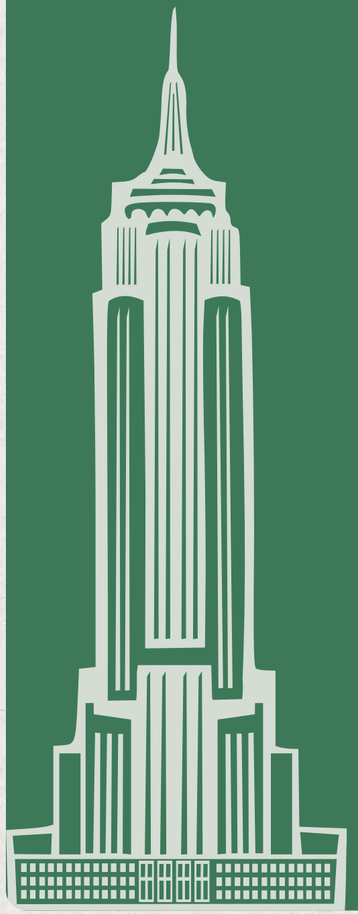
C40 Cities- Economics of Gas Vs Electric, USA



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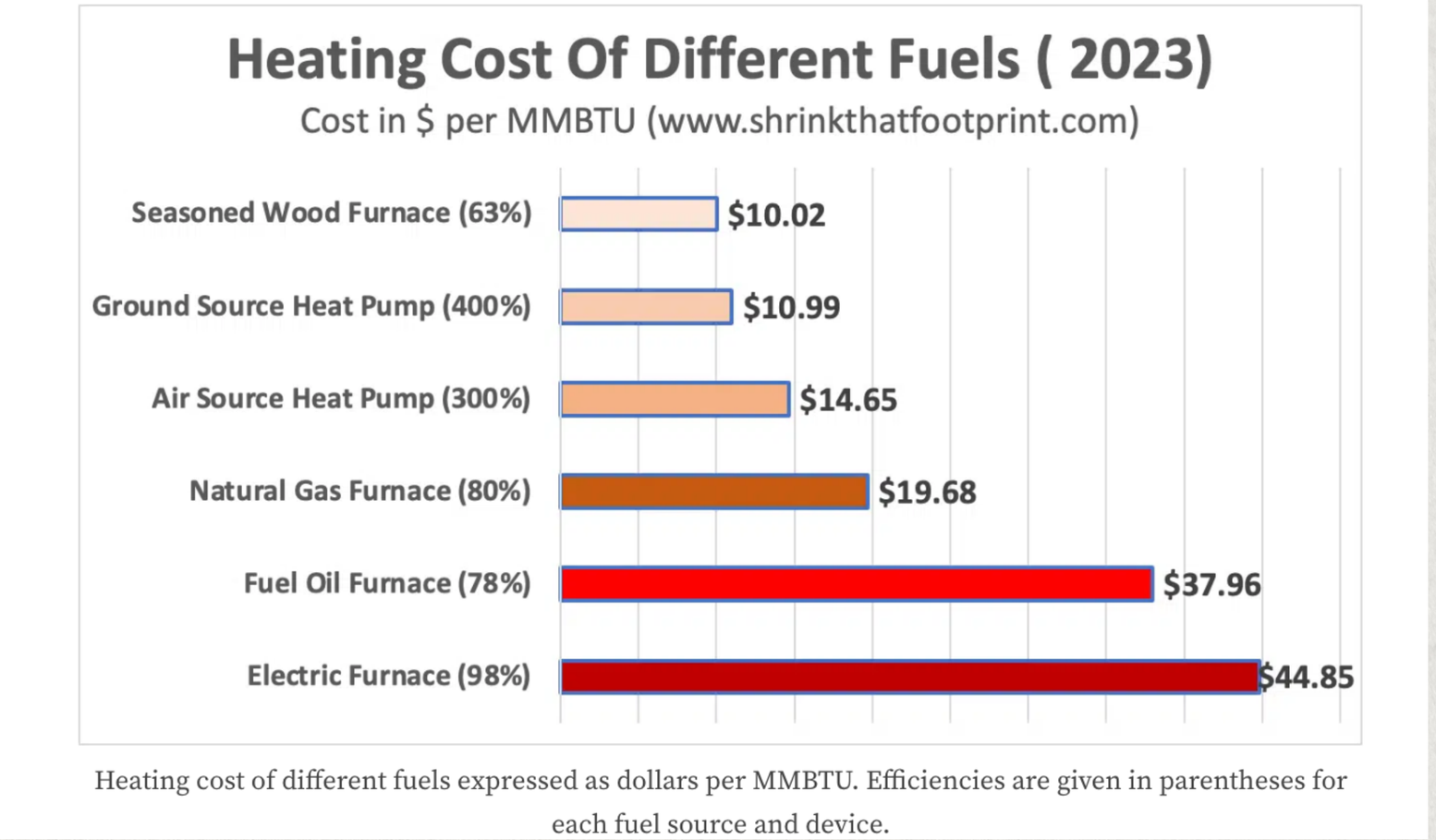
A network of mayors of nearly 100 world-leading cities collaborating to deliver the urgent action needed right now to confront the climate crisis.

C40 Cities

- Mission 1: Help get the world off fossil fuels in order to halt climate breakdown
- Mission 2: Address the impacts and injustice of climate breakdown

Why We Care

- **Cities** consume around **75%** of the **world's energy**
- Cities create over **70%** of energy-related **greenhouse gas emissions**
- **Fossil gas** represents approximately **47%** of **home heating** in the United States and Canada



Heating cost of different fuels expressed as dollars per MMBTU. Efficiencies are given in parentheses for each fuel source and device.

