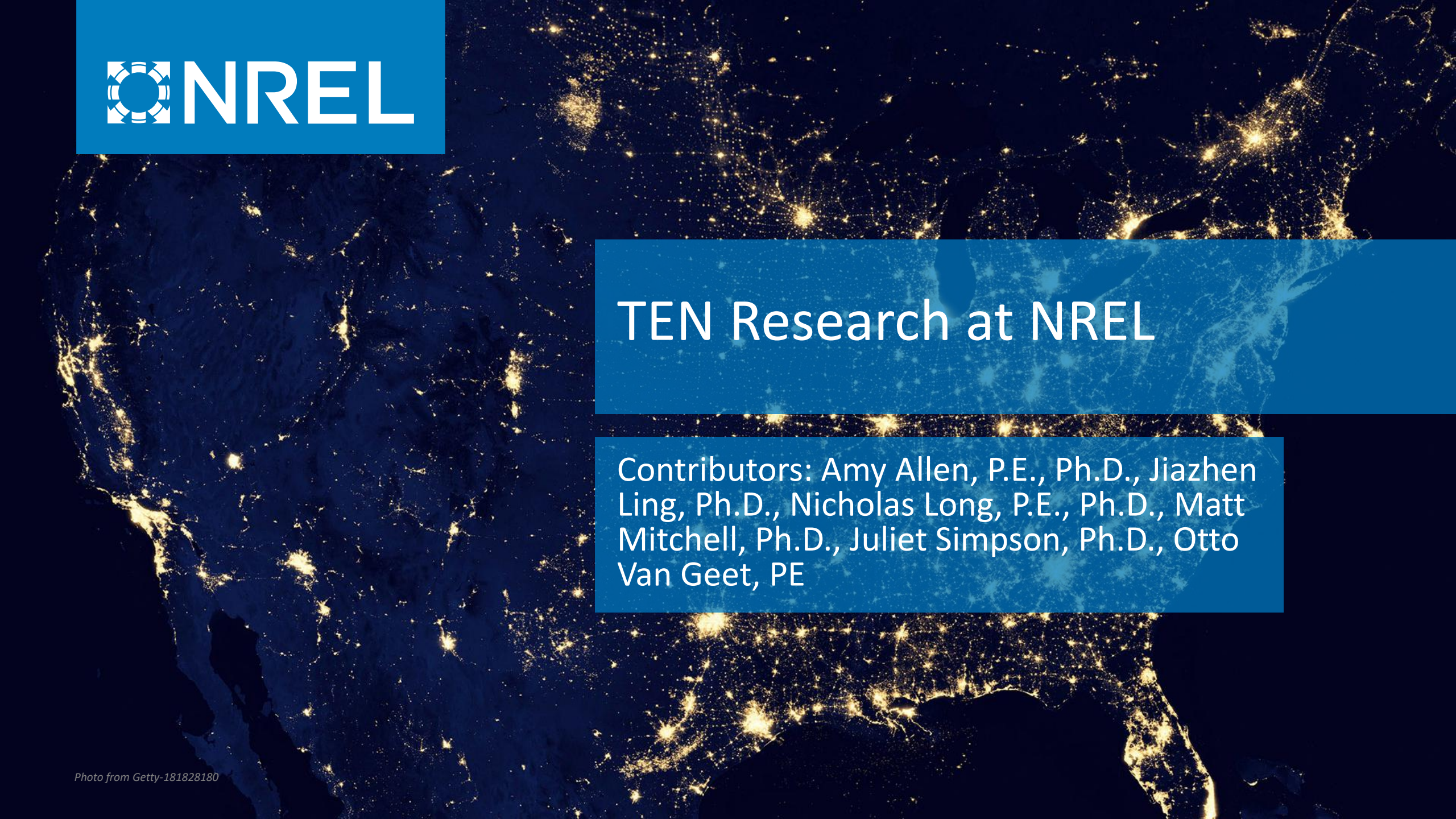


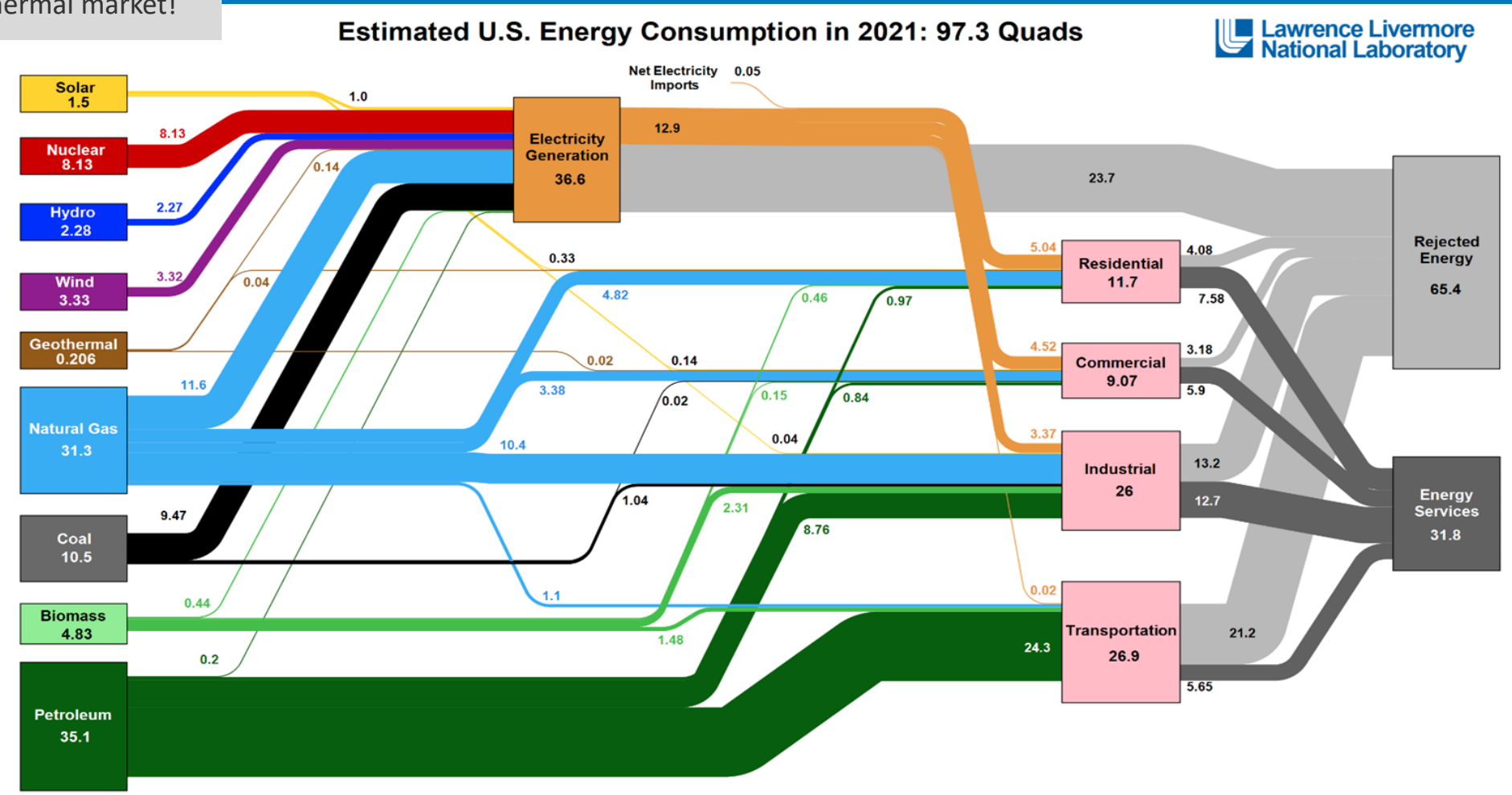
TEN Research at NREL

Contributors: Amy Allen, P.E., Ph.D., Jiazhen Ling, Ph.D., Nicholas Long, P.E., Ph.D., Matt Mitchell, Ph.D., Juliet Simpson, Ph.D., Otto Van Geet, PE

Photo from Getty-181828180

The Opportunity

If you build a TEN you gain access to a very large thermal market!

