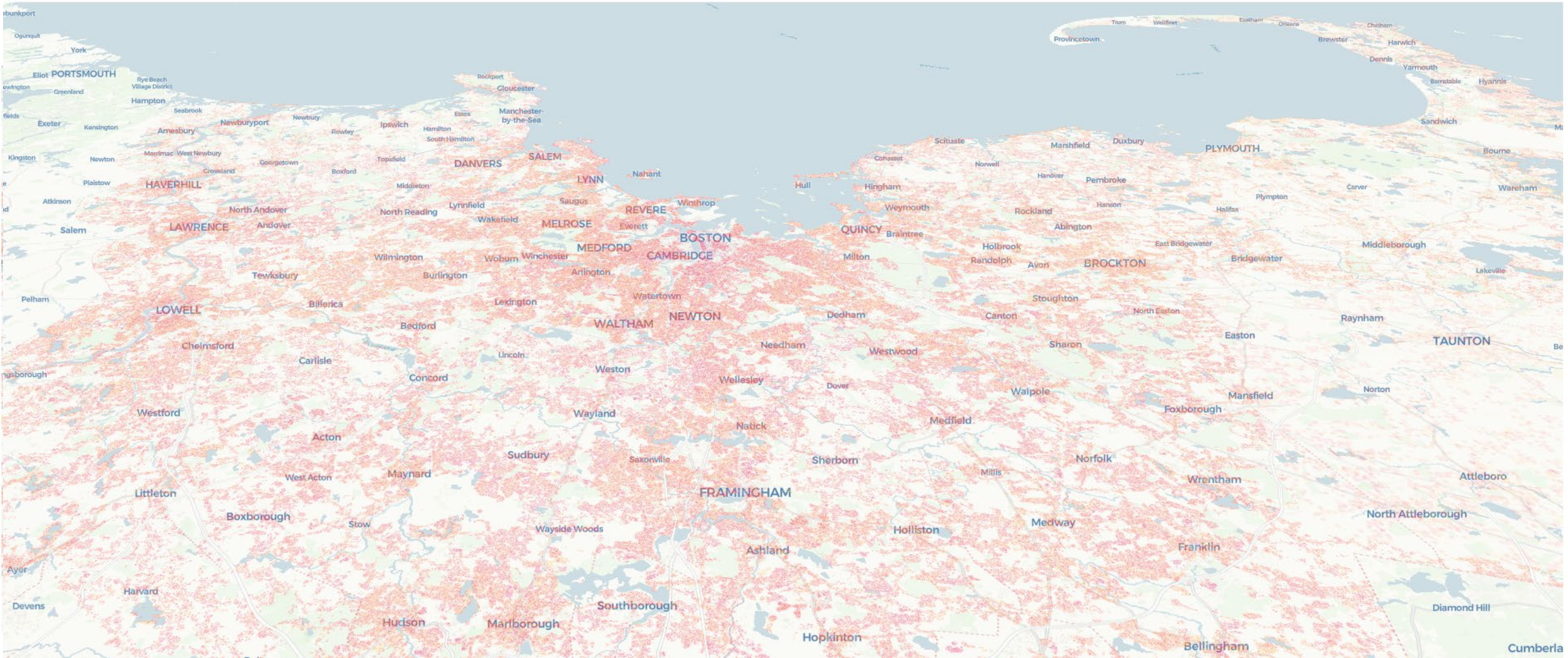


Carbon Reduction Pathways for Building Stocks

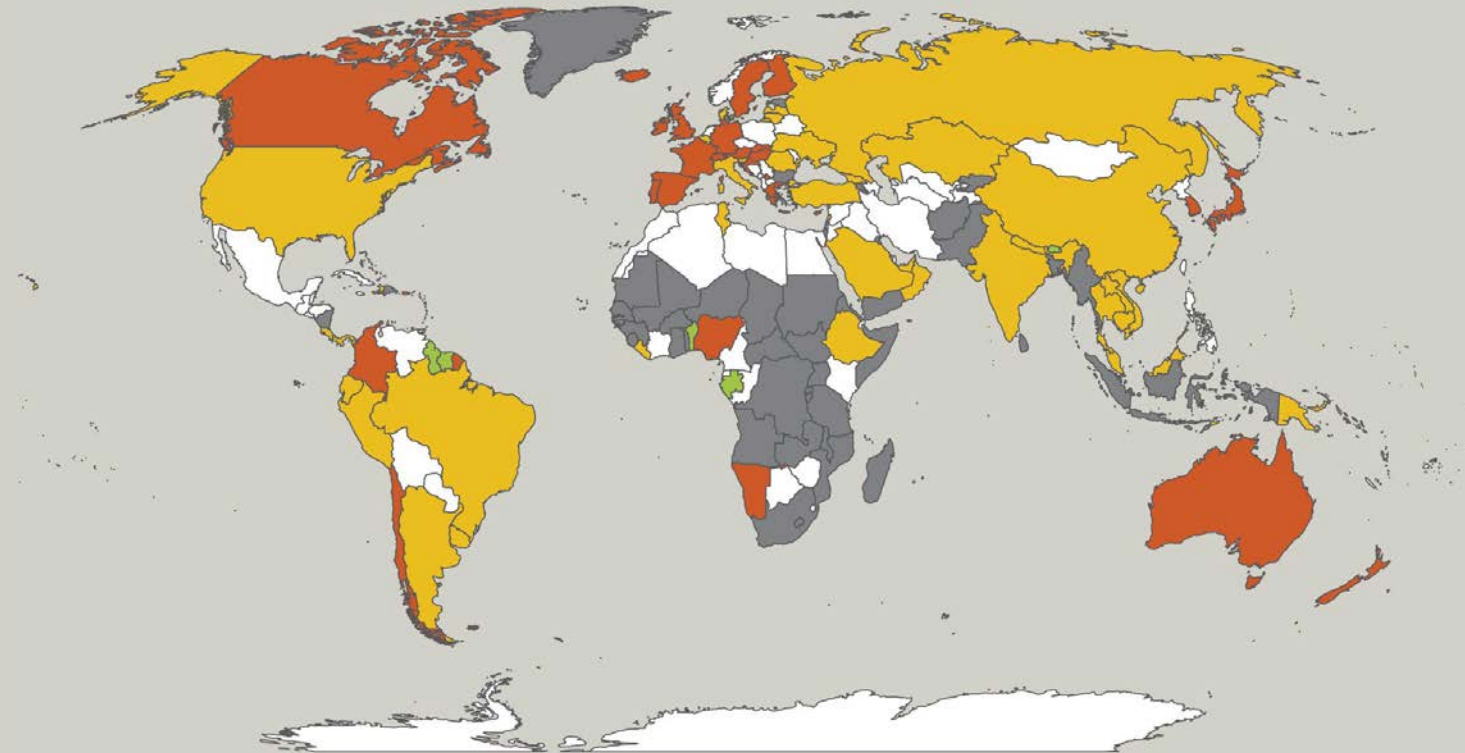


Christoph Reinhart

Geothermal Energy Networks (GENs) - Transforming our Thermal Energy System, January 30 2025

Carbon Neutrality Goals by Country

Figure: Climate Driven Design I
C. Reinhart, 2024

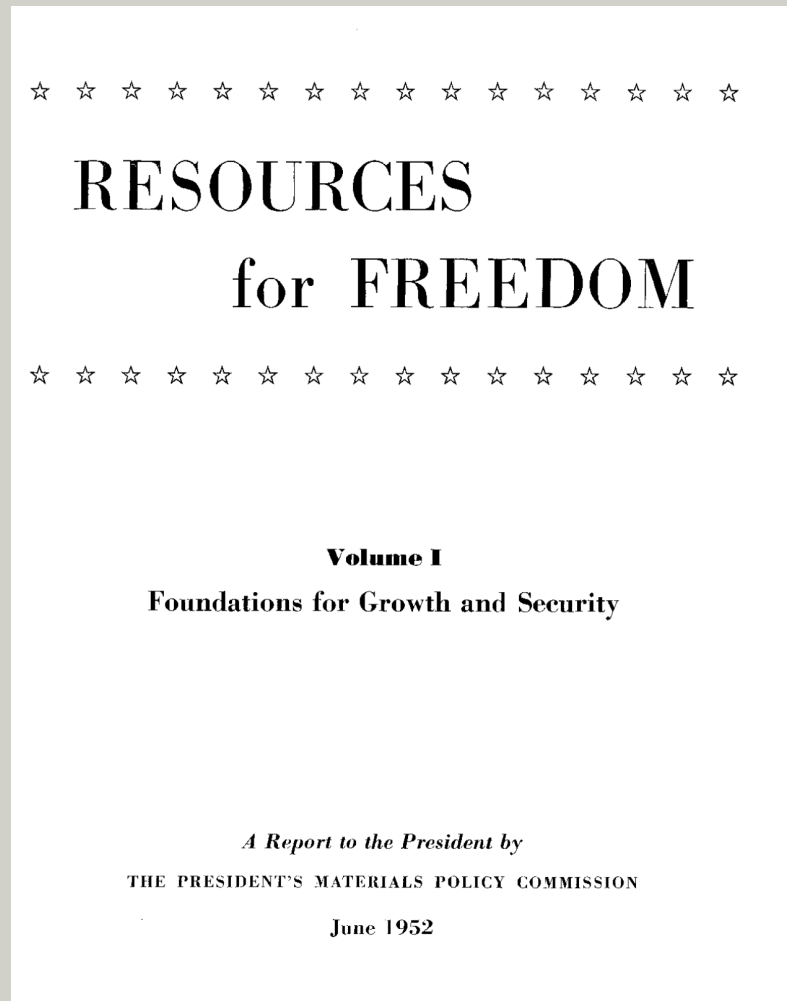


Net zero achieved* **Net zero in policy document** **No goal**
Net zero in law **Net zero in discussion or pledged** *Benin, Bhutan, Comoros, Gabon, Guyana, & Suriname

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□ In April 2024, 148 countries representing 90% of the world's population and GDP achieved, committed or proposed to fully decarbonize their economies by 2070

1952³ Paley Commission “Resources for Freedom”



Source: Public domain

Recommended to President Truman “permanent economic growth, powered by cheap fossil fuels of arbitrary origin, as the over-arching political priority of the twentieth century”

What are the drivers behind these unprecedented goals?

