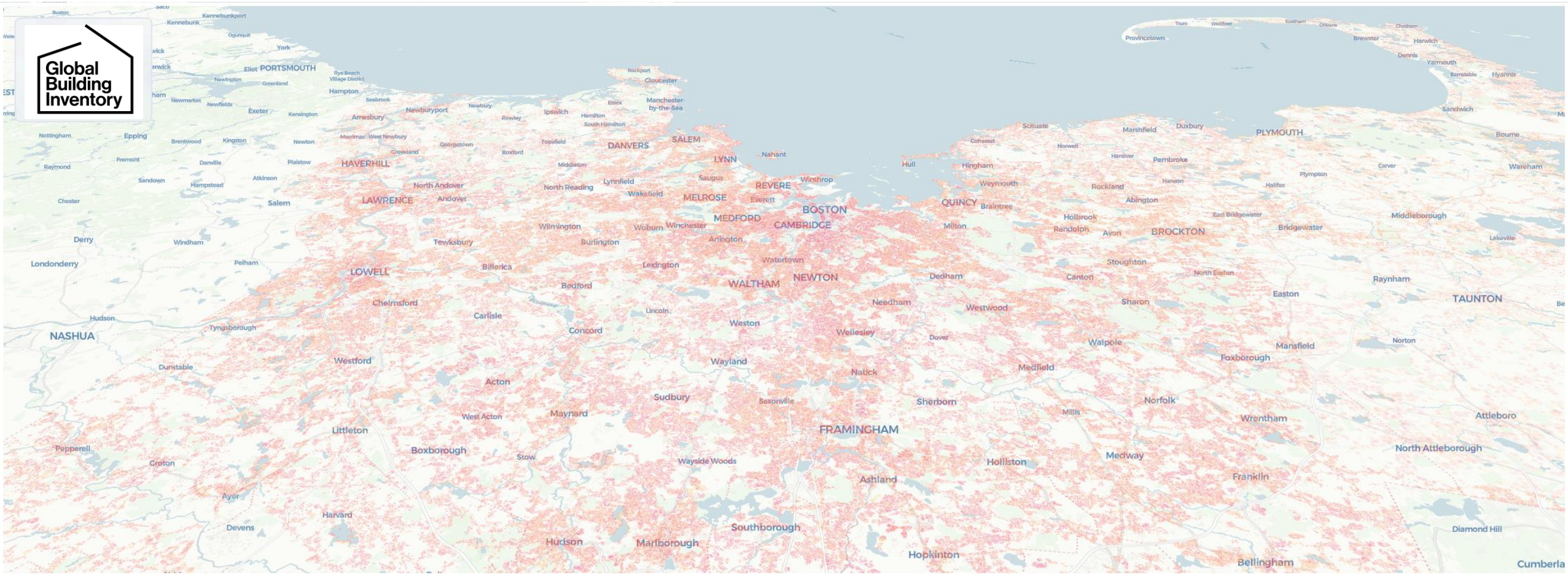
Building Tomorrow: Policy and Data-Driven Solutions for Financing Climate Technologies in Buildings