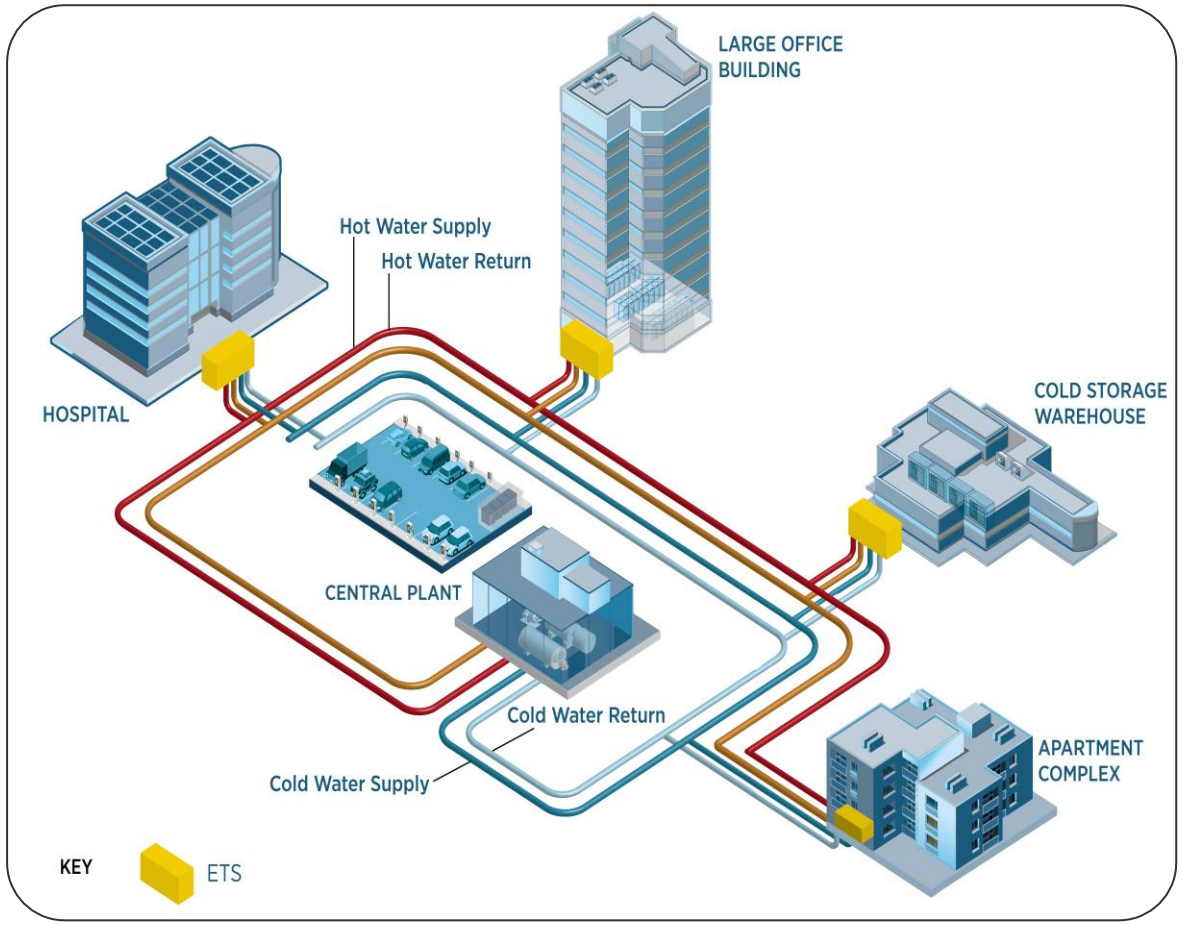


Building heating loads can be met with waste heat.

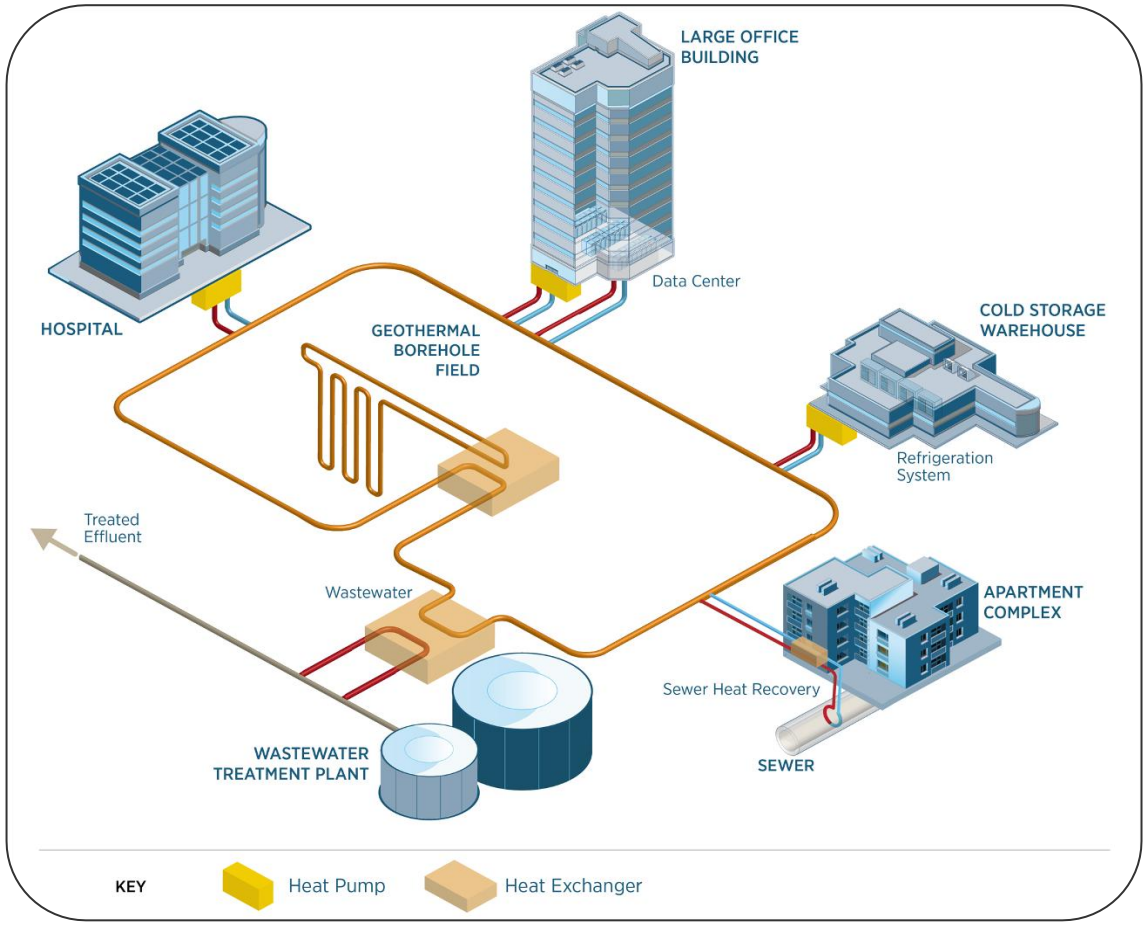
- The rejected energy from industrial and commercial applications is 16.4 quads
- 25% of the waste heat recovered in TENs could displace over half of gas heating in buildings and provide energy savings of >4 quads
- Potential Energy savings for building owners of over $50B annually

TEN/DES Configurations

4G District Energy System



5G District Energy System



Illustrations by Marjorie Schott, NREL

Thermal Energy Networks

Problem Statement

Sixty-five quads of energy is rejected in the US. To leverage we must reduce the investment & technical risks for deployment of TENs, including geothermal energy, thermal storage, cogeneration, & waste heat recovery. Characterizing the grid impacts of TENs, particularly at the grid edge, can support firm base loads, along with optimizing the integration of thermal energy storage into these systems.

