
A
BETTER
CITY
BUILT TO LEAD:
LESSONS IN BUILDING DECARBONIZATION
NEW TECHNOLOGIES & OPPORTUNITIES
LEARN MORE HERE

BUILT TO LEAD: LESSONS IN BUILDING DECARBONIZATION AND RESILIENCE

1. September 24, Built to Lead: Lessons in Building Decarbonization in Existing Buildings

2. October 30, Built to Lead: Lessons in Building Decarbonization in New Construction

3. December 17, Built to Lead: Lessons in New Technologies and Opportunities

4. February 3, 2026 Built to Lead: Lessons in Deconstruction and Embodied Carbon, @ 10-11:30AM Location TBD
   - Dennis Carlberg, Chief Sustainability Officer & Associate Vice President for Climate Action, Boston University – *Retrofit of BU's Warren Tower*
   - Irmak Turan, Associate, Climate and Sustainability, Arup – *Circularity and embodied carbon at airports*
   - Caroline Murray, Regional Sustainability Manager, Turner Construction Company – *Deconstruction and reuse of office space*
   - Andrew Thompson, Interim Executive Director, Boston Building Resources – *Material donation and reuse*

5. Built to Lead: Lessons in Resilience, TBD

A BETTER CITY

AGENDA

10:00 AM	**Kate Dineen, A Better City**—Welcome
10:02 AM	**Yve Torrie, A Better City**—Introduction
10:06 AM	**John E. Fernández, MIT**—*AI building envelope evaluation*
10:18 AM	**Zeyneb Magavi, HEET**—*Thermal energy potential of water sources*
10:30 AM	**Colin Schless, Turner Construction**—*Hybrid electrification*
10:42 AM	**John Kastrinos, Haley & Aldrich** and **Jacob Knowles, BR+A**—*Right sizing of geothermal energy projects*
10.54 AM	**Q+A**
11:30 AM	**Event Concludes**

JOHN E. FERNANDEZ, MIT

ZEYNEB MAGAVI, HEET

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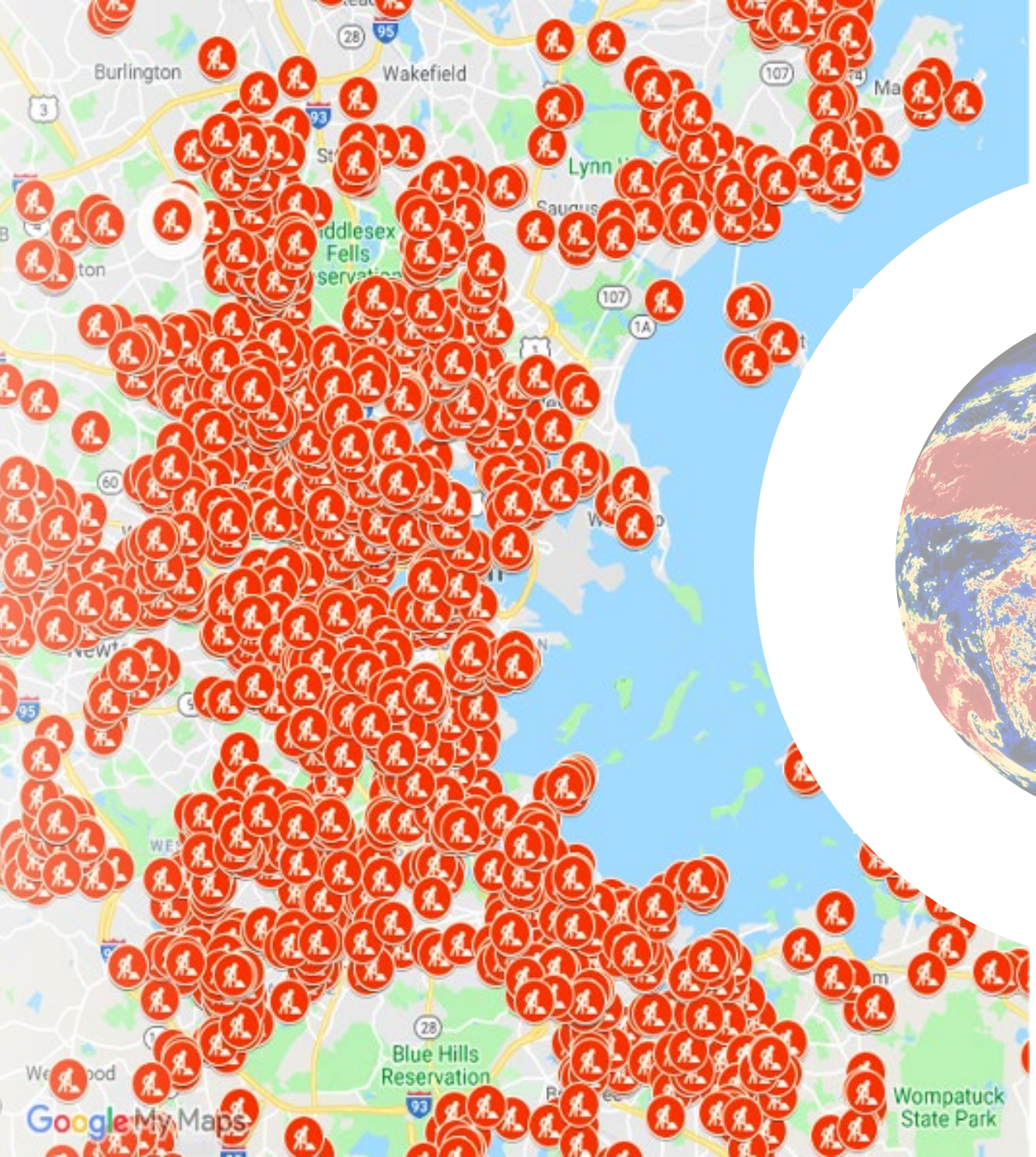
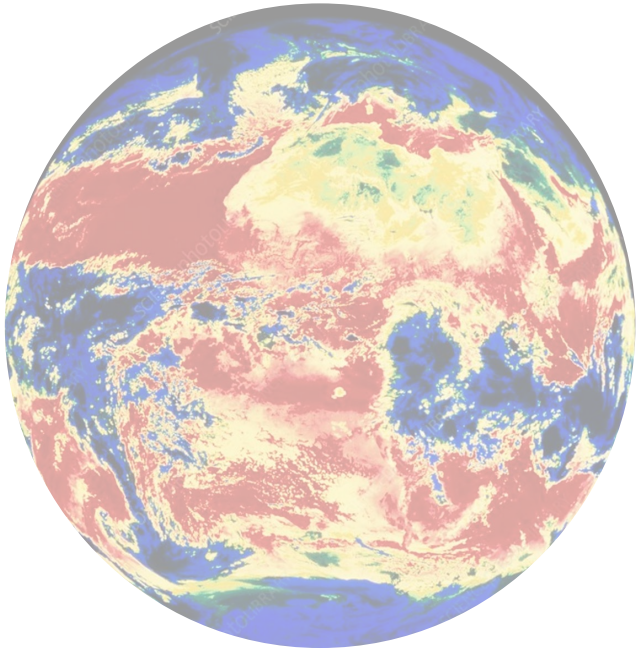
The Thermal Energy Opportunity





Connecting the challenge of ‘end of life’ infrastructure to climate change to the thermal energy opportunity?

Ambient geothermal energy IS earth’s temperature.

Every year our earth absorbs over 10 times the energy all of humanity uses/year.

As Thermal Energy.

Tapping it can multisolve

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Engage All Stakeholders

Identify System Levers

Innovate & Iterate to Align

MOVES AT SPEED OF TRUST

DEMONSTRATED

- ☑ High Safety & Security
- ☑ 100% Combustion-Free
- ☑ Reliable & Resilient
- ☑ Scalable & Adaptable
- ☑ Workforce Transition
- ☑ Ethical Distribution
- ☑ Affordable for consumer
- ☑ Economic for utility
- ☑ Speed & Scale needed
- ☑ Benefits Electric Grid

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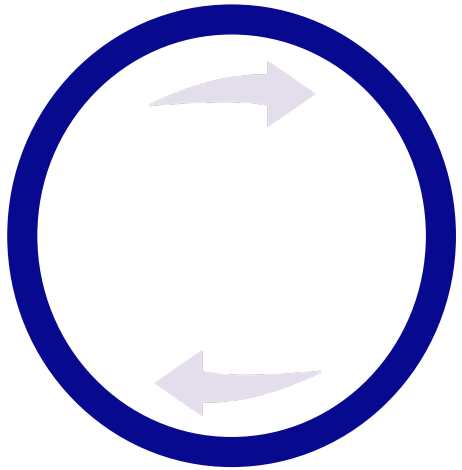
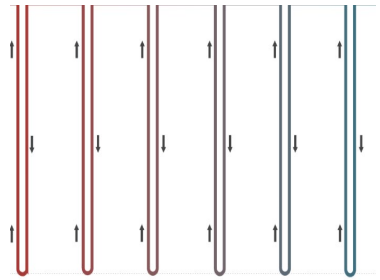
BUILDINGS :
(GEOTHERMAL HEAT PUMP)



DISTRIBUTION LOOPS:
(THERMAL ENERGY NETWORK)



THERMAL RESOURCES:
(GEOTHERMAL BOREHOLES)

Also . . .
WASTEWATER EXCHANGE
INDUSTRIAL WASTE HEAT
LAKES, RIVERS, PONDS
OTHER THERMAL . . .

HOW DOES A THERMAL ENERGY NETWORK TAP THERMAL ENERGY ?

Every component of a Geothermal Energy Network contributes efficiencies. Together they are the most efficient heating and cooling.

Each component is OLD TECH.

Together they are NEW TECH

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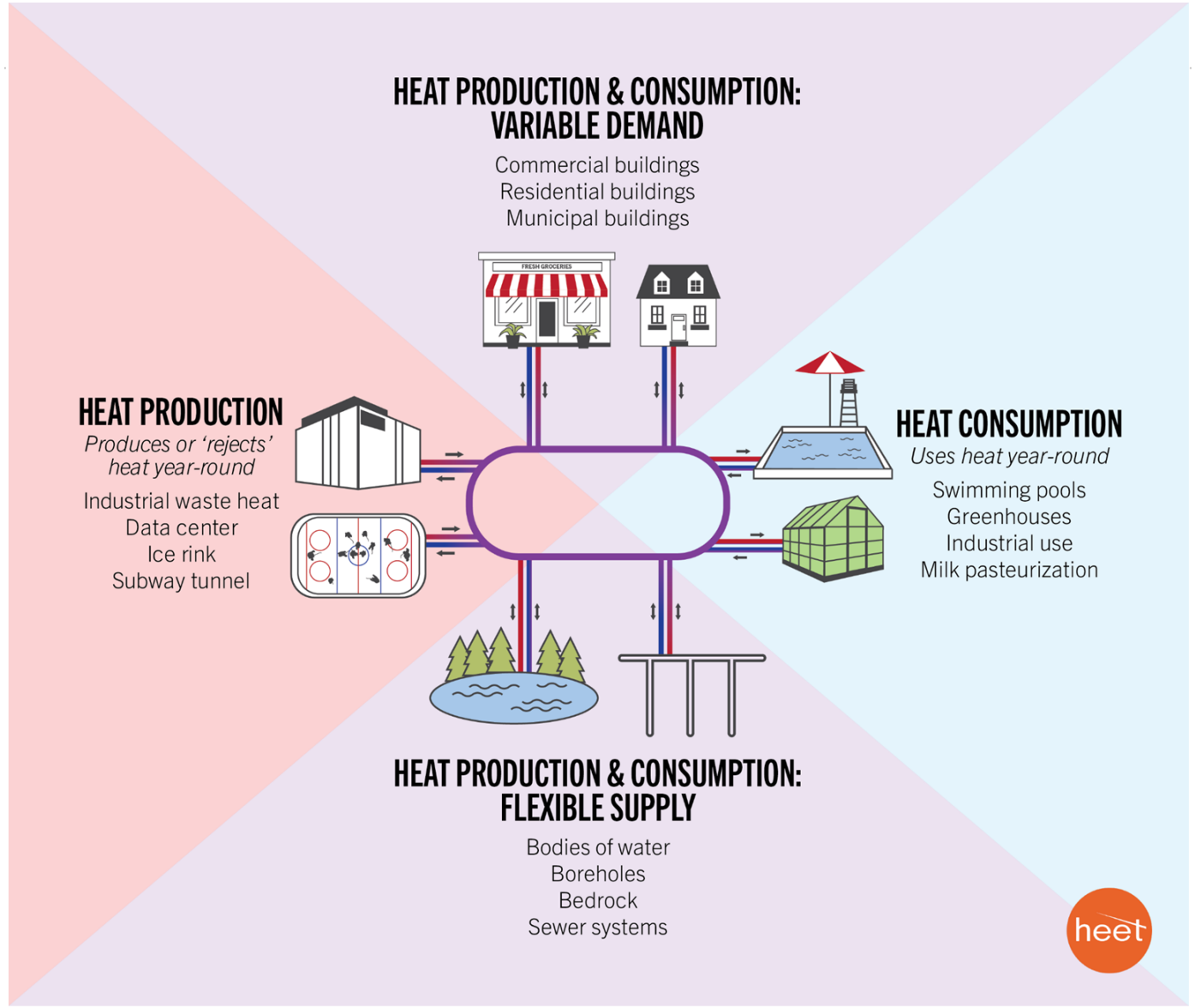
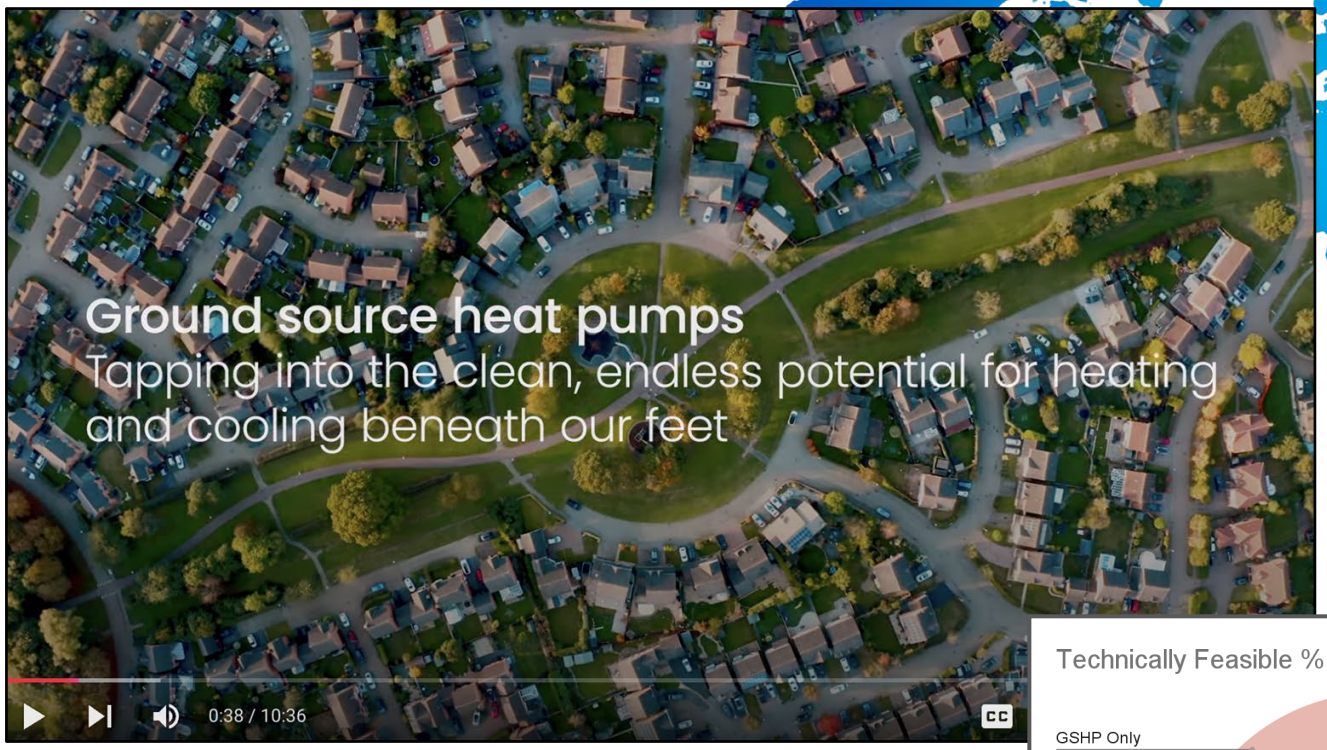


WHAT IS A THERMAL ENERGY RESOURCE ?

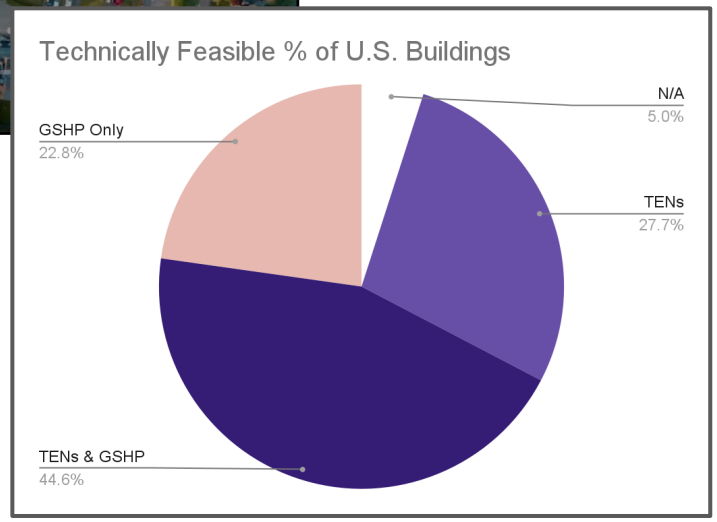
A thermal utility should prioritize closest, least cost thermal resources. The defining parameters are illustrated in four quadrants.

The flexible supply quadrant is the MOST valuable resource.

Magavi, Z., Alberto Escobar, A., and Varela, I. (2024). A Definitional Taxonomy for (Geo)Thermal Energy Networks, GRC Transactions, Vol. 48.



https://www.youtube.com/watch?v=mvOoBL-et7U

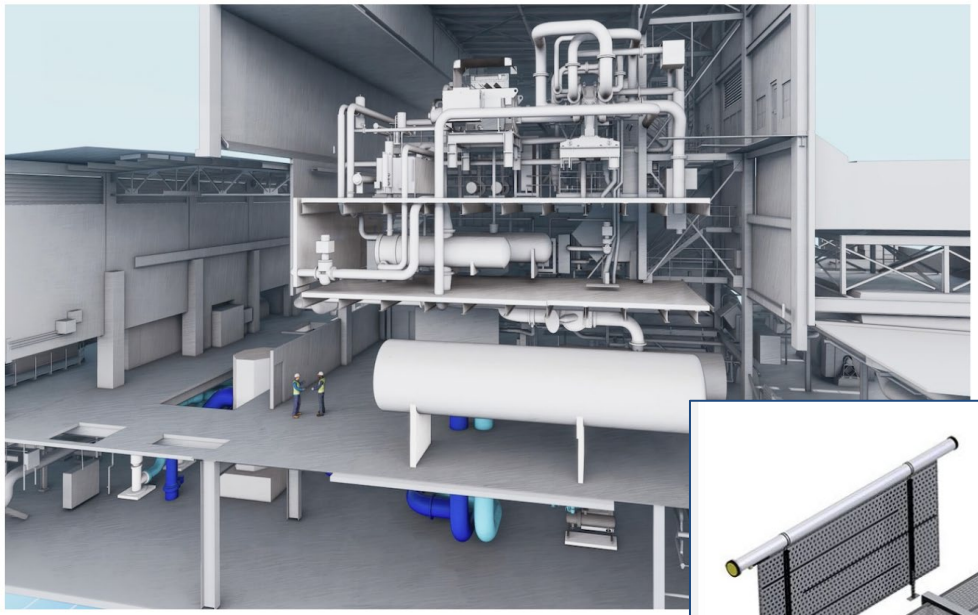


The World Bank Group's International Finance Corporation has initiated in seven countries a program to scale investment in geothermal networks at the 10,000 building scale.

HEET's utility growth model unlocking the financing of geothermal has "awakened a sleeping giant"

Press Release | Vicinity Energy | November 4, 2025

Vicinity Energy Commences Construction of Industrial-Scale Heat Pump Complex in Partnership with DCO Energy and Everllence



Värtan Ropsten – The largest sea water heat pump facility worldwide, with 6 Unitop® 50FY and 180 MW total capacity

Client

AB Fortum Värme samägt
med Stockholms stad
11577 Stockholm, Sweden

Stockholm's district heating system

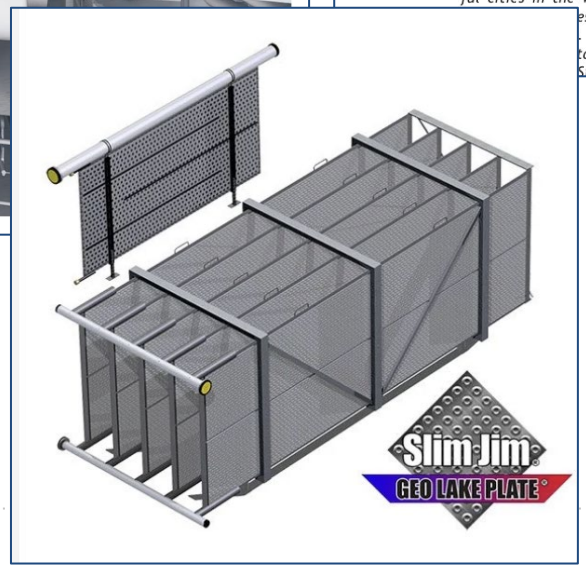
Stockholm, the Royal Capital of Sweden, is situated on 14 islands and is considered as one of the most beautiful cities in the world. Its clean sea
esult of stringent en-
. The district heating
tal part of the total
Stockholm.

