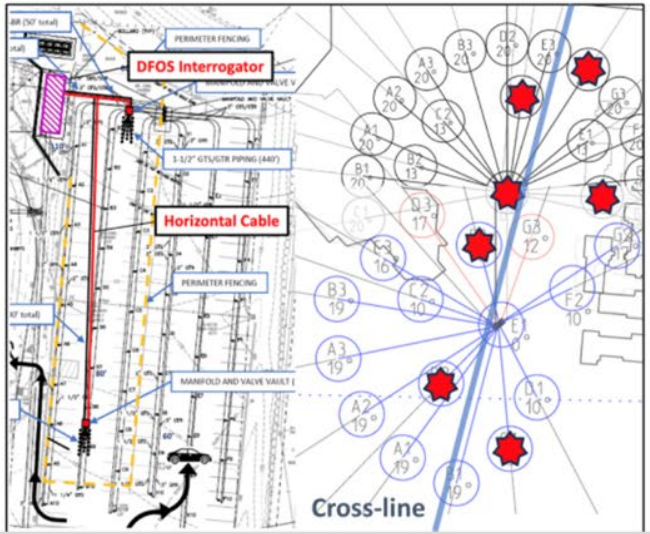
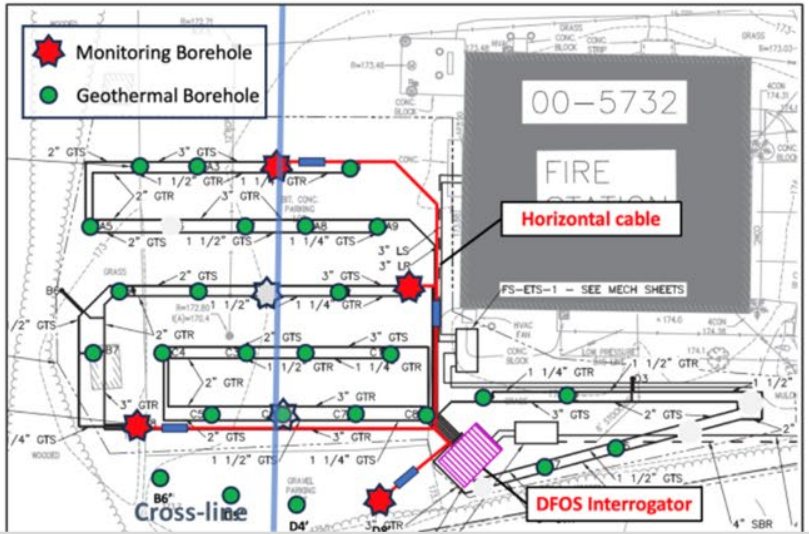
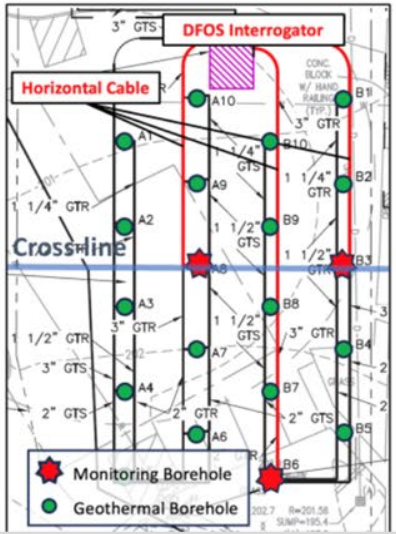
SOGA RESEARCH GROUP

