FROM OIL TO HEAT PUMPS: UNDERSTANDING ADOPTION ACROSS MASSACHUSETTS MUNICIPALITIES

CELT Clean Energy & Environment Legacy Transition

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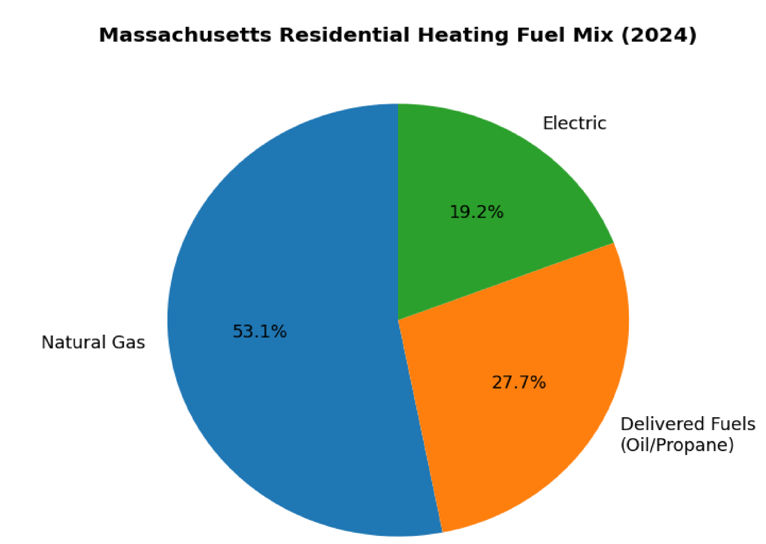
Project Overview & Objectives

Background
- Massachusetts is transitioning residential heating from fossil fuels to heat pumps.
- Many homes still rely on heating oil and propane.
- Direct measurements of oil-to-heat pump switching is difficult because heating oil consumption is not centrally reported.

Research Question
What factors explain differences in heat pump adoption across Massachusetts municipalities?

Objectives
- Build a municipality-level dataset combining heat pumps, fuel mix, electricity use, and weather.
- Identify structural and behavioural drivers of adoption.
- Detect municipalities adopting more or less heat pumps than expected.

Why it Matters?
- Supports Massachusetts decarbonization goals.
- Helps identify communities most likely to transition away from heating oil.



Approach and Methods

Data Integration

Merged municipality-level data from: Mass Save heat pump installations, ACS household & heating fuel data, ISO-NE electricity consumption, Weather (HDD/CDD).

Feature Engineering

Created metrics to compare municipalities: Installs per 1000 households, Delivered fuel share, Gas share, Electricity per HH per HDD, Electricity per HH per CDD.

Adoption Modeling

Used correlation analysis and multivariate regression to identify factors associated with heat pump adoption.

Residual Analysis

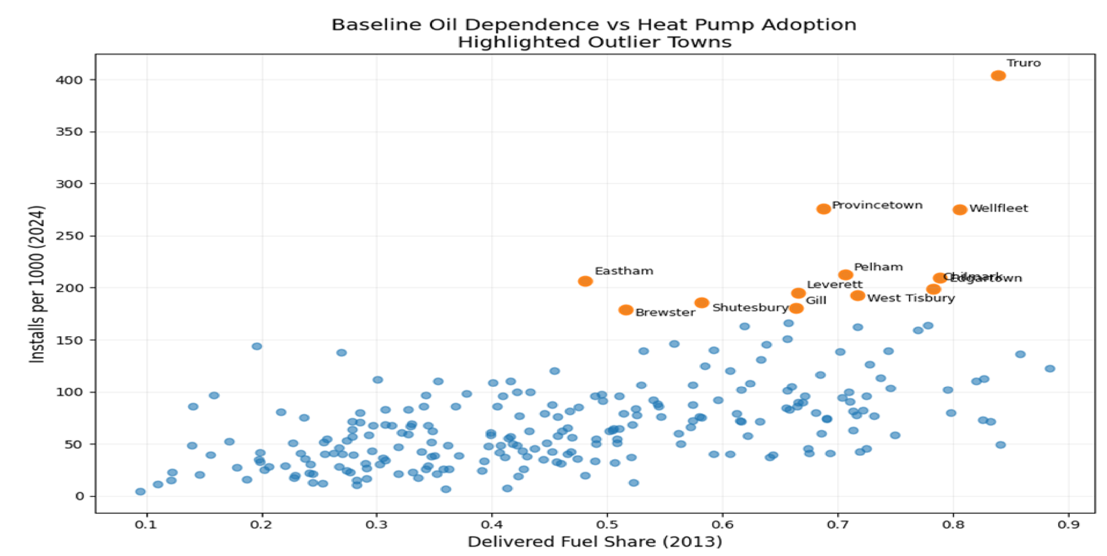
Compared actual adoption to model predictions to identify overperforming and underperforming municipalities.