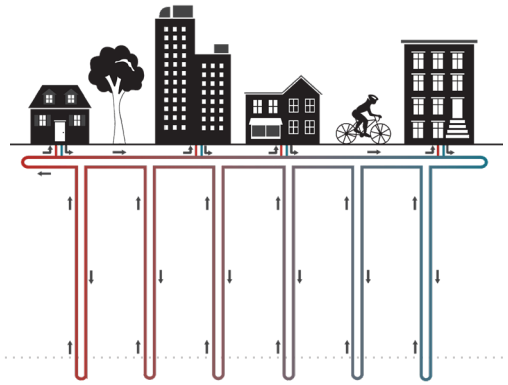
Heat supply for District Heating

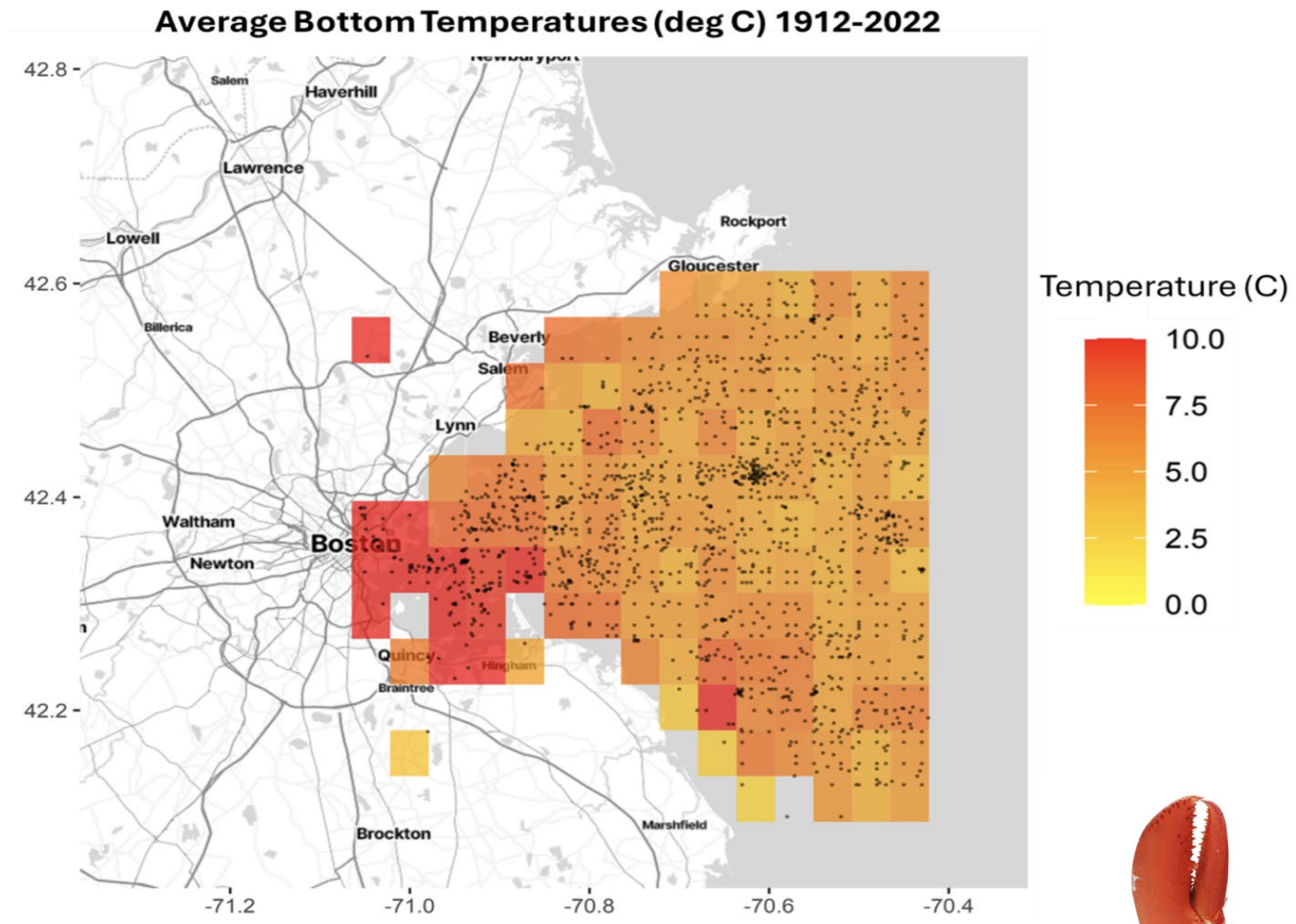
Plant	Network	Heat
Värtan	Central	2,600 GWh

The heat pumps (total 420 MW) are used for base load production along with the bio fuel-fired plants (total 200 MW). Oil-fired plants are used in times of high energy demand only.

Fortums district heating production system is increasing the use of bio fuels and solar energy sources. In addition, for large heat pumps, hydro-electric power is utilized. All these measures add up to nearly 50% of renewable energy used for the production of district heat.



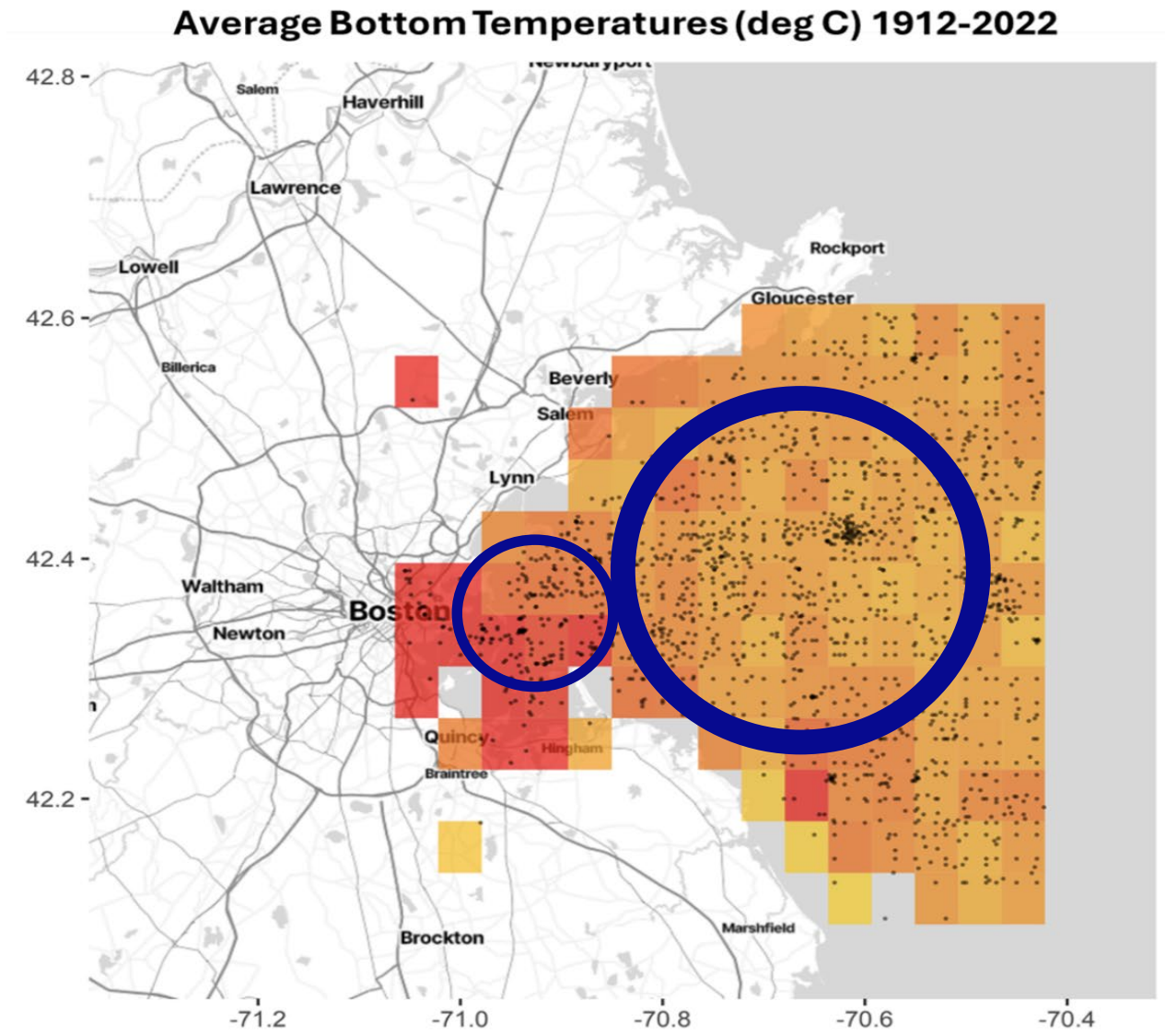




According to NOAA data, Boston Harbor is 3.4 degrees Celsius warmer than in 1912.

That is enough heat for over 1 Million homes annually.

It might even make lobsters think Boston is cool again.



HEET is proposing that the quantification and mapping of thermal energy resources allows thermal energy planning, which communicates the scale of the opportunity.

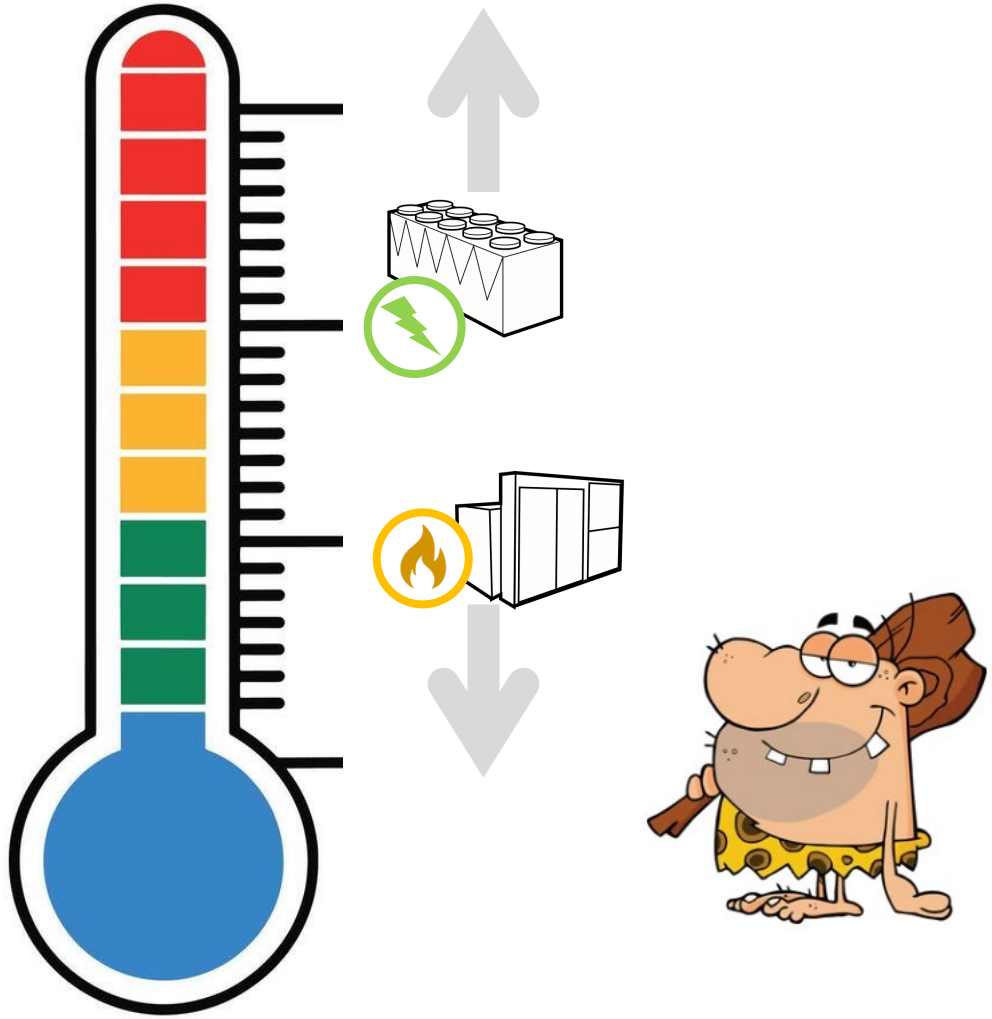
The availability of local energy with no price volatility, total stability, and no global security implications... and also no emissions and significant grid benefits... can be unlocked incrementally.

#ThinkThermalTogether

Zeyneb.Magavi@heet.org

Want Geo Service?

COLIN SCHLESS, TURNER CONSTRUCTION



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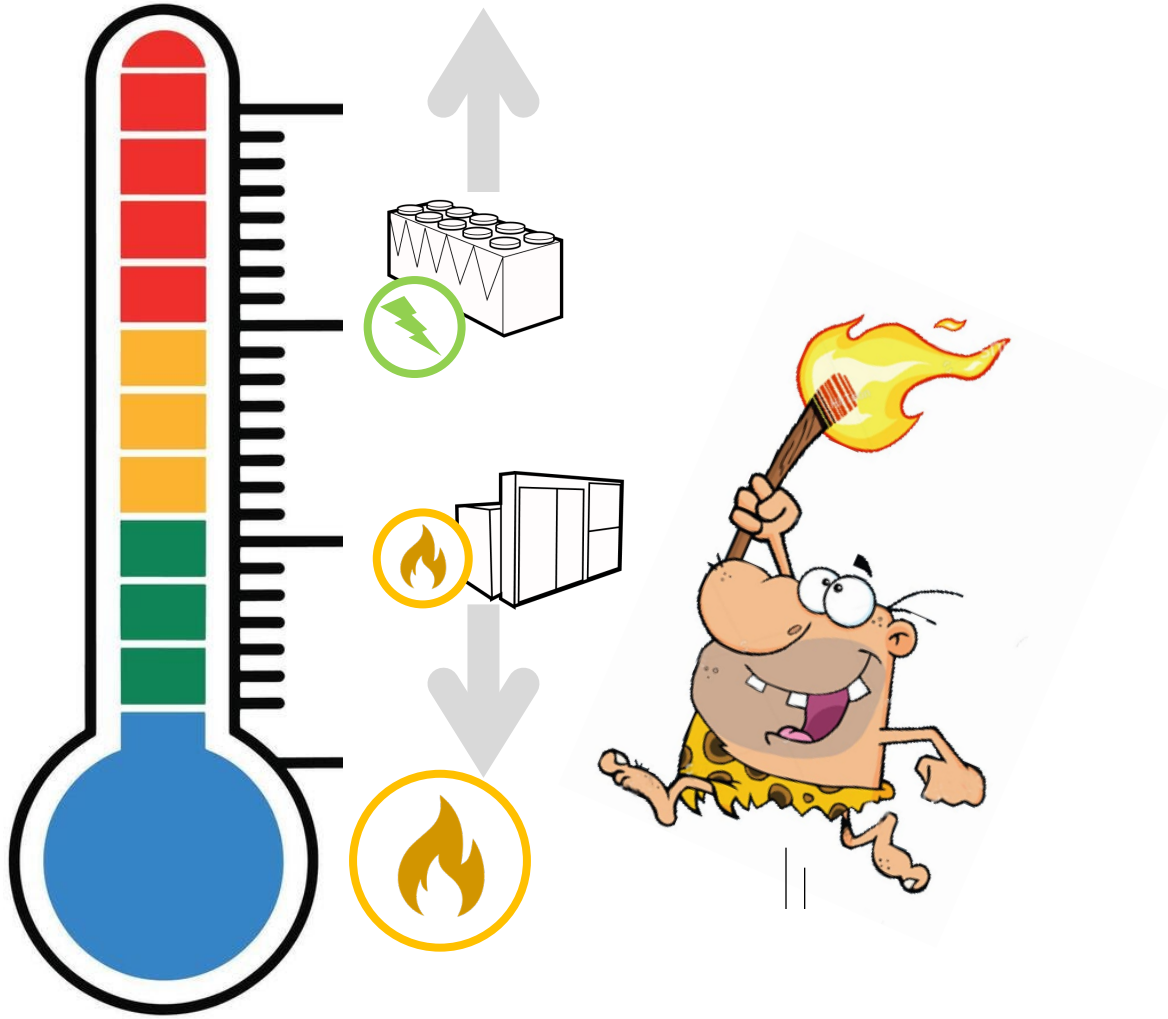

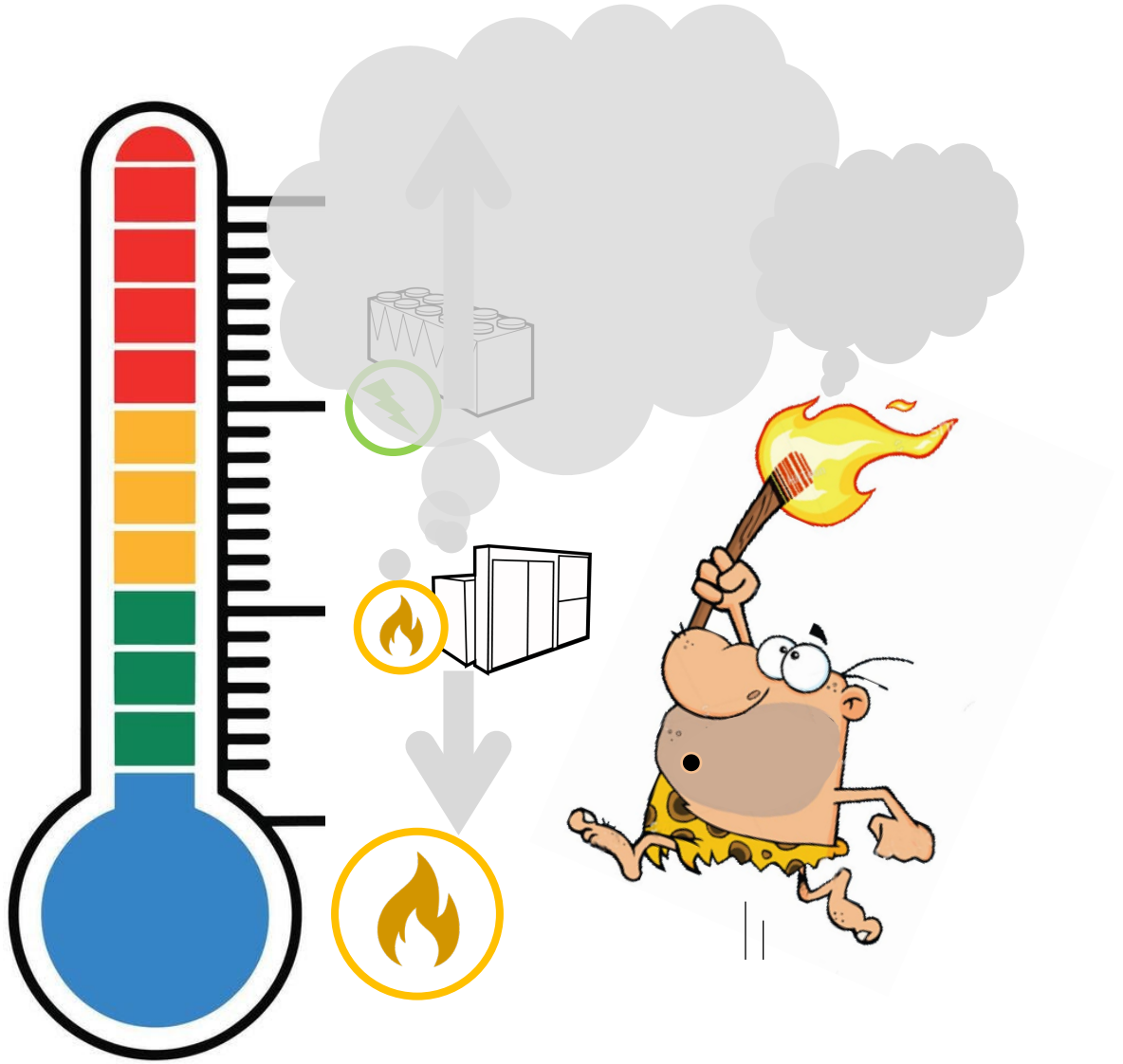

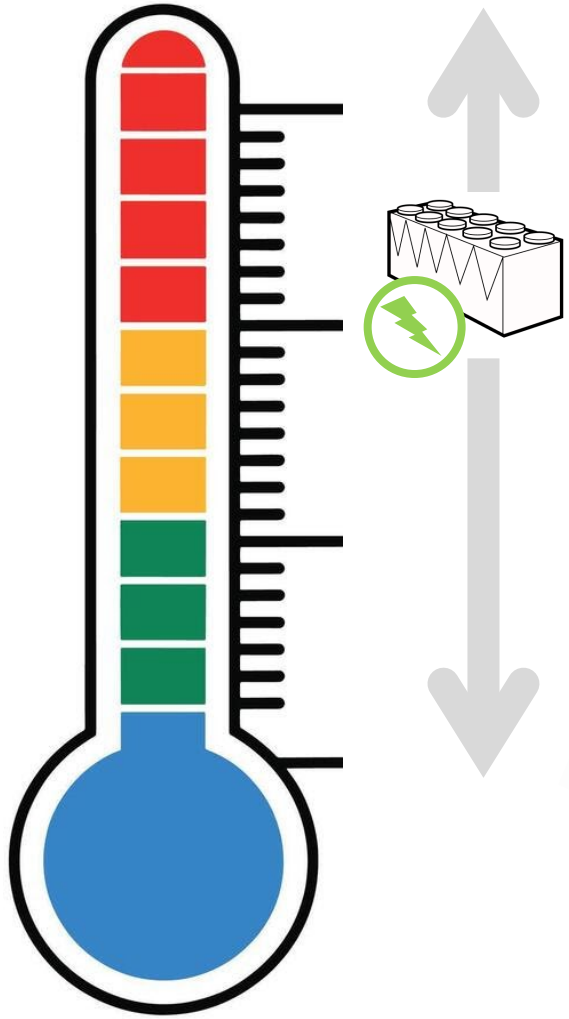

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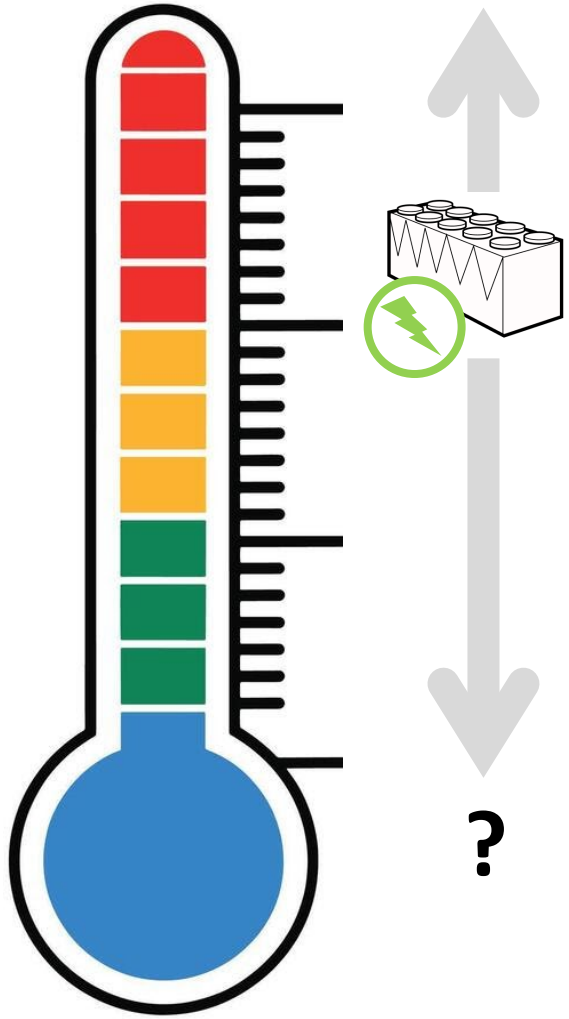

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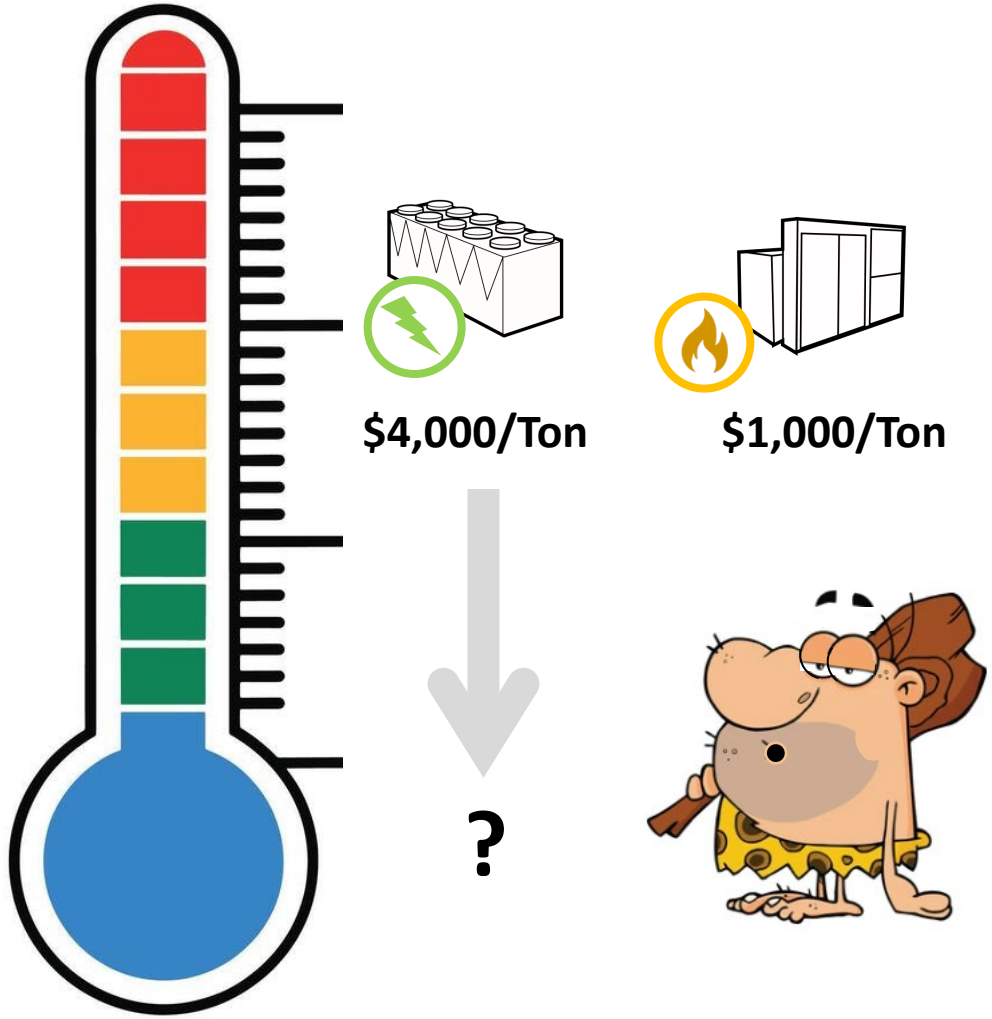

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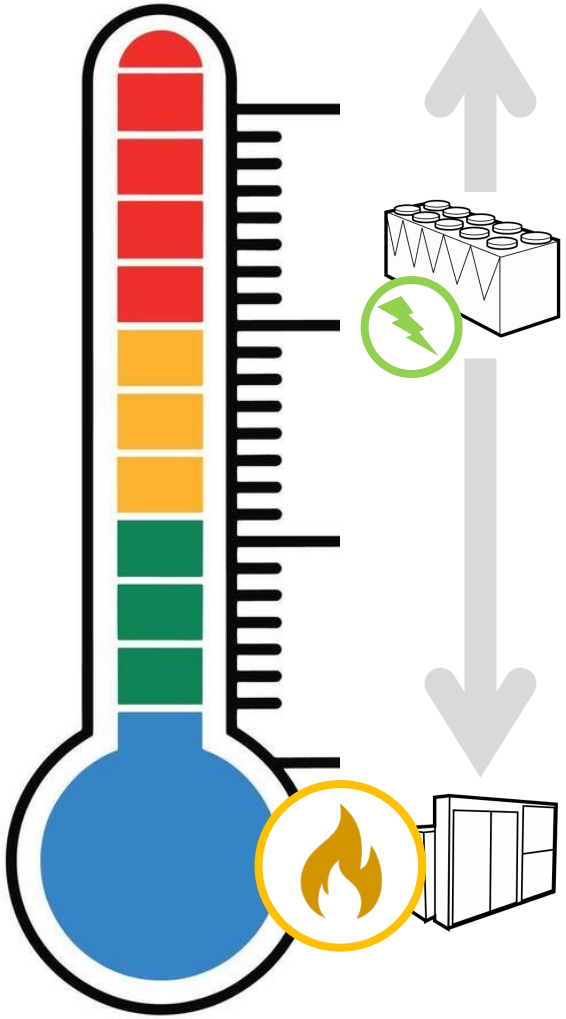

Hybrid Electrification

Turner

225 CMR

C401.4 *Add Section as follows:*

C401.4 Building electrification. Building projects which utilize Section C407.2.1 shall conform with C401.4.1. Building projects which utilize Section C402.1.5.2 shall conform with C401.4.2 except for buildings using the Relative Performance pathway because average ventilation at full occupancy is greater than 0.5 cfm/sf which shall comply with C401.4.1 rather than C401.4.2. Building projects which utilize Section CC104.1, Part 1 shall conform with C401.4.3.