Technical Description

Develop a multi-office strategy for an innovation hub (consortium) and derisking platform that addresses foundational barriers to the integration of geothermal systems, thermal storage, grid edge technologies, and distributed energy resources in thermal energy networks.

NREL is working with partners (design firms, utilities, engineers) to analyze and deploy these systems. M&V is needed from these systems to loop back into our core research to further innovate.

On-going Work

NREL is actively involved in over 30 DES/TEN-related projects around the world. This includes the development of core modeling and analysis tools (e.g., URBANopt, dGeo, GHEDesigner, HEATNETS) for modeling district-connected systems and ground heat exchangers. This includes evaluating electric and thermal grid impacts for grid reliability and national-scale market potential. We have ongoing work on technical support on nearly a dozen campus-scale designs, feasibility studies and support the State of Washington in evaluating their state-wide DES efficiency plans.

Barriers

Complex solutions that require multidisciplinary coordination: Development of these systems takes decades and upwards of a billion USD.

All DESs are unique engineering solutions: existing controls typically not optimized for scaling and interoperability; Consistency of design needed for scaling.

Design and Engineering: Lack of modeling and engineering tools to design, evaluate, and deploy.

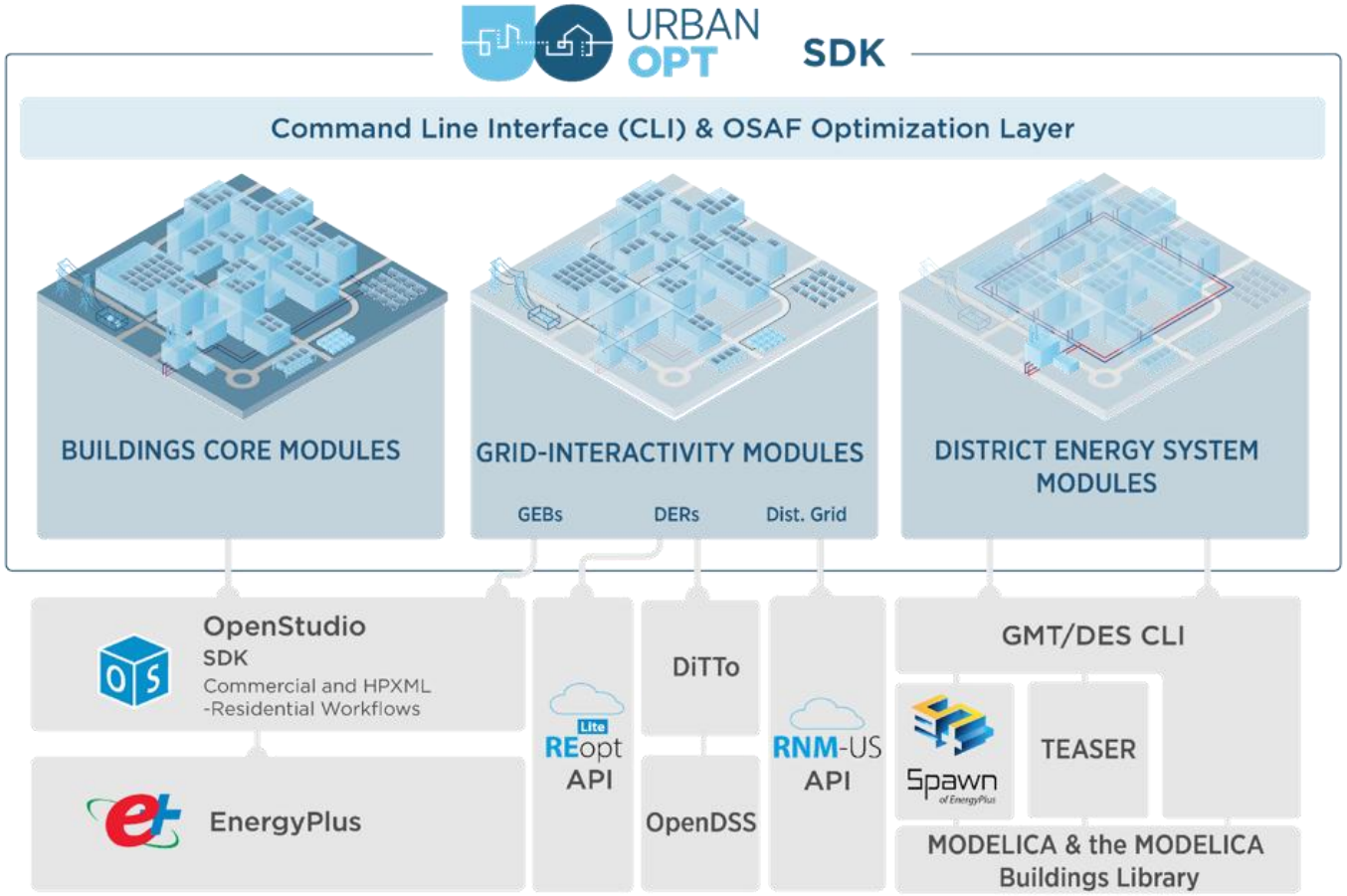
DOE Funding Impact on Industry

Existing funds have enabled the development of foundational modeling and simulation platforms, such as URBANopt, DES workflows, GHEDesigner, and ThermalNetwork

Future funding will further derisk the design and implementation of TEN (and DES) through the development of industry consortium, and NREL lab investments to test controls and grid impacts.