Christoph Reinhart

On the Intersection of technology, policy, data and financing, June 18, 2025

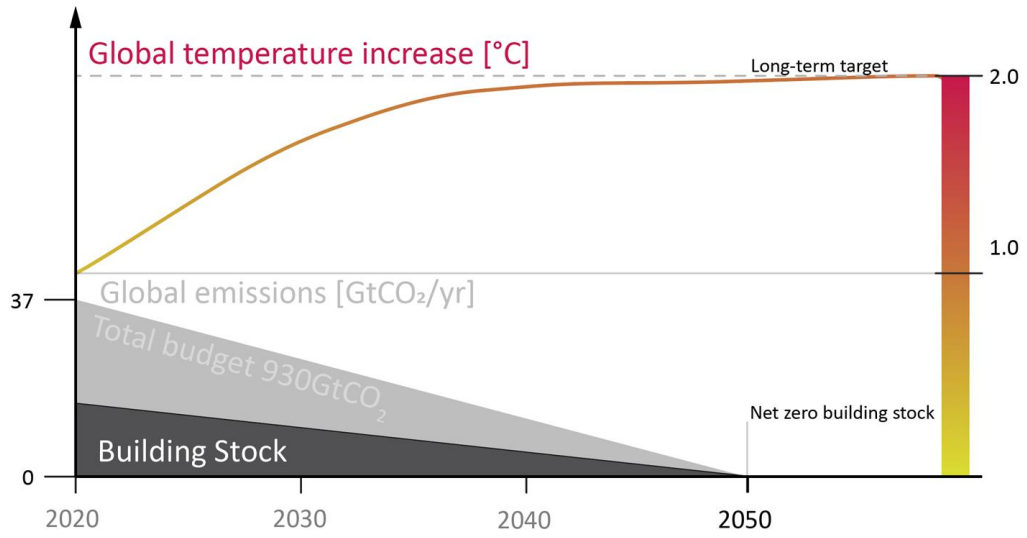
MIT SUSTAINABLE DESIGN LAB

Designing Resilient and Prosperous Cities

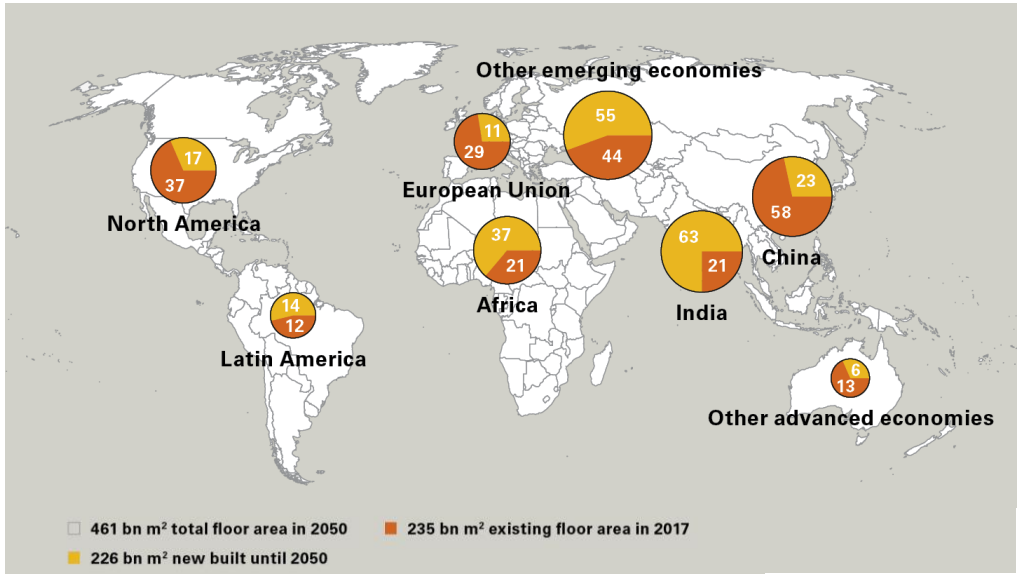
Key Ideas

- Many technologies for decarbonization buildings are already available.
- Policymakers, utilities and building owners need a shared techno-economic model for aligned decision-making.

Climate Change and the Building Sector



We have 340 GtCO2 and 25 years left to make the global building stock carbon neutral.



The global building stock is projected to double by 2050.

R Weber, C Mueller and C Reinhart, Christoph, Building for Zero, The Grand Challenge of Architecture without Carbon (October 8, 2021). http://dx.doi.org/10.2139/ssrn.3939009

MIT-SDL Pursues a Three-pronged Solution:

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

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Most Economical Strategy: Go “All electric”

Rooftop PV

Owner perspective

- ❑ Heat pump + rooftop PV pays for itself in 12 years buts uses the grid as a free battery.

Air Source Heat Pump

Grid perspective

- ❑ Installing a heat pump increases the electric peak by 25%

Scalable Strategy: Deep Retrofit + HP + PV

	Baseline	LED lighting	Eff. appliances	Thermostat	DHW ASHP	Attic floor	Basement	Walls	Windows	Heat pump	Rooftop PV
Total upgrade cost [US$]	-	0*	1050	1150*	2000	2935	5320	19,320	26,900	44,900	61,400
Utility Cost [US$/yr]	4024	3806	2961	2786	2361	2095	2008	1609	1424	3488	0
Emissions [tCO_2e]	10.7	10.6	9.7	8.9	8.4	7.0	6.4	4.2	3.2	0.3	0.3
Overall payback [yr]	-	0	1	1	2	2	2	7	10	85	15

*) after rebate

Cooling **Heating** **Hot Water**
Lighting **Equipment**

Figure: Climate Driven Design I (C Reinhart)

Our Vision

Empower building owners, operators nd policymakers everywhere to conduct such an analysis via actionable online platforms.

Urban Building Energy Modeling (UBEM)