C401.4.1 Partial space heating electrification. Electric air source, *exhaust source*, or ground source heat pump systems shall supply 25% of the building's peak space heating and ventilation air heating load at the ASHRAE 99.6% winter climatic design condition. Heat pumps used for space and ventilation air heating shall comply with C401.4.4.

C401.4.1.1 Heat pump primary operation. The heat pumps shall be controlled to prioritize their primary operation, prior to operation of supplemental fossil-fuel equipment, during non-emergency conditions.

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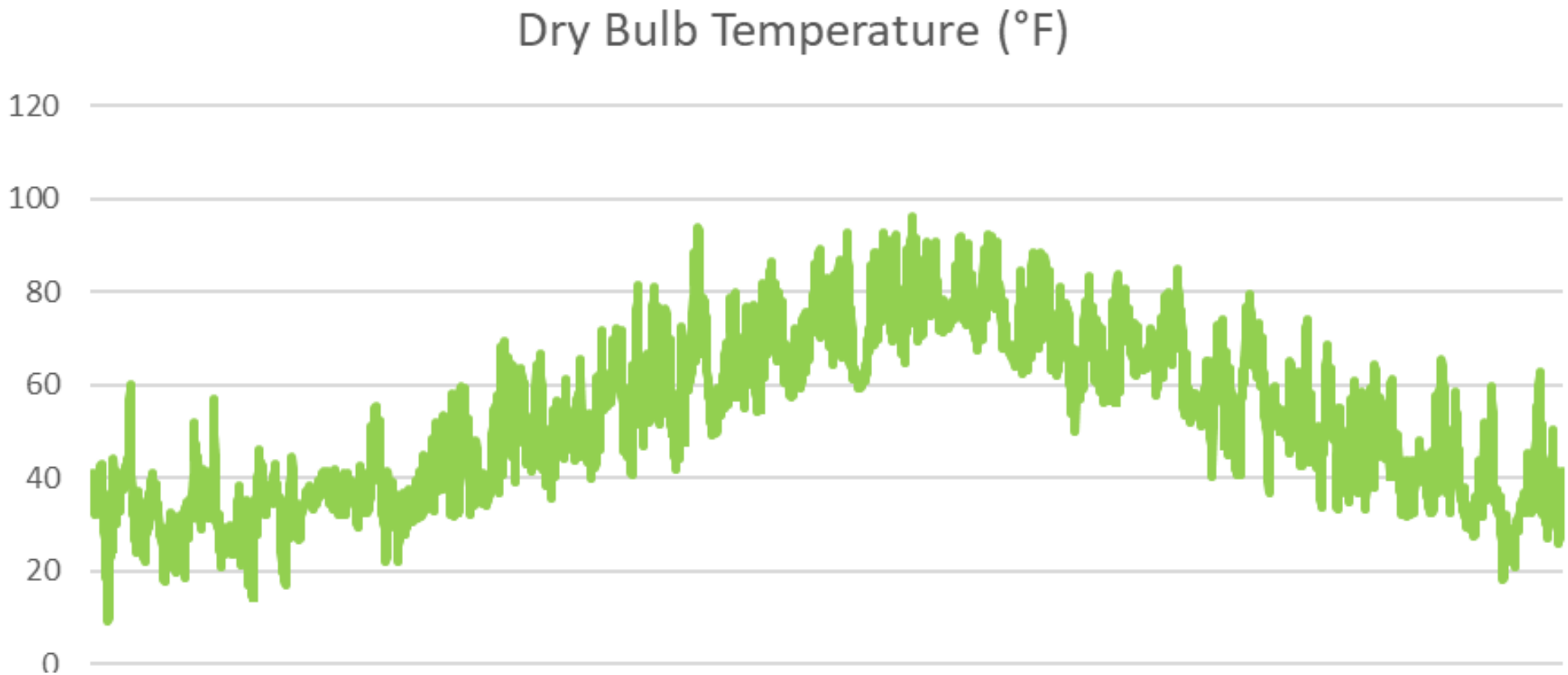

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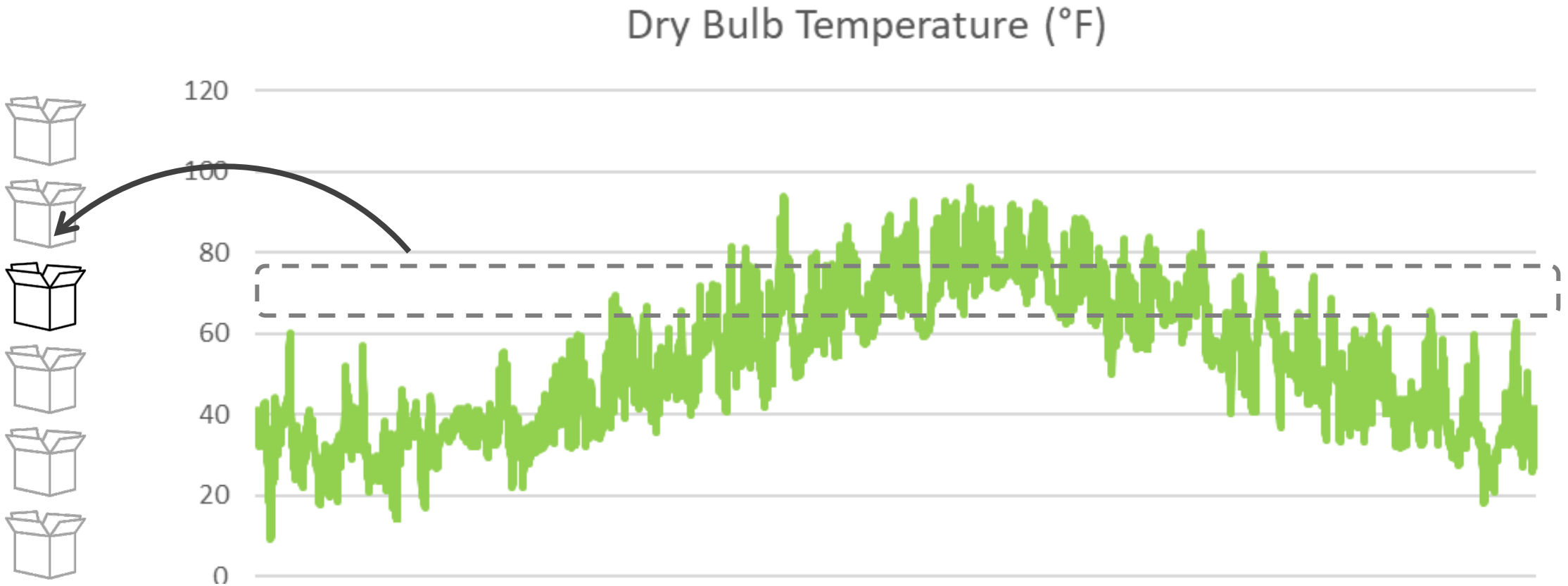

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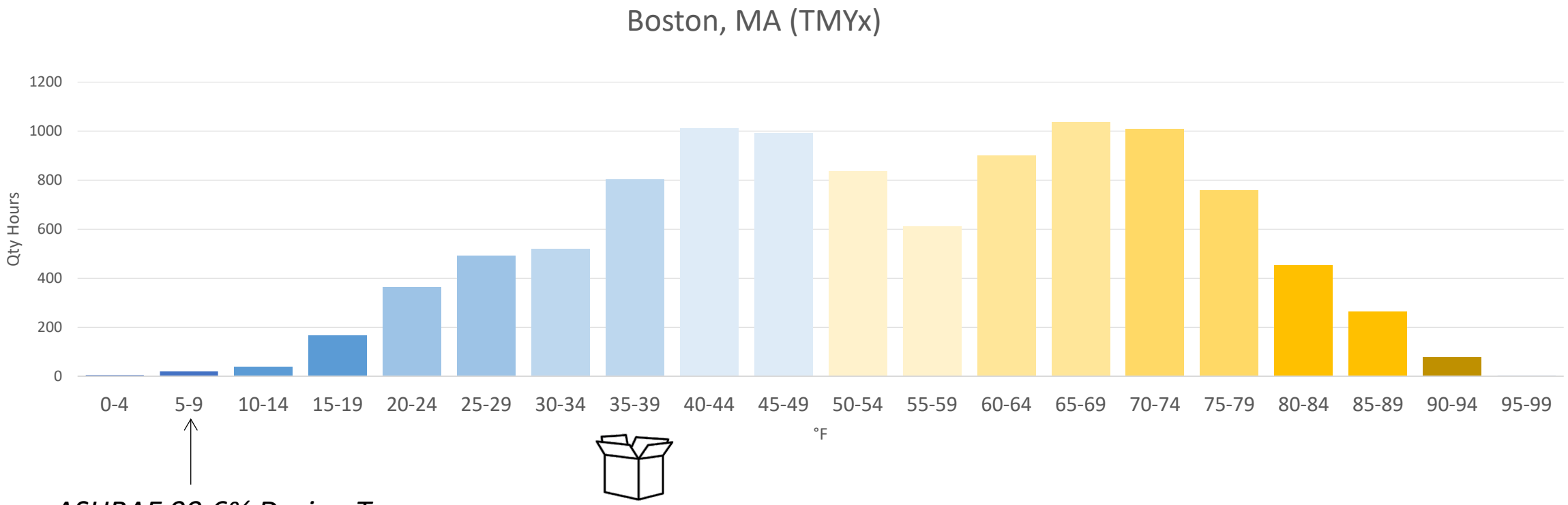
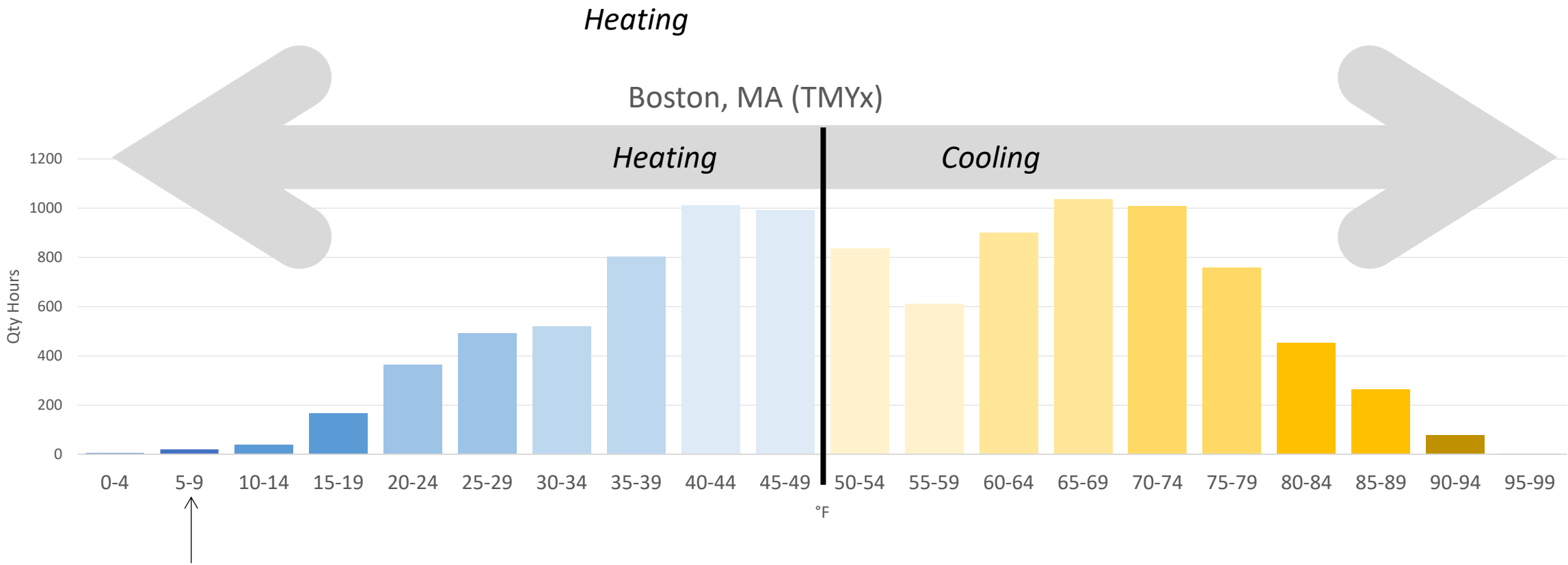


ASHRAE 99.6% Design Temp
= 8.4°F

Turner



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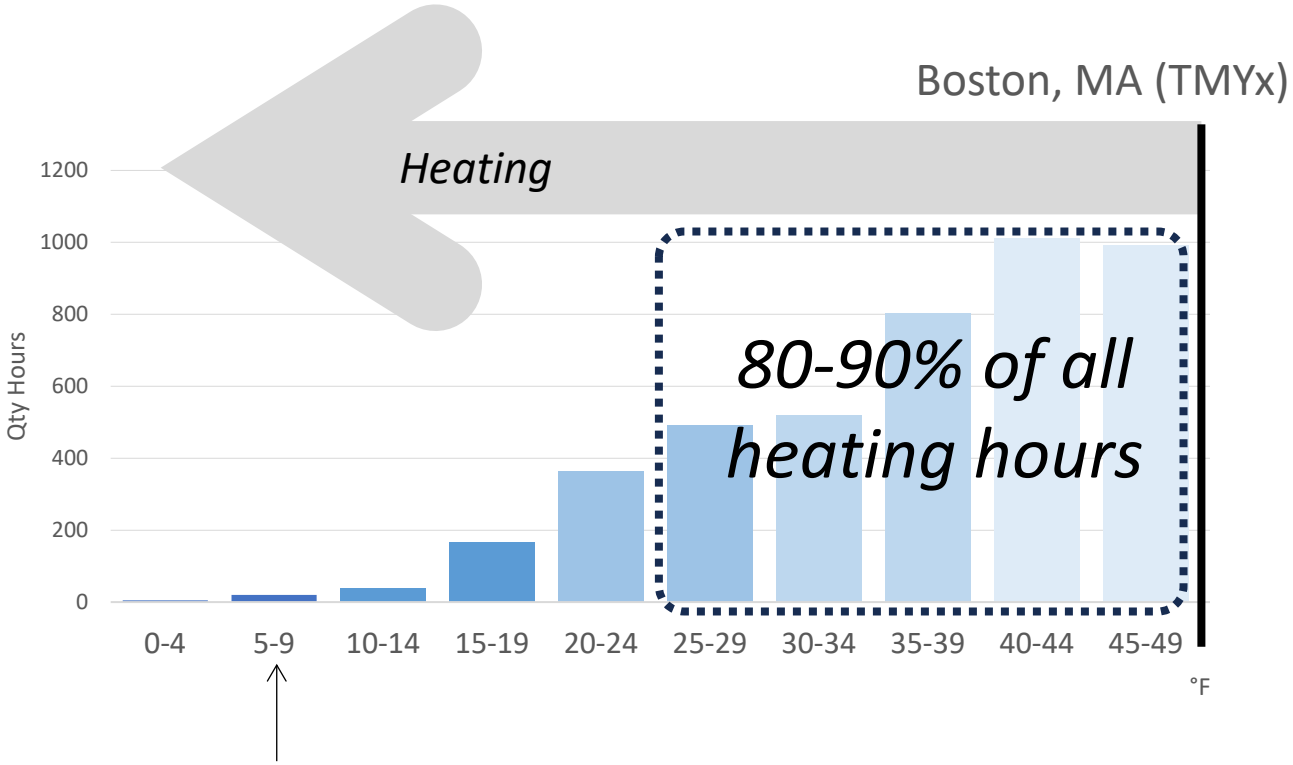

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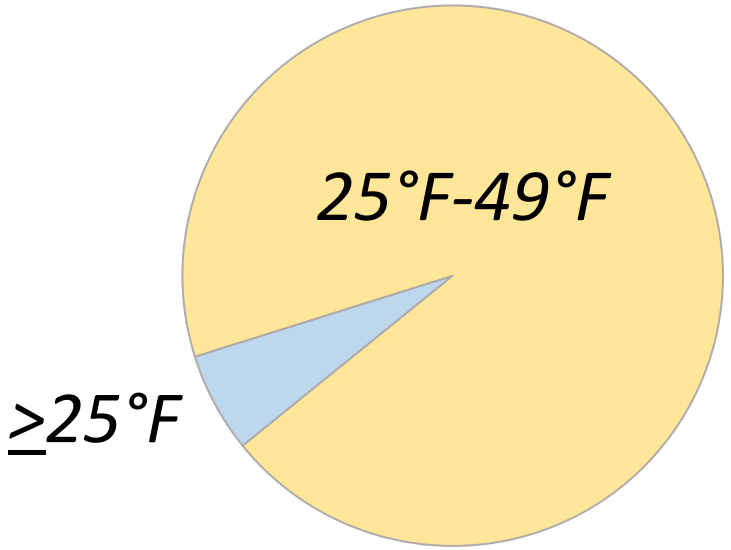

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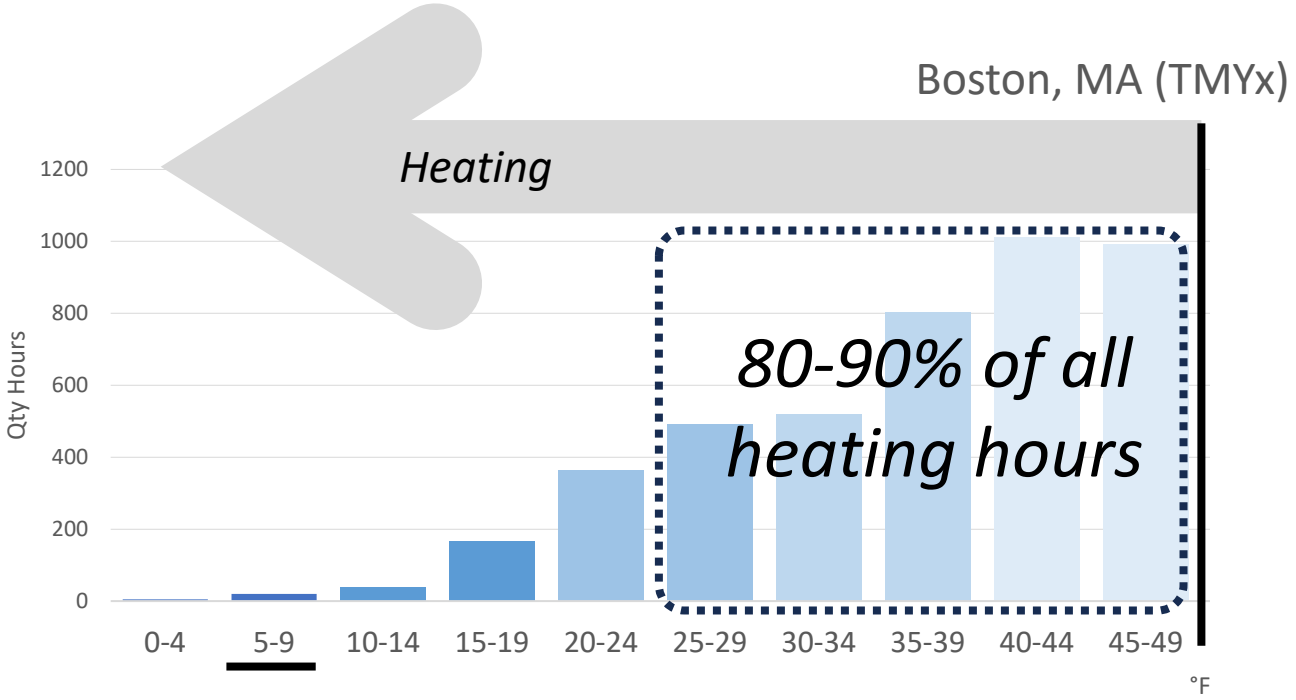
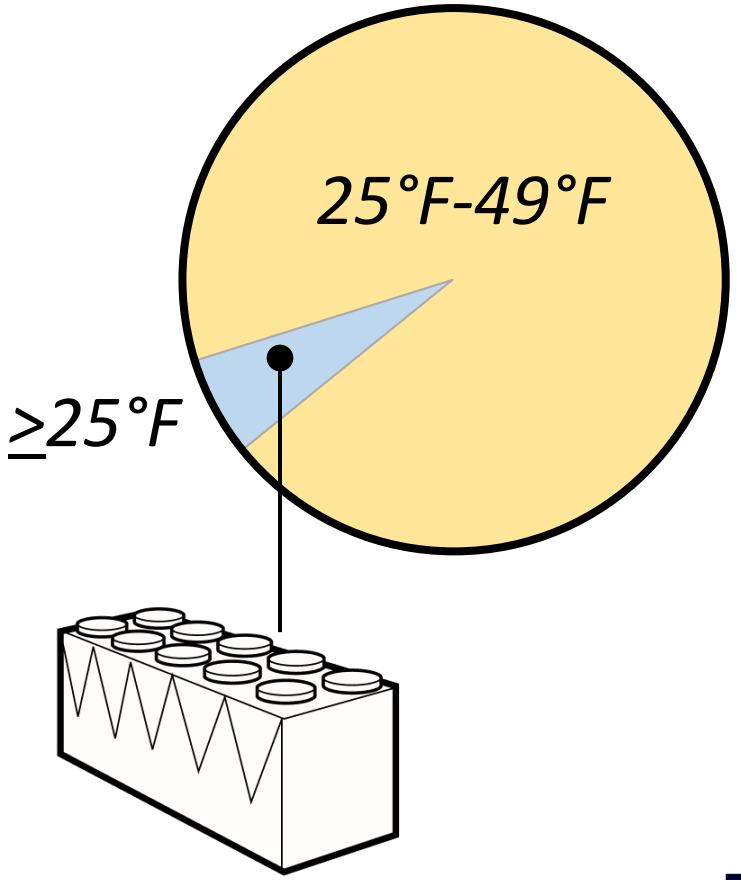

