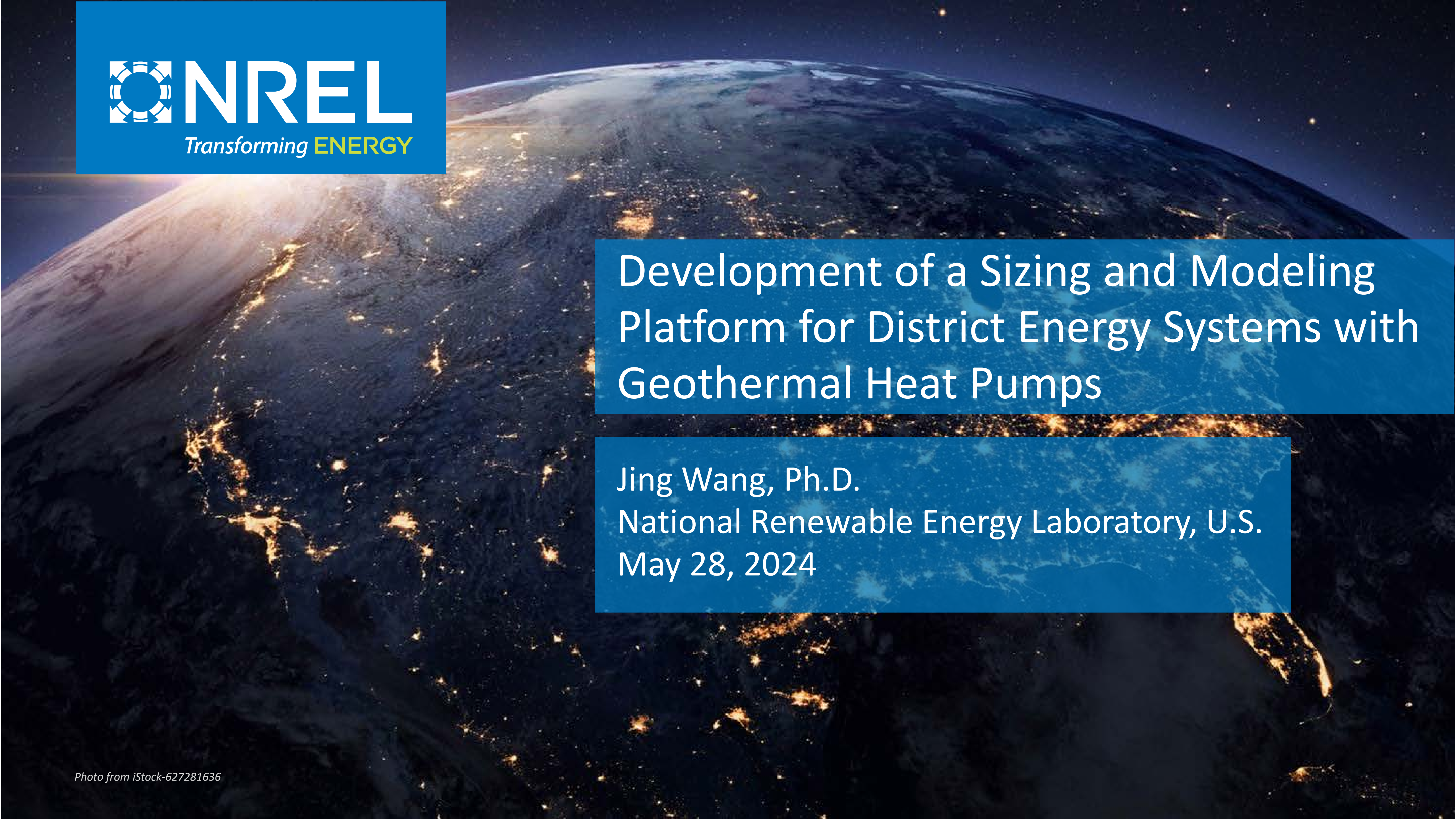

Development of a Sizing and Modeling Platform for District Energy Systems with Geothermal Heat Pumps