- Combing big urban data with building performance simulation

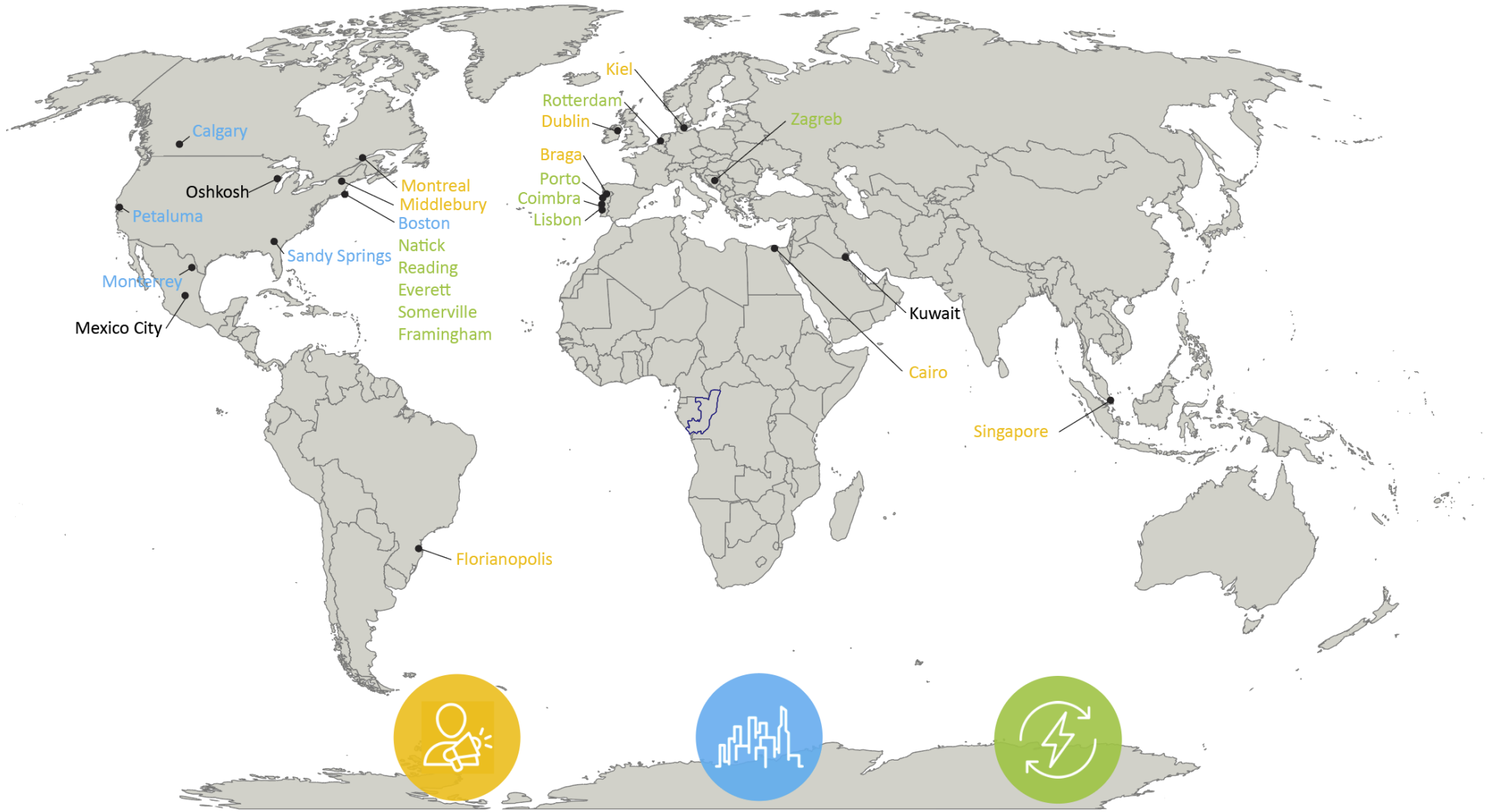
C F Reinhart and Cerezo, 2016, "Urban Building Energy Modeling – A Review of a Nascent Field," *Building and Environment*, 97:196–202

2016 - Boston Building Energy Study

- In collaboration with the Boston Redevelopment Authority with support from the Massachusetts Clean Energy Center we created an UBEM with has over 80,000 buildings.
- The model to explored new energy supply technologies such a micro-grids and district heating/cooling.

C Davila Cerezo, J Bemis and F Reinhart, "Modeling Boston: A workflow for the efficient generation and maintenance of urban building energy demand models from existing geospatial datasets," *Energy*, 117, pp. 237-250, 2016