Locations of TEN related projects NREL is supporting

TEN Modeling for Design Refinement: URBANopt

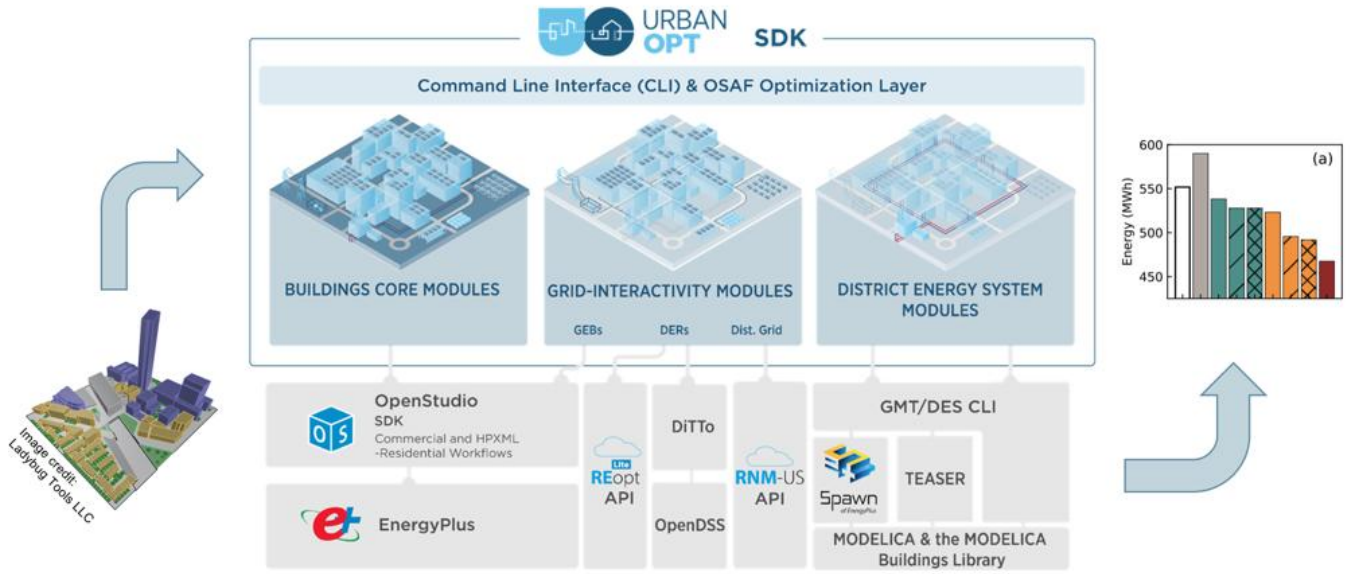


URBANopt™ Modeling Architecture

Image Credit: Marjorie Schott, NREL

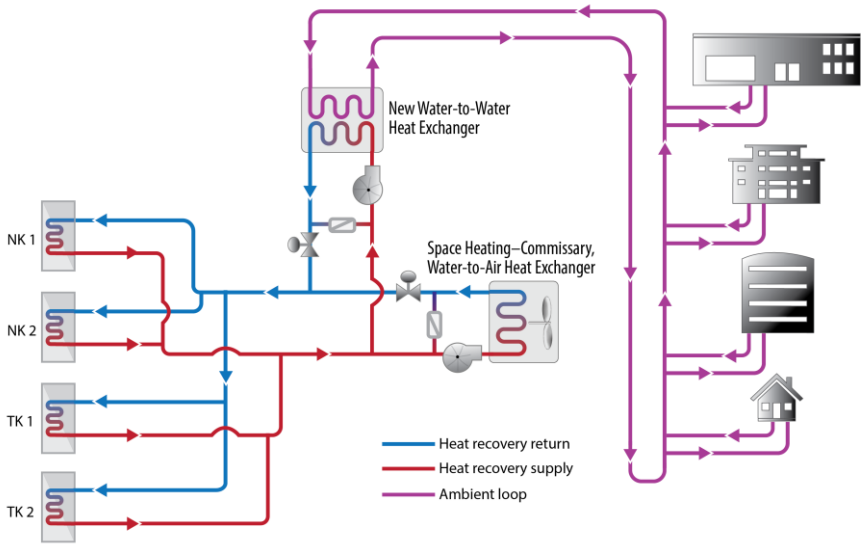
Simulation and Validation

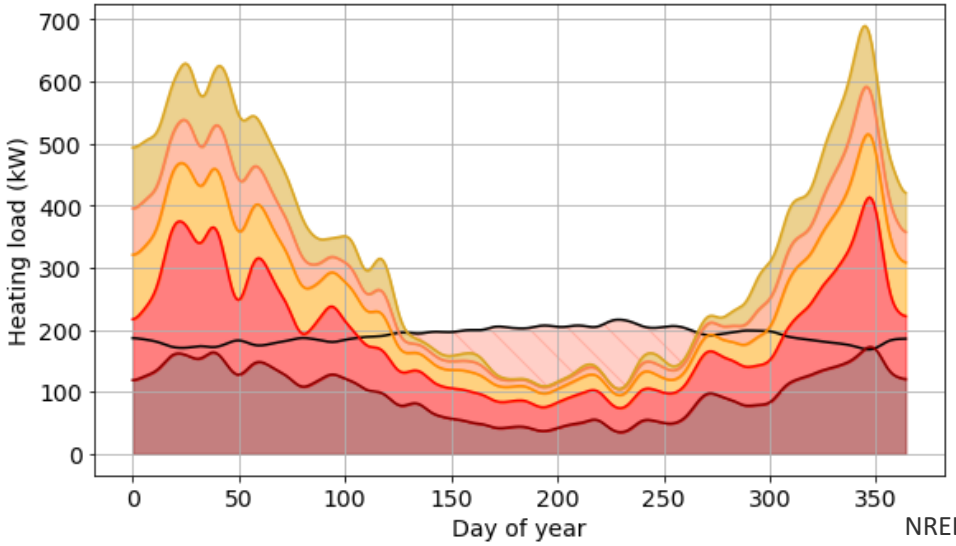
- Integration with simulation platforms (e.g., URBANopt, EnergyPlus, HEATNETS, ThermalNetwork, GHEDesigner, Modelica Buildings Library)
- Development of a digital twin for scenario testing (digital model, digital shadow)
- Advanced control strategies for optimizing energy flows, MPC, RLC, etc.
- Flexible screening tool (Municipal and Thermal Resources Options Connector, METROconnect) to allow developers and consultants to assess TEN opportunities efficiently



TEN Feasibility Studies

- NREL is carrying out feasibility studies of TENs for a variety of applications, including for small communities and military installations
- NREL is performing detailed modeling analysis using the URBANopt platform and URBANopt-DES
- As part of these studies, NREL is investigating opportunities for use of a variety of heat sources and sinks, including **ground heat exchangers** and **waste heat**
- NREL is leveraging its expertise with TENs to provide **practical insights** in areas including **compatibility** with typical supply temperatures from **water-source heat pumps**

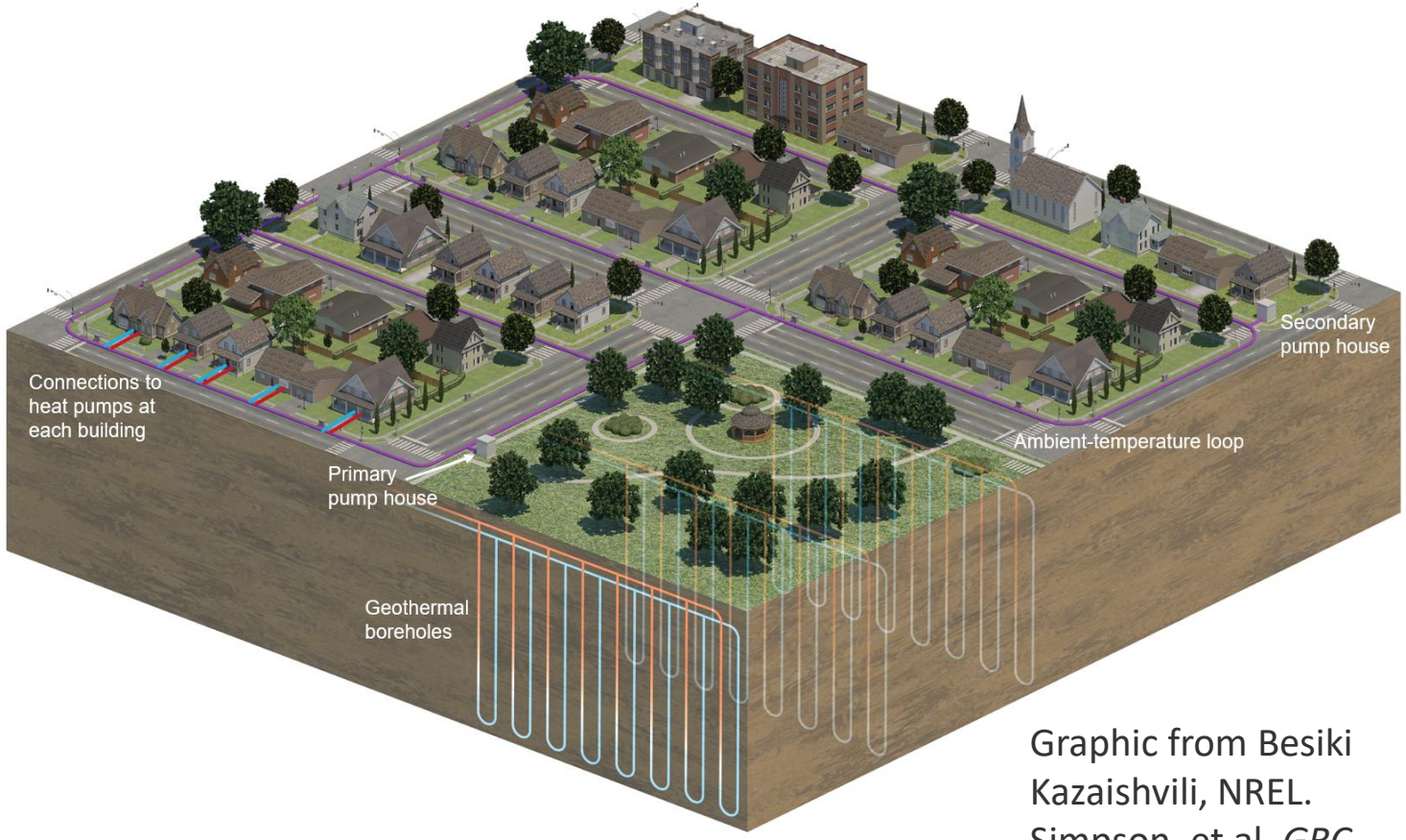




Waste Heat Recovery Opportunity
Upper Right Image Credit: Marjorie Schott, NREL

Gas to Geo transition

- Potential for Utility Thermal Energy Network model to be a pathway for gas utilities to transition to be “thermal” utilities
- Ex: MA is building out regulations for this pathway
- Utility model financing allows for amortizing costs over long time periods and many customers
- Opportunity for transitioning the skilled oil/gas workforce



A thermal utility could provide a thermal loop for every user on the street to connect into, sharing thermal sources/sinks at a community scale.