Boston, MA (TMYx)
Heating
80-90% of all heating hours
Qty Hours
1200
1000
800
600
400
200
0
0-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
°F


25°F-49°F
≥25°F

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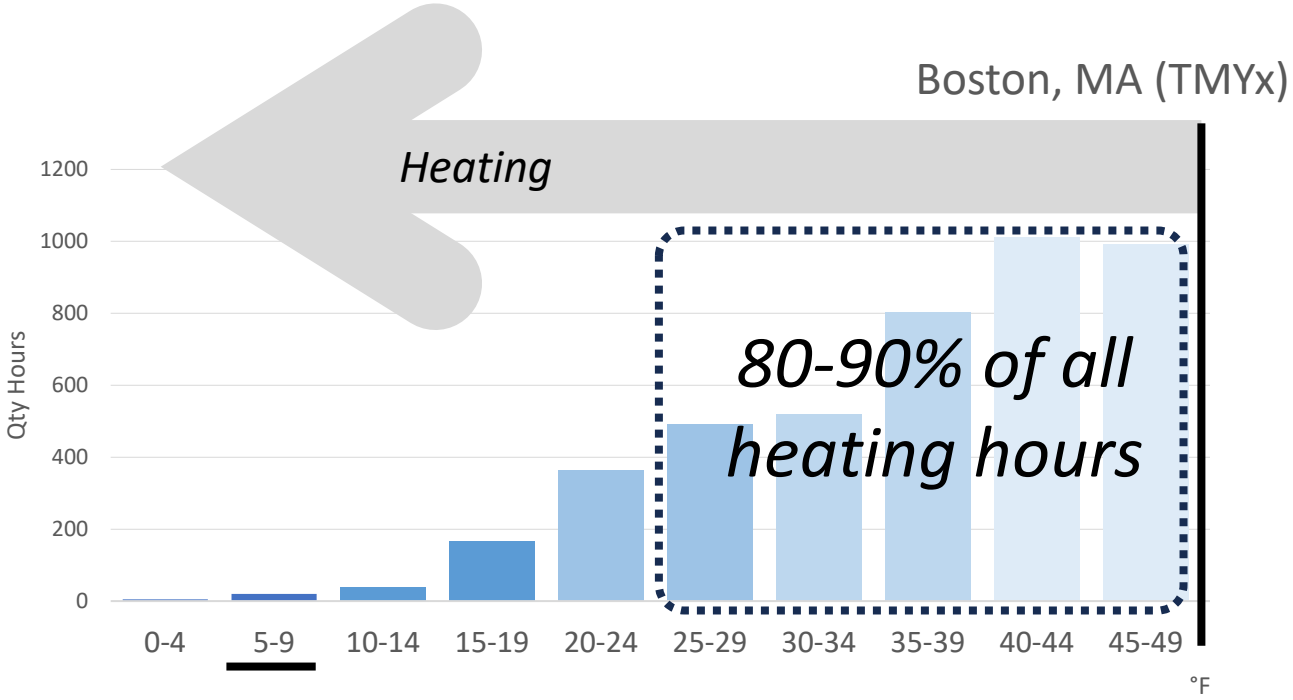
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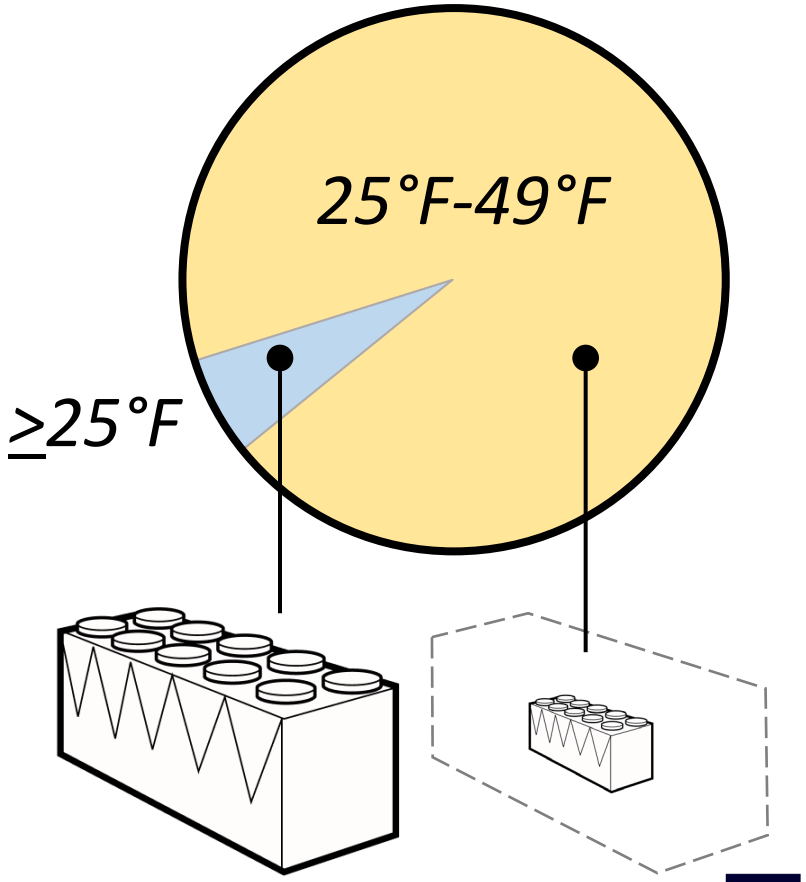
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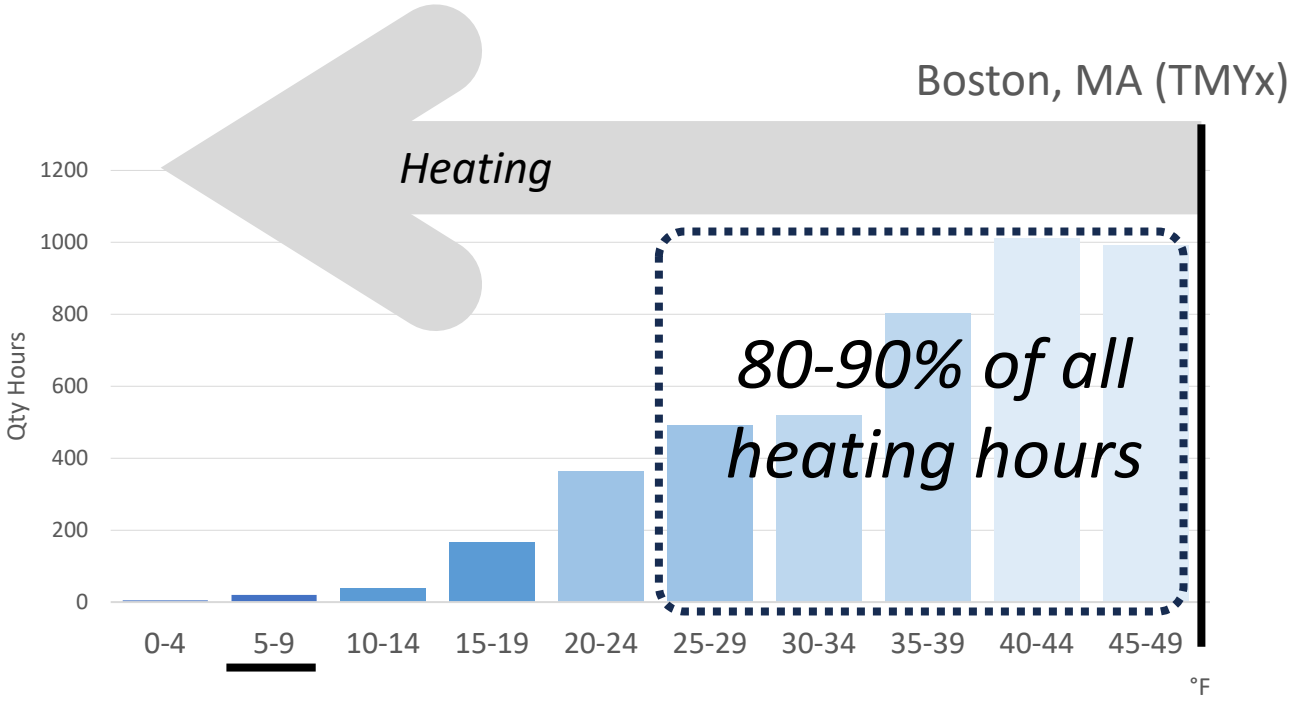
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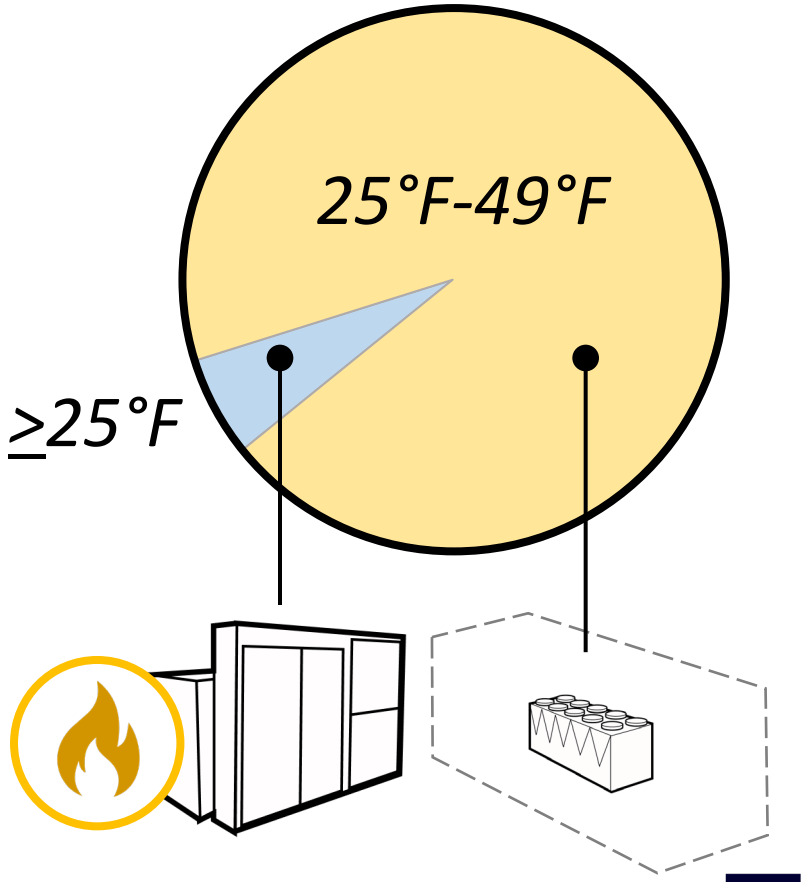
°F


25°F-49°F
≥25°F

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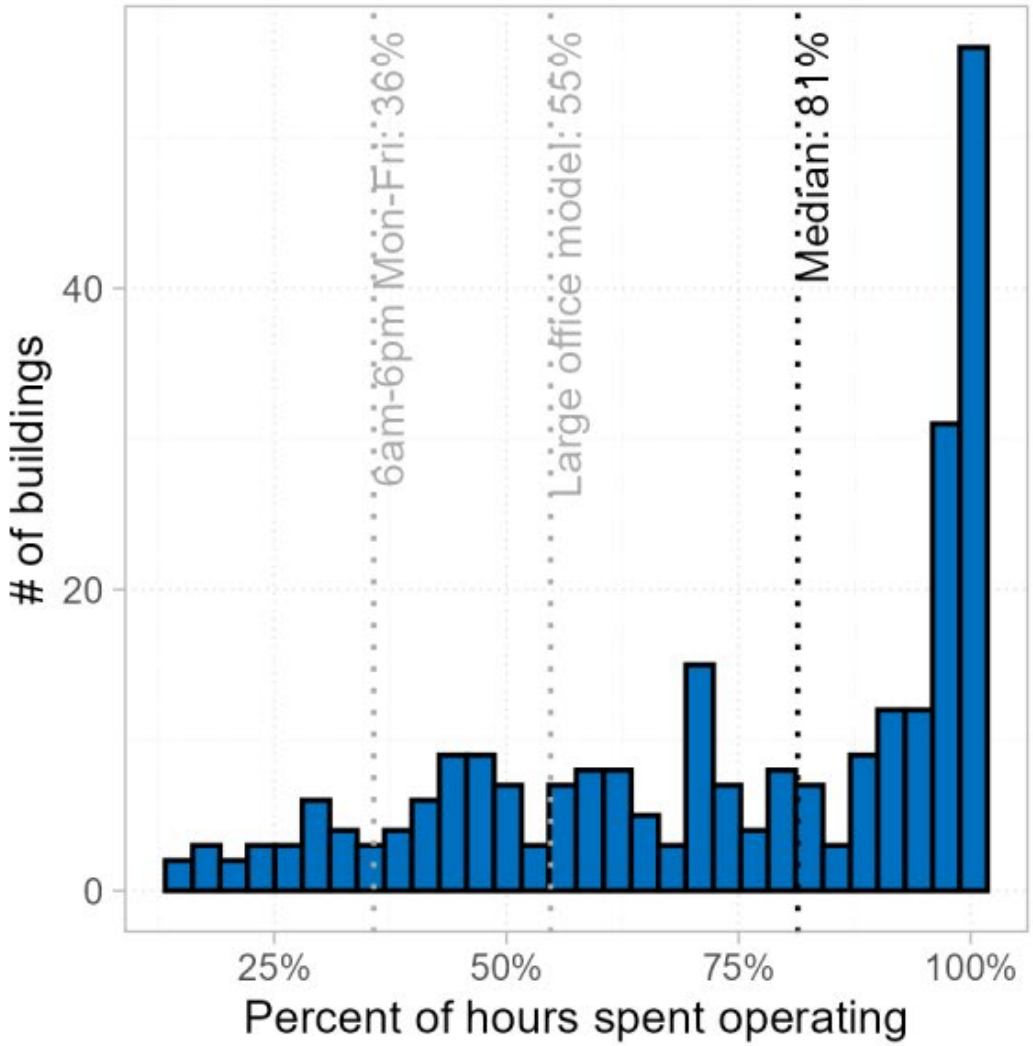
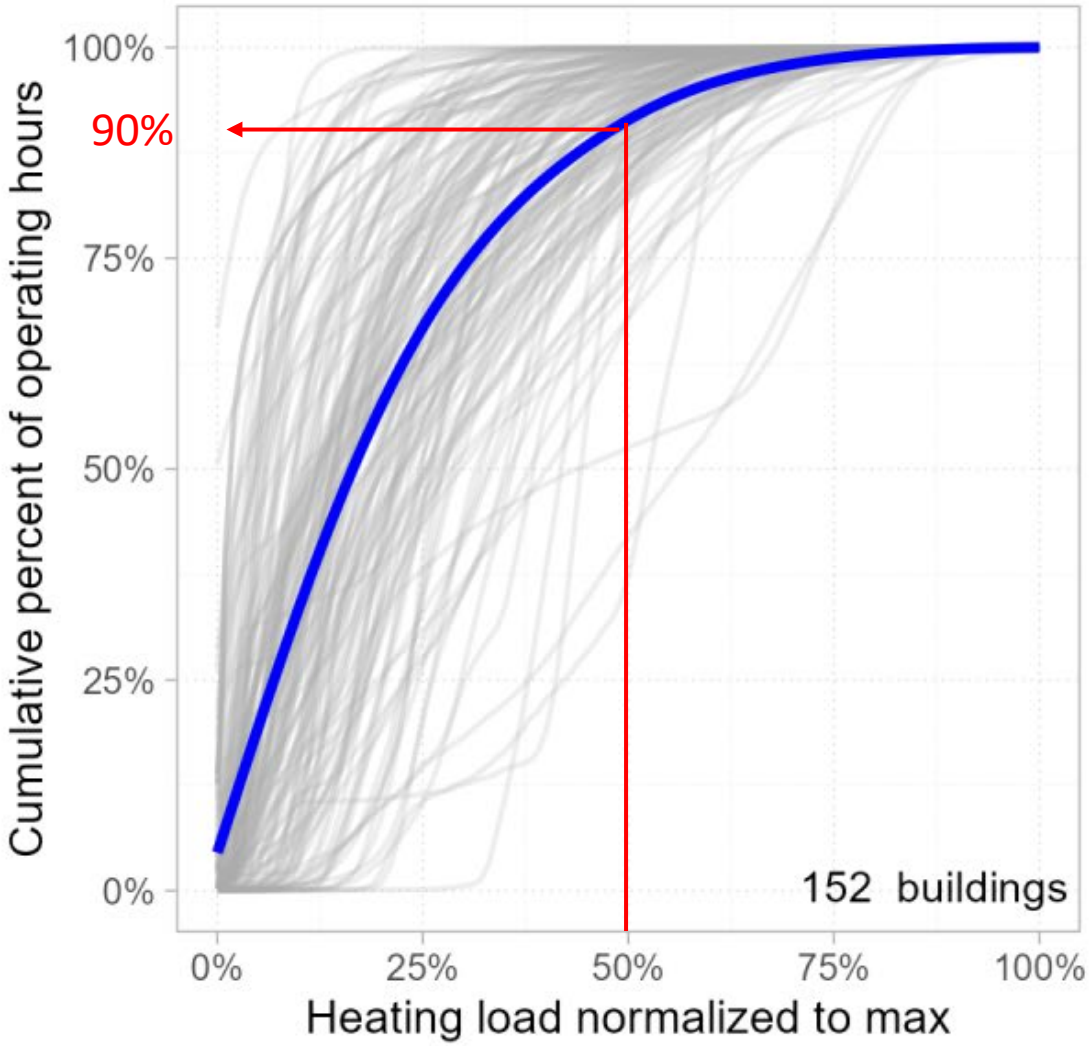
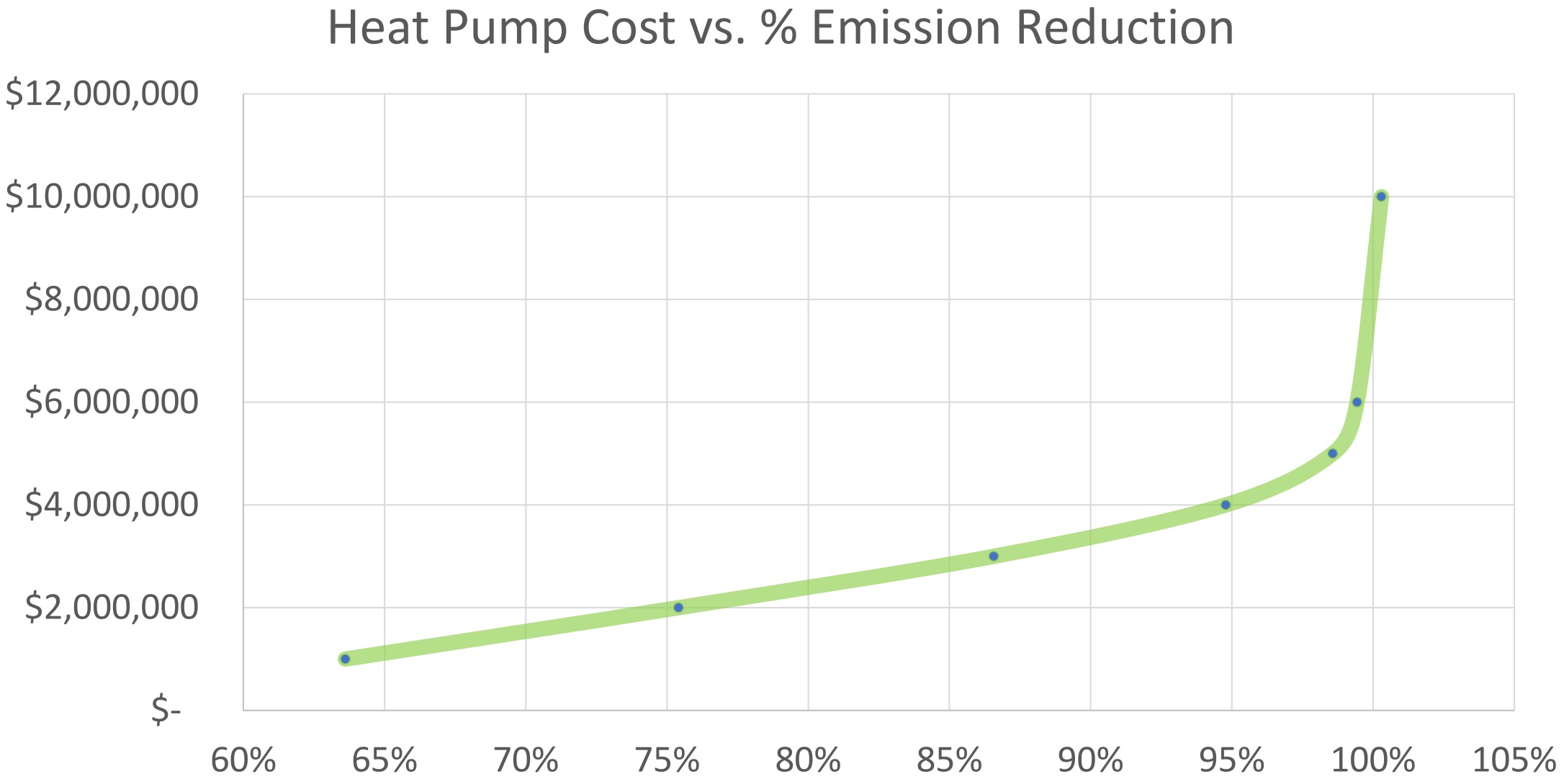
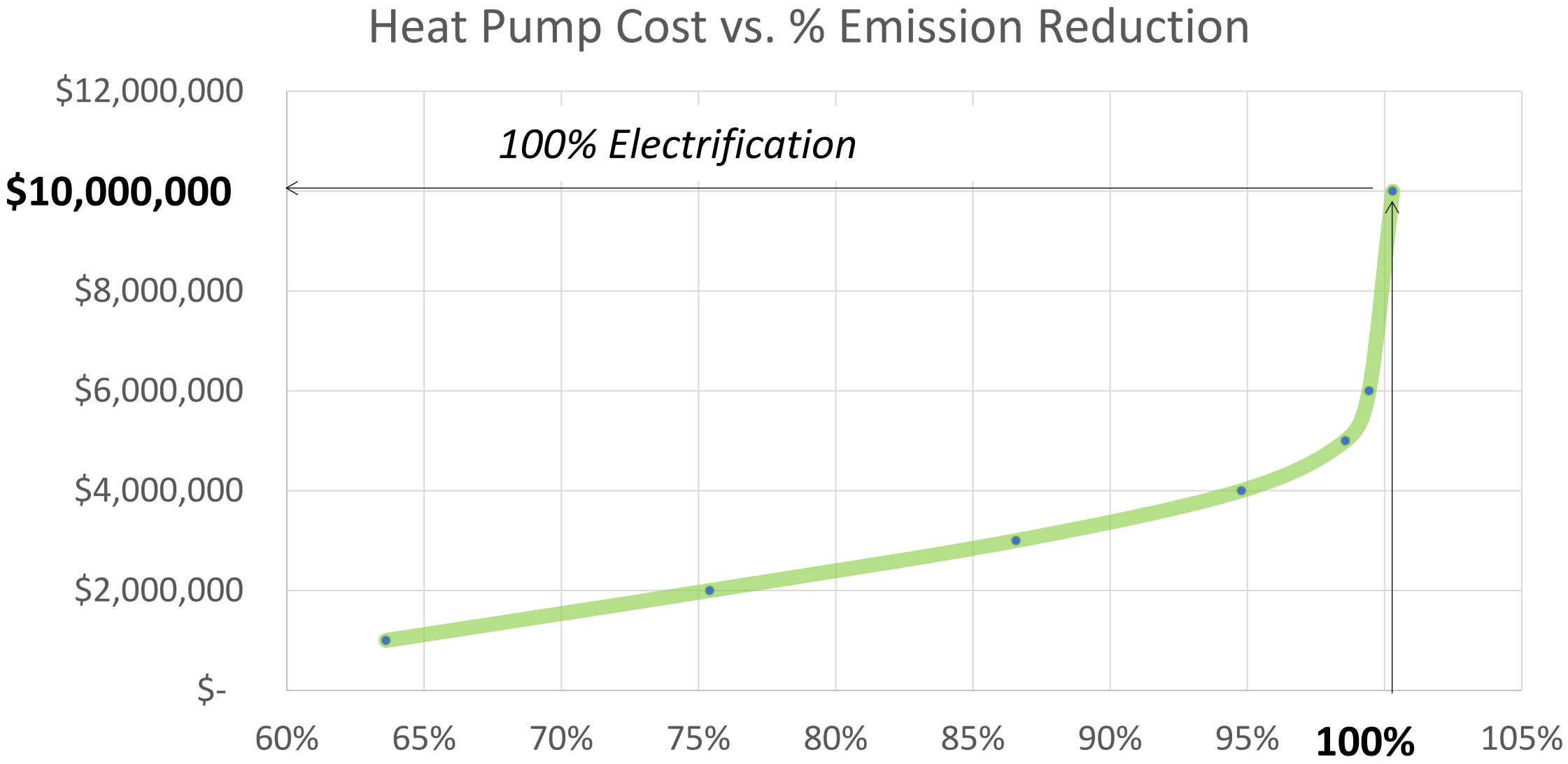
Measured data from hydronic heating systems in 259 commercial buildings