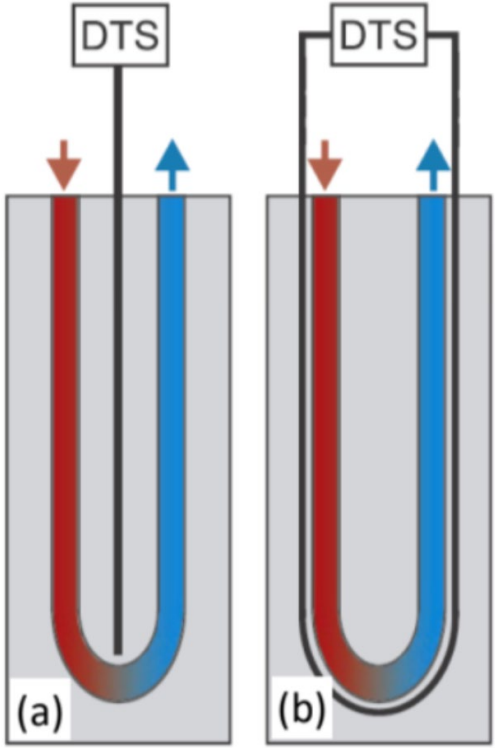
BERKELEY ENGINEERING

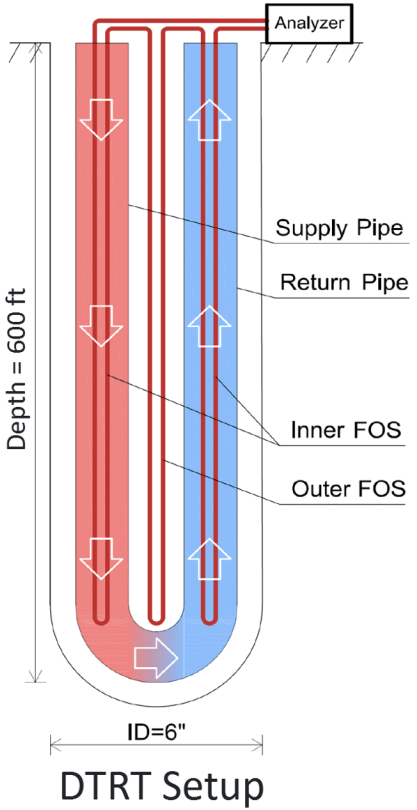






Fiber configurations





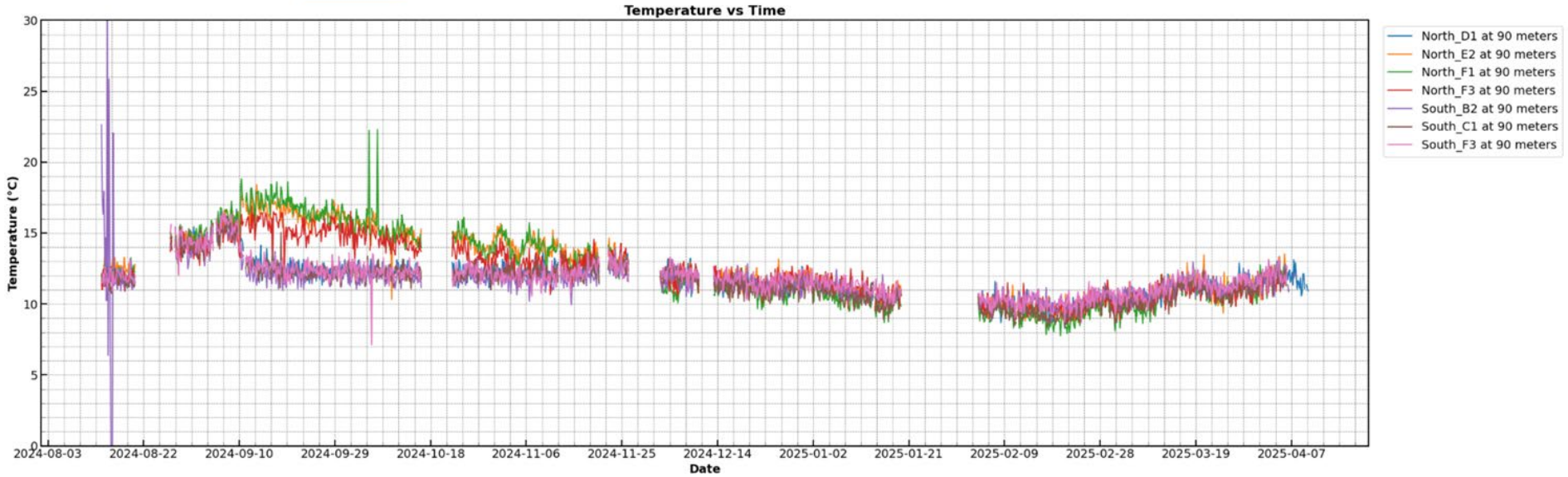
1.2 Temperature variation along time

Borehole ID: North_D1, North_E2, North_F1, North_F3, South_B2

Depth (m): 70, 80, 90, 100, 110, 120

Start Date: 08/14/2 | End Date: 04/23/2

Start Hour: 00 | End Hour: 00



2.2 Temperature variation along time

Borehole ID: B3, B6

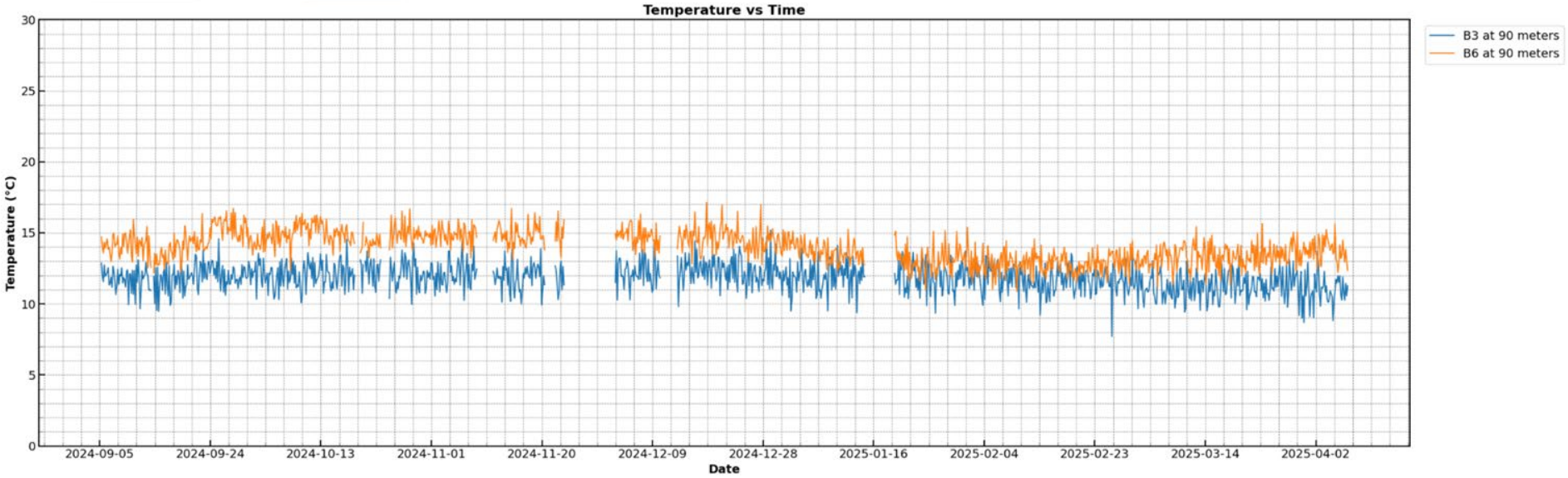
Depth (m): 80, 90, 100, 110, 120

Start Date: 08/14/2