Graphic from Besiki Kazaishvili, NREL. Simpson, et al. *GRC Transactions,* 2024.

Derisking TEN Implementation

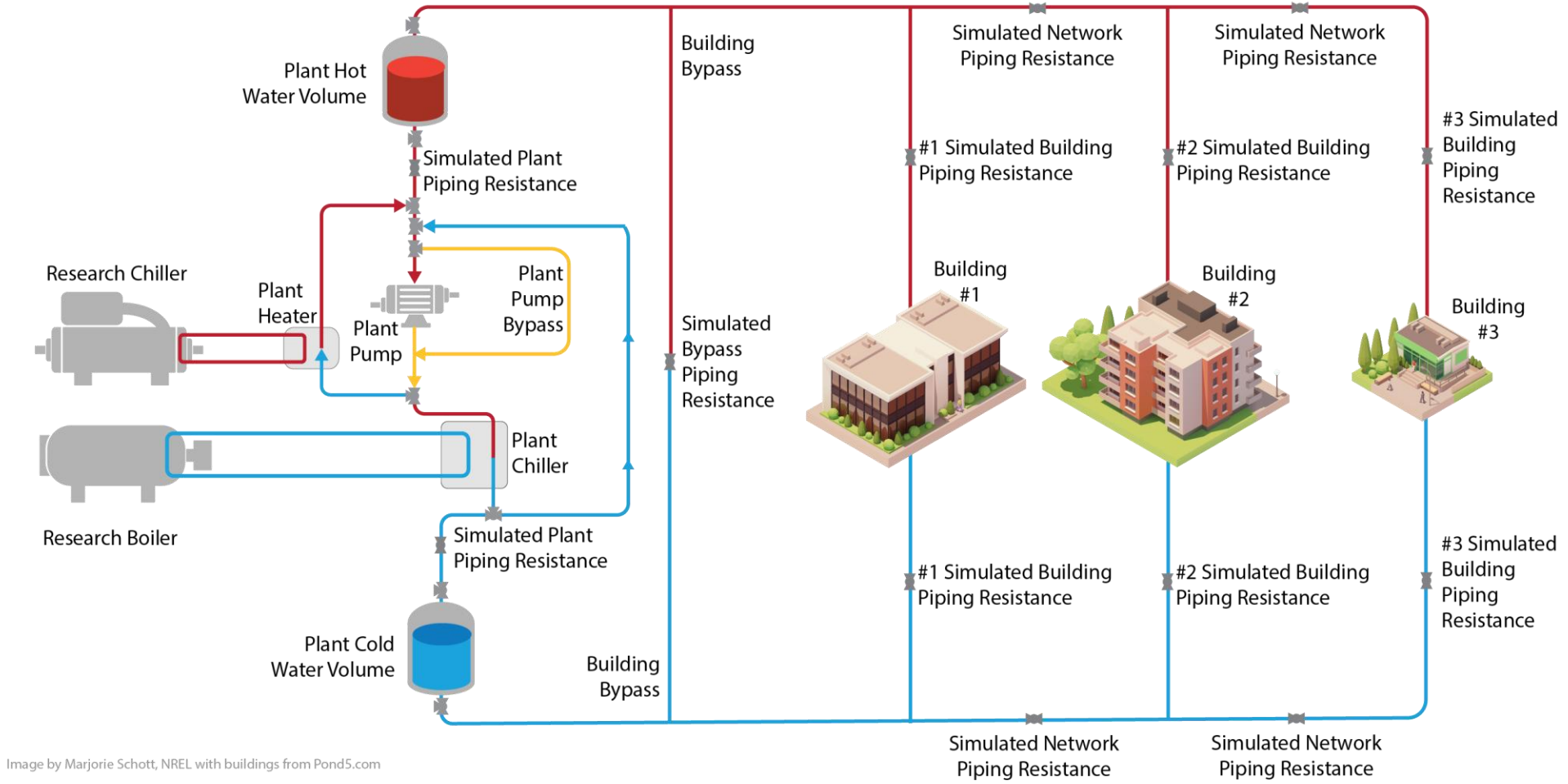
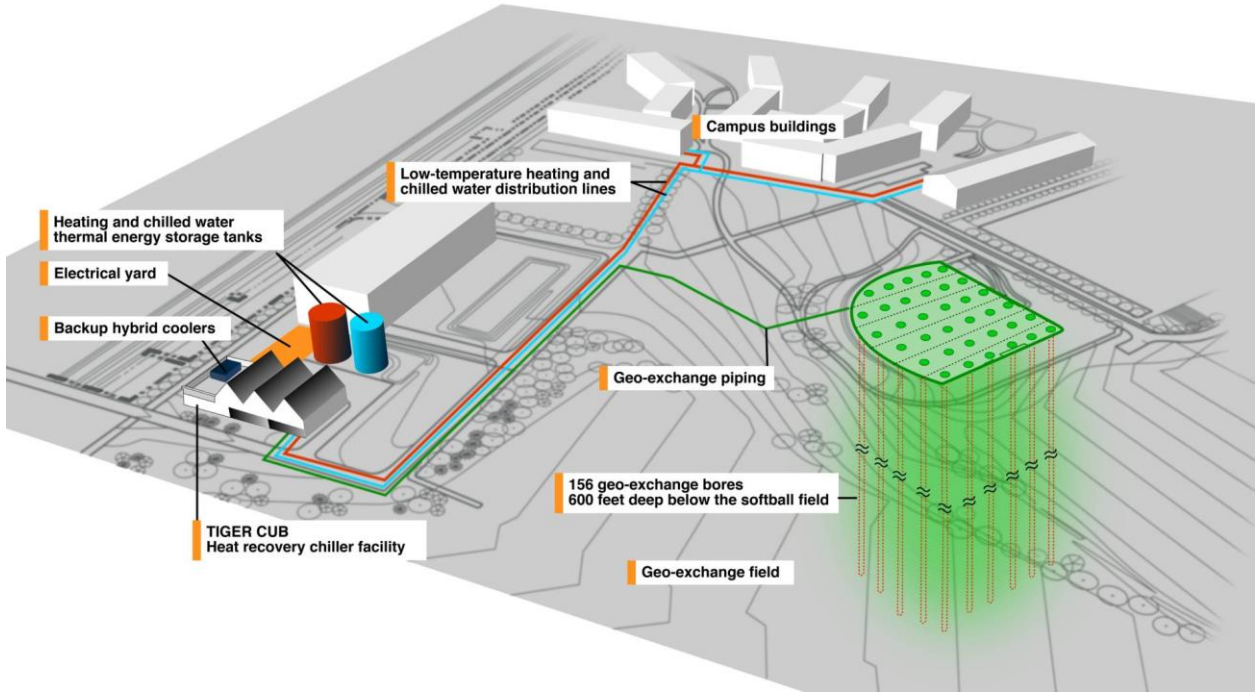
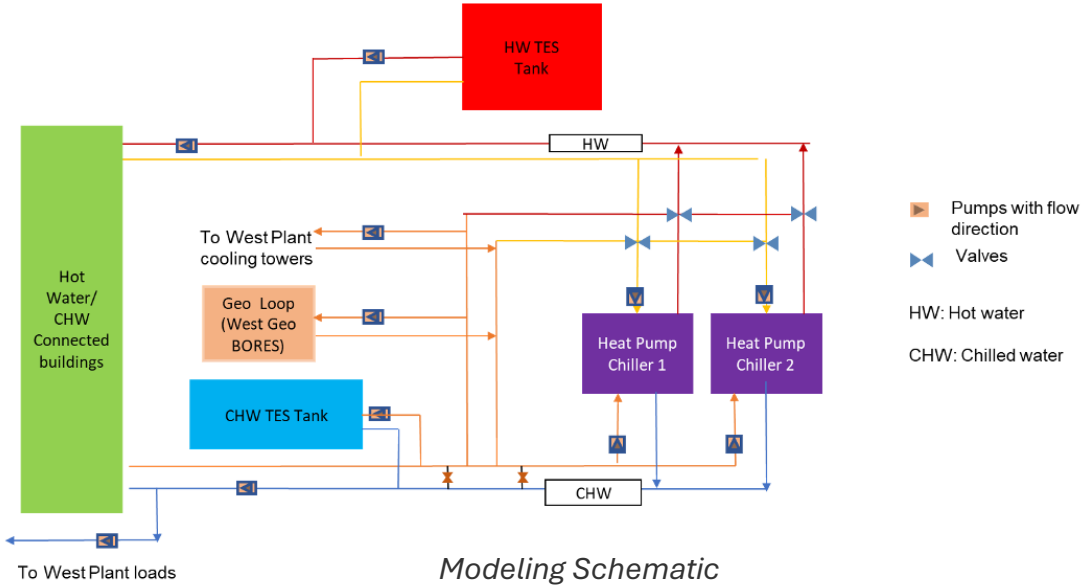