Heat Pump Cost vs. % Emission Reduction
$12,000,000
$10,000,000
$8,000,000
$6,000,000
$4,000,000
$2,000,000
$-
60%
65%
70%
75%
80%
85%
90%
95%
100%
105%

Turner


Heat Pump Cost vs. % Emission Reduction
$12,000,000
$10,000,000
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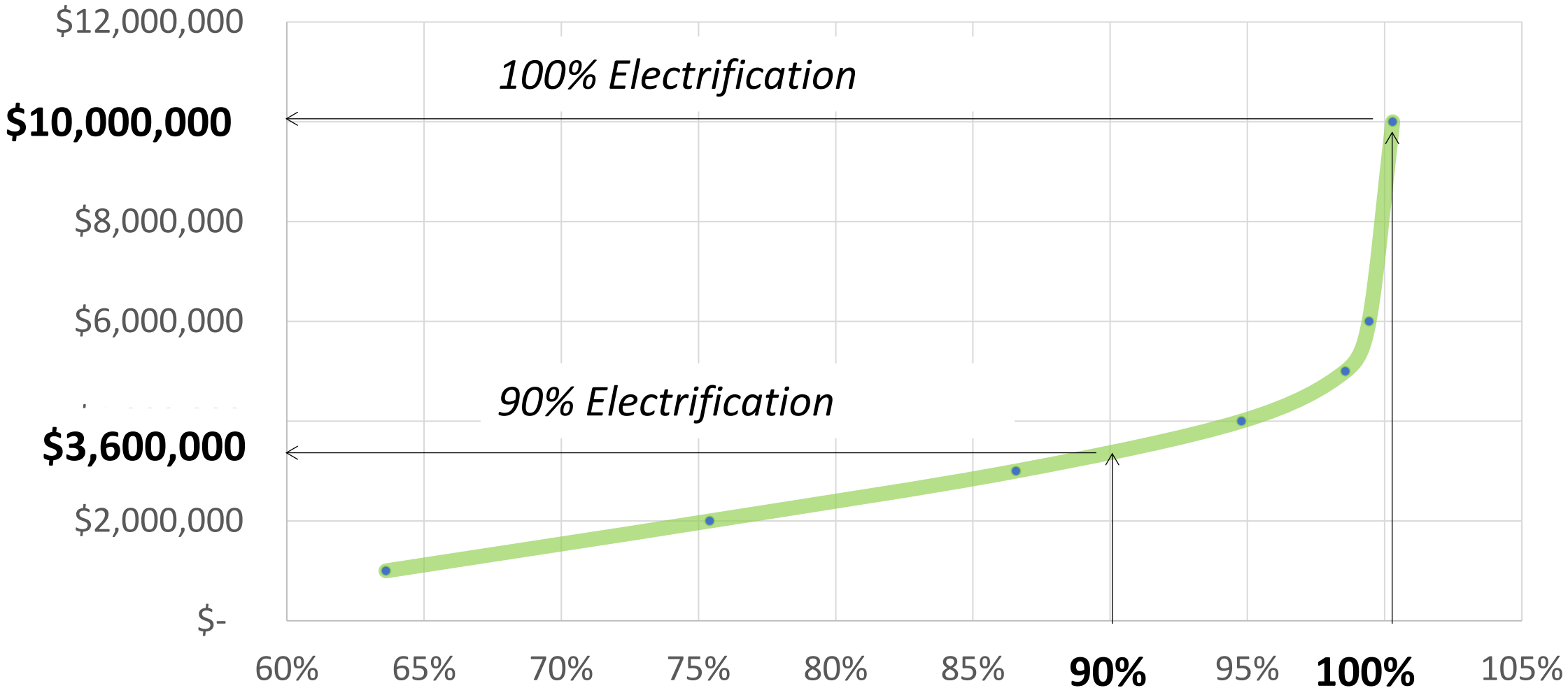
$6,000,000
$4,000,000
$2,000,000
$-
100% Electrification
60%
65%
70%
75%
80%
85%
90%
95%
100%
105%

Turner

Heat Pump Cost vs. % Emission Reduction



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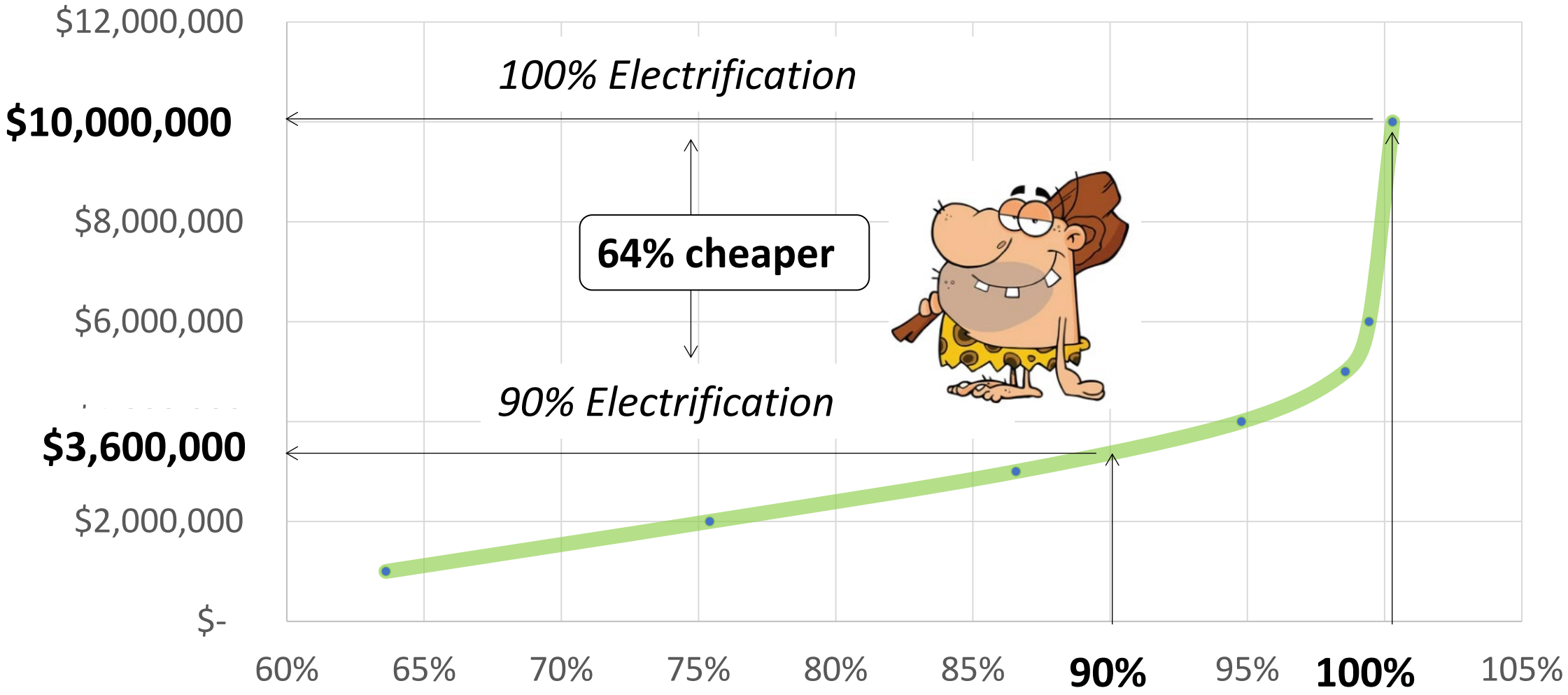
Heat Pump Cost vs. % Emission Reduction



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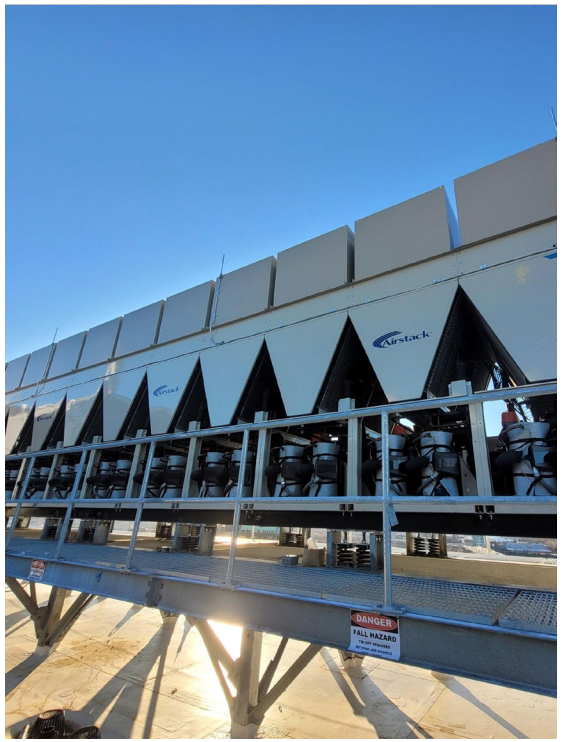
MGH Ragon
323,000 gsf

Comm Pier
705,000 gsf

L5
707,000 gsf



Harvard ERC
440,000 gsf

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Program

360,000 GSF Classroom + Admin Building
New England

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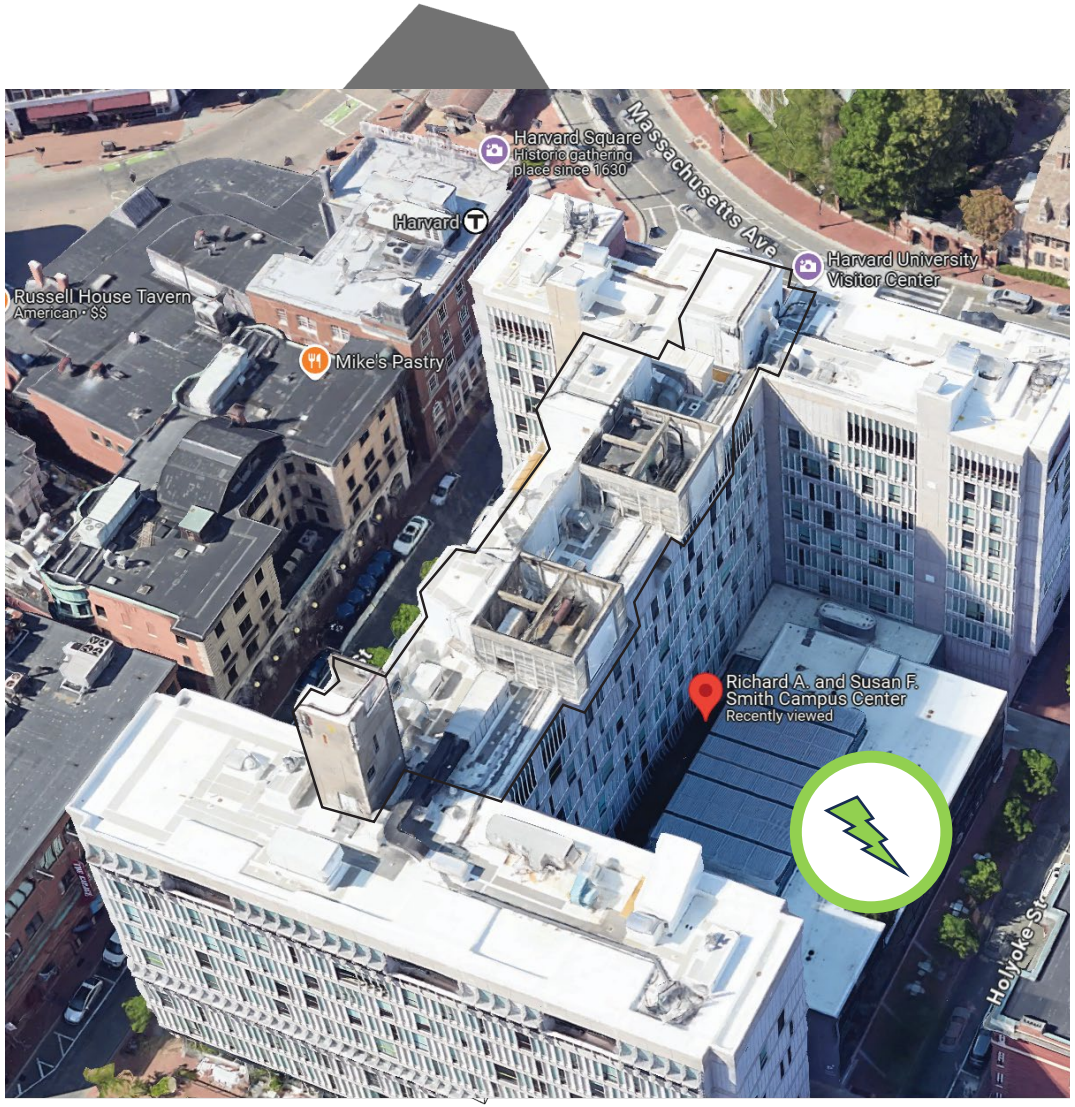
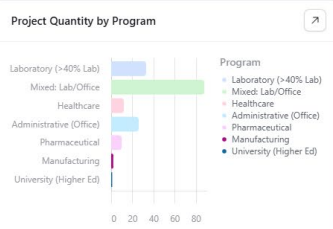
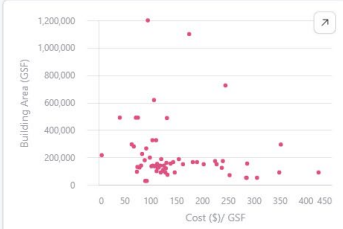


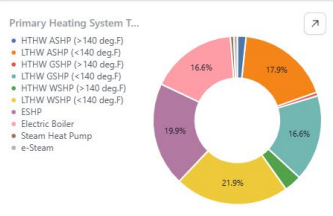
Decarb Project Historical Cost

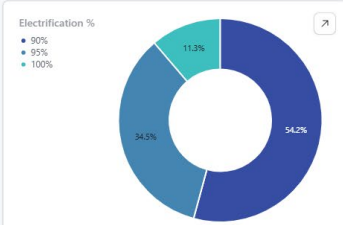
US Market | Program | Climate Zone | Building GSF (Range) | Age of Building | Primary Heating... | More

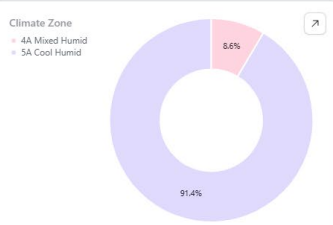
Project Count	Overall Project GSF	Min $/GSF	Avg $/GSF	Max $/GSF	Standard Deviation
152	27,986,000	6	117	425	63