Research Outline

- What is the environmental impact of electrification?
- What are the main factors that determine energy savings?
- How does electrification impact energy bills?
- How does policy influence energy savings?

Cities of choice

New York

GHG Gas emission:

52 mmTCO2e

Stationary: 66%

Transportation: 30%

Waste:4 %

Urban Heat Island Effect

Source: The City of New York

Chicago

GHG Gas emission:

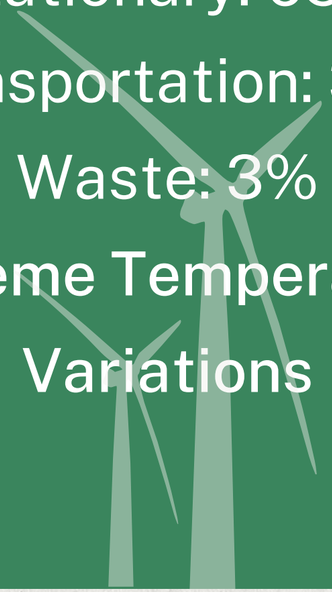
31.04 mmTCO2e

Stationary: 65%

Transportation: 32%

Waste: 3%

Extreme Temperature Variations



Source: City of Chicago

Los Angeles

GHG Gas emission:

26.9 mmTCO2e

Stationary : 69%

Transportation: 24%

Waste: 7%

Mild Mediterranean Climate

Source: Department of Public Works LA Sanitation & Environment

Project Scope

Replacing gas-based heating systems with heat pumps in existing single-family homes*

GHG emissions

Annual savings

Lifetime savings

*inclusive of space and water heating

Model Structure

Appliance performance

AFUE, UEF, SEER,

HPWH COP, ASHP type

Household characteristics

set temperature, house size,

insulation, income level,

all electric vs gas backup

GHG emissions

Annual savings

Lifetime savings

AFUE - Annual Fuel Utilization Efficiency
UEF - Uniform Energy Factor
COP - coefficient of performance
SEER - Seasonal Energy Efficiency Ratio
ASHP - Air Source Heat Pump
HPWH - Heat Pump Water Heater

Key Assumptions

- **Space heating: gas furnace + AC vs ASHP**
- **Water heating: gas boiler vs HPWH (with adjustable efficiencies)**
- **Energy consumption: space heating/cooling systems run non-stop**
- **Heat pump technologies: cold climate, conventional, less efficient ASHPs**
- **Heat pump costs: estimated through Homewyse***
- **CO2 emissions: in the 1st year and 15-year projection**

*https://www.homewyse.com/services/cost_to_install_heat_pump.html

AC - Air Conditioner
ASHP - Air Source Water Heater
HPWH - Heat Pump Water Heater

Research Outline

- **What is the environmental impact of electrification?**
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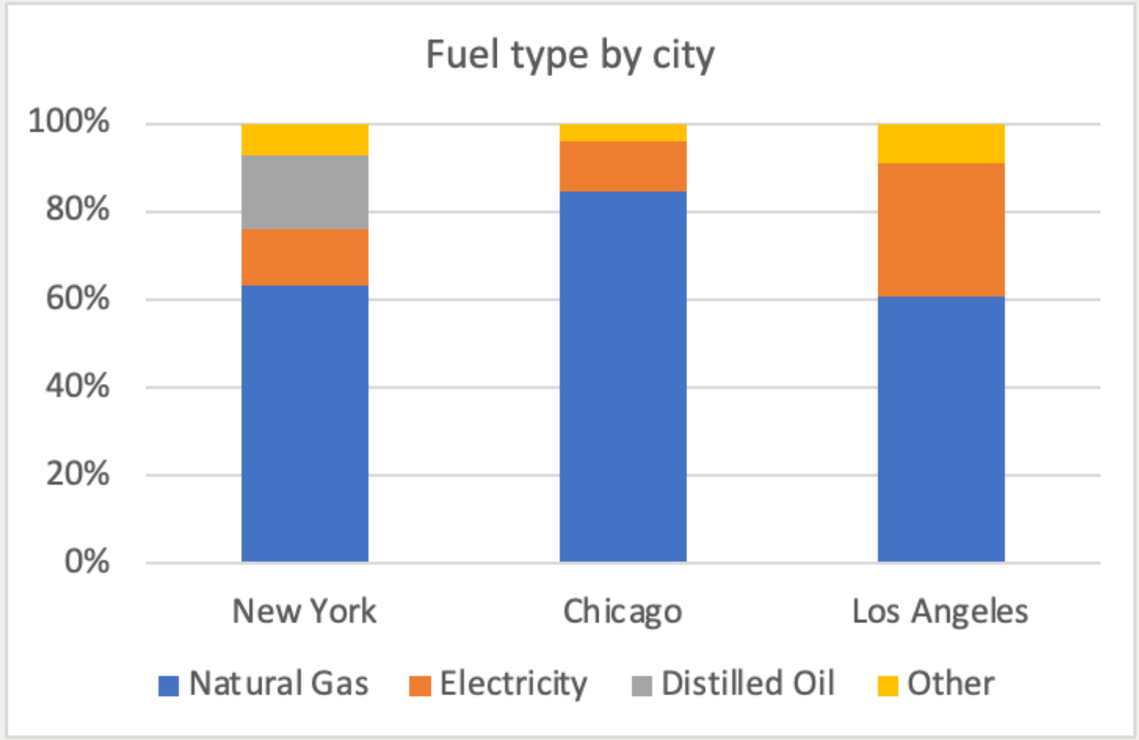
Environmental impact: Background

Residential buildings emissions & energy consumption

	New York	Chicago	L.A.
CO2e emissions from households (% of total)	31%	24%	18%
Yearly CO2e emissions from households (MMt)	16.5	6.5	4.85
Yearly natural gas per household (MMBtu)	61	88	14