Image by Marjorie Schott, NREL with buildings from Pond5.com

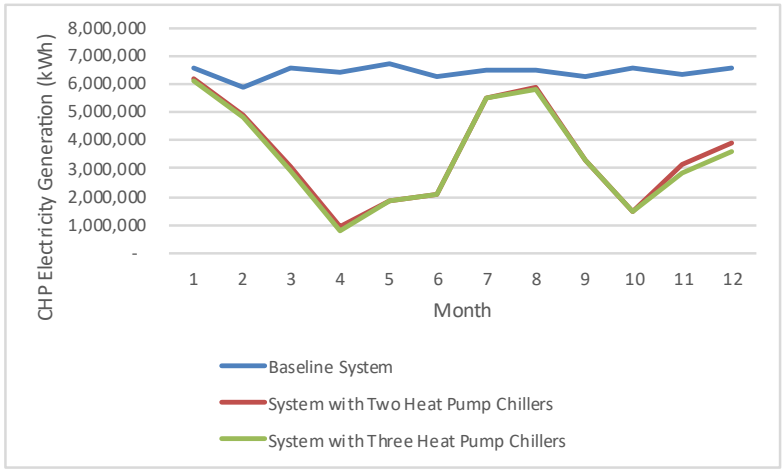
Campus Energy System using Thermal Storage



Campus Energy System Elements and Distribution to Buildings (source: Princeton University)



Modeling Schematic



Impact of Heat Pump System Implementation on Campus CHP Use

P. Lemar, N. Kunwar, J. Ling, M. Bhandari, Modelling and Analysis of Campus Energy System with Heat Pumps and Combined Heat and Power: Princeton University Case Study, Internal Report, 2024

Field Evaluations to Accelerate Market Adoption

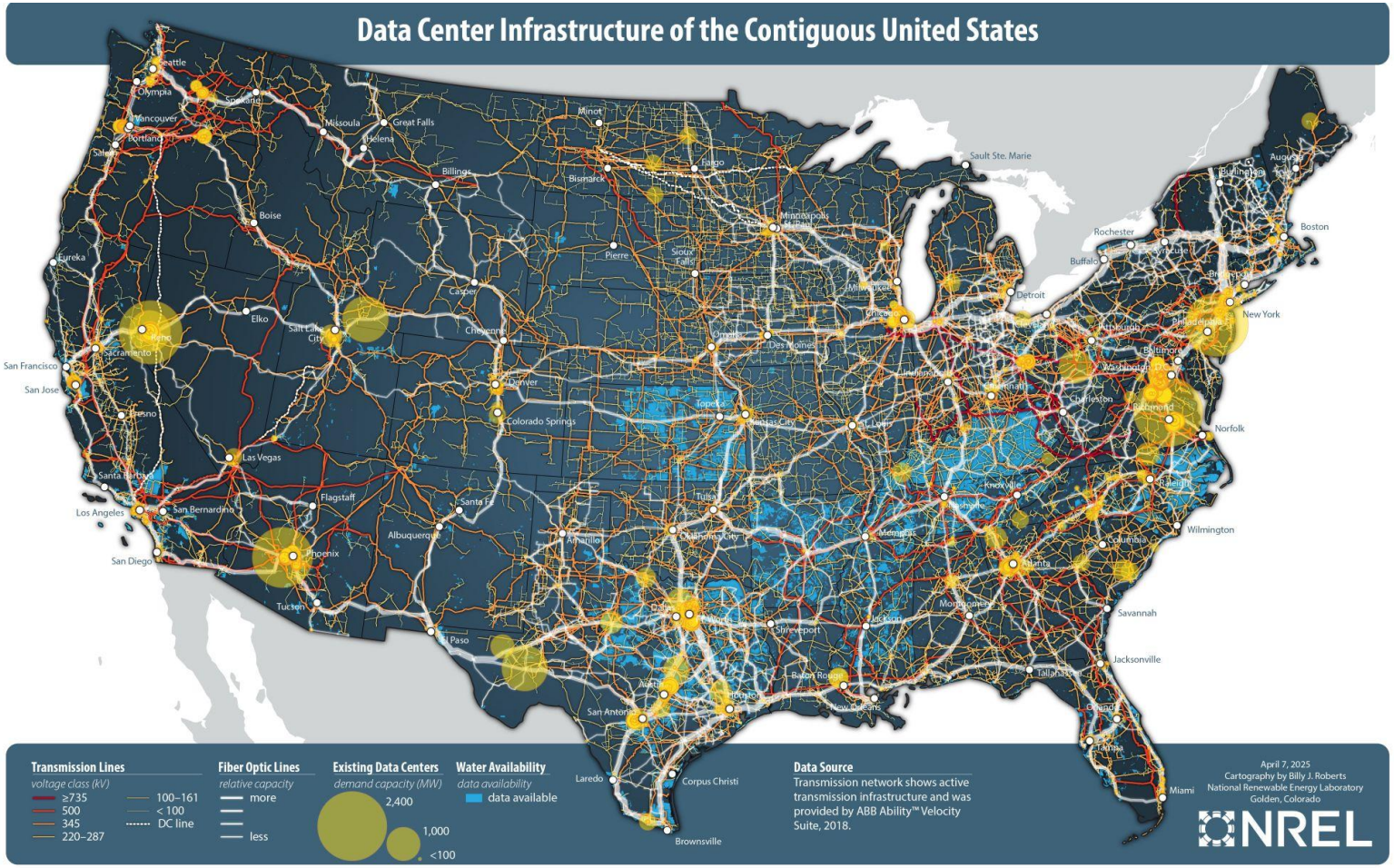
NREL has evaluated **geothermal** ground loops, evening installing them in our **Alaska campus** to understand performance in extremely **cold climates**

Through various programs such as Building America, NREL has assessed many different **residential technologies** including **envelope** and **advanced HVAC** for **prefabricated modular homes**

NREL has evaluated 100's of **commercial building technologies.** Working with commercial building owners like **Walmart, Target** as well as the major HVAC manufacturers, NREL is leading the **Commercial Building Heat Pump Technology Challenge** focused on **cold climate heat pump RTUs**.