Changing Societal Attitudes



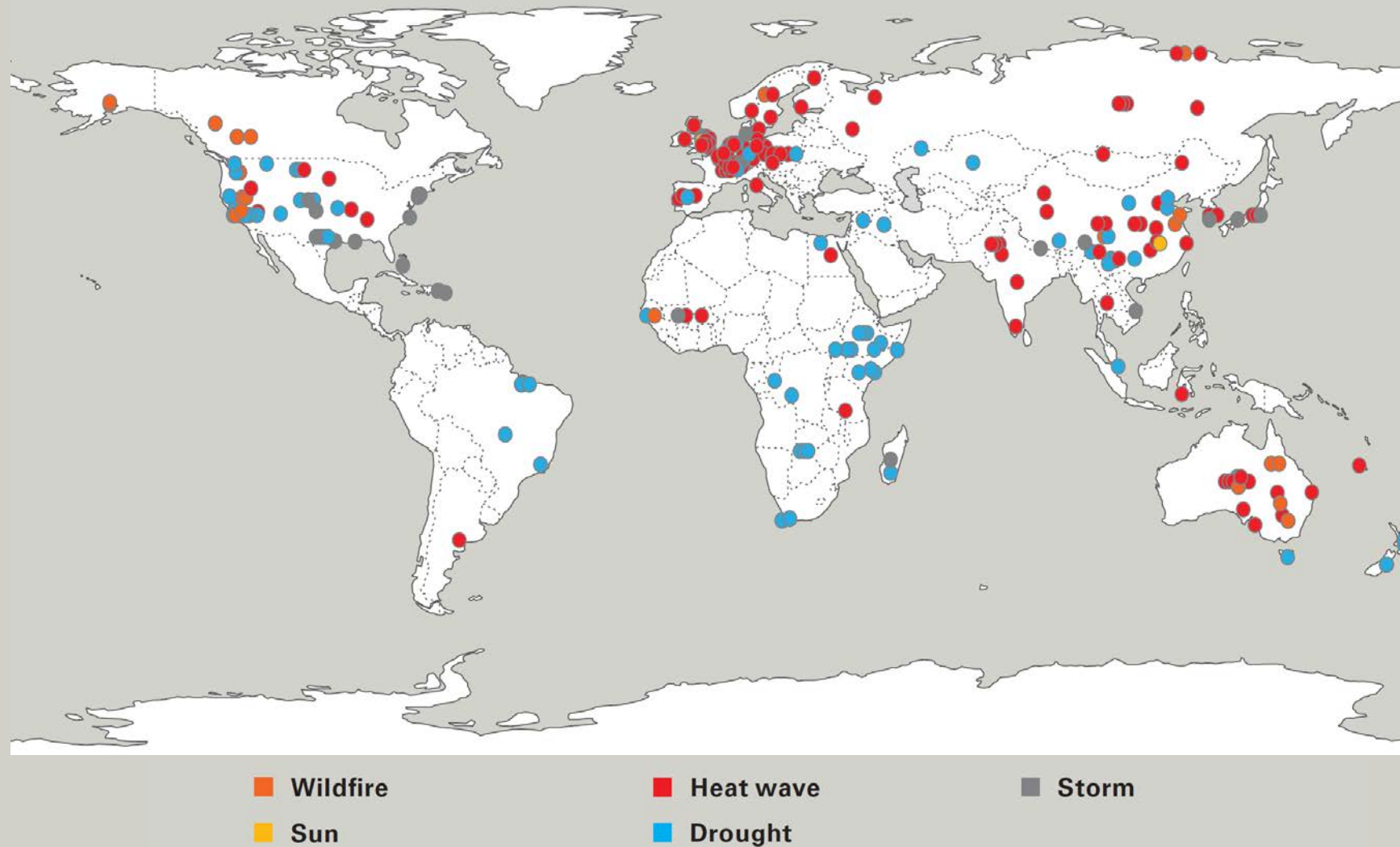
Survival - Coastal Cities are disappearing



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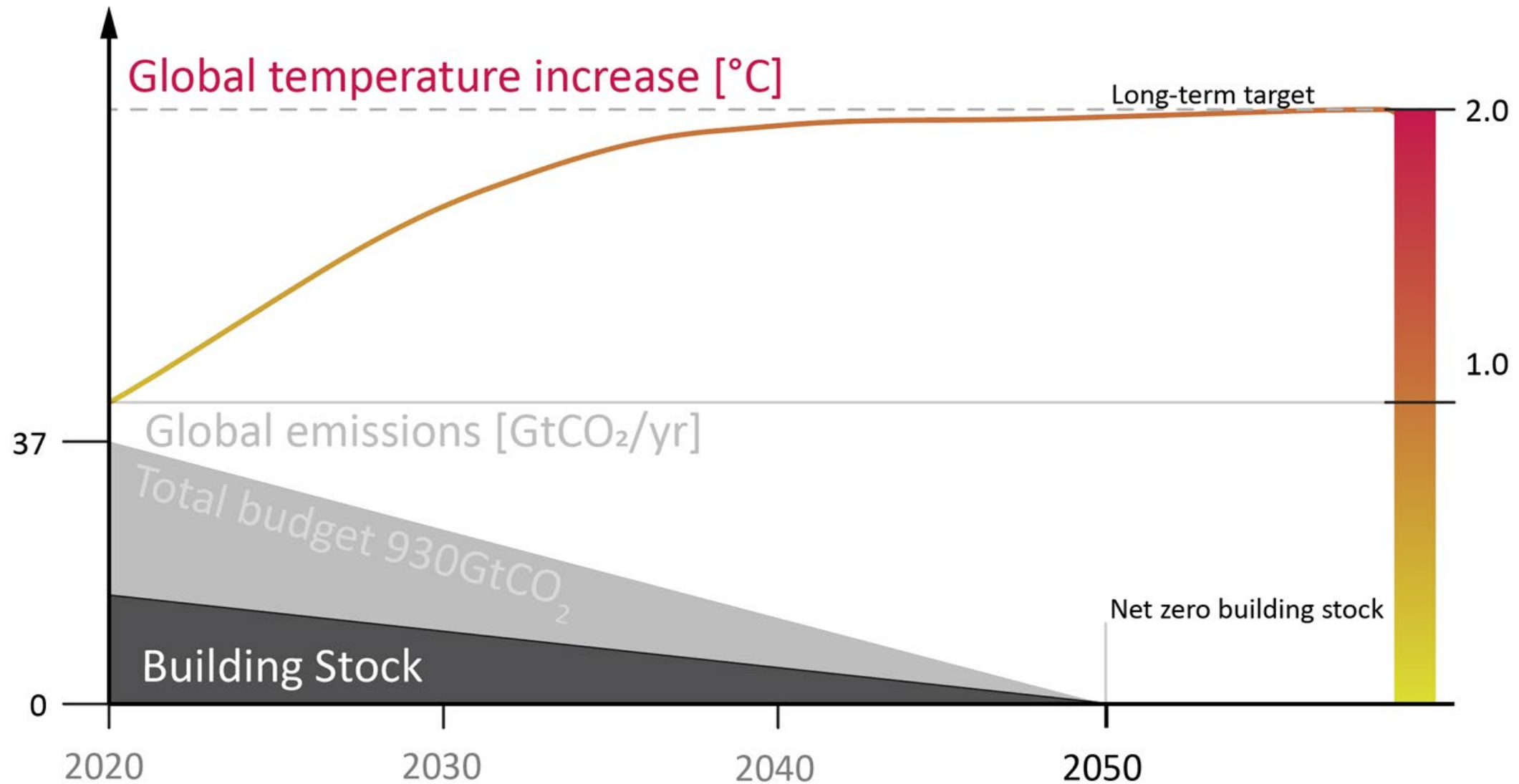
Extreme Weather Events between 1950 and 2020