Yearly total: ~28 MMt CO2e

1 MMBtu of natural gas -> 117 lbs (53kg) of CO2



Over 60% of the fuel used for heating is natural gas

Source: State and Local Planning for Energy (SLOPE) Platform

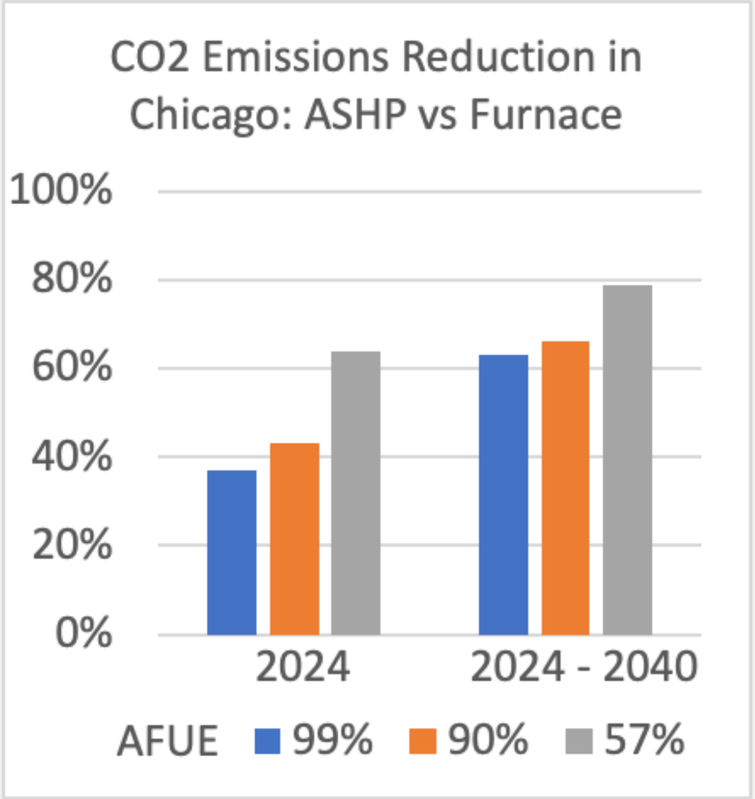
Environmental impact: Results

Day 1 CO2 emissions reduction: electric vs. gas

Furnace \ ASHP		Cold climate	Conventional	Less efficient
New high-end 99% efficient	Chicago	37%	31%	23%
	L.A.	74%	71%	69%
New conventional 90% efficient	Chicago	43%	38%	30%
	L.A.	76%	74%	72%
15 year old 57% efficient	Chicago	64%	61%	56%
	L.A.	85%	83%	82%

Potential to reduce CO2 levels up to 63% over heat pump lifespan

Even the least efficient HP makes a difference in L.A.

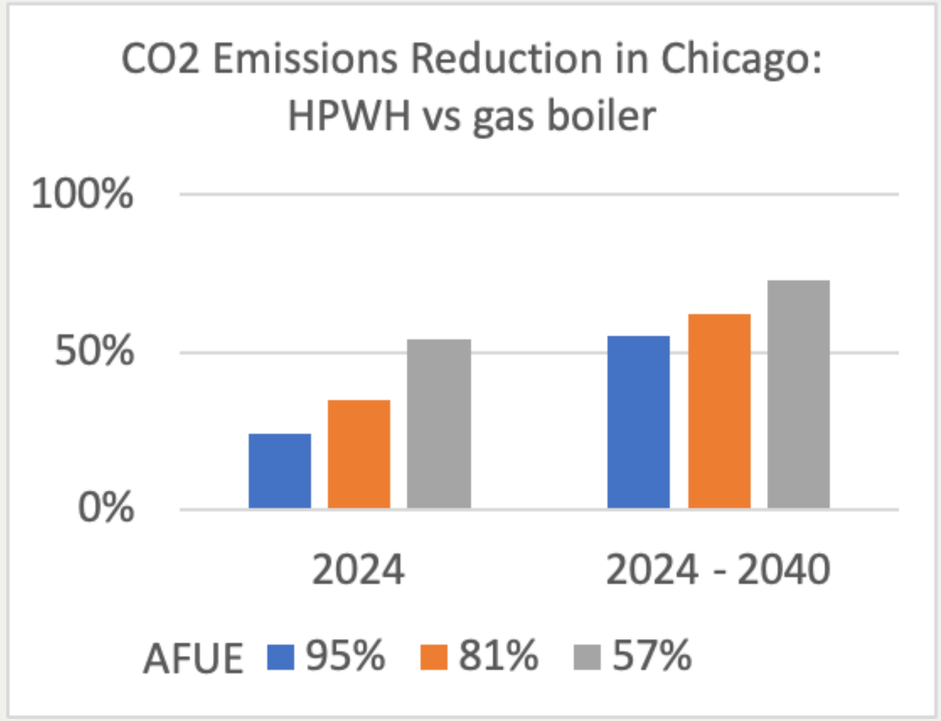


ASHP - Air Source Water Heater

Environmental impact: Results

Day 1 CO2 emissions reduction: electric vs. gas

Gas boiler \ HPWH	COP = 3
New high-end 95% efficient	Chicago 24% L.A. 63%
New conventional 81% efficient	Chicago 35% L.A. 69%
15 year old 57% efficient	Chicago 63% L.A. 78%