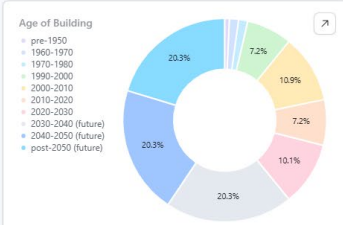




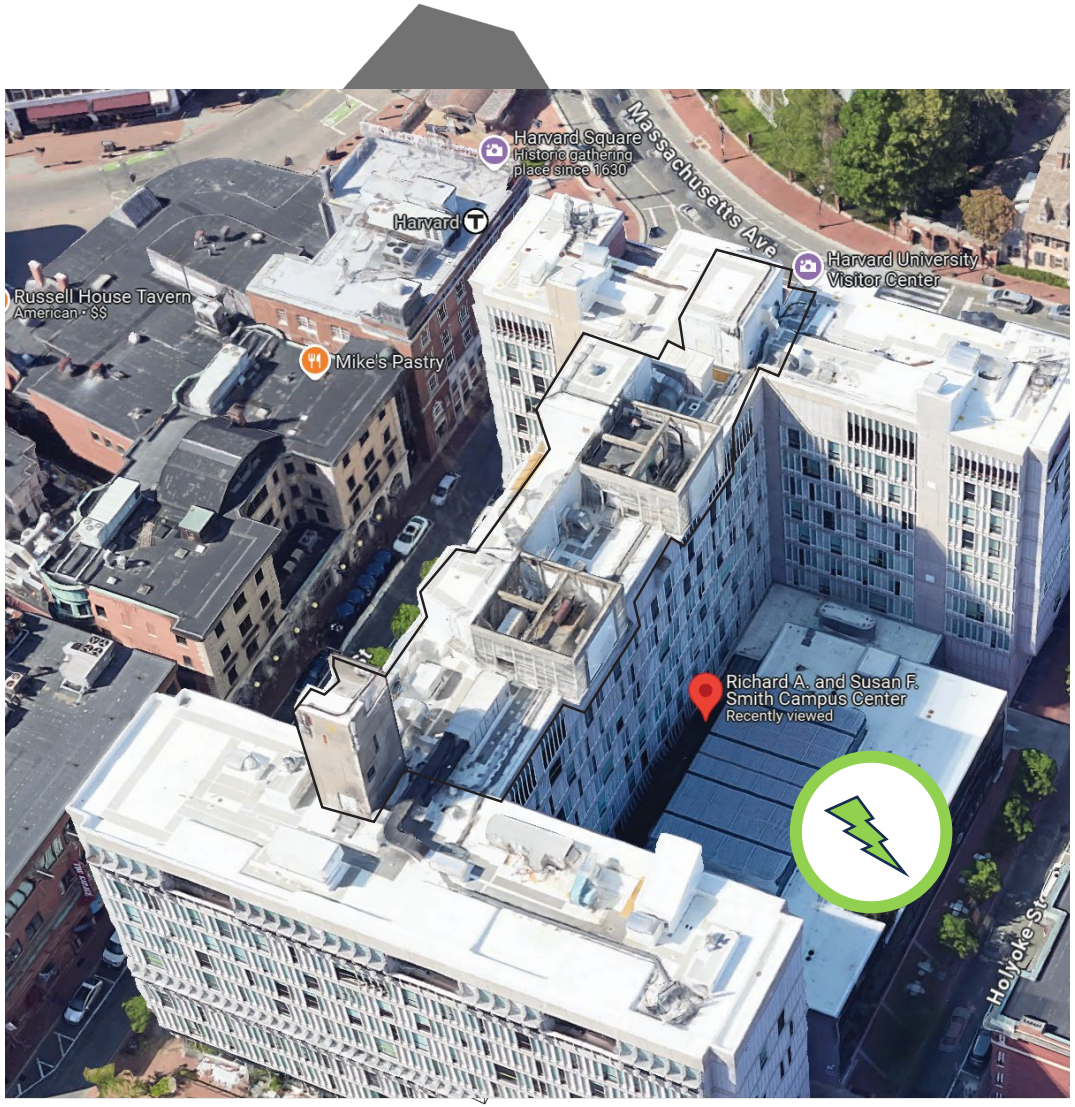


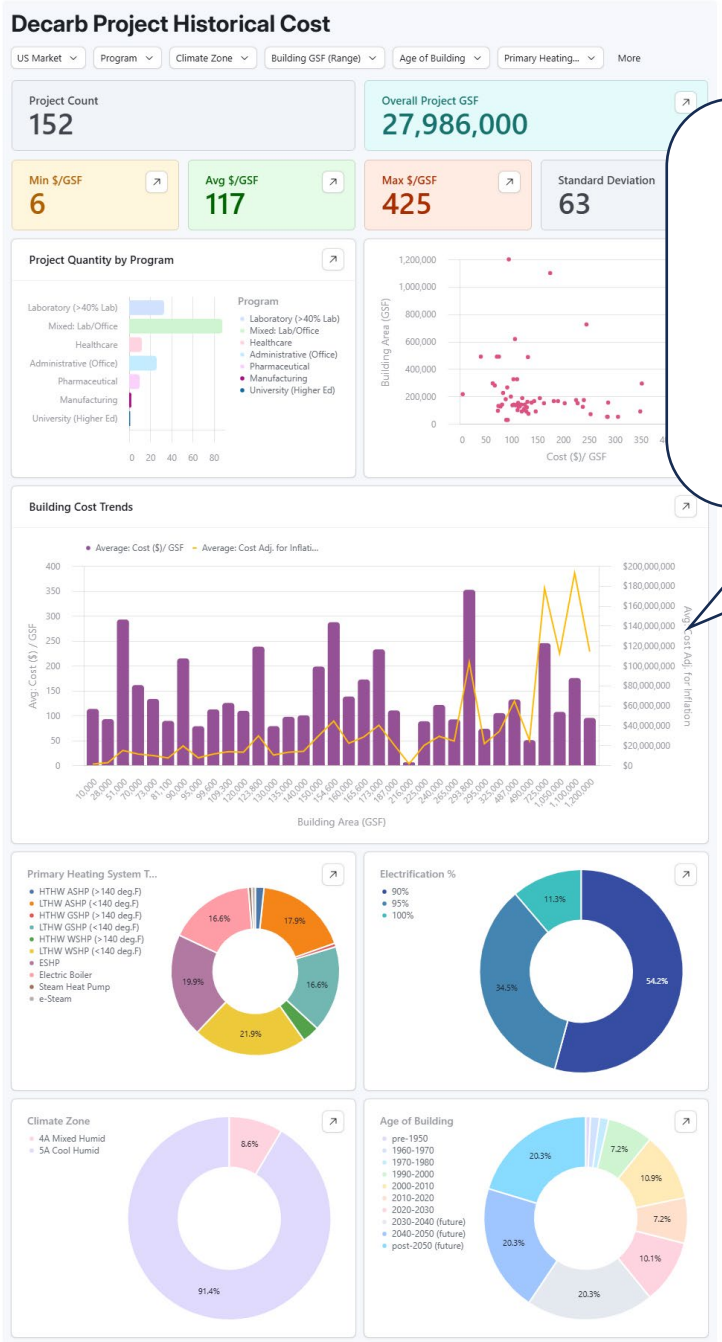






Turner

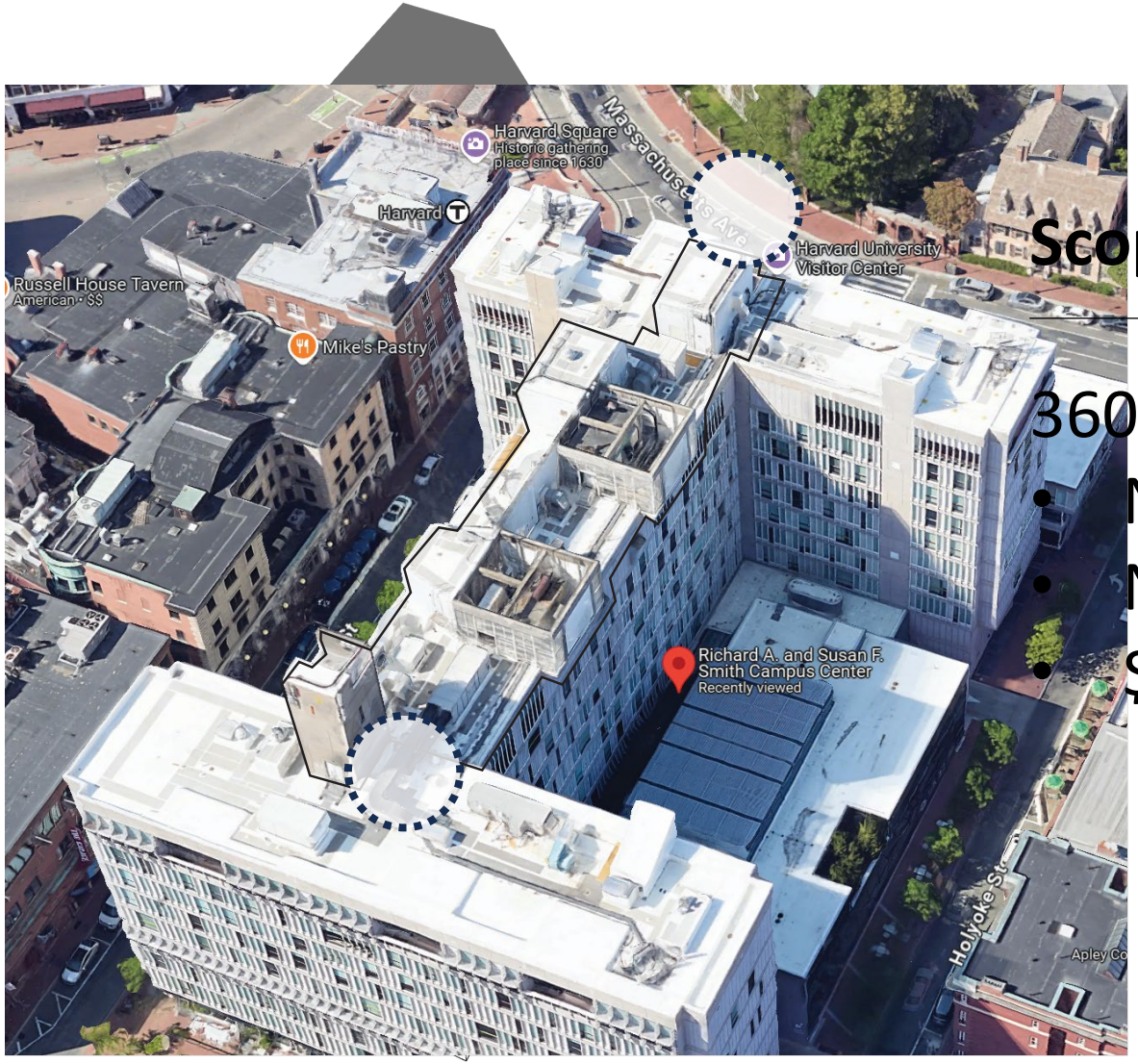




Decarbonization of Classroom + Admin Building 360,000 GSF

$40/SF = $14,400,000

Turner



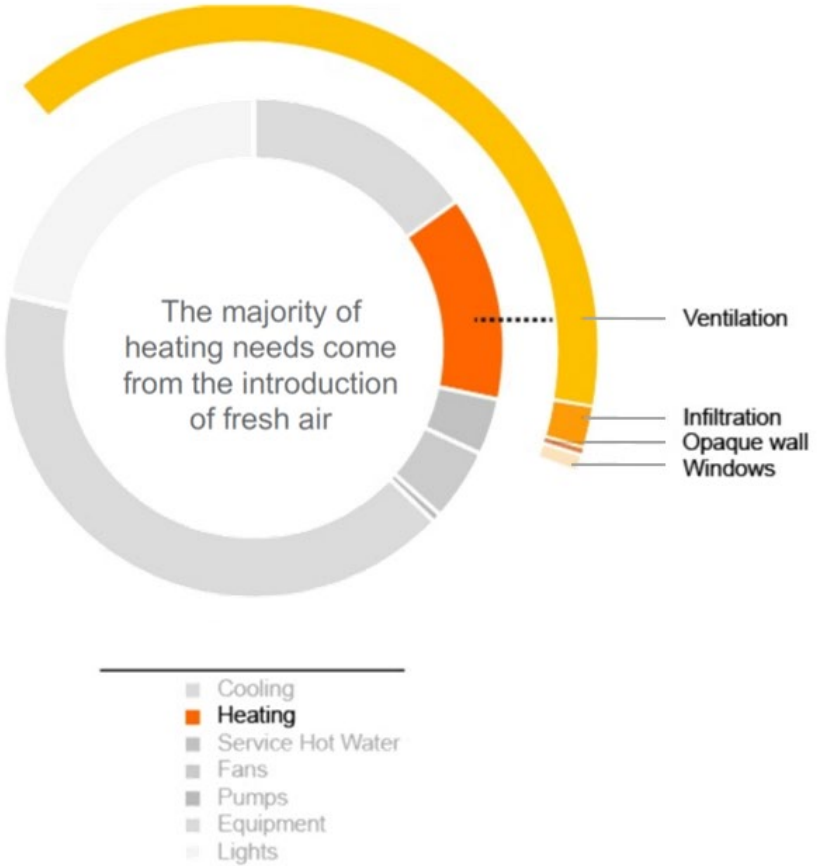
Scope of Work

360,000 GSF Classroom + Admin Building

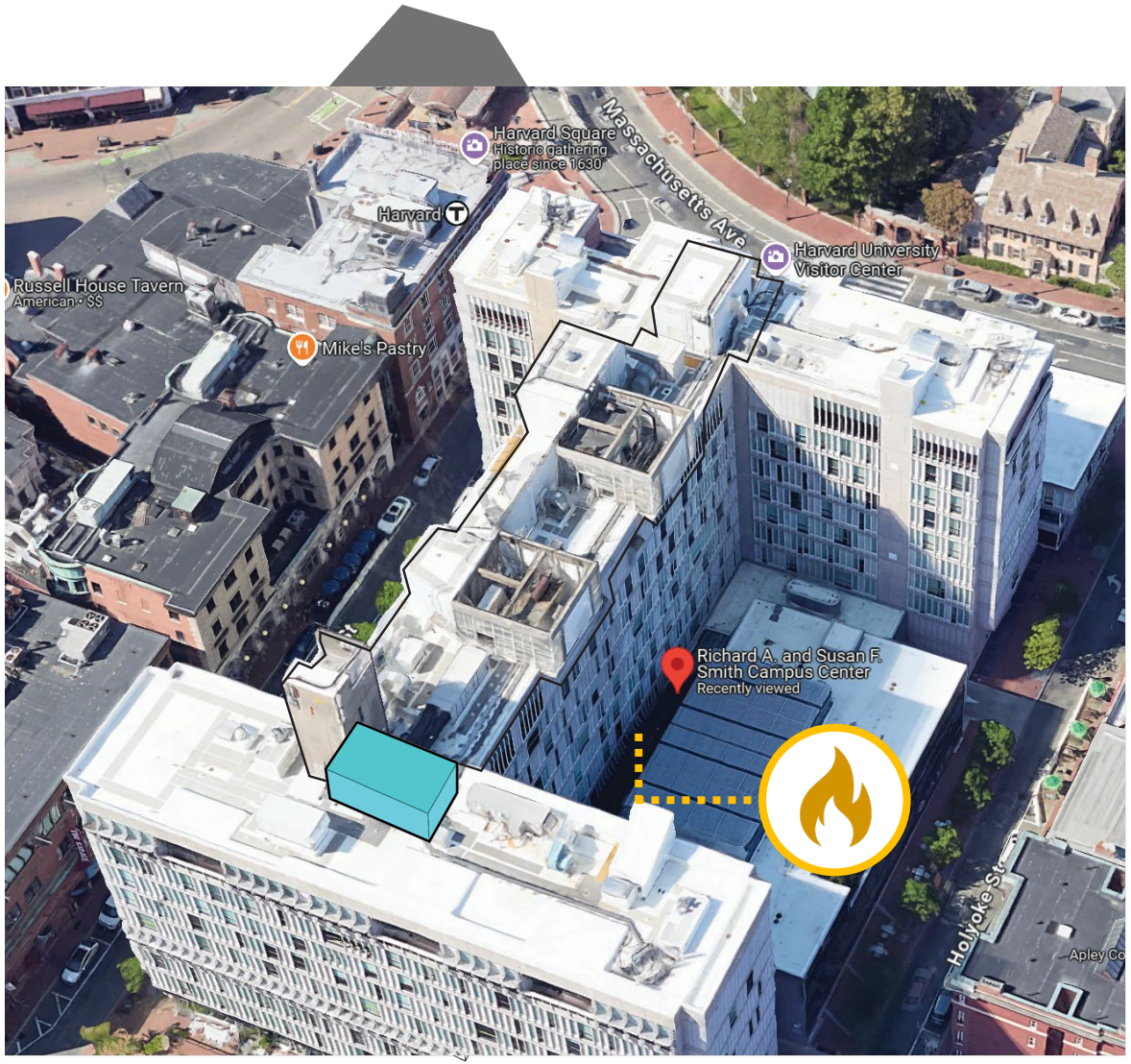
- New AHUs
- New Generator
- $44/cfm = $860,000

Turner

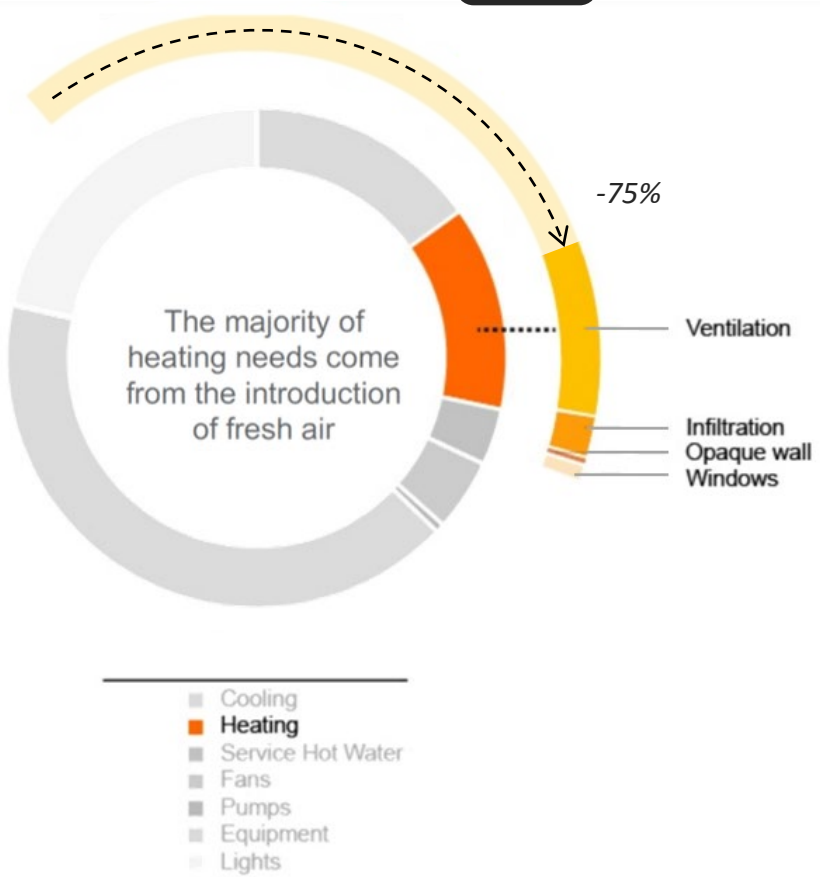

Harvard Square
Historic gathering place since 1630
Harvard
Harvard University Visitor Center
Russell House Tavern
American • $$
Mike's Pastry
Richard A. and Susan F. Smith Campus Center
Recently viewed


The majority of heating needs come from the introduction of fresh air
Ventilation
Infiltration
Opaque wall
Windows
Cooling
Heating
Service Hot Water
Fans
Pumps
Equipment
Lights

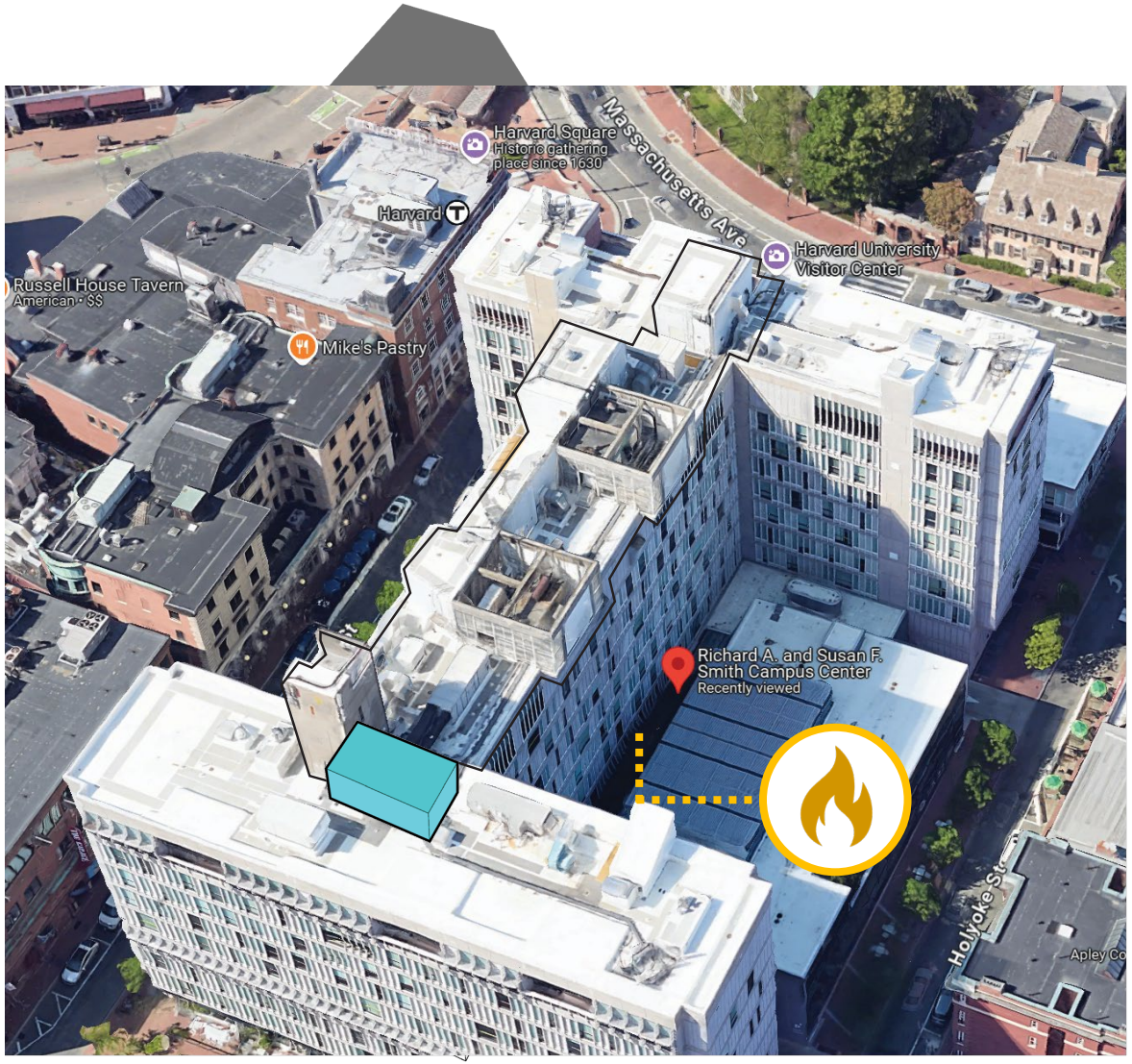
Turner



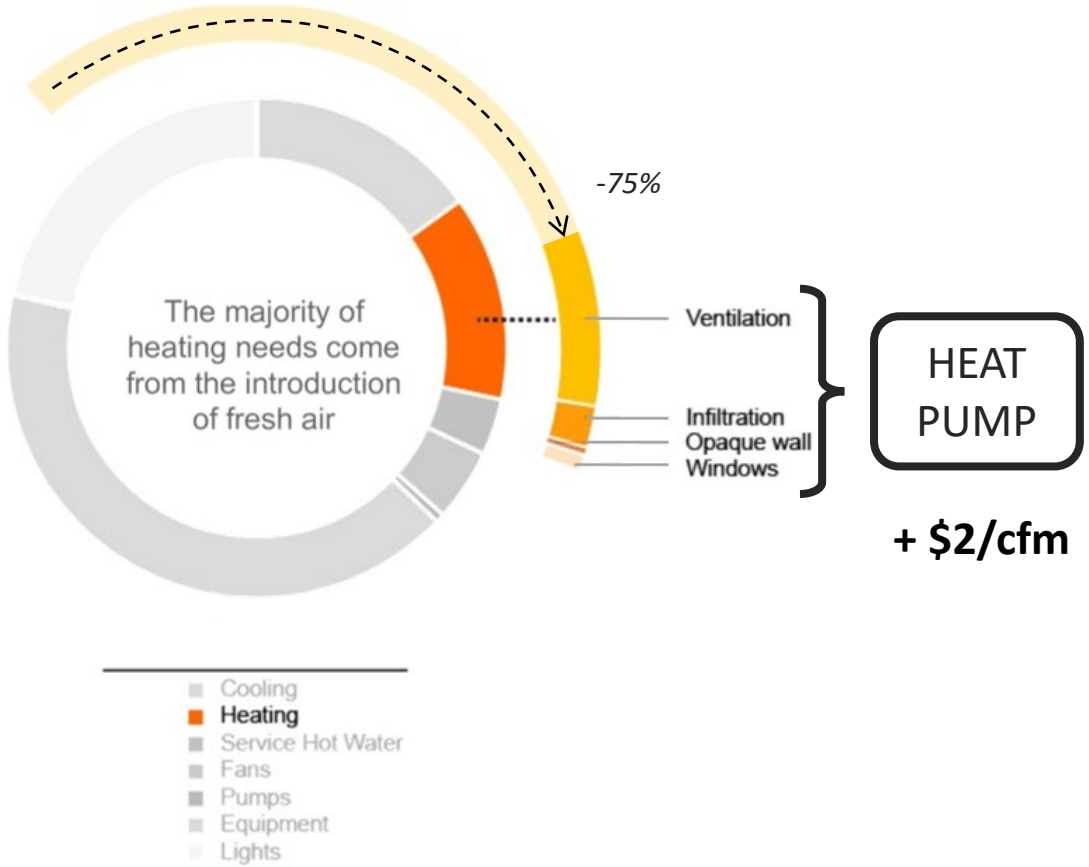
ERV + $10/cfm



Turner



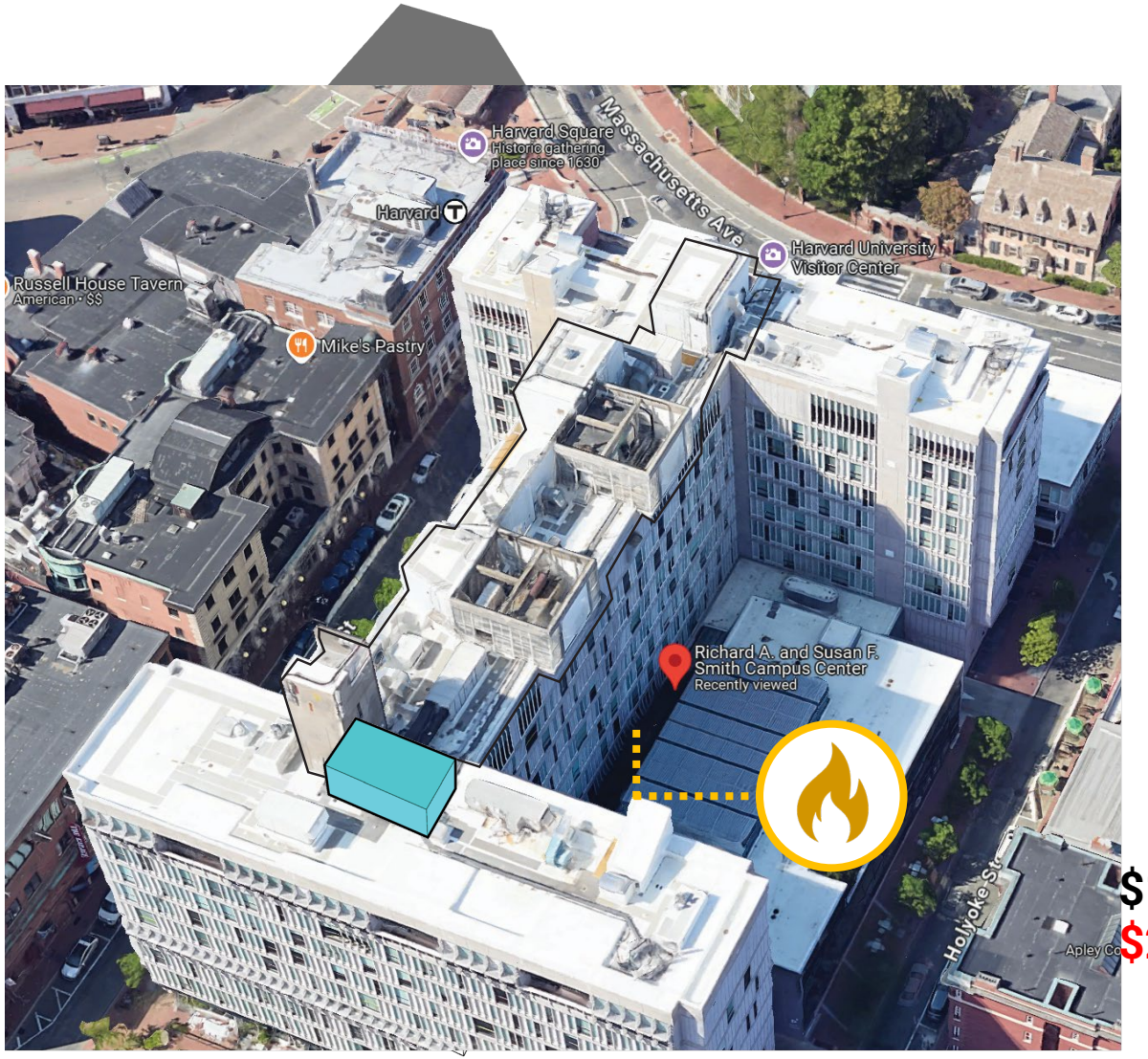
ERV + $10/cfm



HEAT PUMP

+ $2/cfm

Turner



DECARB AIR-HANDLING UNIT REPLACEMENT

$44/CFM ($860,000)