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May 28, 2024

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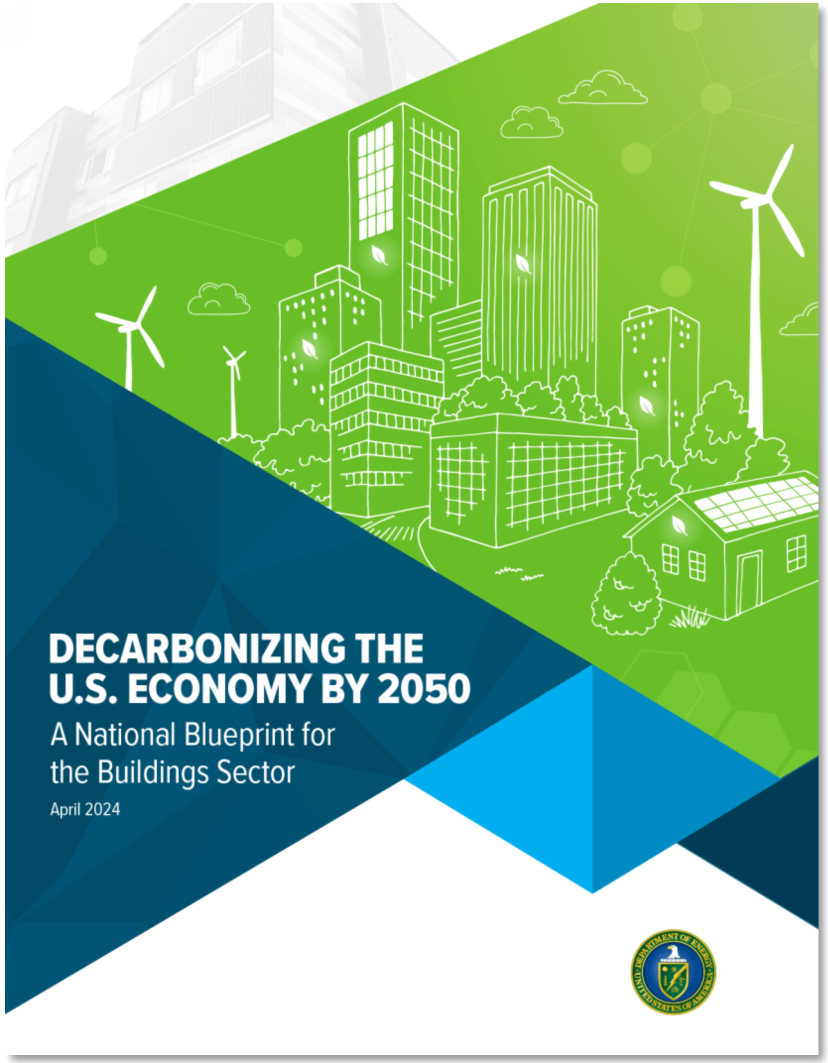
Background



https://www.energy.gov/eere/decarbonizing-us-economy-2050-national-blueprint-buildings-sector

The U.S. Department of Energy (DOE) recently released a national blueprint for **building decarbonization** that shows geothermal playing a key role in decarbonizing U.S. buildings by 2050:

- Geothermal heat pumps are a key measure for **efficient electrification** that supports building decarbonization.
- Ambient-loop thermal energy networks can **reduce the peak demand impacts of electrification** and, when using geothermal wells, can provide **seasonal storage** of thermal energy to smooth out seasonal differences in energy demand.
- **New utility business models**: State regulators can allow gas and electric utilities to explore and develop new business models, such as becoming **thermal utilities** that operate underground thermal pipe networks (e.g., networked geothermal).