COP - coefficient of performance

HPWH - Heat Pump Water Heater

Research Outline

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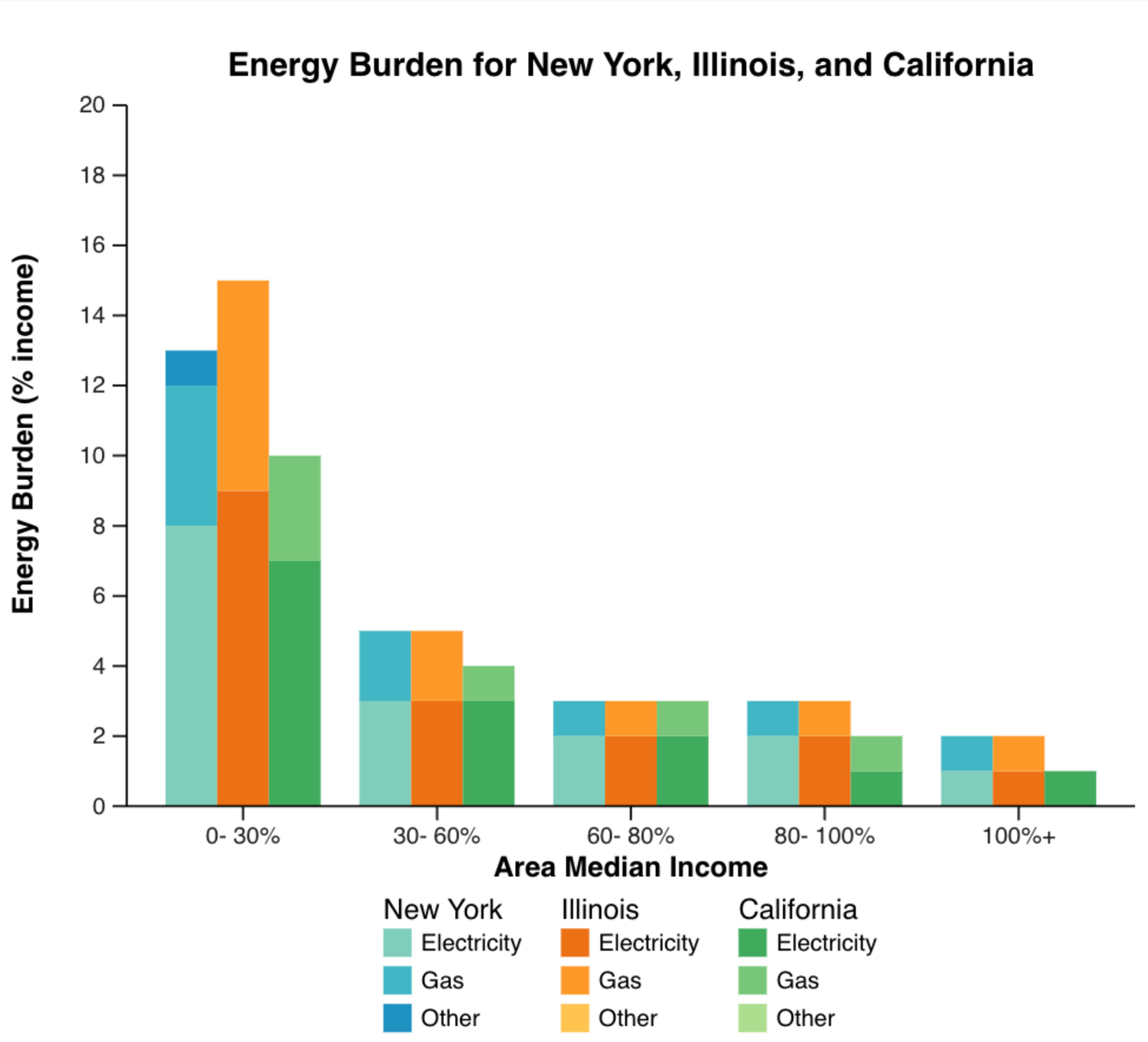
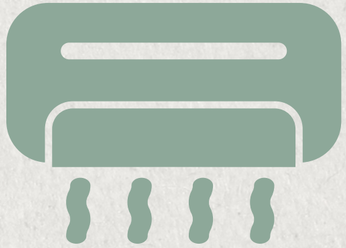


Source: Office of State and Community Energy Program

Comparative Energy Cost Burdens by Income Bracket

- Very low income households pay **over 10%** of their income on energy bills.
- In all cases, heat pumps are useful for reducing that energy burden.