End Date: 04/23/2

Start Hour: 00

End Hour: 00



Next steps

- Resolving intermittency issues
- Integrated analysis with SCADA data
- Analysis of thermal storage and thermal drift
- Integration with other LeGUp models
- Sharing through HEET Databank
- Franklin Field & Framingham 2nd loop installations

LeGUp Core Modeling

NY GEO 2025

Presented by Rebecca Brenneis | Scientist at HEET | April 23, 2025

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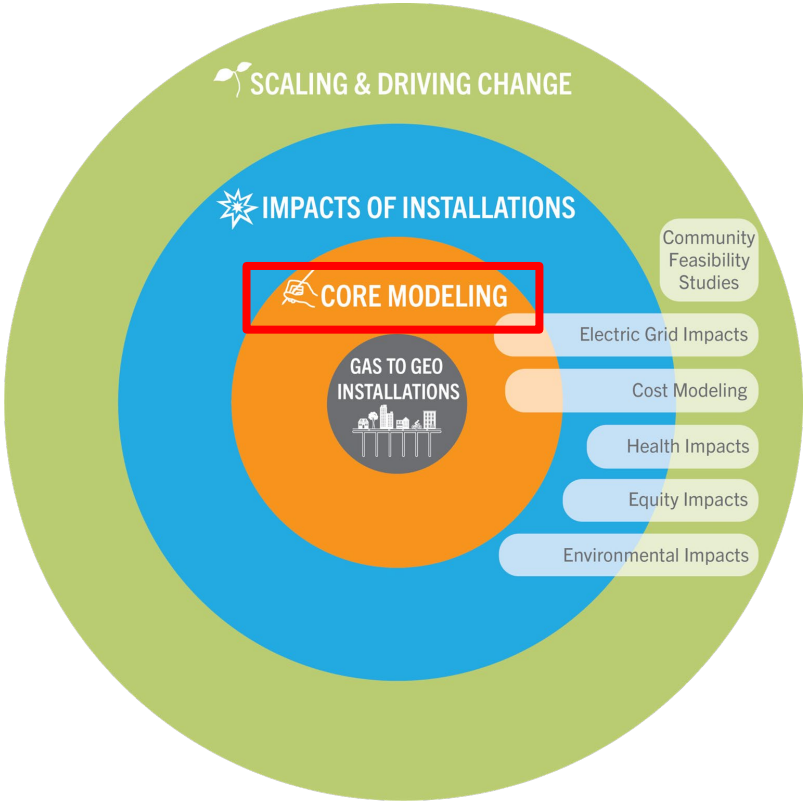
Role of Modeling in LeGUp