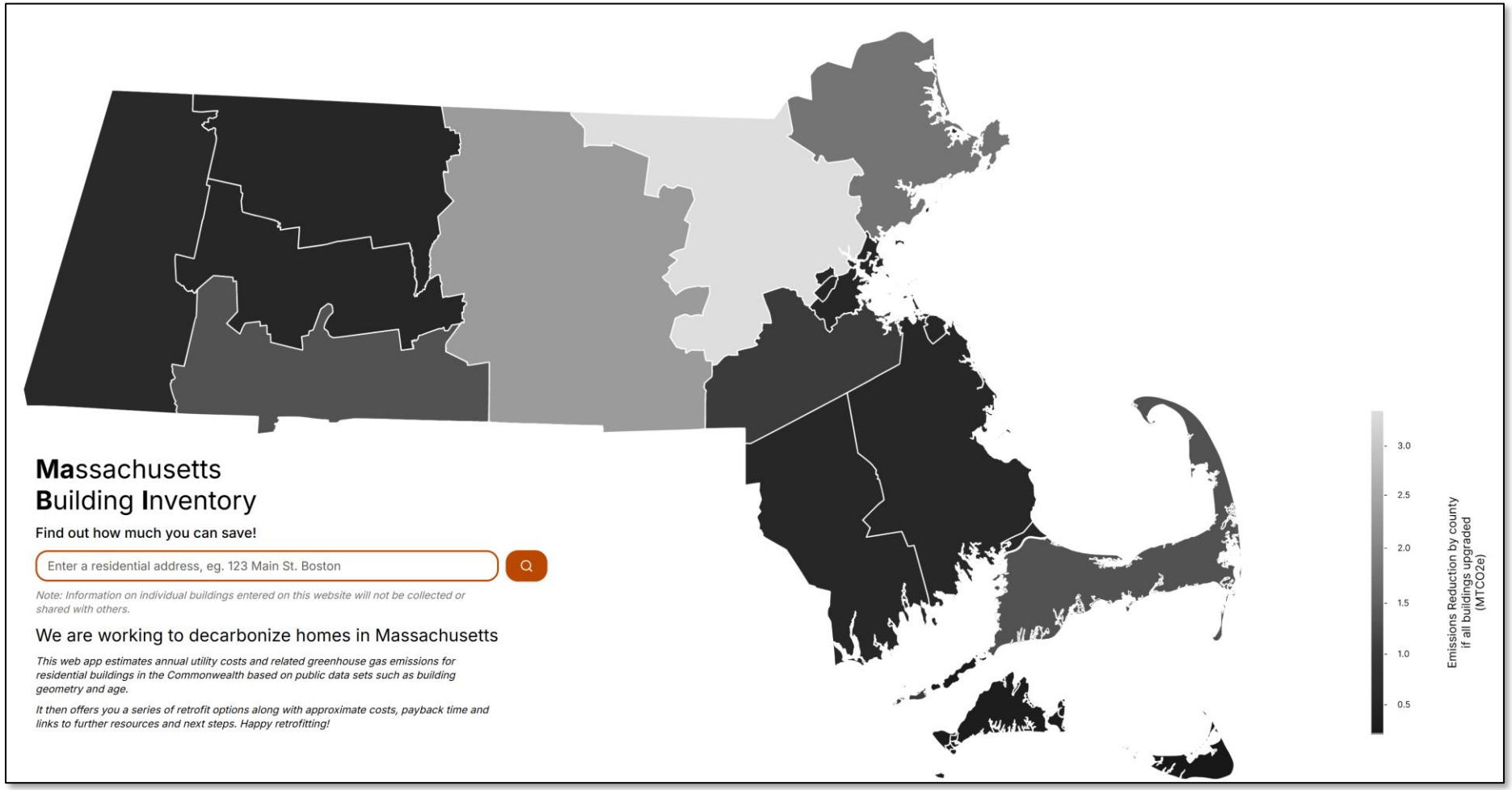
2022-Applied framework in 26 cities



- ❑ Approach scales globally.
- ❑ Need to standardize model input and data collection. (Global Building Inventory effort at MIT)

Y Q Ang, Z M Berzolla, S Letellier-Duchesne, V Jusiega and C Reinhart, 2022, UBEM.io: A web-based framework to rapidly generate urban building energy models for carbon reduction technology pathways, *Sustainable Cities and Society*

Massachusetts Building Inventory (MABI)



- ❑ Collaboration with the Commonwealth of Massachusetts and local utilities
- ❑ The same model is used to inform incentive policies and grid planning and provide recommendations to home owners

Massachusetts Building Inventory (MABI)

89 WENDELL ST

Cambridge, MA 02138

1. Verification | 2. Upgrade

Verify that the description below is accurate.

89 Wendell St in Cambridge, MA is a single-family home built in 1873. The wall cavity has **some insulation**. Most windows are **double pane**. On a cold windy day, the building feels **drafty**. The attic is an **active, conditioned living space** with a **well-insulated roof**. The basement is an **active, conditioned living space** and the walls are **not insulated**. Cooling is provided via a **few window AC units**. The building is mainly heated with an **older natural gas system**. Hot water is provided by a **natural gas water heater**. Heat is distributed via **mostly uninsulated hot water pipes**. The building has **mostly LED fixtures** throughout. There are **high efficiency appliances** in the building. There is **a programmable thermostat**.

VERIFICATION:

Confirm the size of your home.

Gross Living Area (sqft): 2000

Select the options that most describe your building.

Building:

- Wall Insulation: Some insulation in wall cav...
- Windows: Double pane with low-e coating ...
- Weatherization: Leaky envelope
- Attic: Occupied & insulated roof
- Basement: Occupied & uninsulated walls

Systems:

- Cooling: Window AC units
- Heating: Natural gas boiler/furnace
- Hot Water: Natural gas water heater
- Heat Distribution: Hot Water - mostly unins...