Factors of Heat Pump's Cost Effectiveness



Utility Rate Design

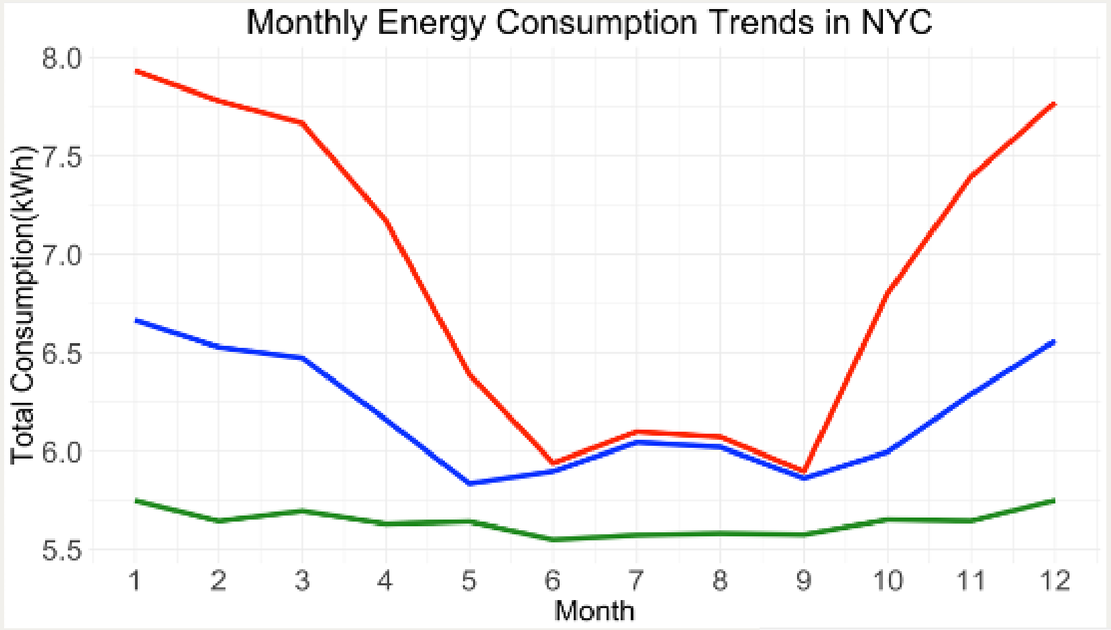
Insulation

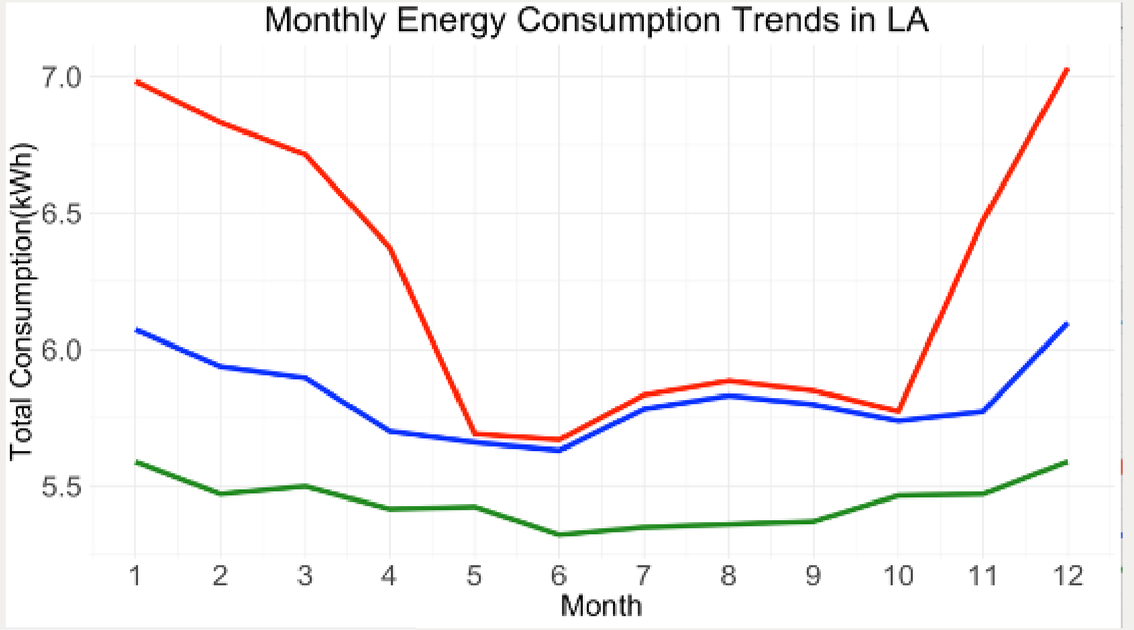
Heating Efficiency

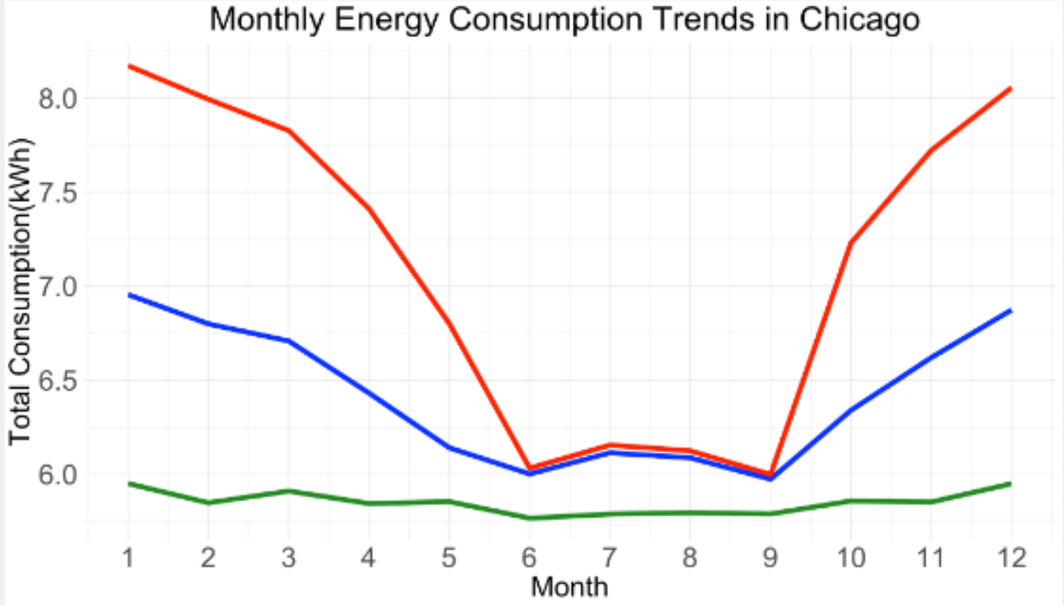
Local Rebates & IRA

Efficiency

Urban Energy Consumption







Key points to note:

COP>1

AFUE<1

Red: Mixed Fuel(kWh)