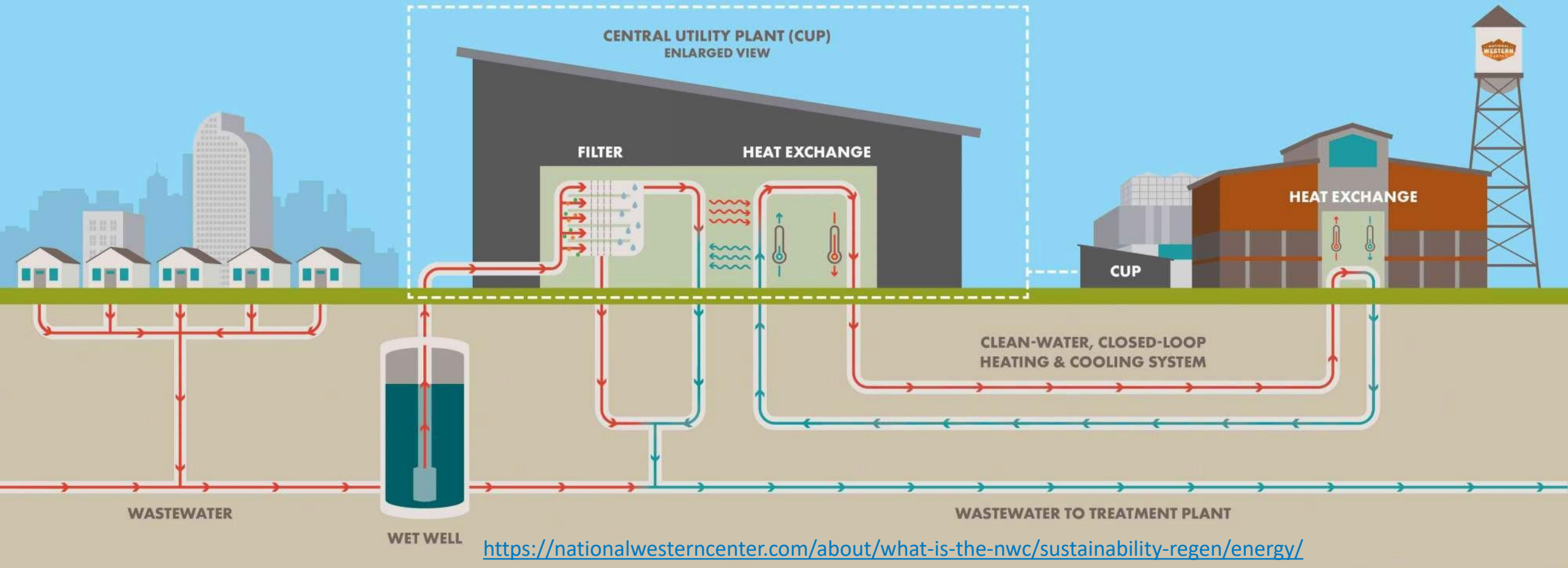
Analysis Addressing TEN benefits for Data Centers

- Analysis focused on data centers and regional- and national-scale issues that TENs can address:
  - Current and projected loads at data centers, compared with grid load capacity
  - Heat recovery potential from data centers vs. aggregated building heating demands
  - Simultaneous evaluation of electrical and thermal capacities and demands



DISTRICT ENERGY SYSTEM

HEATING AND COOLING USING A RECYCLED SOURCE OF THERMAL ENERGY — WASTEWATER



https://nationalwesterncenter.com/about/what-is-the-nwc/sustainability-regen/energy/

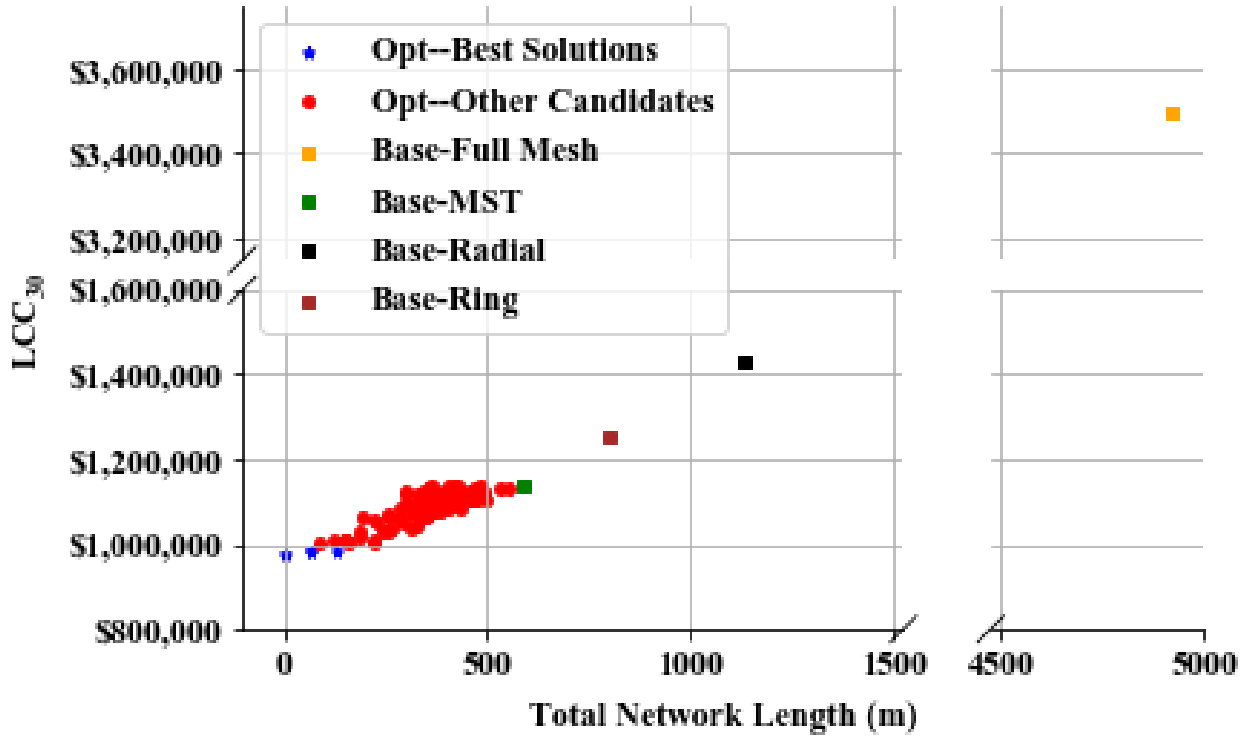
Case Study: Colorado Mesa University

- Colorado Mesa University, located in Grand Junction, Colorado, provides heating and cooling through GHP/TEN.
- 471 boreholes, 952 WSHP, provide 2728 tons heating and 3113 tons cooling.
- Total system cost since 2008 $20M. Estimated to save at least $1.5M energy costs annually.

Images from Xcel, 2022. “Evaluating a Community Ground Source Heat Pump System at Colorado Mesa University.”