Fixtures:

- Lighting: Mostly LED bulbs
- Equipment: Higher efficiency equipment

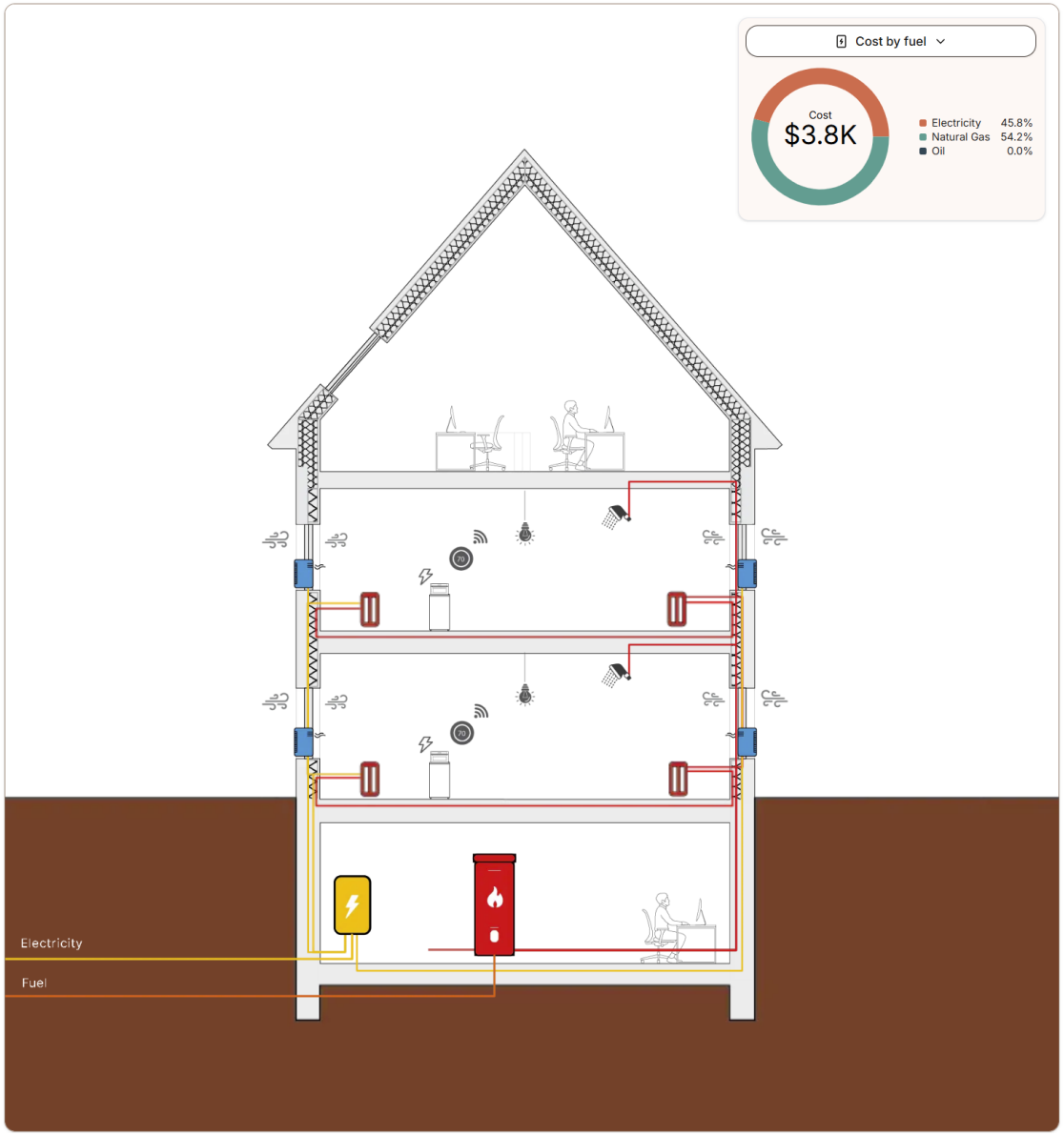
Controls:

- Thermostat: Programmable thermostat co...

CURRENT UTILITIES ESTIMATE: cost *impact*

Annual Utilities	$3.5K to $4.1K
	⚠ 8.3 to 9.6 tCO2e
consisting of:	
Electricity	$1.6K to $1.9K
Natural Gas	$1.8K to $2.4K

EXPLORE RETROFIT OPTIONS >



Massachusetts Building Inventory (MABI)

89 WENDELL ST

Cambridge, MA 02138

1. Verification | 2. Upgrade

89 Wendell St in Cambridge, MA is a single-family home built in 1873. The wall cavity is **fully insulated**. Most windows are **single pane with additional storm windows**. Windows and doors are **air tight** and the building has **heat recovery ventilation**. The attic is an **active, conditioned living space** with a **well-insulated roof**. The basement is an **active, conditioned living space** with **wall insulation**. Cooling is provided via **mini-split air source heat pumps**. The building is mainly heated with an **air source heat pump**. Hot water is provided by a **heat pump water heater**. Heat is distributed via **insulated hot water pipes**. The building has **mostly LED fixtures** throughout. There are **high efficiency appliances** in the building. There is **a programmable thermostat**.