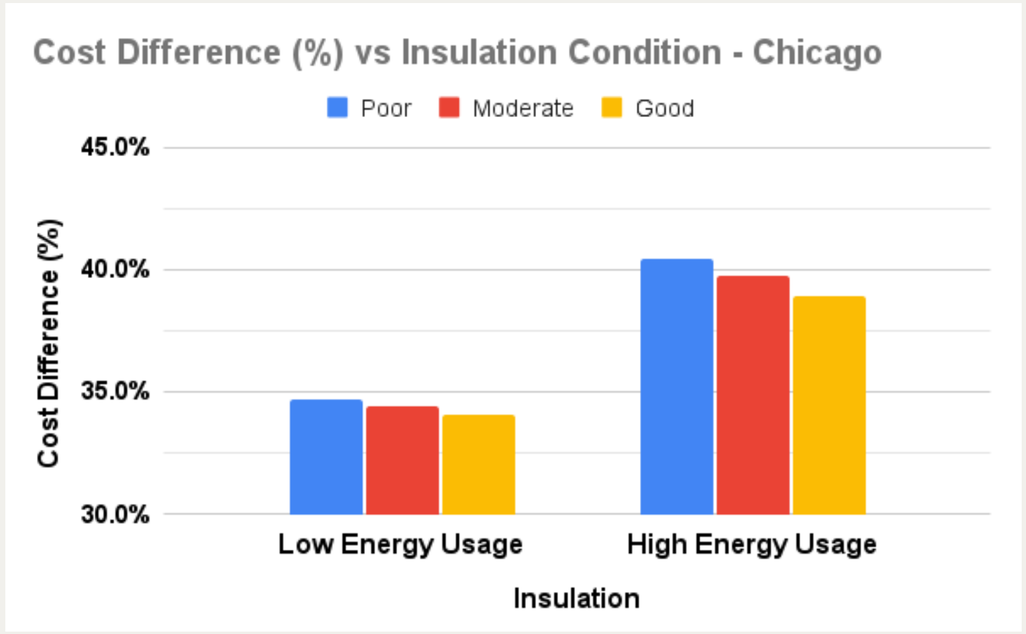
Blue: Electric(kWh)

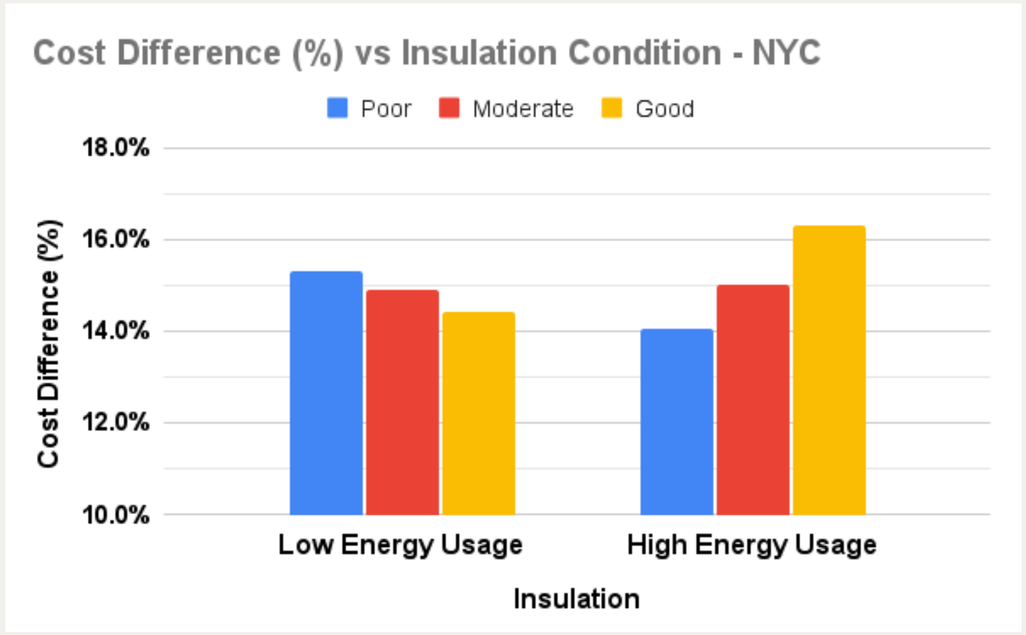
Green: Other End-Uses Electric(kWh)

Sensitivity Analysis

$$\text{Lifetime Cost Savings\%} = \beta_0 + \beta_1 \times \text{Furnace\_AFUE} + \beta_2 \times \text{COP\_ASHP} + \beta_3 \times \text{SEER\_ASHP} + \beta_4 \times \text{Mass\_Wall\_U\_Factor} + \beta_5 \times \text{Income\_Level} + \beta_6 \times \text{Total\_Heat\_Pump\_Incentives} + \varepsilon$$

Predictors	*LA*	*Chicago*	*NYC*
Furnace_AFUE	<2e-16 ***	<2e-16 ***	<2e-16 ***
COP_ASHP	0.000794***	2.11e-06***	1.35e-07
SEER_ASHP	0.678530	0.805	0.238
Mass_Wall_U_Factor	0.219116	<2e-16 ***	<2e-16 ***
Income_Level	2.51e-09***	1.79e-12***	0.419
Total_Heat_Pump_ Incentives	<2e-16 ***	<2e-16 ***	<2e-16 ***
R^2	0.9973	0.9953	0.9891





Insulation

- In Chicago, **poorly-insulated** homes save the most costs
- Poor insulation = ⬆ Heating load = ⬆ Energy saved by heat pump
- At high energy usage, **well-insulated** homes in NYC receive the most cost savings
- These trends depend on rate structure

Rate Structure : Flat Rates (Chicago)