Figure: Climate Driven Design I
C. Reinhart, 2024



92% of events happened during the last out of seven decades

Climate Change and the Building Sector



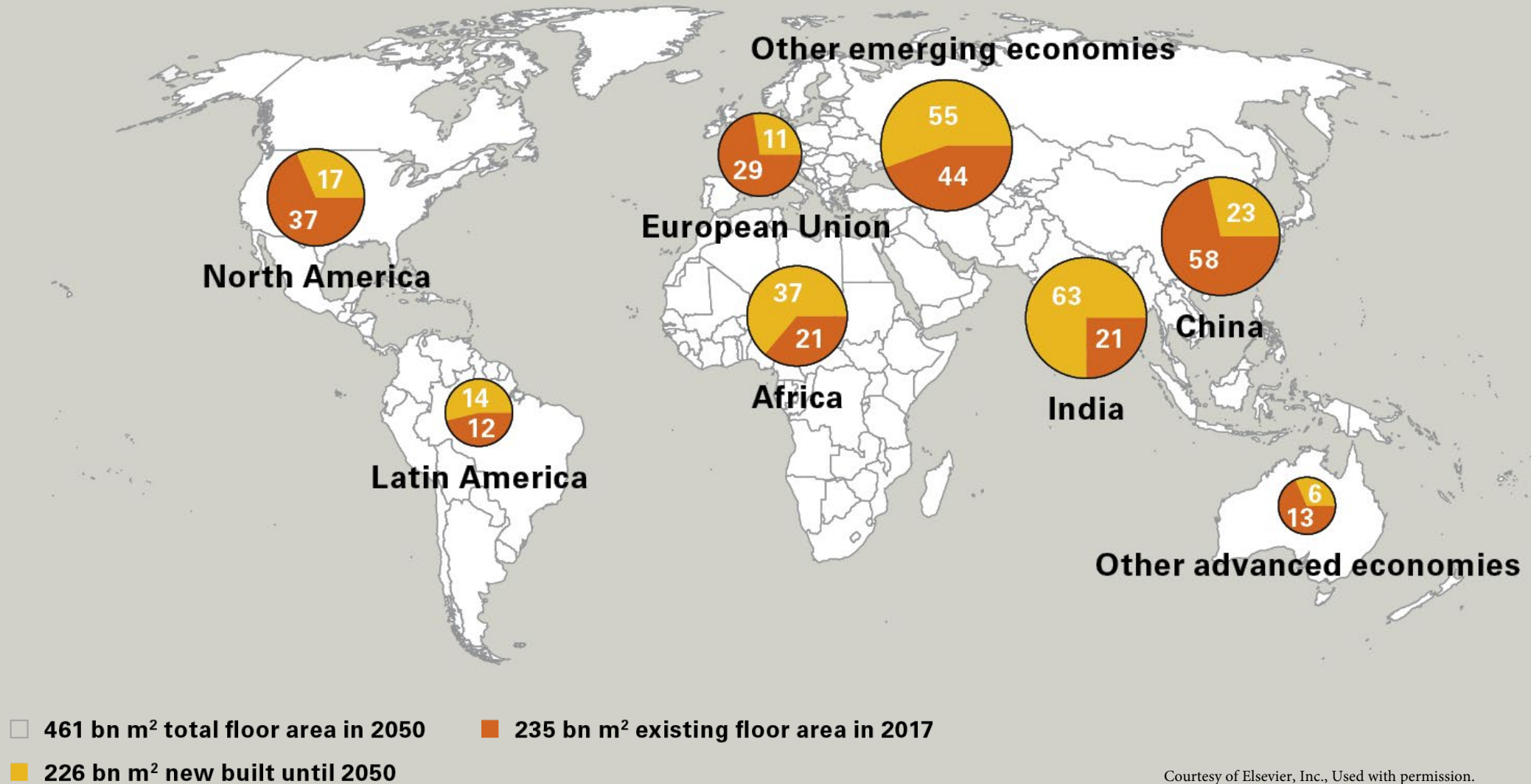
Adapted from Figures 1, 2 and 3 in Weber, Ramon, Caitlin Mueller, and Christoph Reinhart. "Building for Zero: The Grand Challenge of Architecture without Carbon." SSRN, October 8, 2021. <https://doi.org/10.2139/ssrn.3939009>. Courtesy of Elsevier, Inc., Used with permission.

Our Challenge

We have 340 GtCO₂ and 30 years left to make the global building stock carbon neutral.