Significance of Work

Open-source, Techno-economic modeling tool for single-pipe, ambient temperature, thermal energy networks

Assesses the economic feasibility of prospective geothermal energy networks projects and identifies variables that maximize performance

Tool for project managers, developers, financial analysts, engineers and researchers etc.

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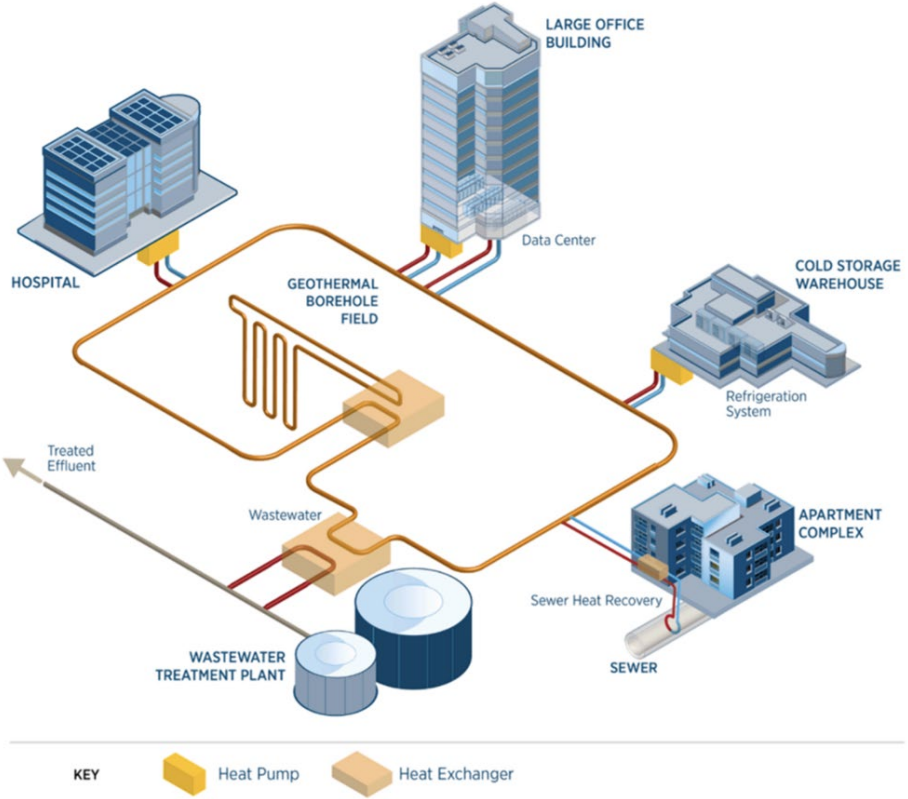