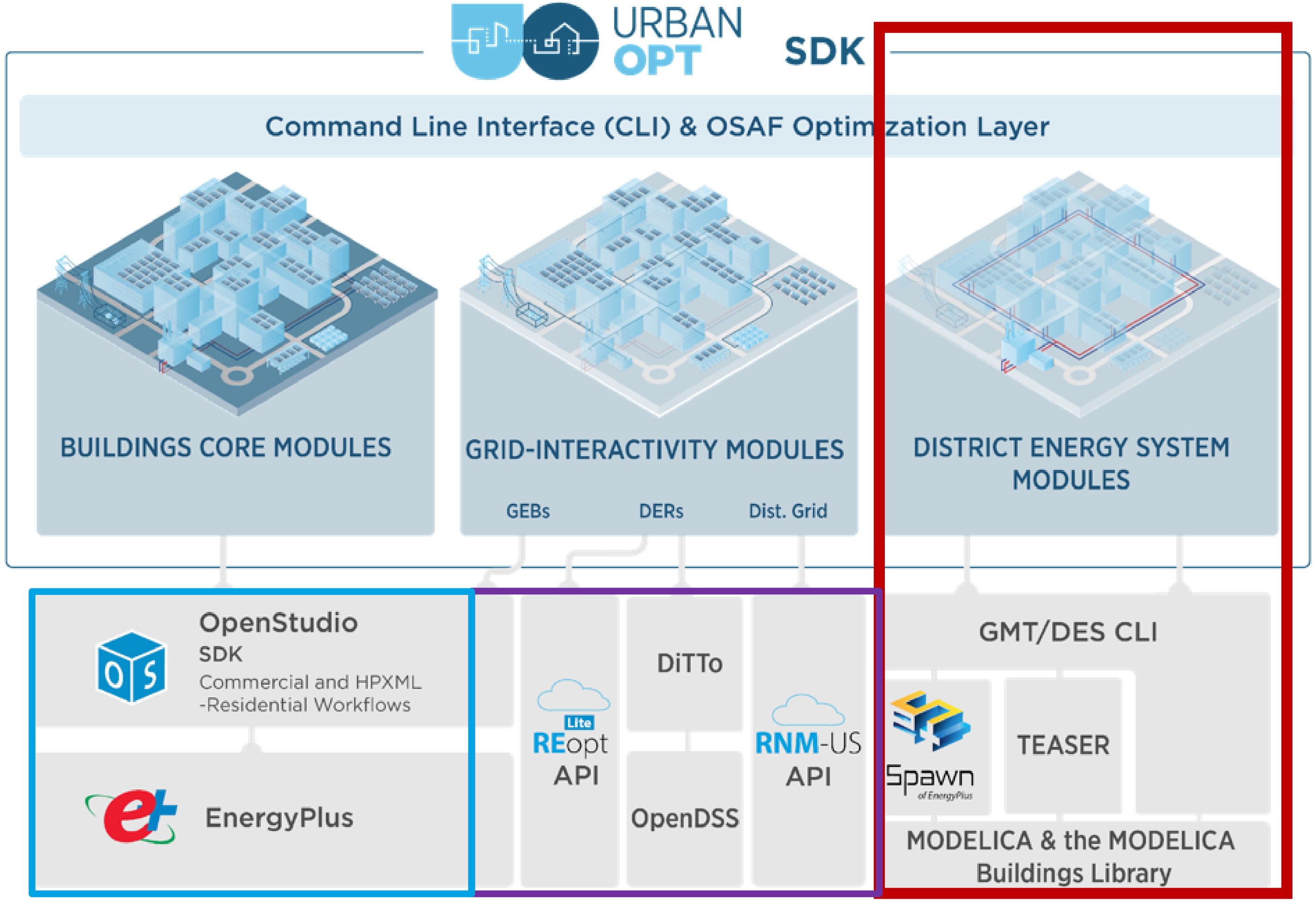
Motivation

- **Existing tools**
  - Focused on building energy modeling and do not provide district energy system modeling capabilities.
  - Often require complex coupling by the users among different domain-specific tools to conduct a comprehensive system-level design and operational analysis.
  - Lack geothermal heat exchanger (GHE) sizing capability.

- **Core goals**
  - Develop workflows to enable geothermal heat pump (GHP) network design, modeling, and simulation.
  - Develop core functionality to enable direct comparisons between network-connected GHP systems and other heating and cooling technologies.

