Initial System Measures for Thermal Energy Networks:

Measurement methodology has been inconsistent across the growing new geothermal network or Thermal Energy Network (TEN) ecosystem. To ensure accurate evaluation and true comparison, addressing this inconsistency must be a priority area for industry standardization. After careful analysis HEET proposes this set of standard measures and language for use with 'thermal energy networks'. (Specifically those thermal distribution systems with ambient temperature, single pipe 'loop' or ring design, and bidirectional energy flow.)

BUILDINGS PEAK LOAD$_{(1)}$ - The sum of all the individual building peak hourly loads met over a given year (BTU/hr, tons or kW_{th}), before connected to a Network (1). The peaks are non-coincident, and are reported for heating (H) and for cooling (C): BPL_{H1} & BPL_{C1}, if summed then BPL_1

> **BUILDINGS ANNUAL LOAD$_{(1)}$** - The sum of the absolute value of individual building hourly loads for heating and for cooling over a given year (BTU, ton-hr, or $kW_{th}hr$) before connected to a Network (1). $|BAL_{H1}|$ & $|BAL_{C1}|$, if summed then BAL_1

NETWORK PEAK LOAD$_{(1)}$ - The peak hourly load of the network 'loop' (1) that connected thermal resources must meet for both heating and cooling over a given year (BTU/hr, tons or kW_{th}), with all buildings connected. Reported for heating (H) and for cooling (C): NPL_{H1} & NPL_{C1}, if summed then NPL_1

> **NETWORK ANNUAL LOAD$_{(1)}$** - The absolute value of the sum of coincident hourly loads of the network 'loop' (1) that connected thermal resources must meet for heating and for cooling over a given year (BTU, ton-hr, or $kW_{th}hr$) with all buildings connected. Reported for heating (H) and for cooling (C): $|NAL_{H1}|$ & $|NAL_{C1}|$, if summed then NAL_1

Network loads require transient or semi-transient modeling tools to adjust summed coincident building load peaks for heat pump thermal energy flow, horizontal network pipe and pump thermal exchange, and thermal flywheel effects of the 'loop' for a given design temperature window.[1]

These definitions allow us to more accurately compare systems and understand costs, savings, scaling benefits, and minimum viable scale for investment.

- The BPL must be used for comparison to an alternate energy system(s)
- Comparisons (& life cycle assessment) must include both heating and cooling
- The NPL is related to system deliverability and the NAL is related to system capacity, together they are central to cost effective design and infrastructure investment
- The difference between building and network loads quantifies a new form of network energy efficiency that changes the evaluation of performance[2]
- Reducing the difference between modeled and actual network loads lowers costs
- All systems should report each load, clearly labeled. Abbreviations illustrated above.

[1] Additional connected network 'loops' (second, third, etc.) can result in lower network loads., which is a network scaling factor.
[2] The 'Network' COP(coefficient of performance) equation is not the standard 'Box' COP as the boundaries are different

<u>TECHNICAL NOTE</u>:

Geothermal Networks in Framingham, MA as an example of understanding Loads, Capacities, and Costs through the proposed System Measures:

Framingham as a Leading Example:

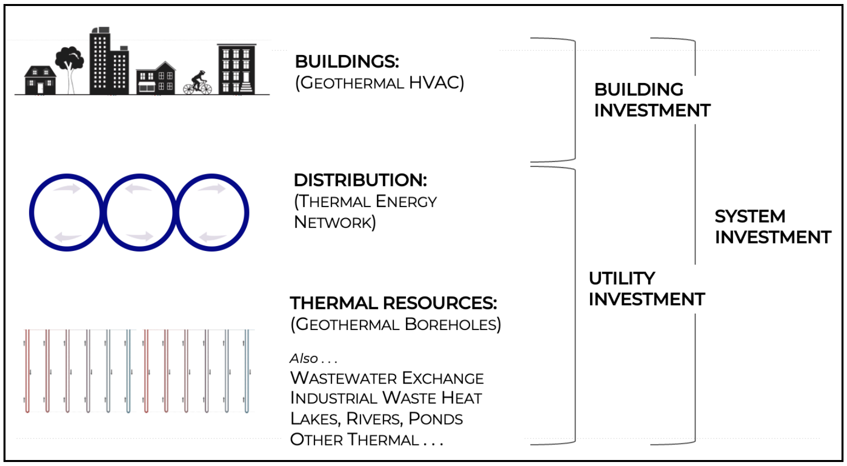
Eversource has been an industry leader on utility deployments of geothermal networks since 2019. Their Framingham Pilot went live in 2024 and the current expansion loop is awaiting regulatory approval. As these projects have progressed and the understanding of system modeling, performance, and loads have advanced, the reporting measures have also subsequently adjusted.

As a result, project information from one phase to the next may not be reported from the same set of assumptions, and thus needs some additional context to be properly analyzed. This challenge is further compounded by third party cost comparisons that may not always take into account different load methodologies, incentives, research funding outside of construction, and other project specific details. Which makes this Framingham project an excellent learning opportunity and a leading example, as it often is, to illustrate the need for an industry standard set of load measures.