Simpson, et al 2024
Energy Conversion and Management

5th Generation Networks

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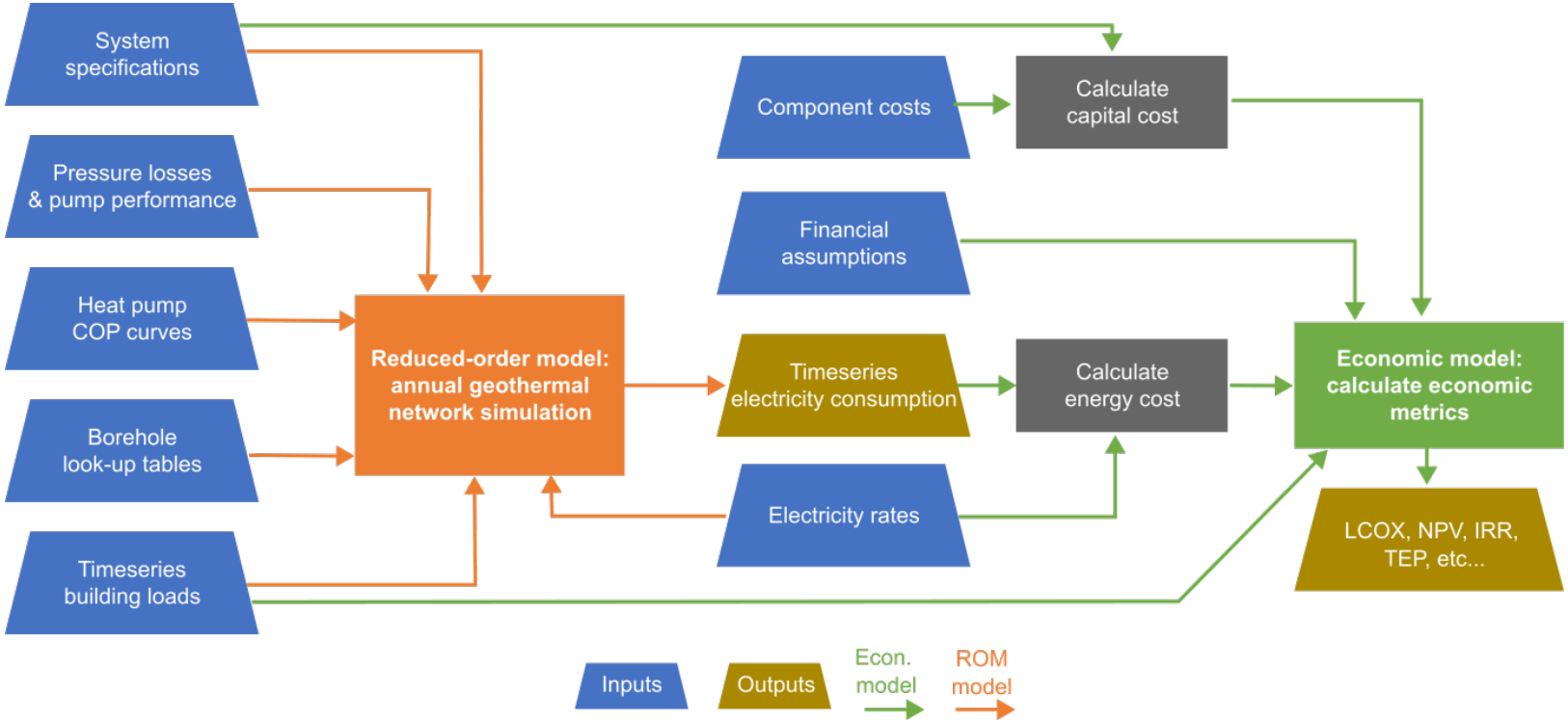
HEATNETS