The building stock is projected to double by 2050¹⁰

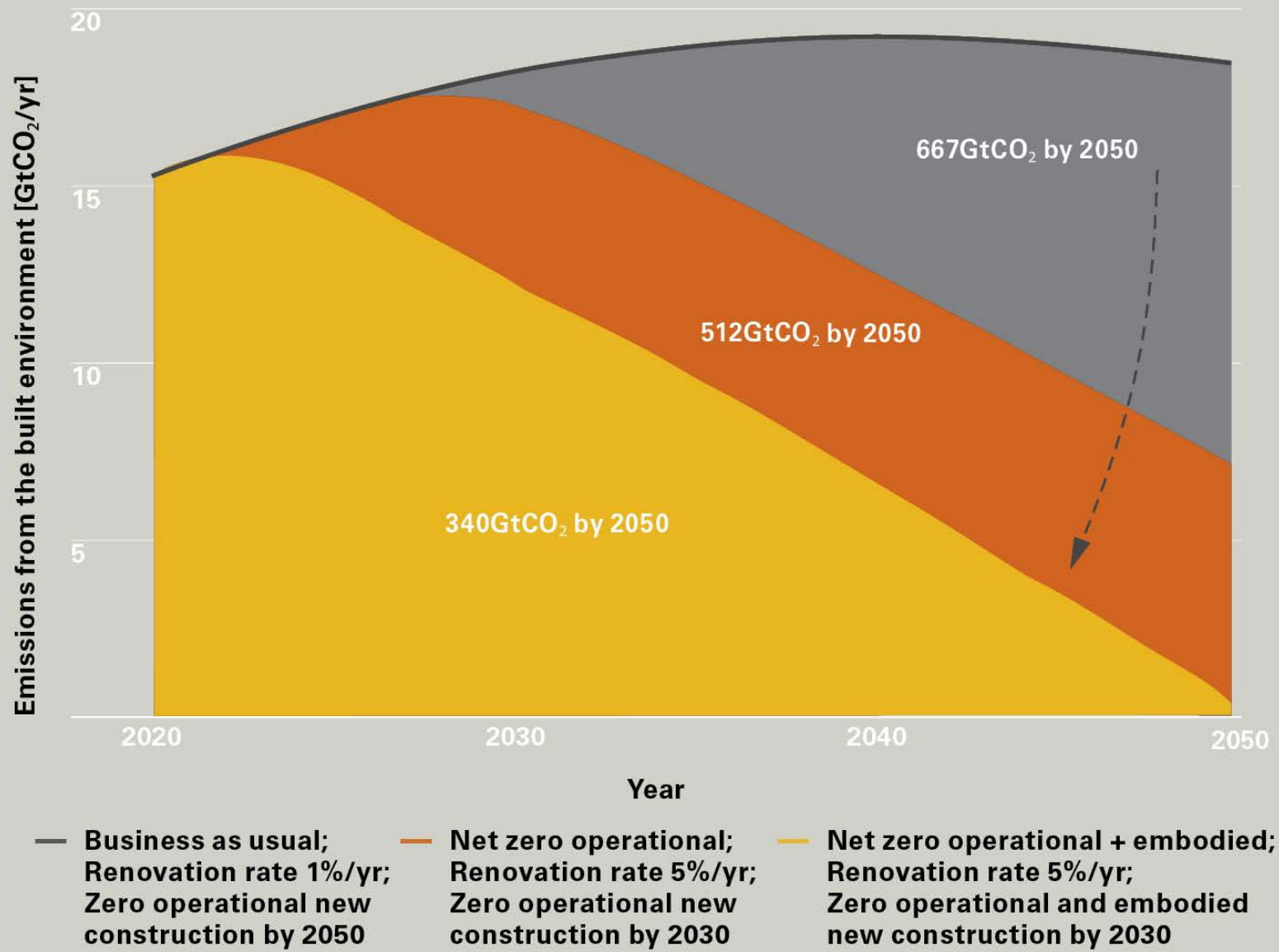
Figure: Climate Driven Design I



Courtesy of Elsevier, Inc., Used with permission.

Total annual carbon emissions from buildings

Figure: Climate Driven Design I
C. Reinhart, 2024

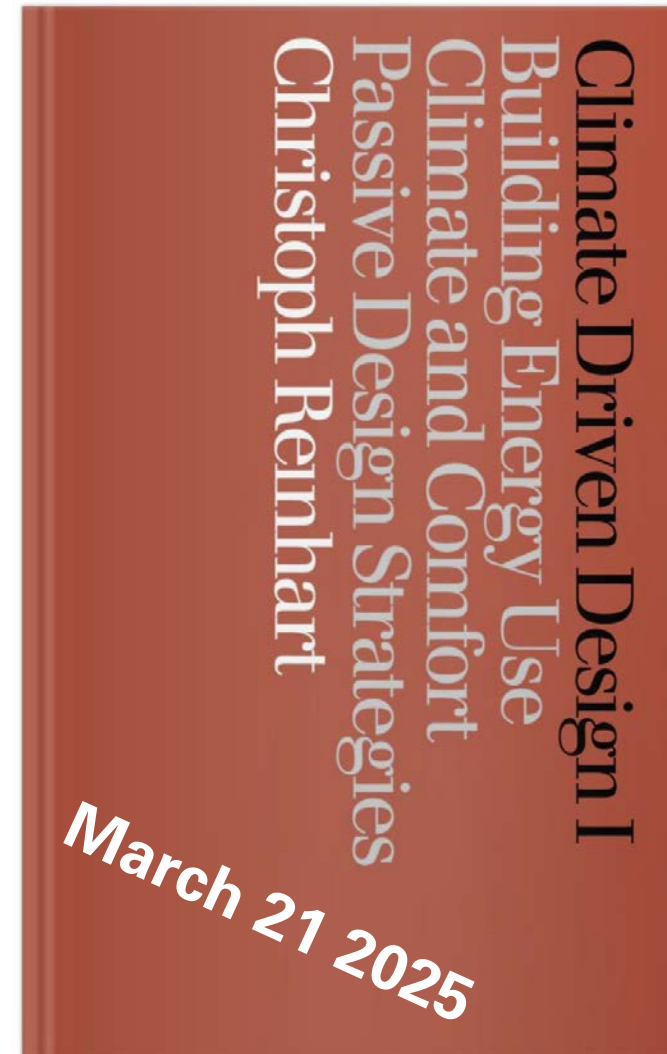


Our goals for 2030

- ❑ Increase annual retrofitting rate to 5%
- ❑ All new construction is carbon neutral
- ❑ More efficient space use.

What technology pathways lead to net zero retrofits?

Case Study - New England Home



- ❑ Detached single-family 1350ft² home in Boston, constructed during the 1920s.
- ❑ How can our residents get to **net zero** while living in the house?