URBANopt™ Platform

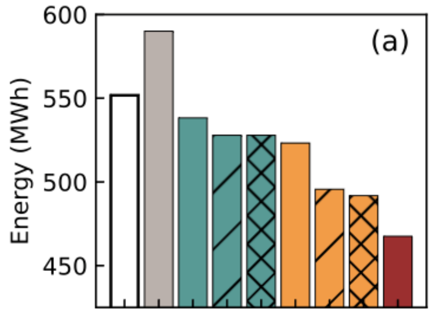
Image credit:
Ladybug Tools LLC



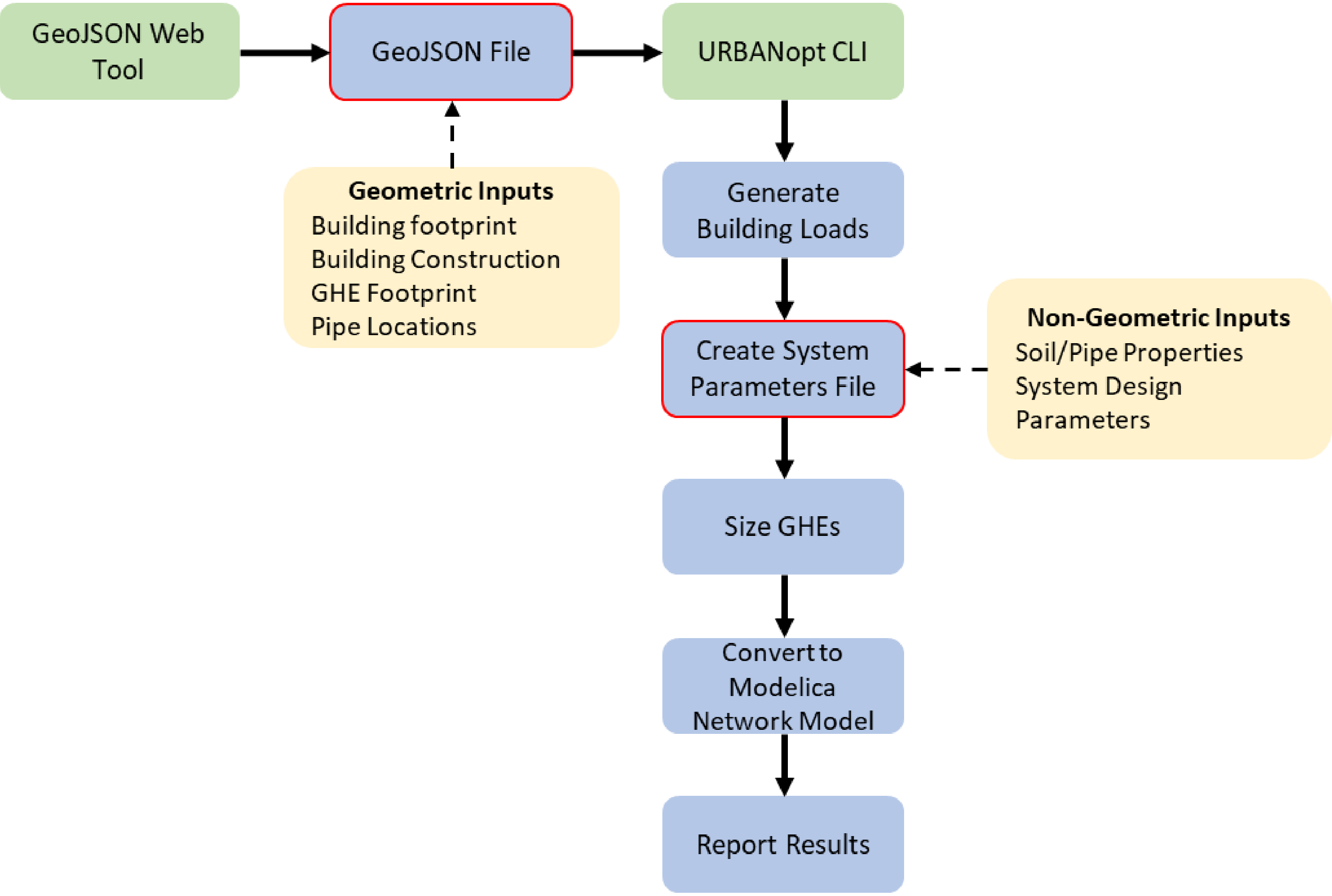
Building energy modeling

Grid/DER and electric distribution modeling

Highly coupled district energy modeling



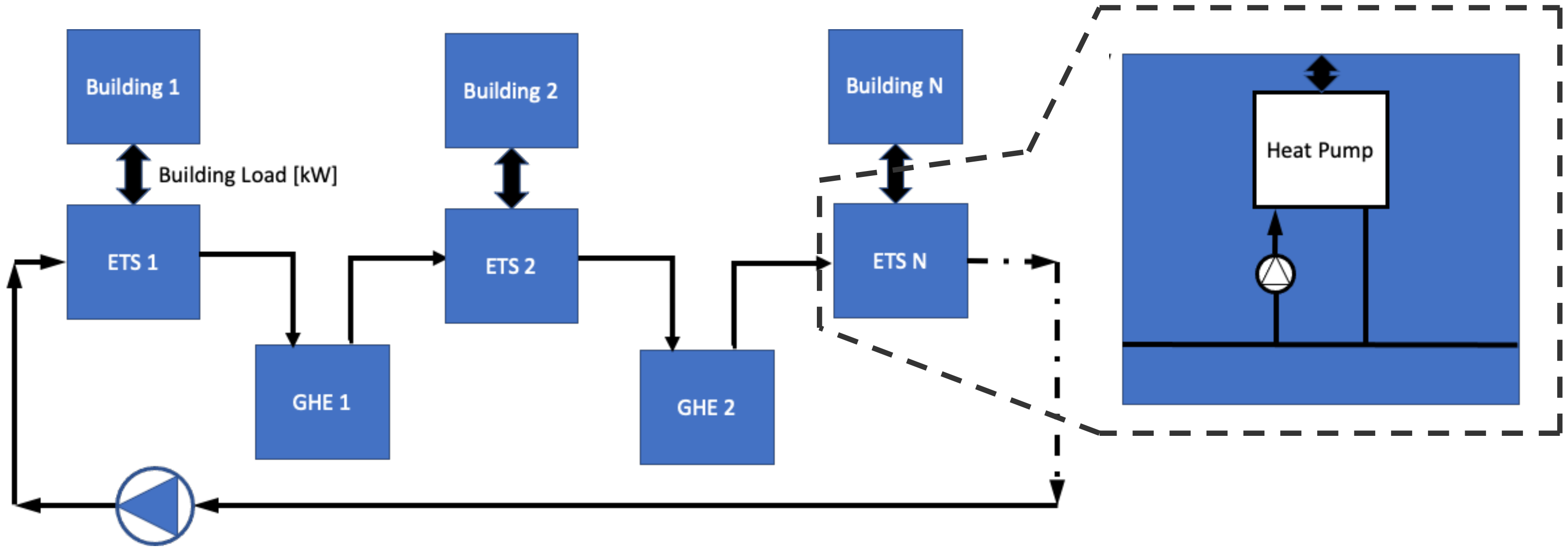
Workflow



1. Generate GeoJSON file that contains geometric inputs.
2. Run building simulations to generate annual 8760-hour load profiles.
3. Create system parameter files that contain non-geometric inputs.
4. Sizing GHEs through the ThermalNetwork python package.