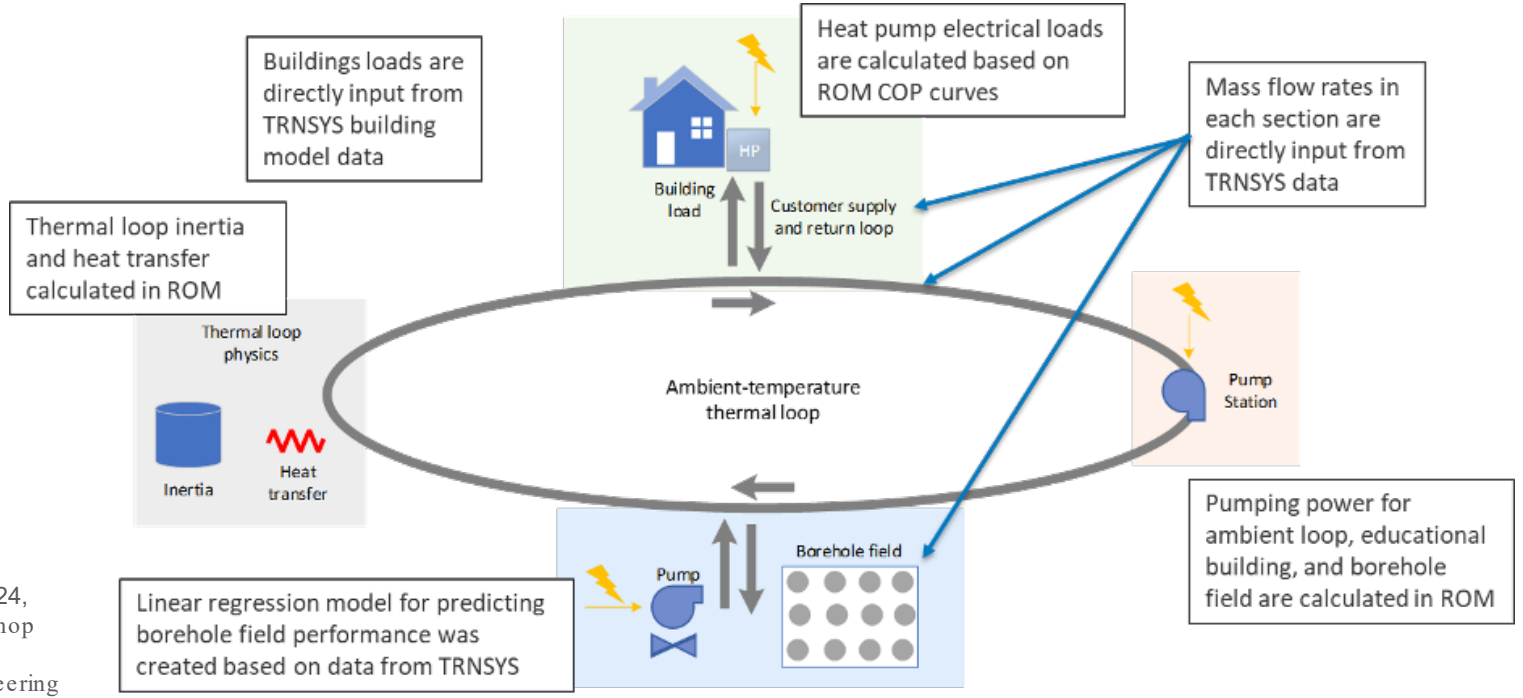
Heat and Economic Analysis Tool for NEtworked Thermal Systems