Standard Advice: Going “All electric”



Rooftop PV

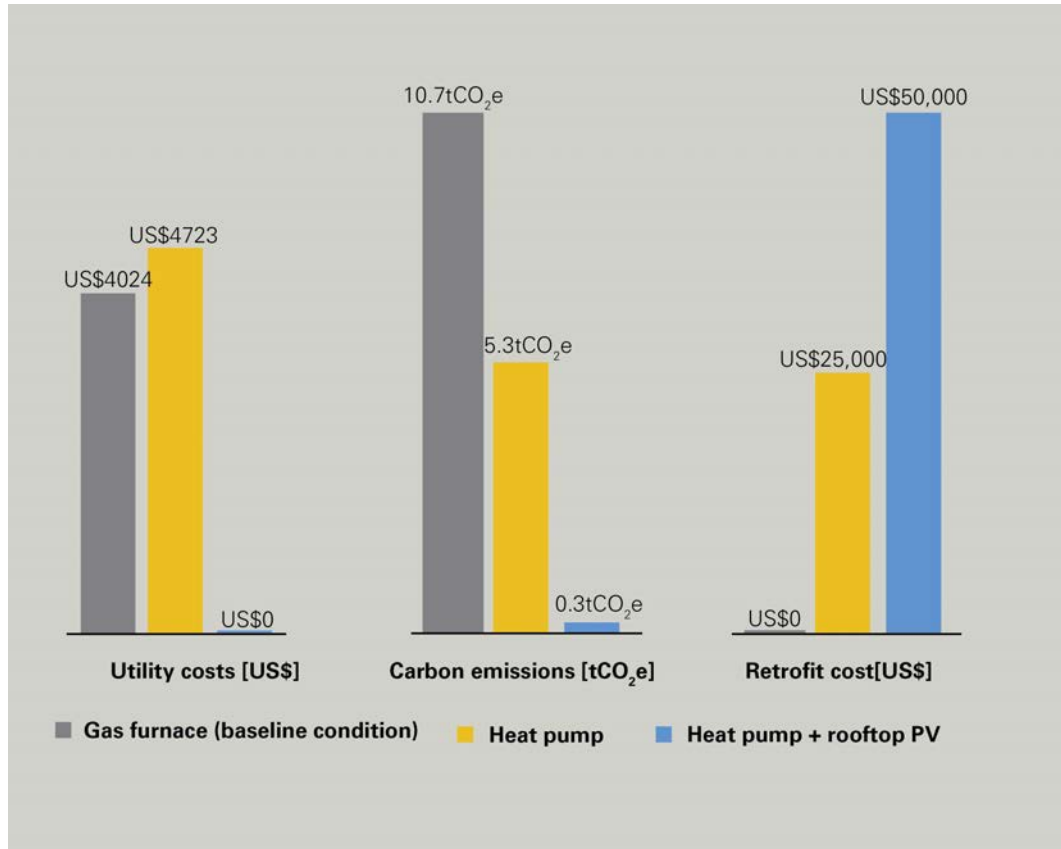


Air Source Heat Pump



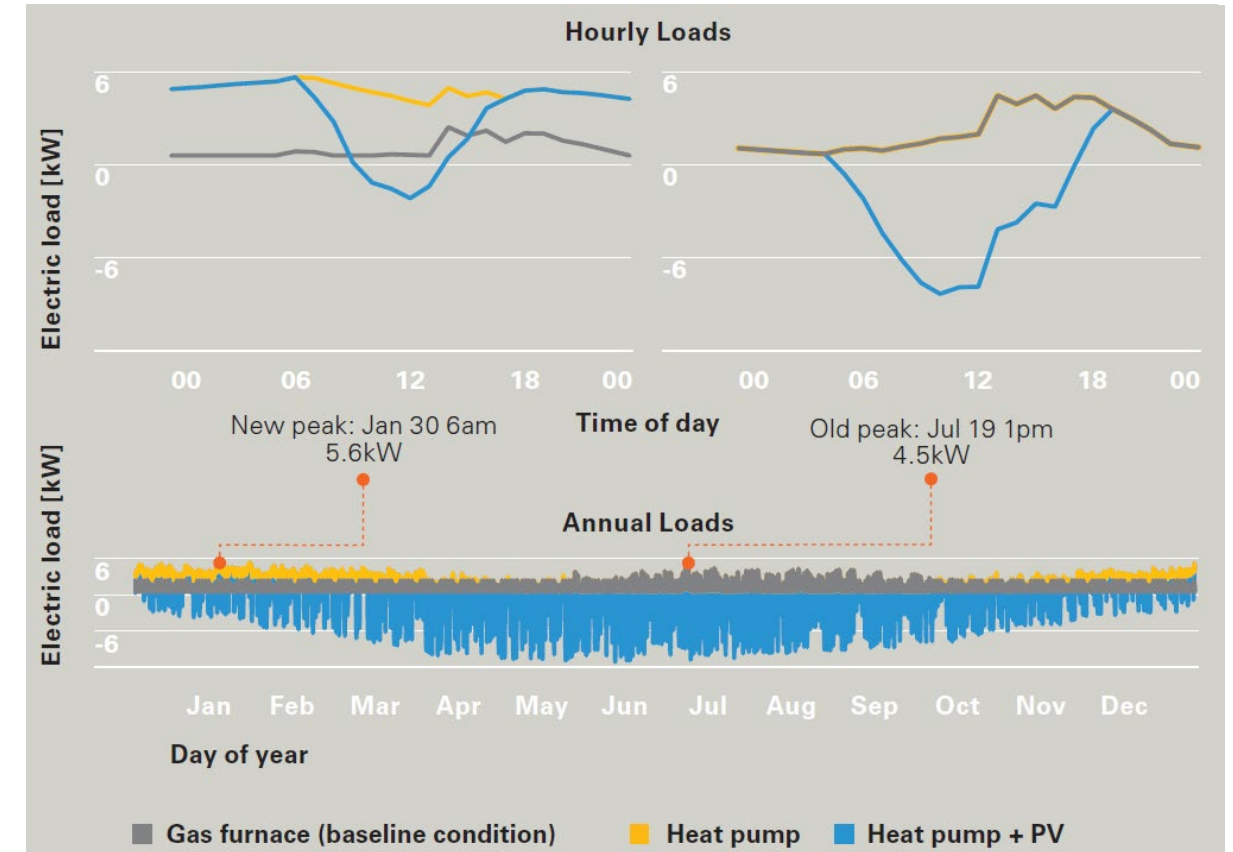
Scenario 1: Going “All electric”