5. Generation and simulation of the Modelica-based network model.
6. Report results on energy and emissions.

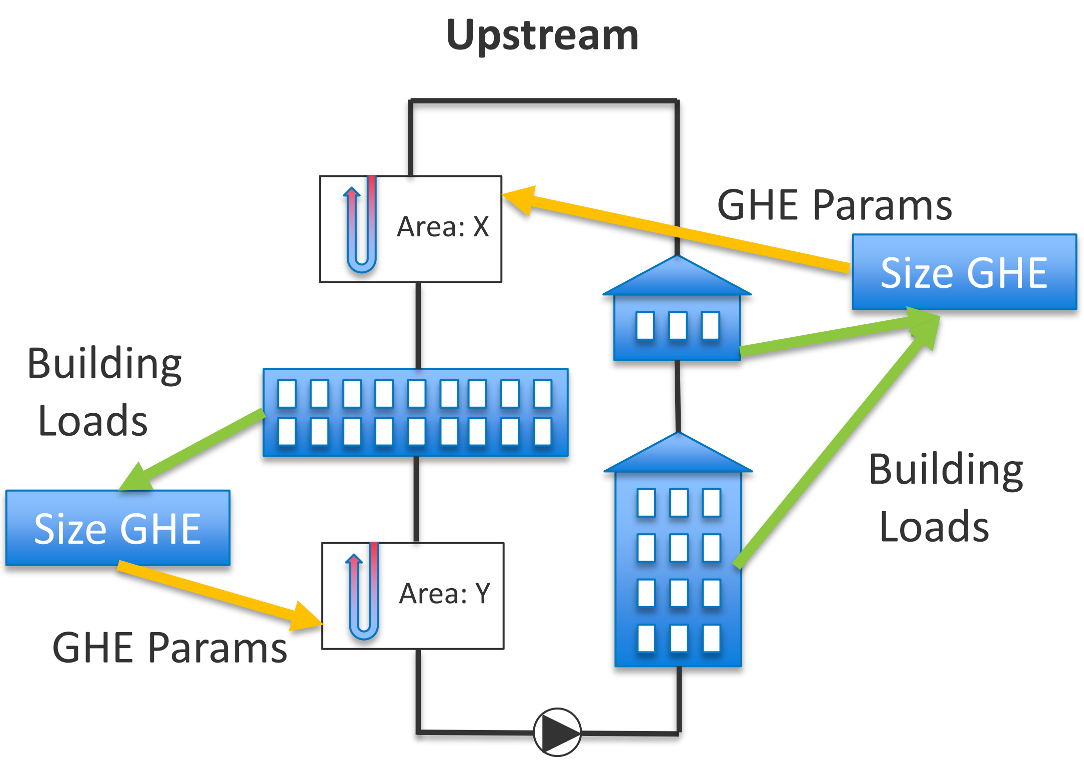
Sizing Networked GHEs

- New software package called "ThermalNetwork" was developed for sizing GHEs distributed around a one-pipe loop.
- Constant-COP heat pump models convert the simultaneous space heating and cooling loads into network loads of the central district loop.
- Two approaches for distributing the loads to each GHE:
  - Area proportional.
  - Upstream.