Barriers to Cost Comparison between First and Second Installations:

1. **The two projects were filed using different size measures.** Loop 1's 375 ton figure is a CDMSmith desktop summation of estimated individual building peak heating loads produced for the original loop layouts. Let's call this the '*Building Peak Load*' for heating or BPL_{H1}. Loop 2's filed 250-ton figure is an interim version of the network's simultaneous load, or '*Network Peak Load*', as stated directly in Eversource's DPU 26-83 testimony ("expand the system capacity by approximately 250 tons"). This is a coincident value that incorporates network effects, rather than the summed building peak load as was filed for the first project. These are not directly comparable measures.
2. **The boreholes are of different types and designs.** The first installation has a mix of 'double U-Bend' angled boreholes and 'single U-Bend' vertical boreholes of varying depths, so borehole count is not directly comparable between first and second installations.
3. **Incentives are not (yet) included in the same way**. Loop 1's net cost reflects the IRA/ITC tax credit (-$7.29M) and MA Alternative Energy Credits (-$0.30M) already applied. Loop 2's ITC "has not yet been applied for", because that is not possible until system construction. An estimate of 30-40% of the construction costs, net of grant funding, is reasonable as federal dollars awarded are not eligible for the ITC.
4. **Awarded dollars for Loop 2 include non-construction spending** but could be easily misinterpreted as fully construction or design costs. Of Loop 2's awarded DOE funding, per Eversource's testimony, there is "a portion of the grant dedicated to workforce development" and similarly other non-construction costs such as a large grid measurement and impacts research project. Total grant or award is not construction cost.
5. **Pilot costs include non-construction spending** as all costs associated with the project are reported within the pilot period, including operations and maintenance for example.
6. **Initial Building Loads were updated during expansion design** for several buildings. This requires carefully using a consistent version of building loads for any direct comparison.

7. **Costs must be 'Functionalized' or categorized as a foundation of cost causation** and to accurately identify real cost drivers. Comparing distribution and thermal resource functions by building load measures avoids individual buildings driving non-representative cost differences.



CAPEX Comparison of Utility Investment using BPL & NPL Measures

Figures below are drawn from the DPU 21-53 Updated Pilot Budget (First Network Loop, 3/29/24) and Eversource's DPU 26-83 Exhibit ES-GEO testimony (Second Network Loop, 5/18/26)

Construction Cost Category	Network Loop 1 (installed)	Network Loop 2 (proposed)
Borefield / Drilling	$9,626,105	$4,036,500
Mains / Loop Distribution	*(incl. above)*	$1,953,800
Pump House / Vaults / Civil	$5,460,000	$2,251,126
Design / Engineering Support	$1,800,000	$750,000†
Monitoring & Controls	$930,000	$776,250
Utility-Side Subtotal (pre-incentive)	$17,974,693	$9,267,676
Buildings Included in BPLs	36 (22 residential + 9 FHA + Farley + 4 commercial)	44 (30 res., 13 FHA, 1 school)
2022 Filed Building Peak Heat Loads BPL_H	~375 tons (1319 kW_{th})	~ 421 tons*(1481 kW_{th})
Prior Filed Network Peak Heat Loads NPL_H	~217 tons**(763 kW_{th})	~ 295 tons**(1038 kW_{th})
2026 UPDATED BUILDING LOADS		
Adjusted Building Peak Heat Load $\boldsymbol{BPL_H}$	~257 tons (904 kW_{th})	~350 tons (1231 kW_{th})
Adjusted Network Peak Heat Load $\boldsymbol{NPL_H}$	~ 105 tons**(369 kW_{th})	~ 193 tons**(679 kW_{th})

† This includes both the filed $250K as well as the $500K of prior Federal Award to HEET for the initial 60% design.

*DPU 21-53 - Eversource Phase II Quarterly Report (5-27-22) Appendix A: Site Plans
**Outputs from Transys modeling tool for each loop on its own

Example statements based on use of the BPL & NPL Measures:

Once the load basis is clarified by using BPL & NPL Measures, and the incentive treatment and cost scope are normalized, we can safely state that the expansion network infrastructure is substantially lower cost than the initial network. (*grey is outdated building loads*)

1. Utility Infrastructure Cost, pre-incentives:
   First Network Loop ≈ $18M vs. Second Network Loop ≈ $9M:
   The cost of the second loop utility infrastructure is roughly half of the first! (50%)

2. Per Eversource's testimony, the expansion is characterized as "roughly doubling" the existing network's capacity, which is true with both old and new building loads in tons[3]:
   BPL_{H1} = 375 and BPL_{H2} = 421: (112%) and BPL_{H1} = 257 and BPL_{H2} = 350: (136% of the first)
   The expansion more than doubles peak heating load met!

3. The $/BPL ton of thermal service (heating and cooling) drops from an infrastructure cost of $37.5K/ton for the pilot to $14.2K/ton for the expansion[4] (62% reduction)
   The cost/ton of expansion infrastructure is less than half of the initial pilot!

4. We can also begin to understand how networking has reduced thermal resource need by subtracting total (both installs) NPL_{1+2} 758 tons from BPL_{1+2} 1132 tons resulting in **an estimated thermal peak load reduction of 374 tons, or 33% less, by networking.**

The use of these measures in comparing between Framingham's initial pilot and pilot expansion geothermal networks is a clear, concrete illustration of why the proposed standard measures are needed. Absent these measures, it is easy for well-intentioned cost transparency efforts to inadvertently draw a misleading conclusion. Widespread reassessment of existing projects nationally to clarify the loads and capacity measures used will help us all learn faster as well as better understand how best to improve performance and affordability rapidly.

Enormous thanks to the LeGUp Research Consortium, HEET team, and Eversource team for the research, data collection, and progress that informed this memo, as well as the MassCEC, U.S. D.O.E., and the Massachusetts public who supported this research and the first utility geothermal networks.

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[3] HEET strongly recommends switching all use of 'TONS' and 'BTUs' measurement units to Kw and KwH thermal measurement units in order to better enable integrated planning and improve understanding of thermal energy resources utilized, however we use tons here to match the units in the regulatory docket referenced.

[4] Pilot: $18M / ($BPL_{H1+C1}$ = 257+222=479) = 37.5K $/ton, Expansion: $9M / ($BPL_{H2+C2}$ = 350+303=653) = 14.2K $/ton