Owner perspective



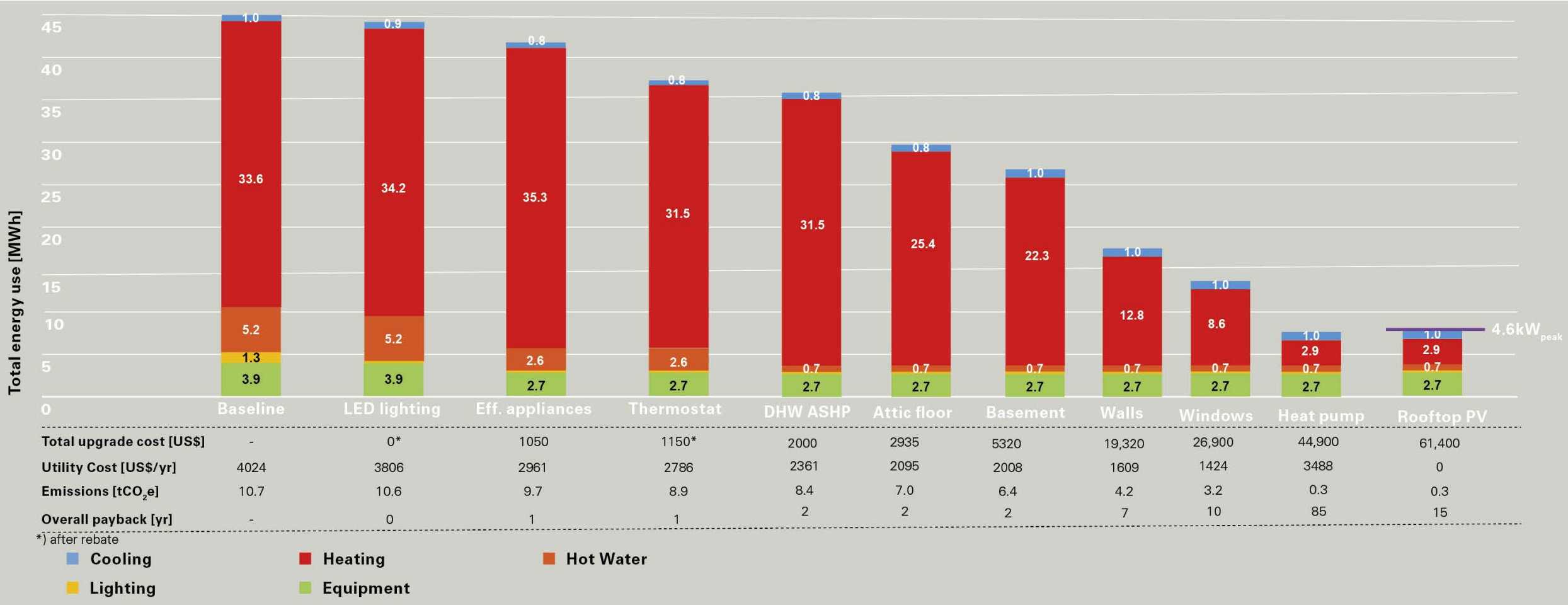
- ❑ Heat pump only has negative payback.
- ❑ Heat pump + rooftop PV pays for itself in 12 years but uses the grid as a free battery.

Utility perspective



- ❑ Installing a heat pump increases the peak by 25%
- ❑ Peak reductions if on-site storage is installed.