UTILITIES ESTIMATE AFTER UPGRADES:

A summary of annual utilities and carbon emissions

Annual Utilities	$2.1K to $2.4K
	⚠ 2.1 to 2.3 tCO2e

SELECT BUILDING UPGRADES BELOW:

Choose precompiled packages or select individual upgrades

Deep Upgrade | Shallow Upgrade | Custom Upgrade

Building:

- Wall Insulation: Fully insulated wall cavity ~$7.7K
- Windows $0
- Weatherization: Tight envelope with ventil... ~$2.5K
- Basement: Occupied & insulated walls ~$7.7K

Heating and Cooling:

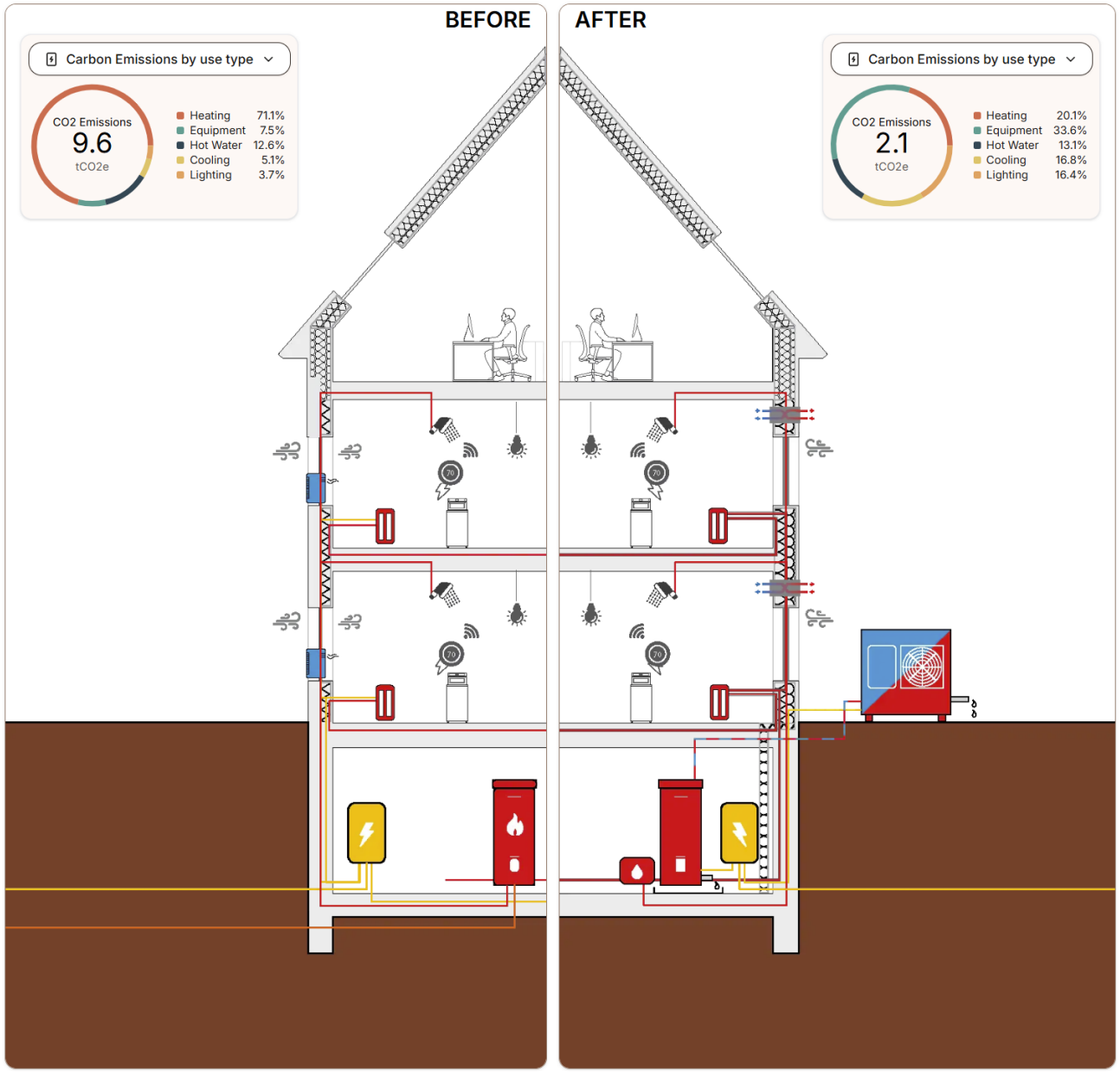
- HVAC: Air Source Heat Pump (heating and ... ~$15K
- Heat Distribution: Hot Water - mostly insul... ~$600
- Hot Water: Heat pump water heater ~$3.2K

UPGRADE INVESTMENT PROFILE:

Estimate of costs and payback time for selected upgrades

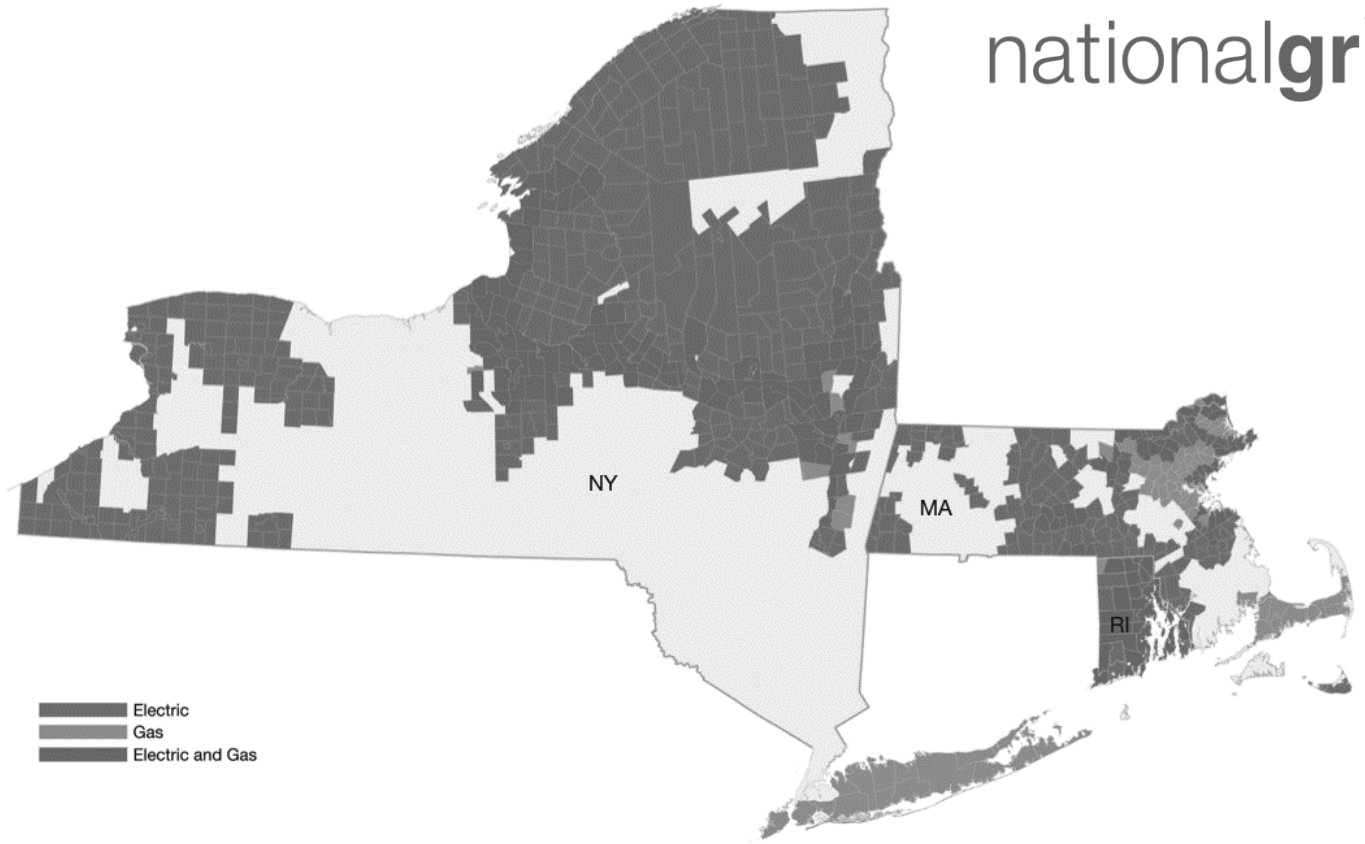
26 to 38 Yrs.	$1.7K	$51K to $52K
Payback time	Est. Annual Savings	Upgrade cost

GENERATE REPORT ›



Are homeowners willing to pay that much?