Municipal Investigation

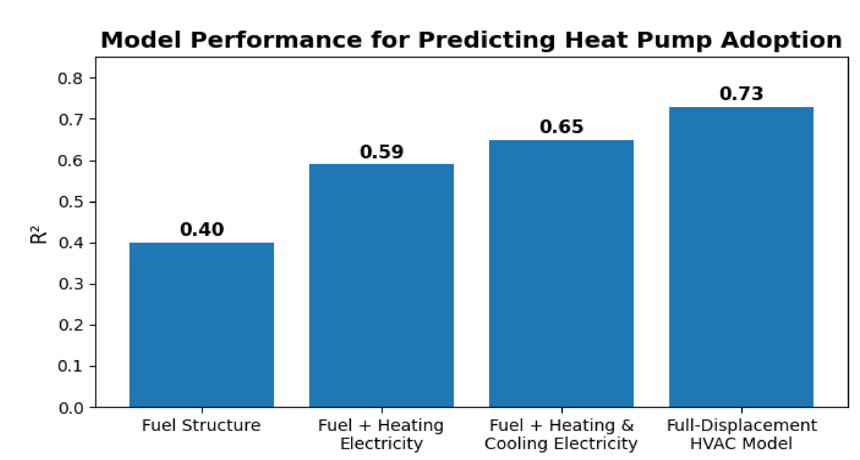
Explored potential explanations beyond the model, including:
Coastal location, Seasonal housing, Home values, Income, Municipal climate initiatives

Deliverables and Findings

Using public datasets, I built a municipality-level adoption model to identify what explains heat pump uptake and which towns behave unexpectedly.



Finding 1: Historical fuel dependence is a strong predictor of heat pump adoption.
Municipalities with higher delivered-fuel (oil/propane) dependence in 2013 generally experienced higher heat pump adoption by 2024. Many of the highest-adoption municipalities, including Wellfleet, Eastham, Provincetown, and Truro, were historically highly dependent on delivered fuels.



Finding 2: Fuel structure explains approximately 40% of variation in municipal adoption. Adding weather-normalized electricity consumption improves model performance substantially. The highest explanatory power is achieved when focusing on full-displacement HVAC installations, which most closely represent oil-to-electric heating transitions.
First three models: All heat pump installs
Final model: Full-displacement HVAC installs

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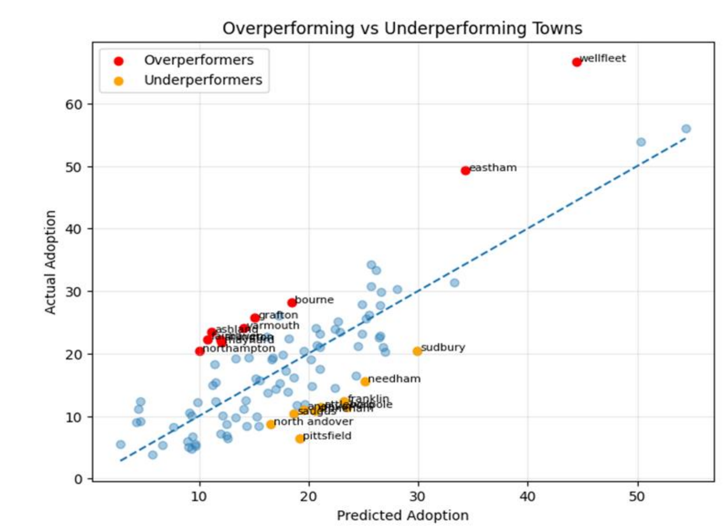
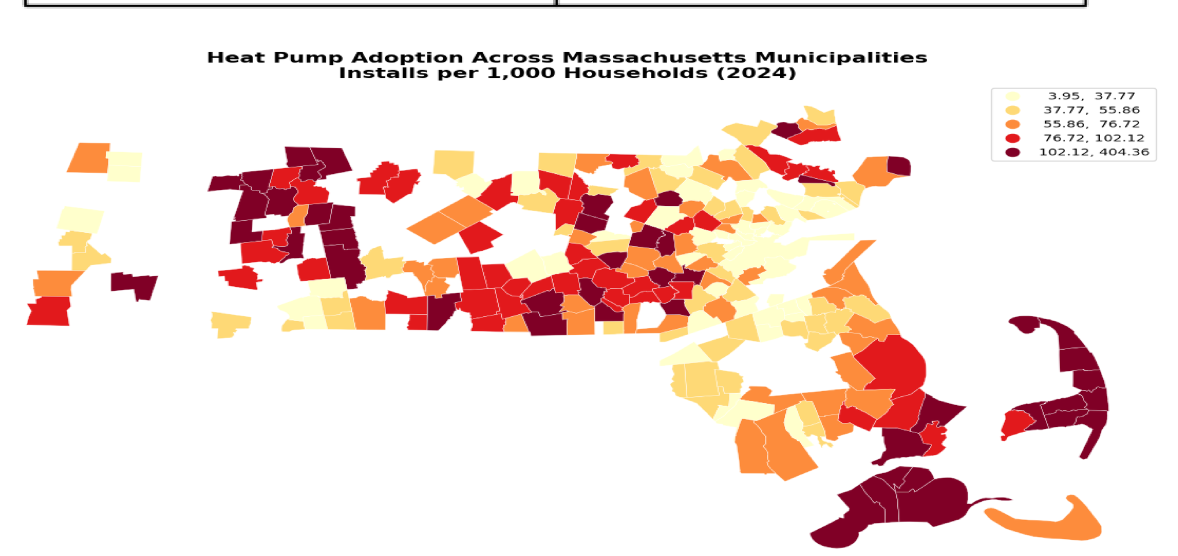