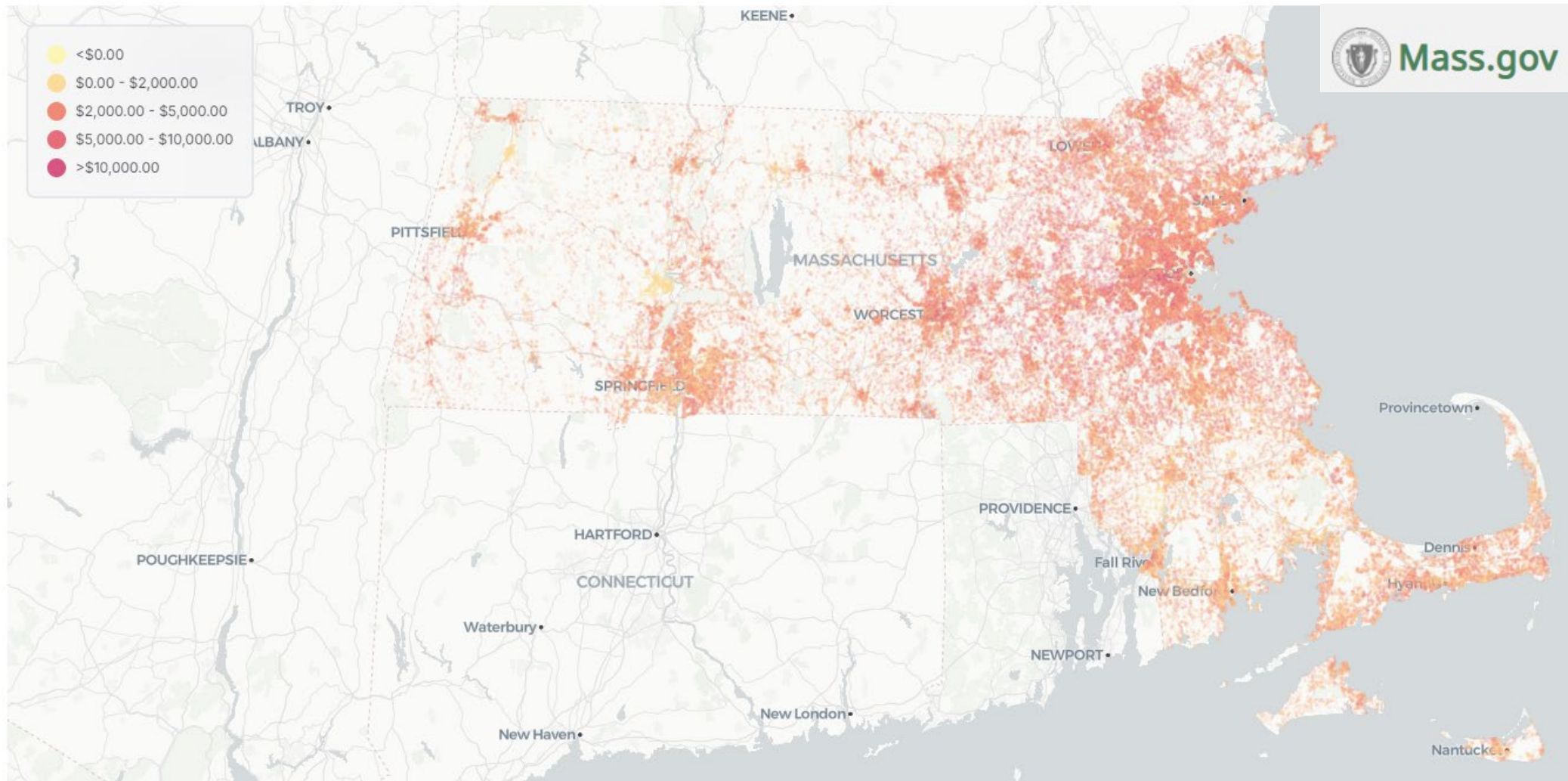
Nuanced Advice: Deep Retrofit + HP + PV



☐ A longer payback time but a future-proof and comfortable home.

Commonwealth Building Energy Map

Annual utility cost (electricity + heating fuel)

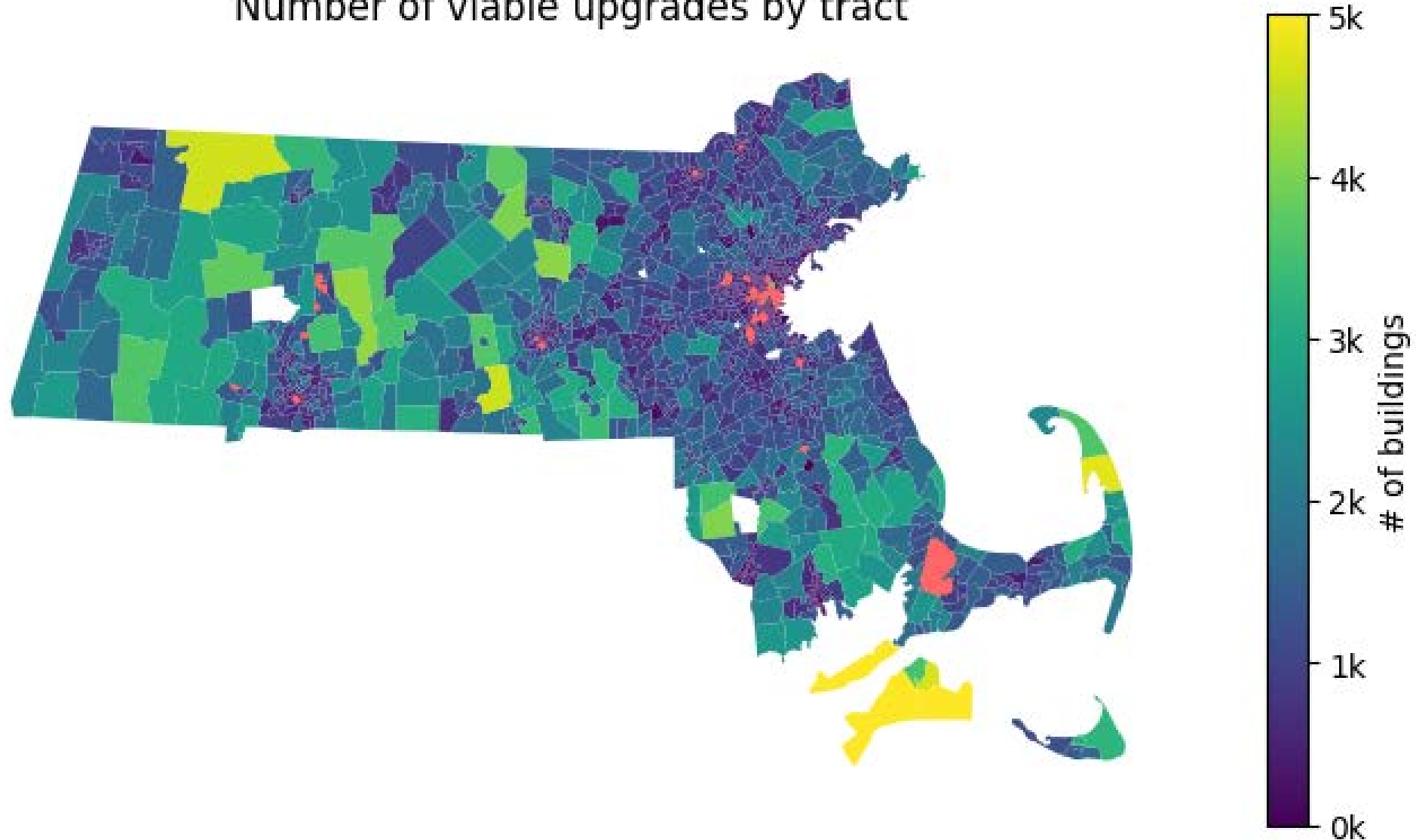


2.5 million buildings in Massachusetts; collaboration with the Office of Climate Innovation and Resilience



Commonwealth Building Energy Map

Number of viable upgrades by tract



❑ Where are the viable projects? Where will be the jobs?



Commonwealth Building Energy Map

MASS.

Search Property

500 Main Street

Smallville, MA

67 Cambridge St in Smallville, MA, is a single-family home, constructed in the 1940s. It has not been renovated since then. The furnace has an 80% to 20% chance of being heated by natural gas or oil.

Current Utilities Estimate

Annual Utilities

\$1,200 - \$2,000

~10-50 tonsCO2e

Electricity

\$900 - \$1,200

~8-20 tonsCO2e

Natural Gas /Propane

\$300 - \$800

~2-30 tonsCO2e

Verification

✓ \$30,000 - \$60,000

✓ Natural Gas

✓ Insulated

✓ Air Tight



+
-

TAKE ACTION →

MIT SUSTAINABLE DESIGN LAB

20
Graphic: S Ajenka , M A Jin, S Wolk and C Reinhart under preparation

Thank You



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RES.ENV 007 Geothermal Energy Networks (GENs): Transforming our Thermal
Energy System
IAP 2025

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