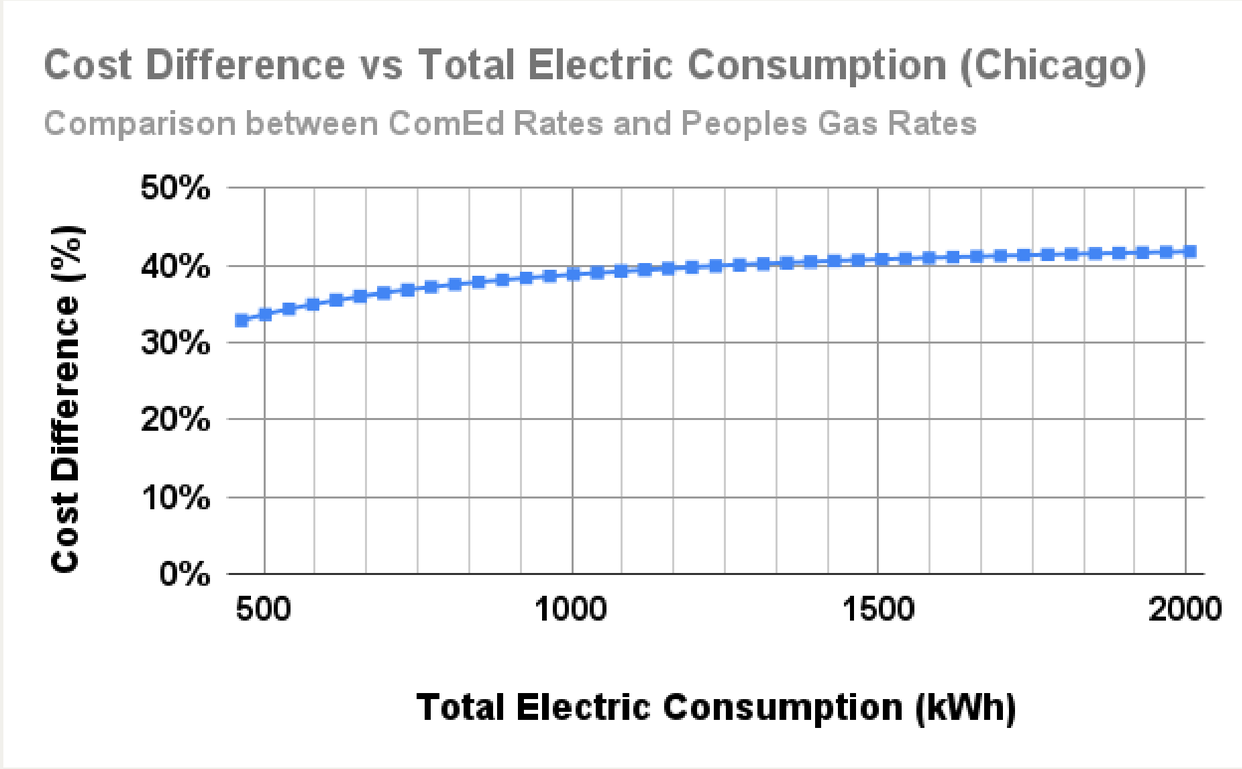
Chicago's Electric Rates

Base Charge per Month	Energy Charge Oct-May	Energy Charge Jun-Sept	Distribution Charge
$15.33	6.87¢ / kWh	6.81¢ / kWh	1.89¢ / kWh

Chicago's Gas Rates

Base Charge per month	Delivery Charge	Gas Supply Charge
$25.74	46.46¢ / therm	35.61¢ / therm

*Based on Jan 2023 rates



Rate Structure : Tiered Rates (NYC)