\+

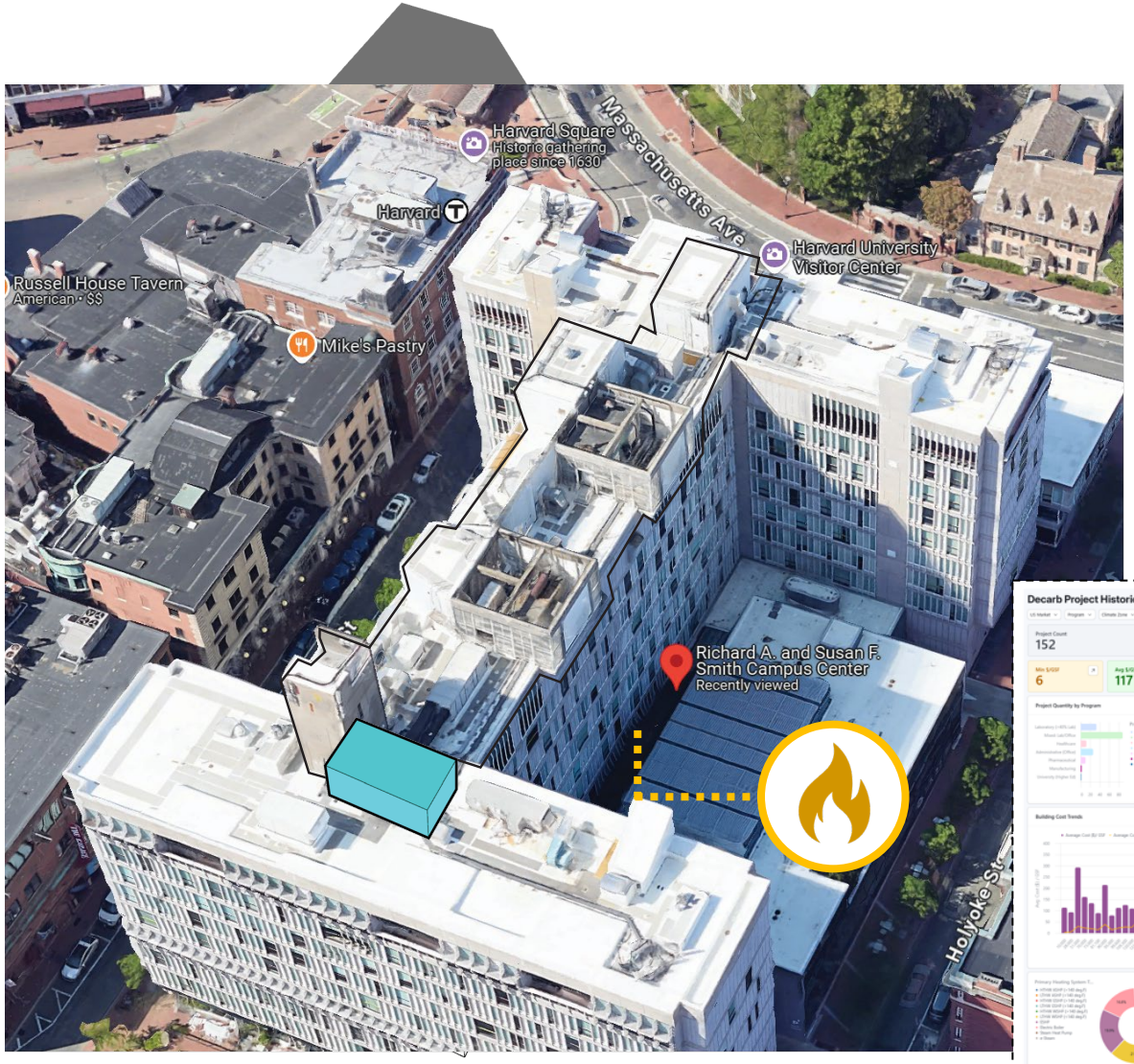
$10/CFM ($200,000 – ERV)

$2/CFM ($40,000 - REMOTE CONDENSING UNITS)

$56/CFM *(27% EQUIPMENT COST PREMIUM)*

$10/CFM+$2/CFM = $12 /cfm premium)
$240,000 add

Turner



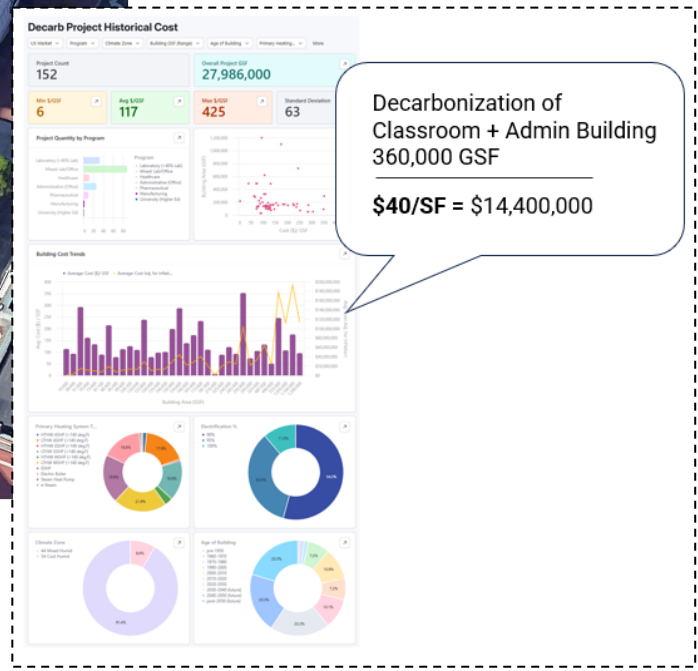
DECARB AIR-HANDLING UNIT REPLACEMENT

VS.

$240,000 ($0.66/sf decarb premium)

$14,400,000 ($40/sf)

98% COST REDUCTION



90% CO2 reduction

Turner

Colin Schless |Director, Client Decarbonization Services
Turner Construction Company | 2 Seaport Lane, 2nd Floor,
Boston, MA 02210
mobile 978.501.2623 | cschless@tcco.com

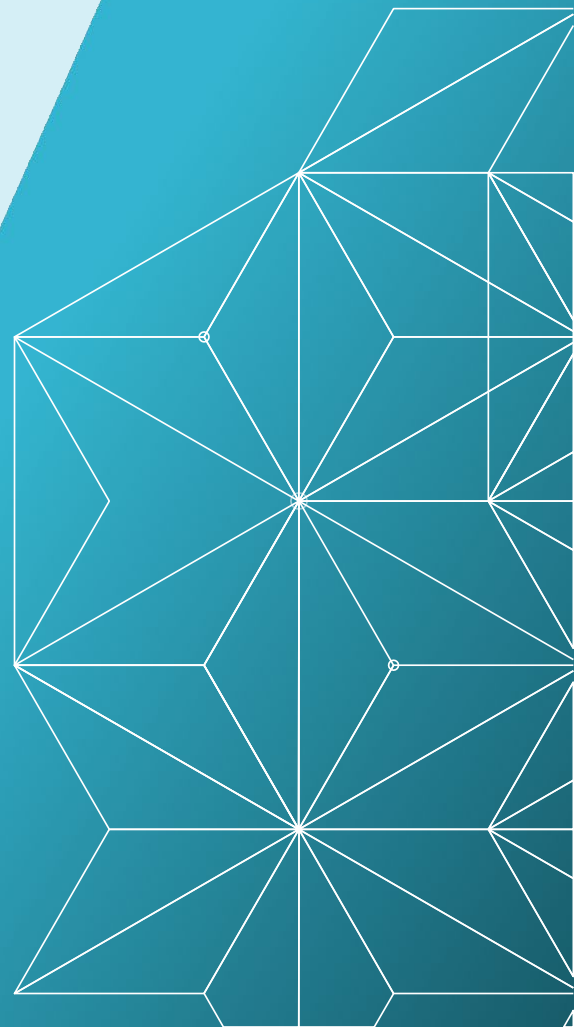
Turner

JOHN KASTRINOS, HALEY & ALDRICH

JACOB KNOWLES, BR+A

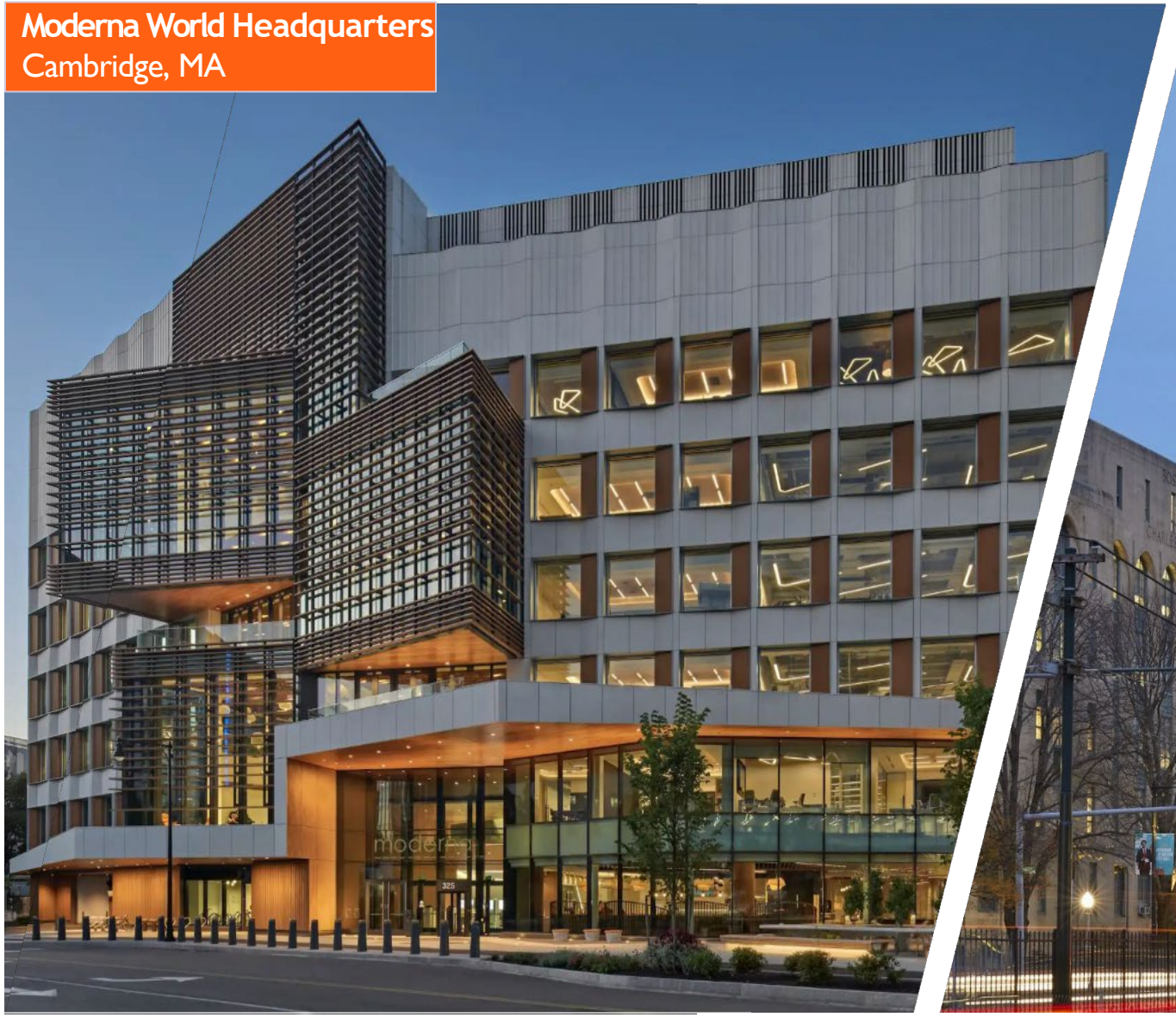
Optimal Sizing Approaches for Geothermal Borefields

Jacob Knowles
BR+A Consulting Engineers, Inc.
John R. Kastrinos, P.G. (PA)
Haley & Aldrich, Inc.

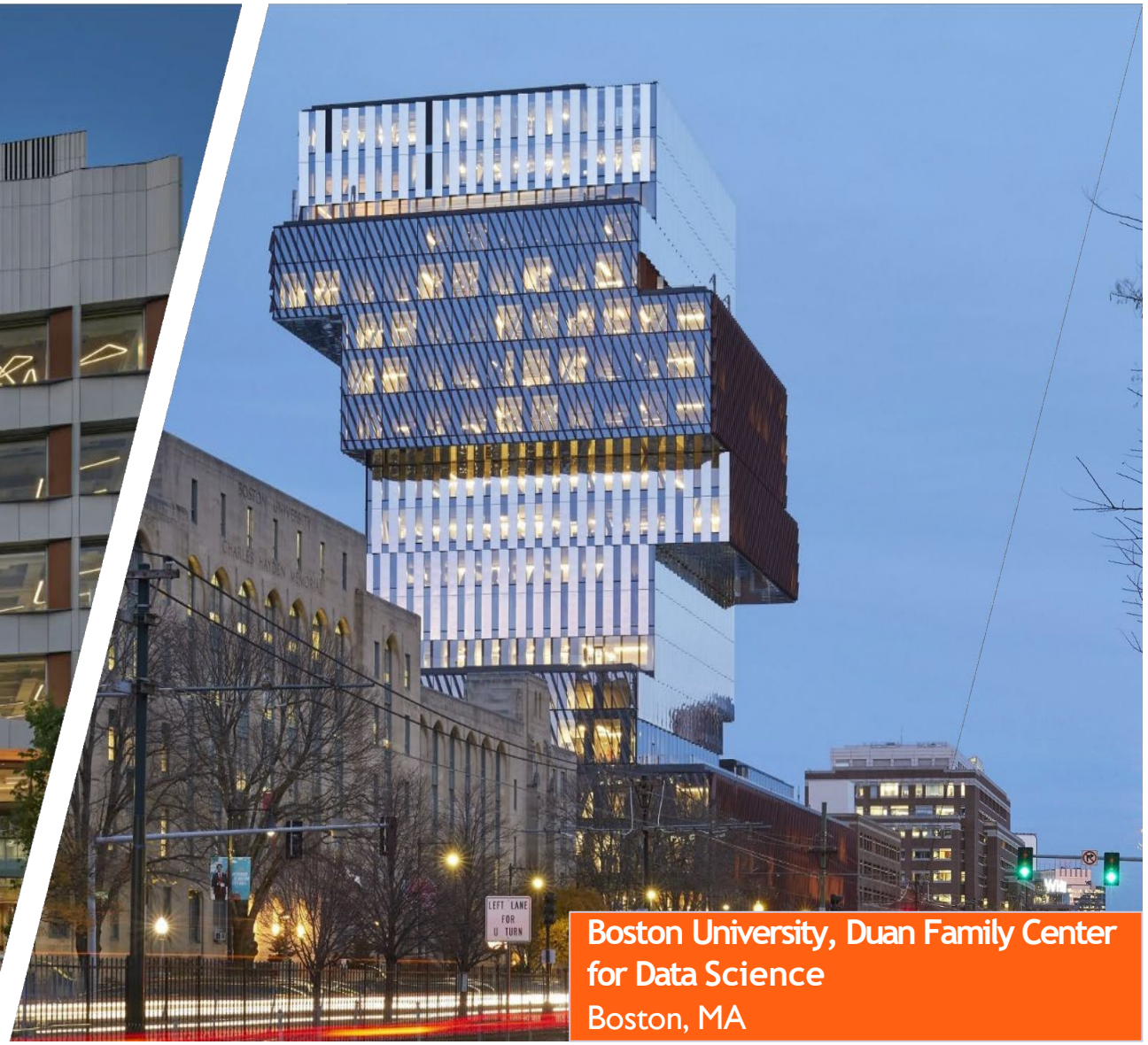


Agenda

1. Case Studies – Project Goals that Drive Design
2. Case Studies – Load Reduction Strategies and Electrification Technologies
3. Load Profiles – Effect on Borefield Design
4. Questions



Moderna World Headquarters
Cambridge, MA



Boston University, Duan Family Center for Data Science
Boston, MA

GEOTHERMAL GOAL SETTING

MODERNA HQ

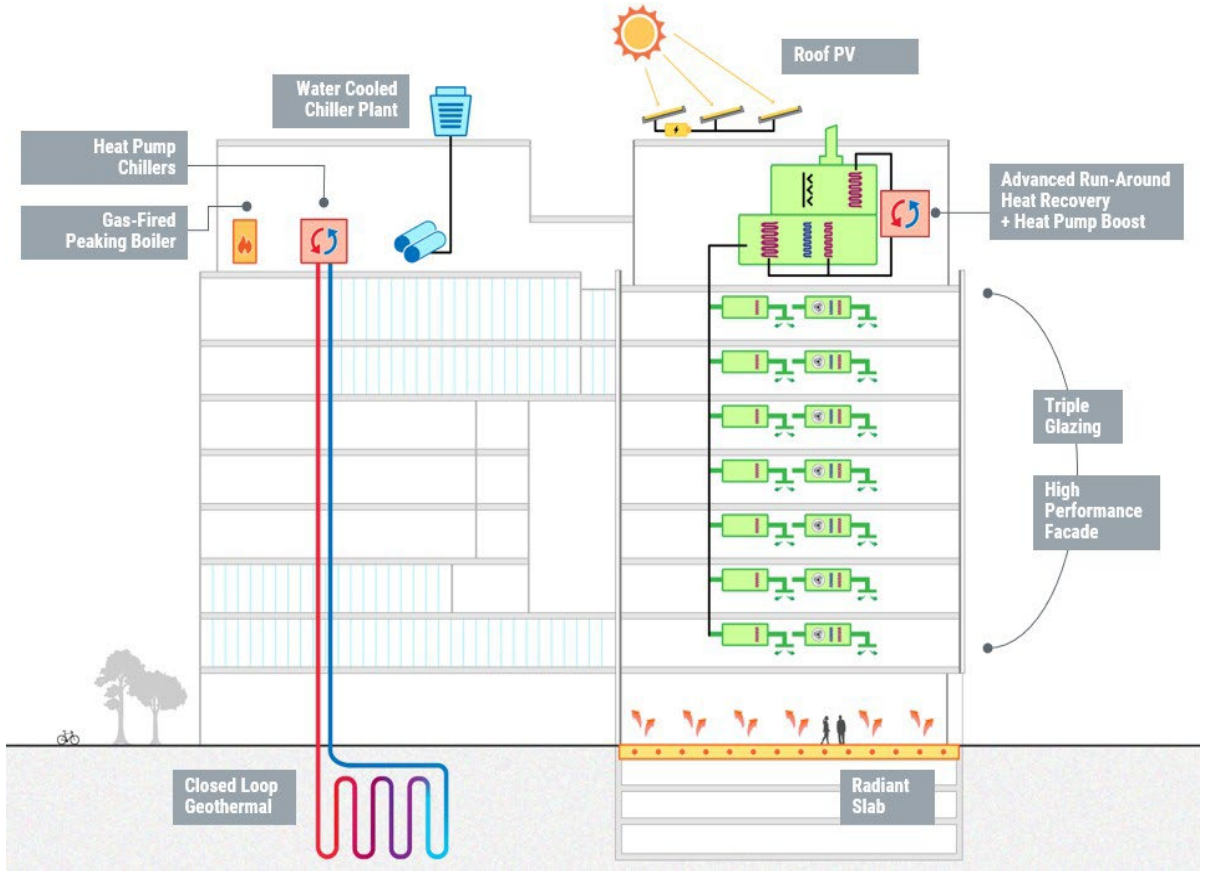
- Lowest fossil fuel use for developer lab in cold climate
  - >90% fossil fuel reduction

BU DATA SCIENCE

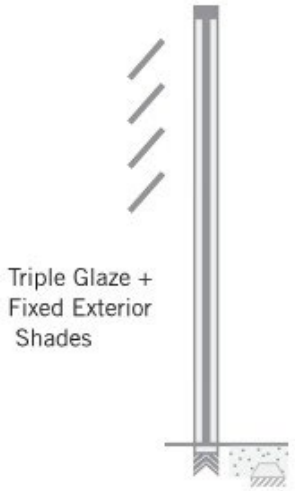
- Fully electric
  - 100% fossil fuel reduction

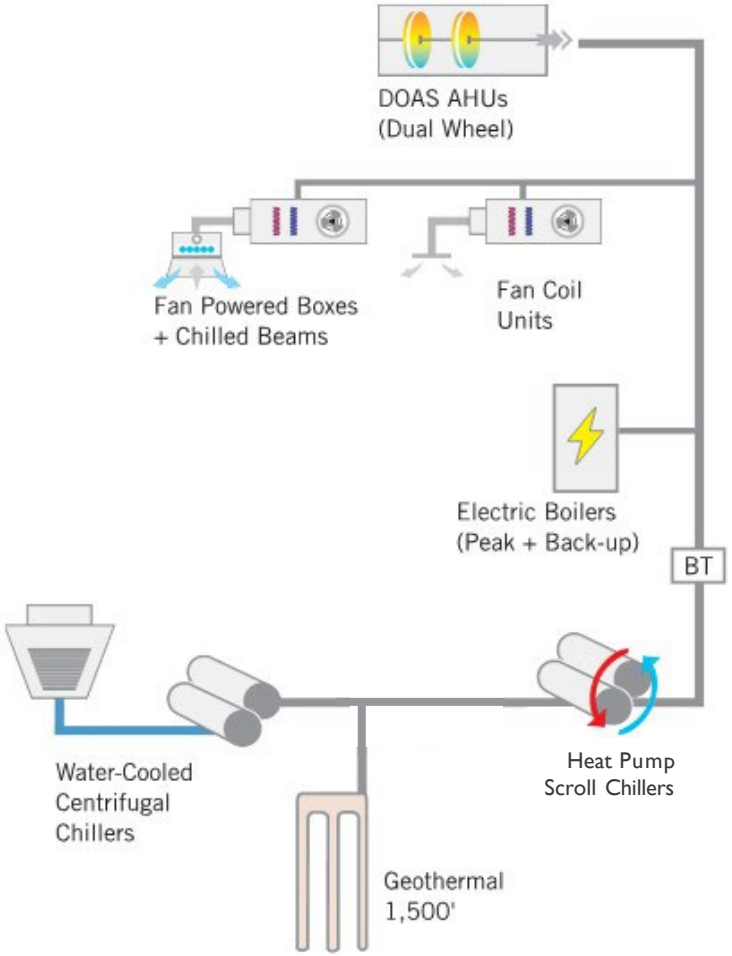
LOAD REDUCTION STRATEGIES

MODERNA HQ



BU DATA SCIENCE





ELECTRIFICATION TECHNOLOGIES

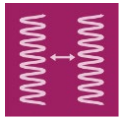
MODERNA HQ

HEATING EQUIPMENT

GAS BOILER

GROUND-SOURCE HEAT PUMP

HEAT RECOVERY CHILLER



EXHAUST-SOURCE HEAT PUMP

BU DATA SCIENCE

HEATING EQUIPMENT

ELEC BOILER

GROUND-SOURCE HEAT PUMP

HEAT RECOVERY CHILLER

ELECTRIFICATION TECHNOLOGIES

MODERNA HQ

HEATING EQUIPMENT

GAS BOILER

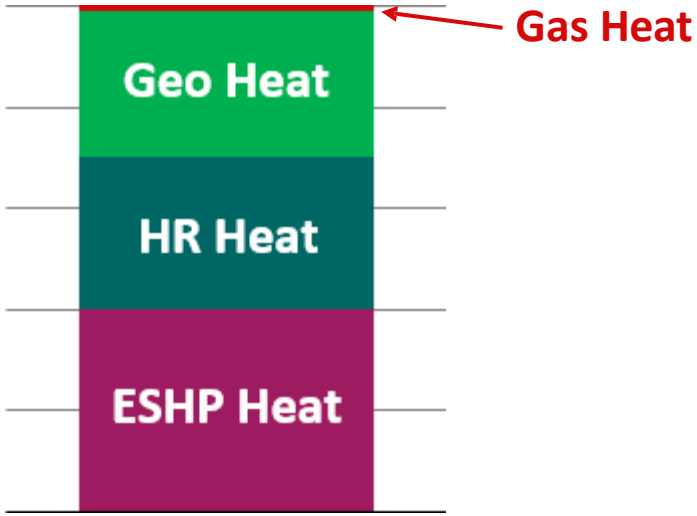
GROUND-SOURCE HEAT PUMP

HEAT RECOVERY CHILLER

EXHAUST-SOURCE HEAT PUMP

BUILDING HEATING ENERGY USE

BY EQUIPMENT TYPE



BU DATA SCIENCE

HEATING EQUIPMENT

ELEC BOILER

GROUND-SOURCE HEAT PUMP

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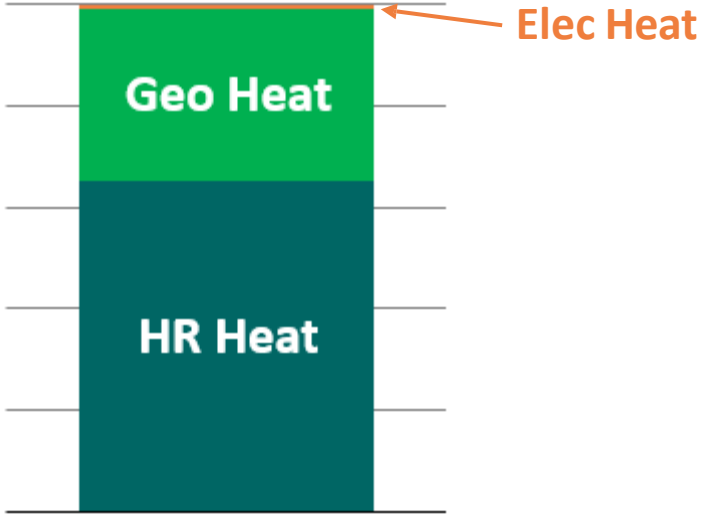
BUILDING HEATING ENERGY USE