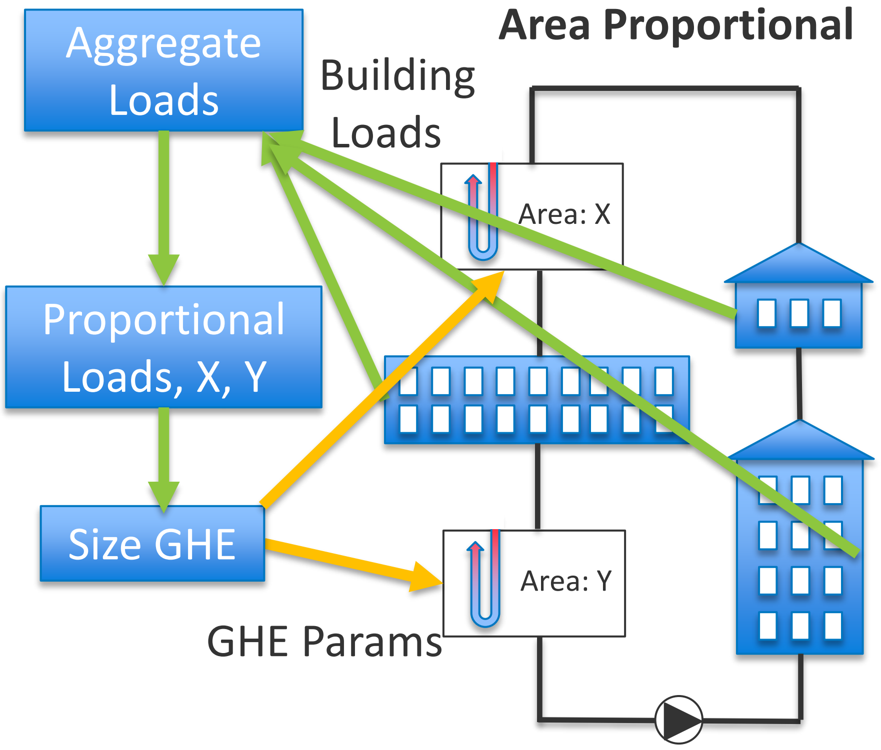


https://github.com/NREL/ThermalNetwork

Sizing Networked GHEs



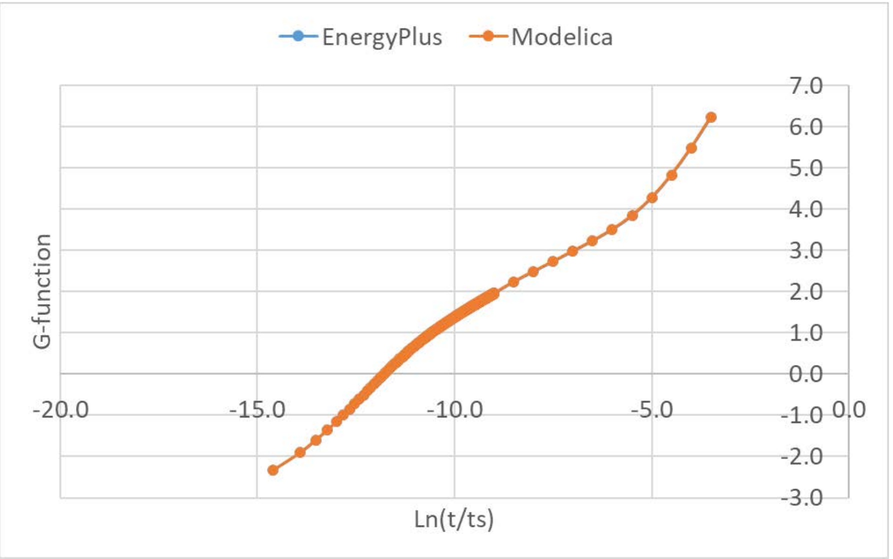
- Aggregate building loads upstream of each GHE.
- Size each respective GHE.



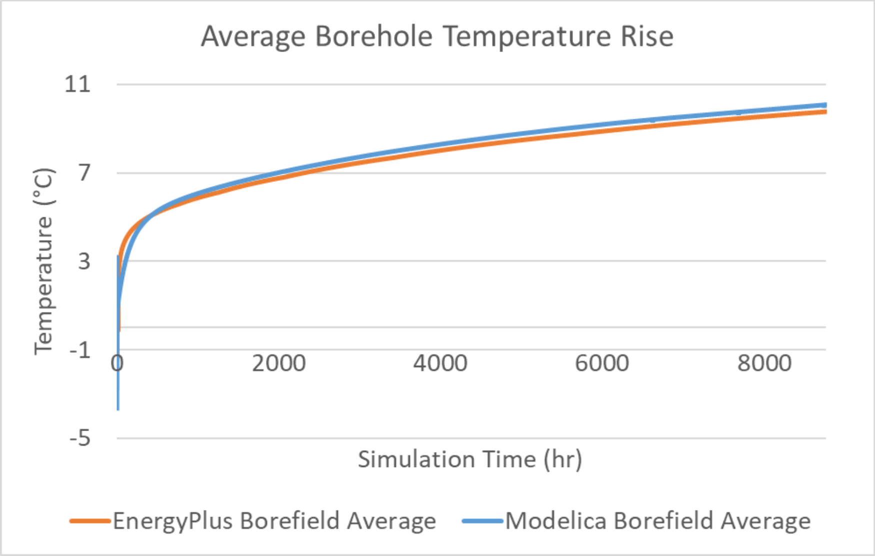
- Aggregate all building loads.
- Apportion building loads based on each GHE available surface area.
- Size each respective GHE.