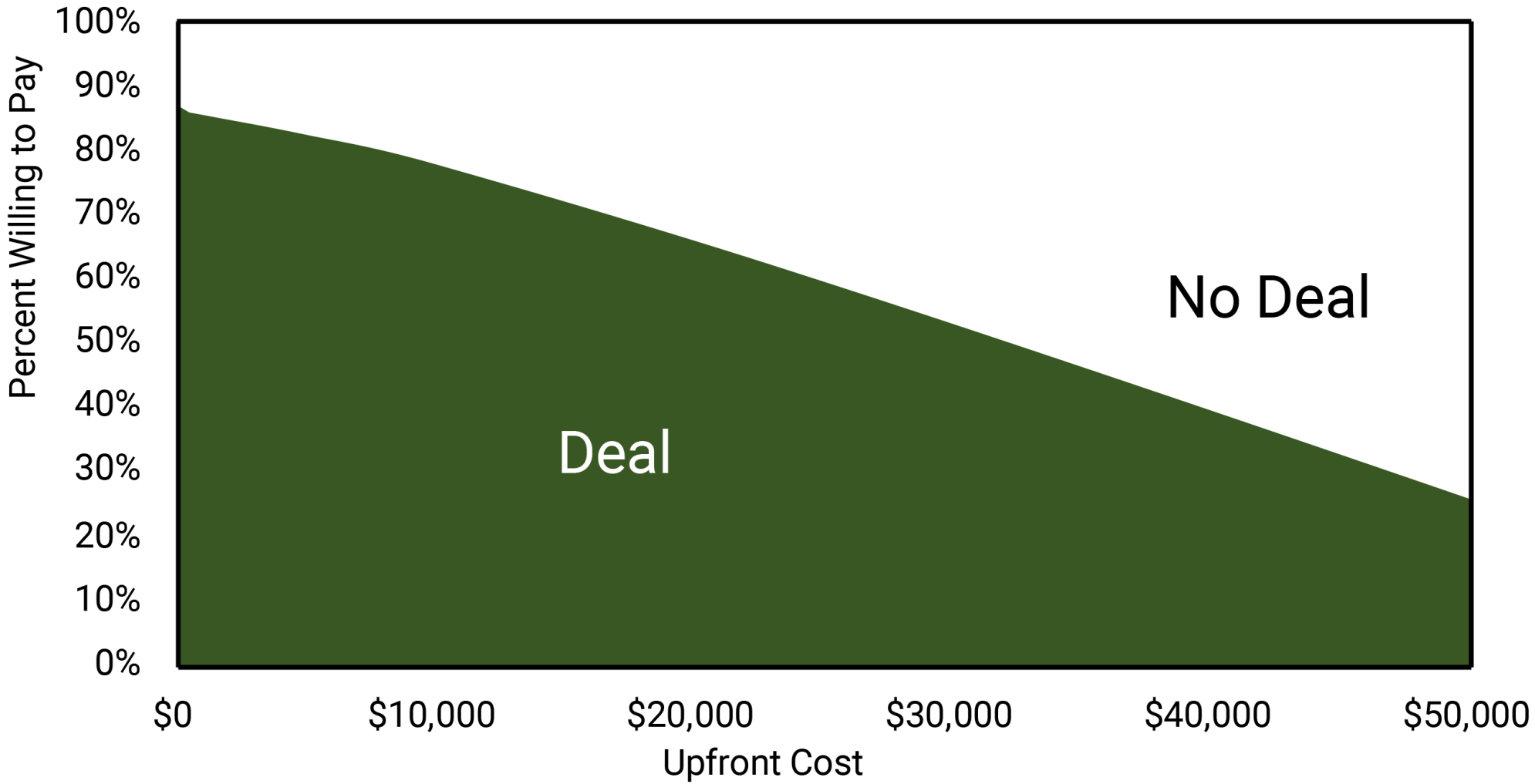
Willingness to Pay Survey + Regression Model



What is the minimum payback time that you would accept for a retrofit upfront cost of $x, or is it too expensive?

Z. Berzolla, T. Meng, and C Reinhart, 2025, "Deal or No Deal: U.S. Homeowners' Willingness to Pay for Residential Building Retrofits", *Environmental Research: Infrastructure and Sustainability*

Willingness to Pay | Deal or No Deal



- Key input variables are household income, upfront cost and concern about emissions
- Costs will vary depending on location.

Z. Berzolla, T. Meng, and C Reinhart, 2025, "Deal or No Deal: U.S. Homeowners' Willingness to Pay for Residential Building Retrofits", *Environmental Research: Infrastructure and Sustainability*

Upgrade Prediction for Oshkosh, WI

- ❑ The Landlord/Tenant Challenge
- ❑ High-income, high-ownership neighborhoods adopt
- ❑ Low-income neighborhoods left behind

Low retrofit

Medium retrofit rate

High retrofit rate (approaching net zero)

Z. Berzolla, Y. Q. Ang, S. Letellier-Duchesne, and C Reinhart, 2023, “An eight-step simulation-based framework to help cities reach building-related emissions reduction goals”, *Environmental Research: Infrastructure and Sustainability*

MIT –Energy in Action

- ❑ Fall 2024: Three evening workshops to inform residents about state retrofit incentive programs which are mostly used by affluent household
- ❑ **Direct impact:** Workshops resulted in a waitlist of 600 energy-efficiency (MassSave) projects in Everett

M. Arcaya, S. Rimenez Riofrio, N. Ting, C. Reinhart; Collaborators: La Comunidad, Electrify Everett, Everett Community Growers, MAPC, City of Everett; Photos https://www.instagram.com/electrifyeverett/

Closing Thoughts

- ❑ Many technologies for decarbonization buildings are already available.
- ❑ Policymakers, utilities and building owners need a shared techno-economic model for aligned decision-making.
- ❑ There is a acute need for green workforce training.
- ❑ Crucial gap for critical cooling situations.
- ❑ We are scaling the MABI effort globally. Current partners are located in Brazil, India, Norway, Portugal and Singapore and the UK. Reach out if you would like to learn more.

Thank You

MIT Building Technology Program 2023
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