Design Refinement: Network Topology Optimization

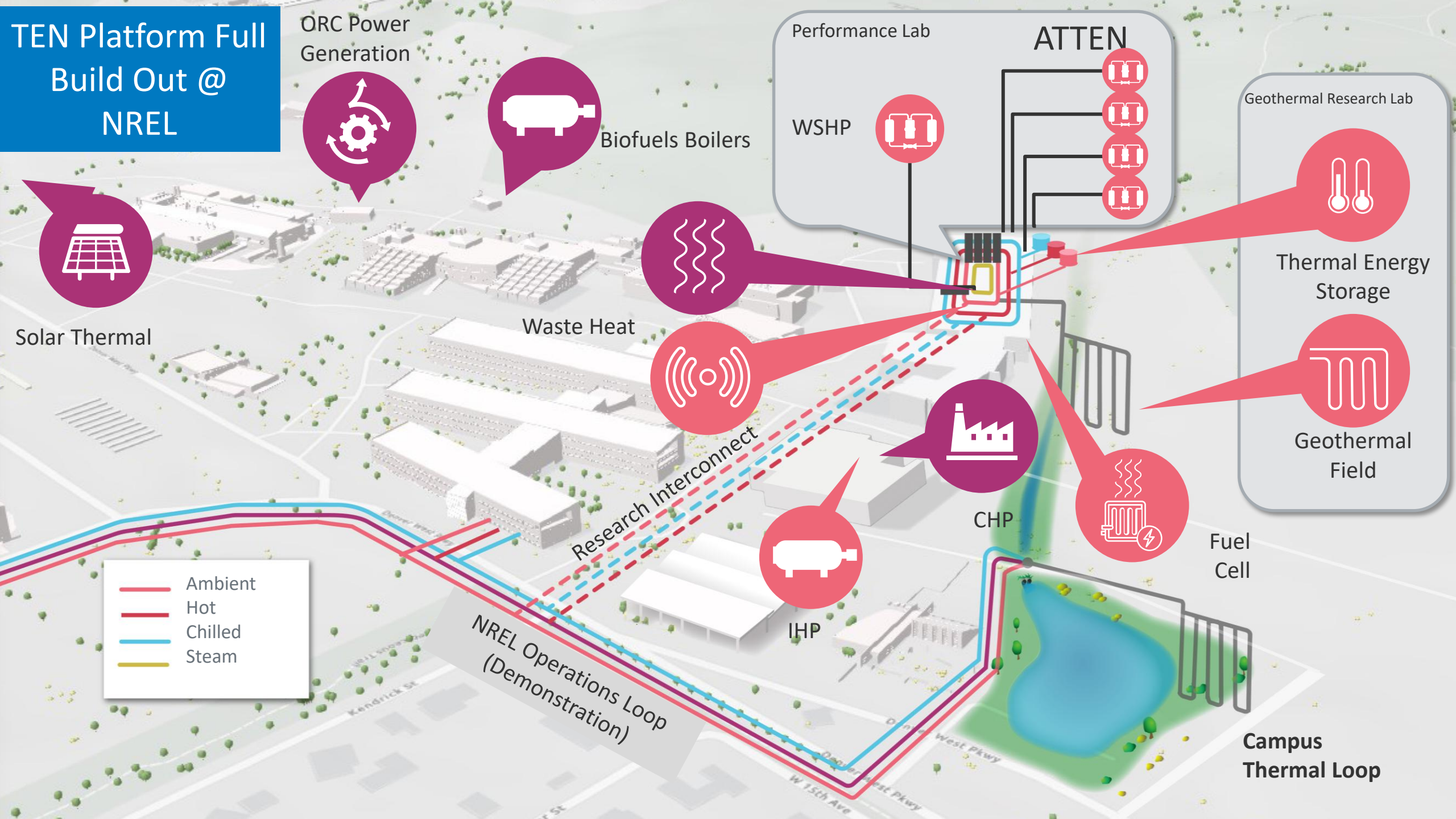
- NREL has developed a network topology optimization framework for TENs
- Wide variation (70%) exists in the life cycle cost (LCC) performance of different TEN configurations
- Research results indicate the strong influence of the selection of loads on the network energy and LCC performance



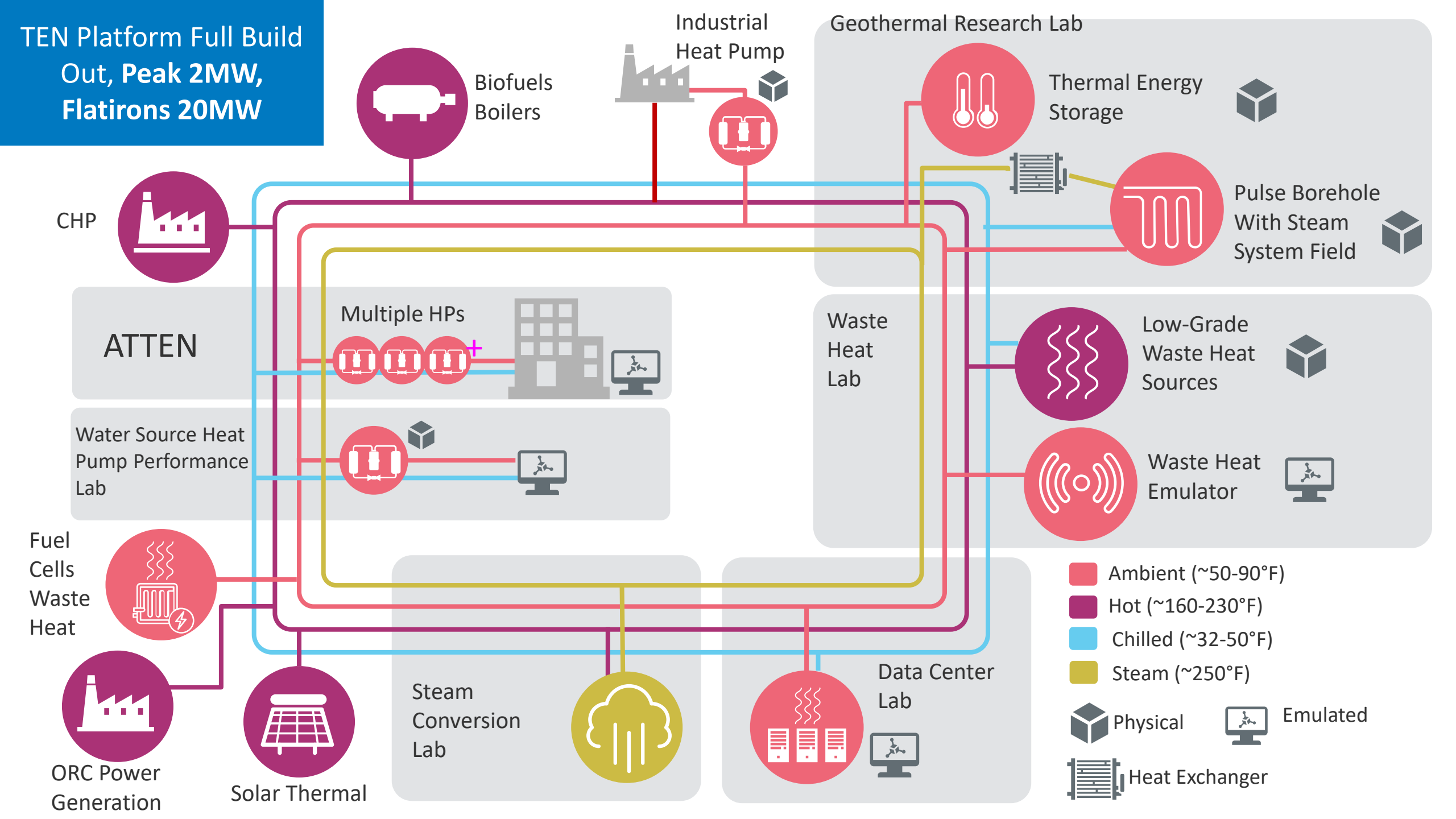
Allen et al. (2021)

NREL Thermal Energy Network Lab

Design and development in progress


TEN Platform Full Build Out @ NREL
ORC Power Generation
Biofuels Boilers
Performance Lab
ATTEN
WSHP
Geothermal Research Lab
Thermal Energy Storage
Solar Thermal
Waste Heat
Geothermal Field
Research Interconnect
CHP
Fuel Cell
IHP
NREL Operations Loop (Demonstration)
Ambient
Hot
Chilled
Steam
Campus Thermal Loop

TEN Platform Full Build Out, **Peak 2MW, Flatirons 20MW**



Demonstration

South Table Mountain campus and South Table Mountain Energy Park (STEP)
Demonstrations at STM and STEP

- Leverage $10M in FEMP's AFFECT funds received by NREL for capture of data center waste heat for heating of EMAPS at STM
- Leverage NREL's ongoing efforts to build an ambient loop serving building heating and cooling at STM
- Opportunity to further demonstrate technologies through renovations of existing buildings at STEP

Deployment

Local TENs Access to local state-of-the-art TENs

- NREL is in proximity to multiple TENs in use or under development including National Western Complex, Colorado Mesa University, University of Colorado Boulder, River Mile, CoorsTek
- Opportunity to evaluate systems in a "real-world" application and gather real-time performance data
- Opportunities to facilitate collaboration with industry around emerging technologies through the incubator