BY EQUIPMENT TYPE



LOAD PROFILES

MODERNA HQ

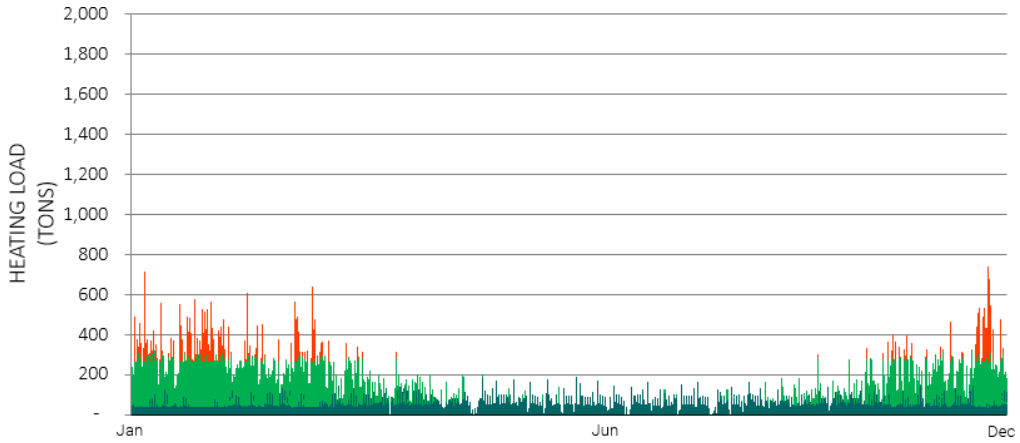
HEATING EQUIPMENT

GAS BOILER

GROUND-SOURCE HEAT PUMP

HEAT RECOVERY CHILLER

EXHAUST-SOURCE HEAT PUMP



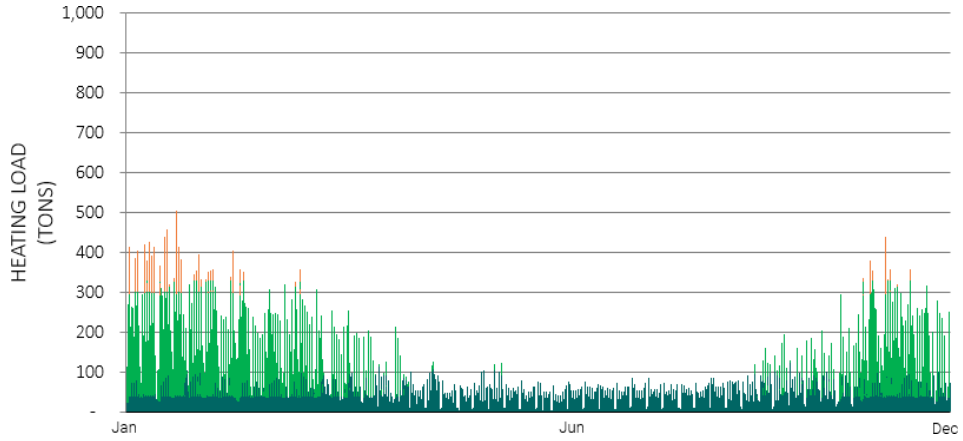
BU DATA SCIENCE

HEATING EQUIPMENT

ELEC BOILER

GROUND-SOURCE HEAT PUMP

HEAT RECOVERY CHILLER



LOAD PROFILES

MODERNA HQ

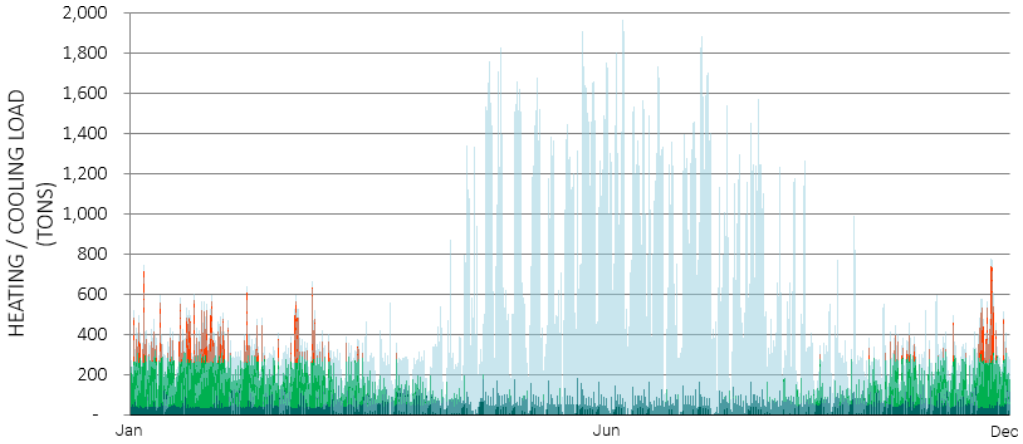
HEATING EQUIPMENT

GAS BOILER

GROUND-SOURCE HEAT PUMP

HEAT RECOVERY CHILLER

EXHAUST-SOURCE HEAT PUMP



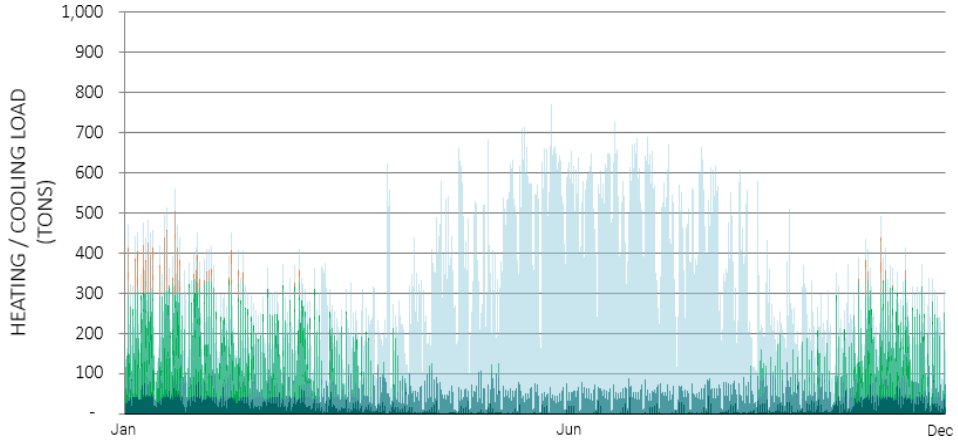
BU DATA SCIENCE

HEATING EQUIPMENT

ELEC BOILER

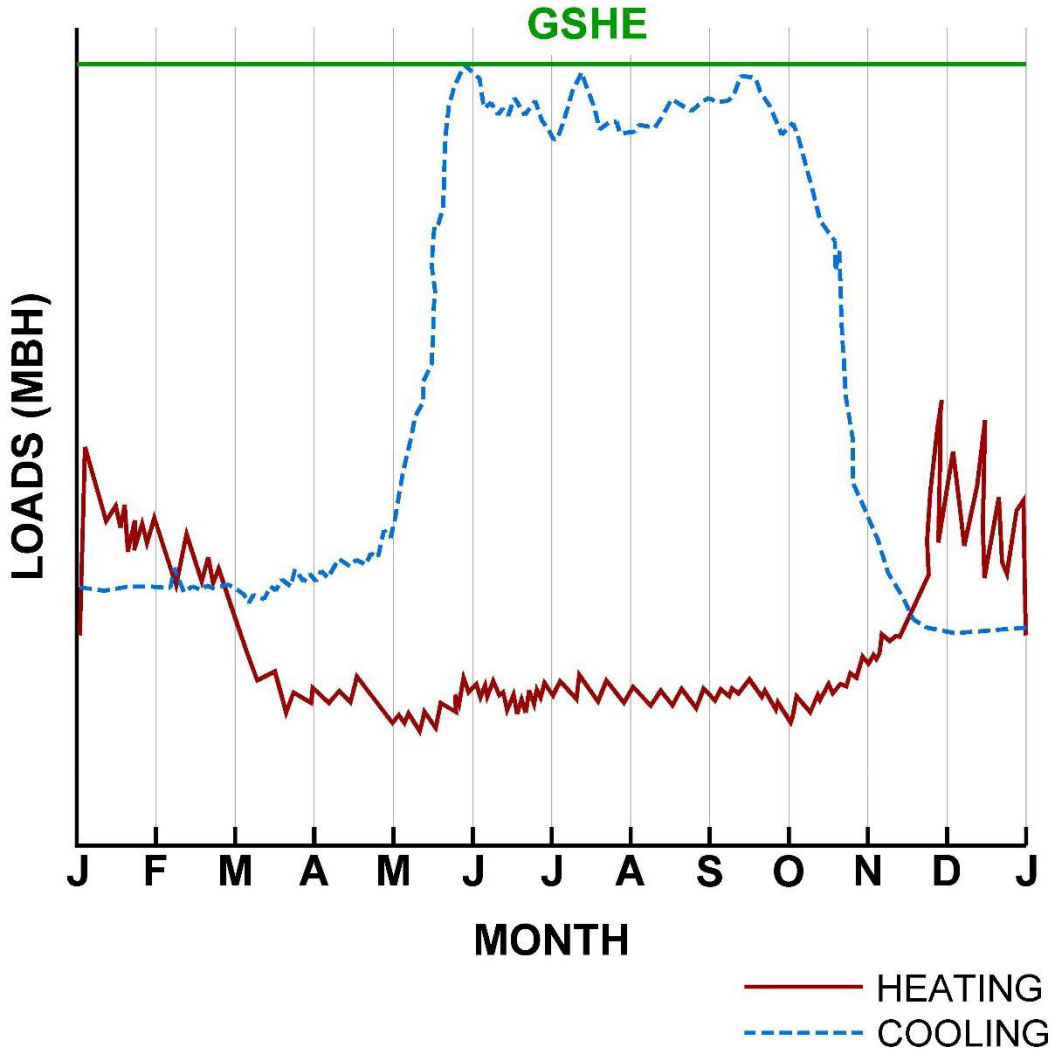
GROUND-SOURCE HEAT PUMP

HEAT RECOVERY CHILLER



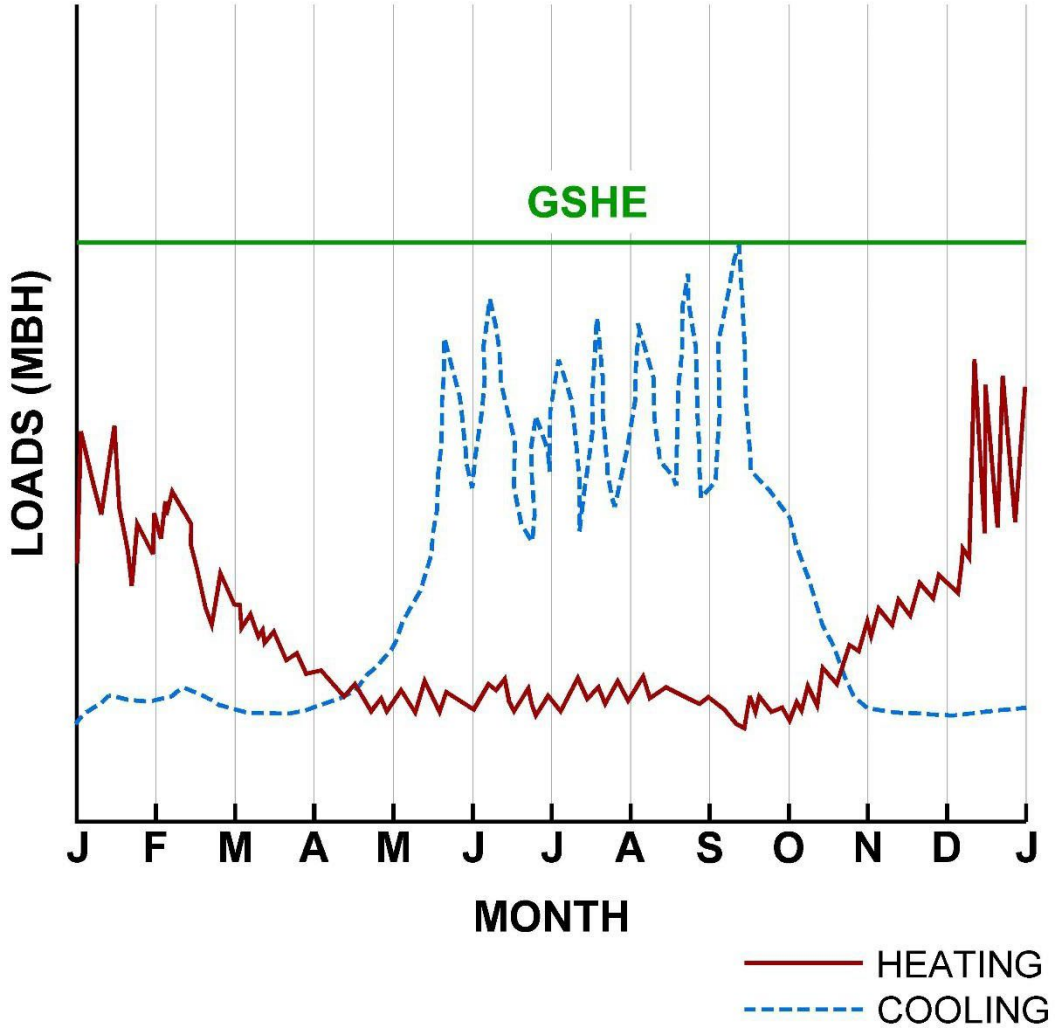
Load Profiles – Type 1

- Imbalanced load (cooling-dominated)
- Ground-Source Heat Exchange (GSHE) (geothermal) covers 100% of the load
- Significantly over-sized (low thermal exchange [tons] per borehole) to compensate for load imbalance



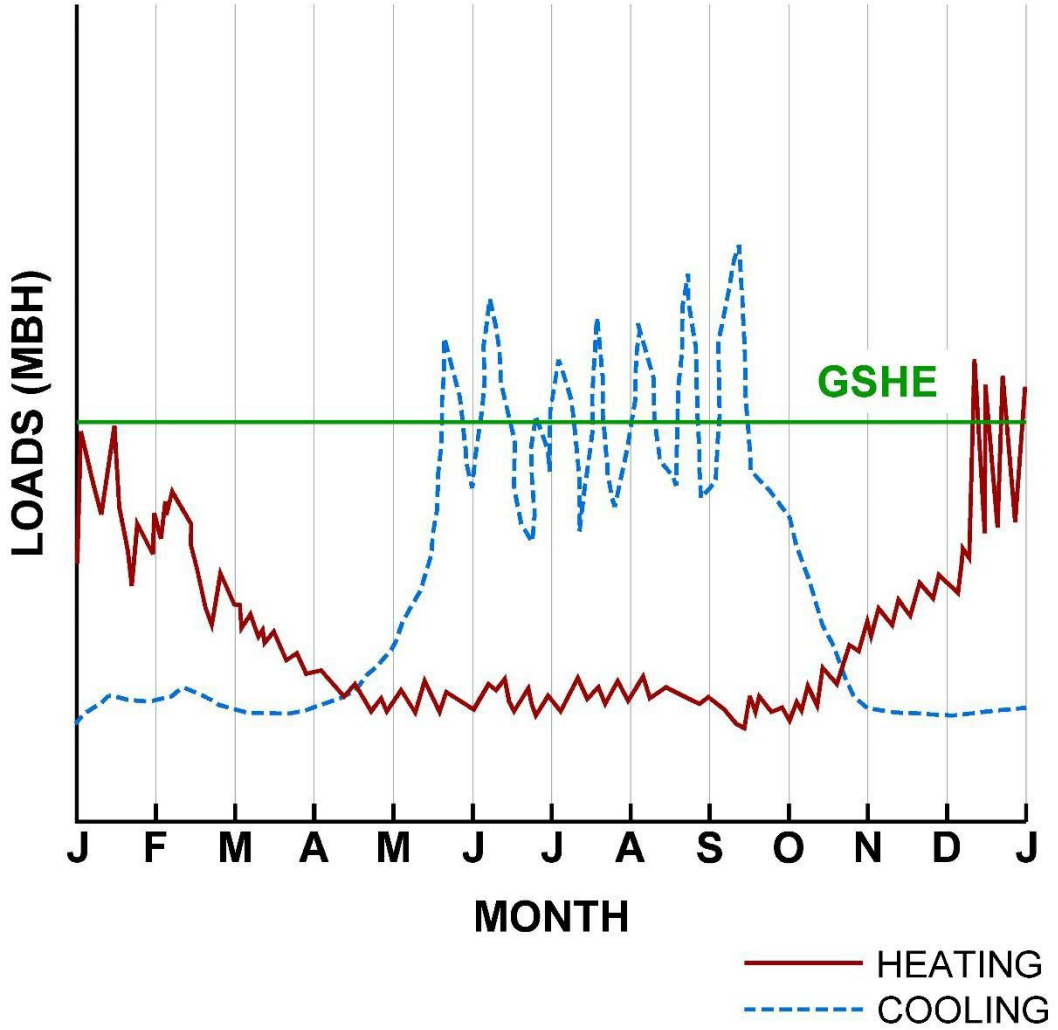
Load Profiles – Type 2

- Balanced load
- GSHE covers 100% of the load
- Over-sized (low to moderate thermal exchange per borehole) as borefield covers short-duration peak loads



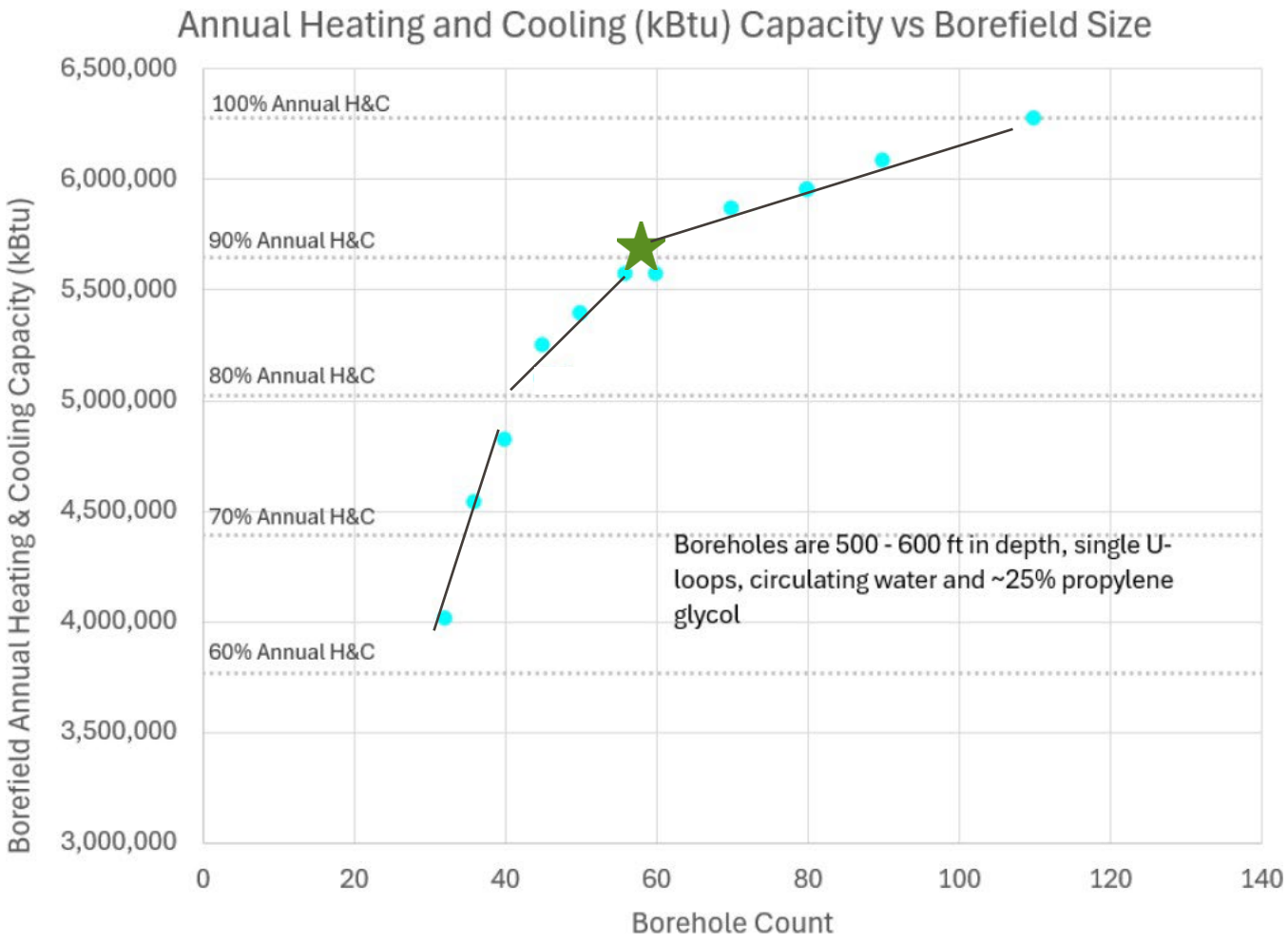
Load Profiles – Type 3 (Hybrid)

- Balanced Load
- GSHE covers 80% to 90% or more of the annual load
- Supplemental equipment covers short-term peak loads
- Thermal exchange per borehole is generally consistent with expectations (ton/borehole rules of thumb)



Example

- Diminishing returns in thermal exchange with increasing borehole count



Thank you…..

Questions ?

To contact us

Jacob Knowles
BR+A

John R. Kastrinos
Haley & Aldrich


Q&A

SAVE THE DATE

Built to Lead: Lessons in Deconstruction and Embodied Carbon

February 3, 2026 @ 10-11:30AM, Location TBD

- **Dennis Carlberg**, Chief Sustainability Officer & Associate Vice President for Climate Action, Boston University – *Retrofit of BU's Warren Towers*
- **Irmak Turan**, Associate, Climate and Sustainability, Arup – *Circularity and embodied carbon at airports*
- **Caroline Murray**, Regional Sustainability Manager, Turner Construction Company – *Deconstruction and reuse of office space*
- **Andrew Thompson**, Interim Executive Director, Boston Building Resources – *Material donation and reuse*