Technical + **Economic**

Model Data Flow

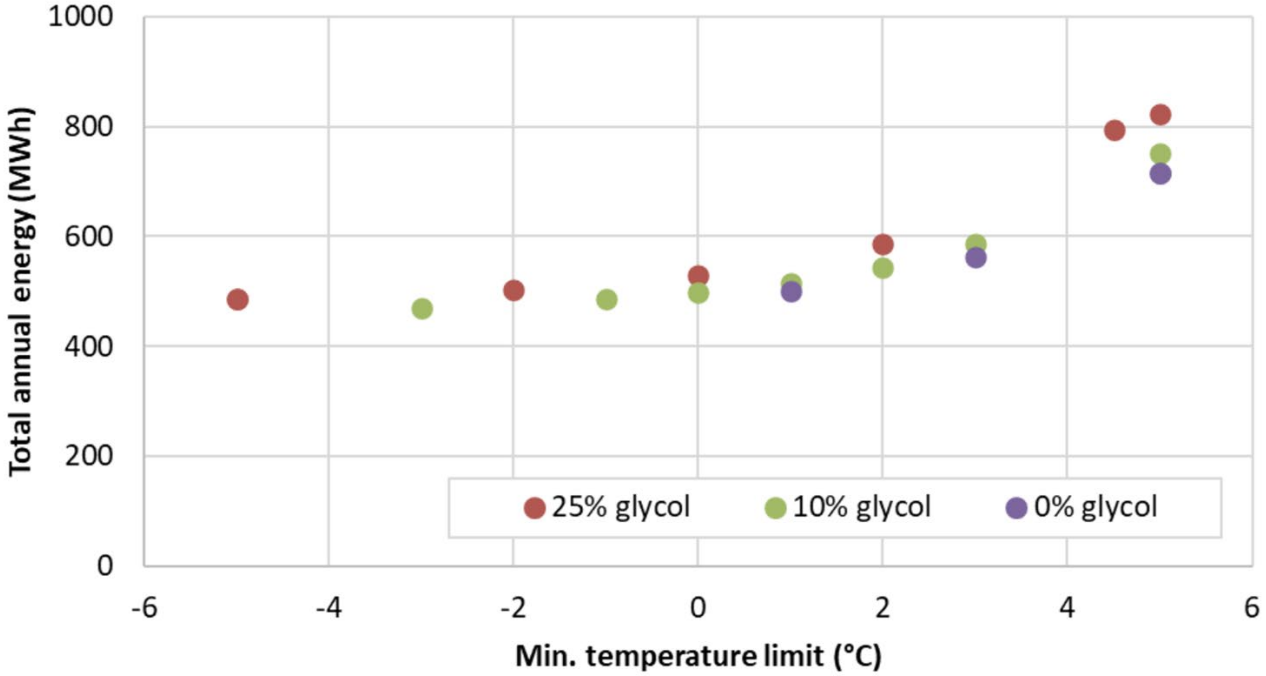


Engineering Reduced Order Model



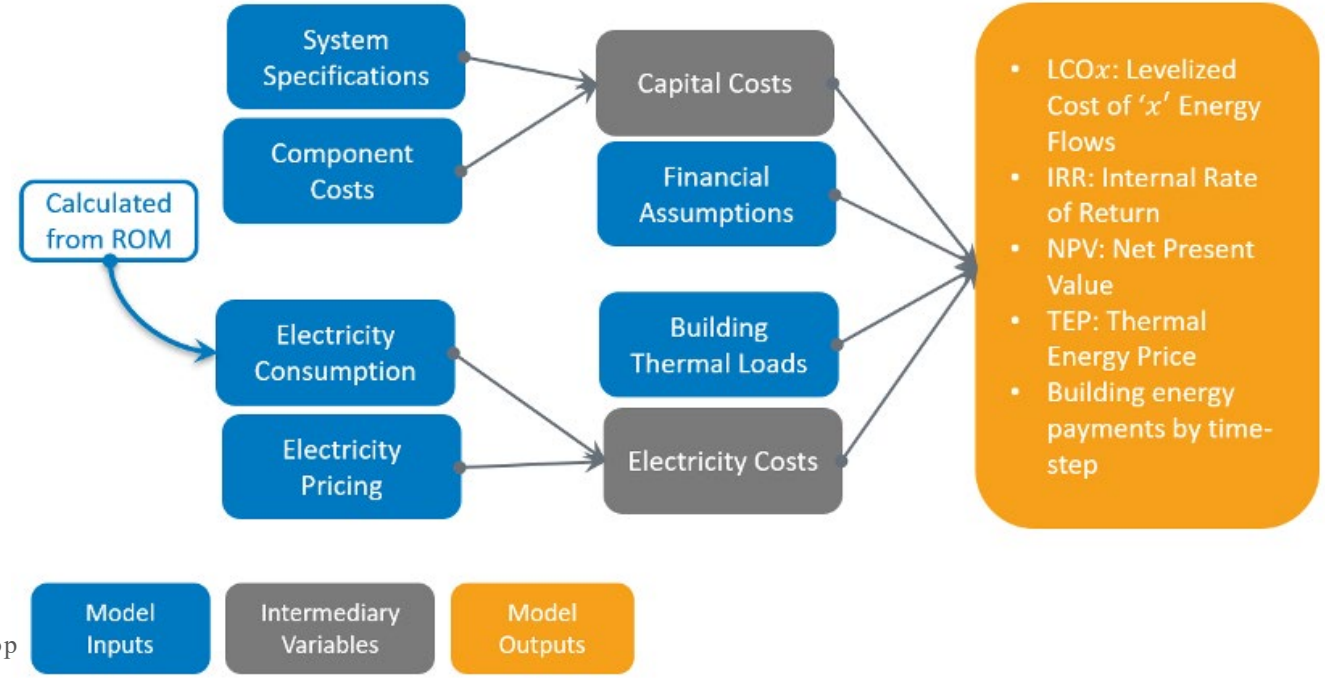
Barney, et al 2024, Stanford Workshop on Geothermal Reservoir Engineering

ROM Parametric Analysis



Simpson et al 2024, Geothermal Rising Conference

Techno-Economic Model



Jiang, et al 2024, Stanford Workshop on Geothermal Reservoir Engineering

Decision Use Cases

Land Use Tradeoffs

Building Demand Profiles

Existing Energy Economics

Thermal Source Potential

NREL Transforming ENERGY

heet

Key Takeaways

➔ HEATNETS is an open source, techno-economic model for single pipe, ambient temp loops

➔ Integrates TENs and GENs into broader energy feasibility decision making and informs scalability

➔ **Next steps**: Launch tool to the public and continue improvement with real world data training

Register for LeGUp Annual Meeting

heet

LeGUp Open Day

Findings from Geothermal Networks Research Consortium

April 28

Agenda & Register

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