Model Validation

- A comparative testing validation case was built between the URBANopt GHP platform and EnergyPlus.
- A two-by-two borefield hydronic loop with a constant annual cooling load of 10 kW.
- Annual simulation was conducted with both tools using the same input parameters.
- The same external G-function file used by EnergyPlus was processed and then used by URBANopt in the generated GHE models.



Validated G-function conversion process



Accurate borehole temperature prediction

Case Study: Health Care Facilities in New York State

- Developed a case study to demonstrate the GHP network sizing and modeling capability.
- Hypothetical community in Buffalo, NY. Network with one GHE and two buildings (health care facilities).
- Rectangular borefield (232.5 m × 158.0 m) is sized to have 50 boreholes with 99.6 m lengths.
- User-selected parameters and constraints: the boundary size, max/min borehole depth, borehole to borehole spacing, etc.

Visualized GeoJSON file

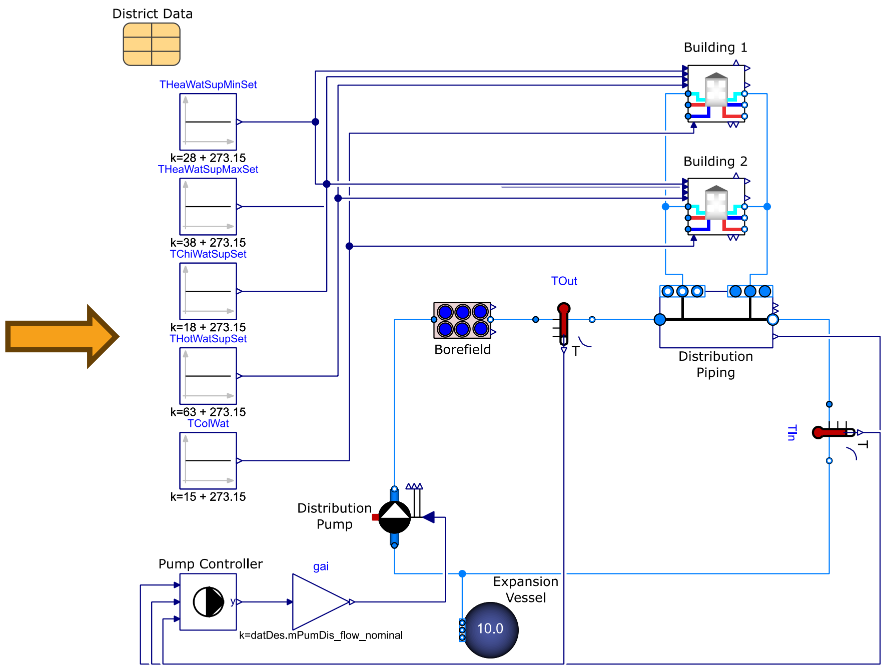
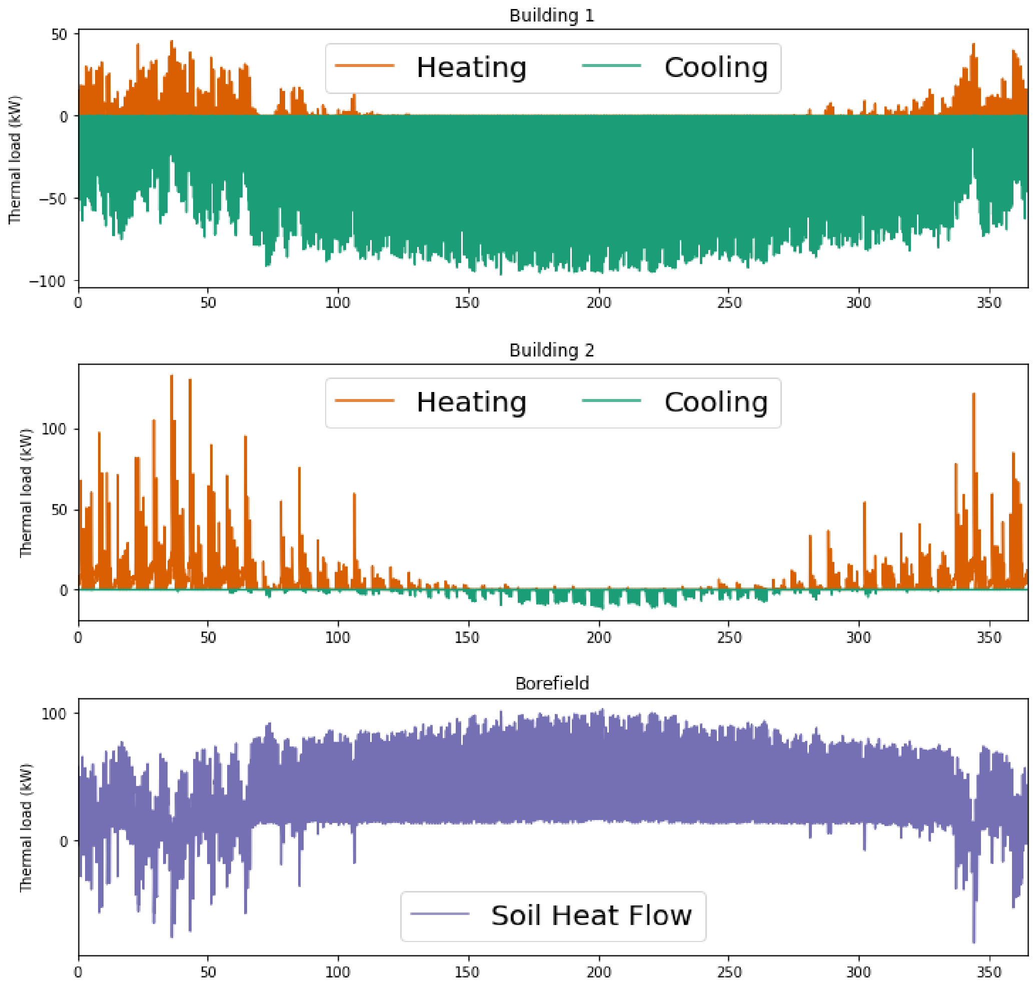
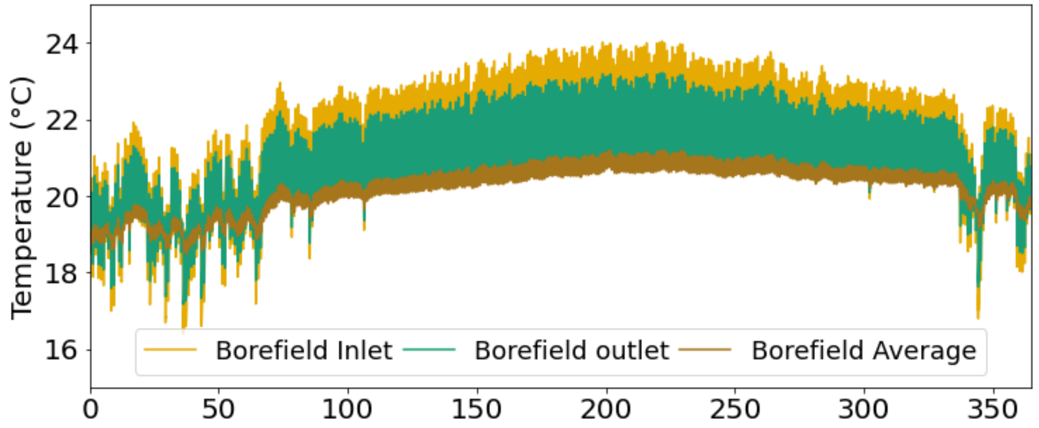


Diagram of the district model

Results



- Building 1 is cooling dominant, while Building 2 is heating dominant.
- The asynchronization of thermal loads leads to a smaller total loop load on the borefield as the building loads offset each other, thus a smaller GHE size.
- Annual simulated borefield average temperature lies within the 18°C–21°C range.



Conclusion and Future Work

- We proposed a sizing, modeling, and simulation platform for district energy systems with geothermal heat pumps.
- The users can specify geometric and non-geometric inputs related to the buildings, GHE, and district energy loop.
- Our platform sizes the GHE, generates a corresponding district energy system model, and runs an annual simulation automatically.
- This tool can be used by researchers and practitioners to facilitate their design and study of district energy systems with GHPs.

- Ongoing work:
  - Horizontal piping modeling.
  - Life cycle analysis as post-processing.
  - Site demonstration in preparation.

Q&A

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NREL/PR-5500-89994

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Building Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

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