Finding 3: Several municipalities adopt significantly more or fewer heat pumps than predicted.
Residual analysis revealed municipalities whose adoption cannot be fully explained by fuel structure and electricity consumption patterns. Wellfleet, Eastham, and Bourne adopted substantially more heat pumps than expected, while Needham, Sudbury, Franklin, and Pittsfield adopted fewer than predicted.

Largest Positive and Negative Residuals

Overperformers	Underperformers
Wellfleet	Sudbury
Eastham	Walpole
Dennis	Oxford
Fairhaven	Gloucester
Bourne	Springfield



Finding 4: Heat pump adoption is geographically concentrated.
Higher adoption rates are observed in Cape Cod, Island, and several oil-dependent municipalities, while adoption remains lower in many gas-served communities.

Main Takeaways

Key Takeaways

1. **Historical fuel dependence is a strong predictor of heat pump adoption.**
Municipalities with higher heating oil and propane dependence generally show higher heat pump adoption rates.

2. Electricity consumption patterns improve prediction of adoption.
Adding weather-normalized electricity use increased model performance from **R^2 = 0.40** to **R^2 = 0.73**, indicating that electricity data captures important electrification behavior.

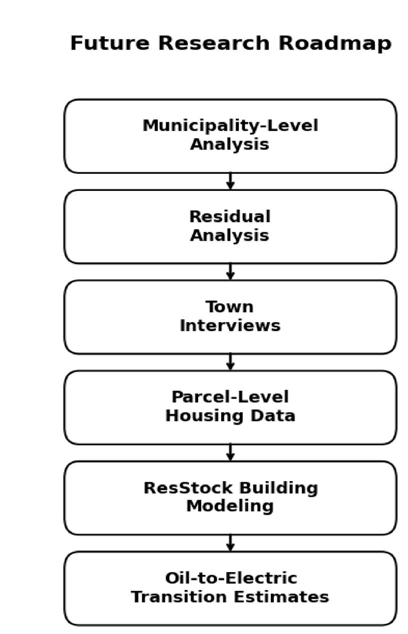
3. Adoption is not uniform across Massachusetts.
Residual analysis identified municipalities adopting substantially more or fewer heat pumps than expected, suggesting the importance of local policies, outreach, housing characteristics, and community factors.

4. Geographic clusters of adoption are evident.
Cape Cod and Island communities show some of the highest adoption rates in the state, consistent with their historical reliance on delivered fuels.

Impact
This work demonstrates how publicly available energy, weather, and housing data can be used to identify likely oil-to-electric heating transitions and guide building decarbonization efforts. The approach can help policymakers and municipalities target programs, incentives, and outreach where electrification potential is greatest.

Future Work

- Municipal interviews (Arlington, Needham, Wellfleet, Eastham)
- Analysis of local policies and outreach efforts
- Parcel-level housing characteristics
- ResStock-based building stock modeling
- Improved estimation of oil-to-electric heating transitions



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