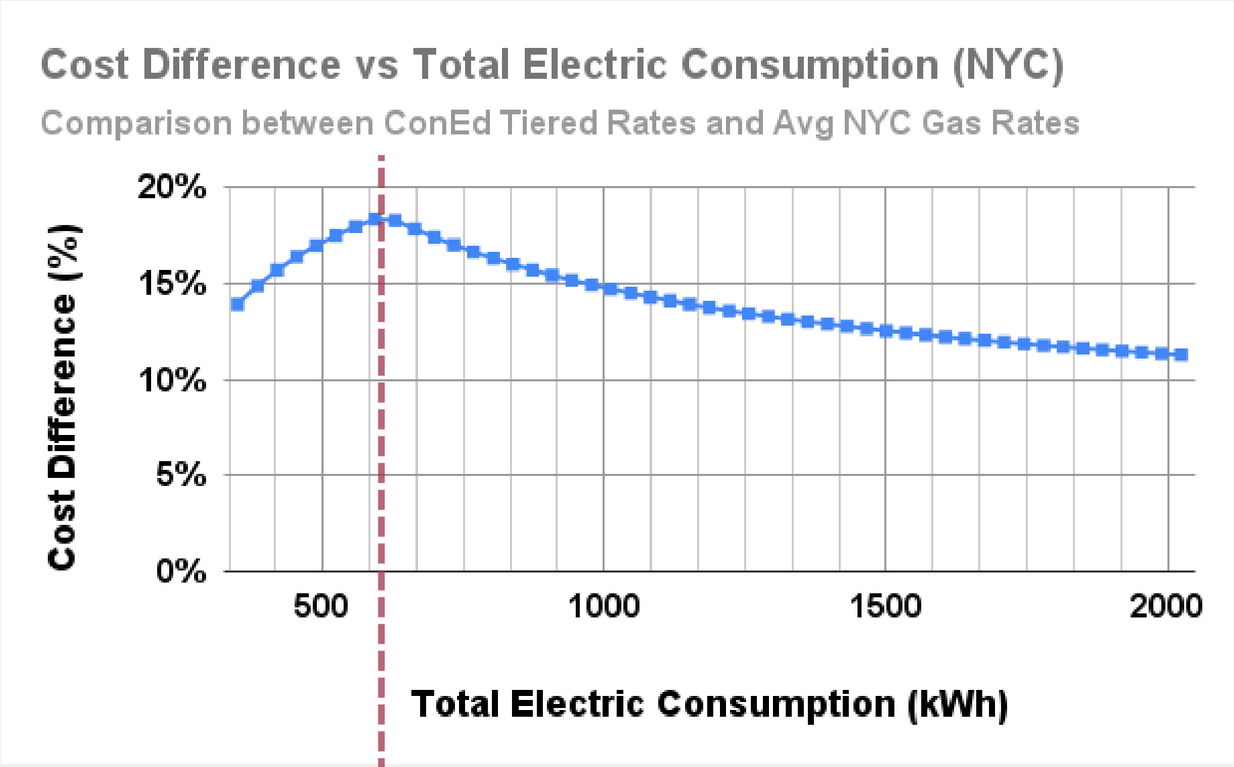
NYC's Electric Rates

	Non-Summer	Summer
Base Charge	$18.00	$18.00
<= 250 kWh	$0.14 / kWh	$0.14 / kWh
> 250 kWh	$0.14 / kWh	$0.16 / kWh
Gas Supply Charge	$0.12 / kWh	$0.12 / kWh

NYC's Gas Rates

	National Grid	ConEd
<= 3 therms	$21.55	$30.00
3 - 50 therms	$1.28 / therm	$1.73 / therm
> 50 therms	$0.48 / therm	$1.73 / therm
Gas Supply Charge	$0.53 / therm	$0.65 / therm

*Based on Jan 2023 rates



Rate Structure : Tiered Rates (LA)

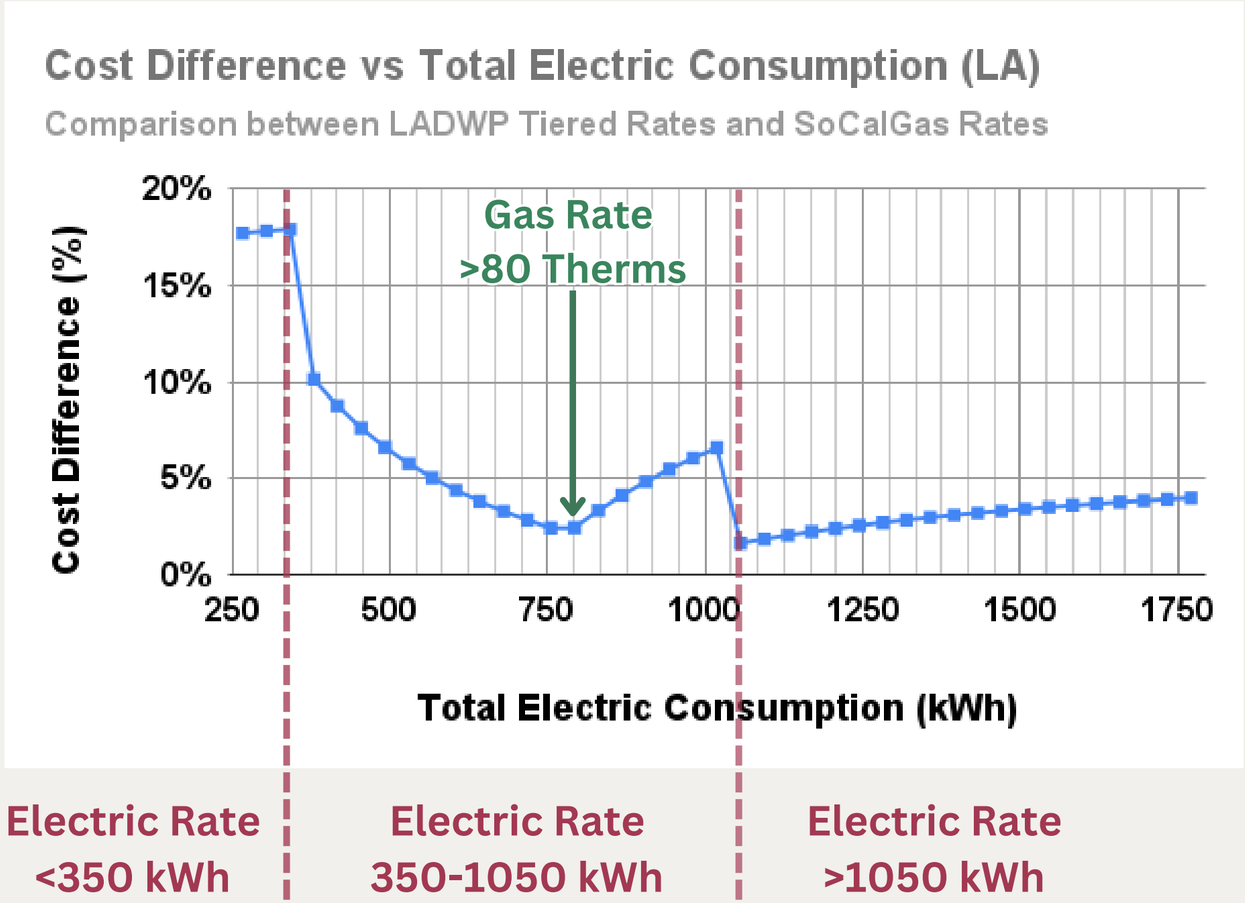
LA's Electric Rates

Total Consumption Charge		Base Charge
First 350 kWh	18.86¢ / kWh	$2.30 / month
Next 700 kWh	24.72¢ / kWh	$7.90 / month
Over 1,050 kWh	24.72¢ / kWh	$22.70 / month

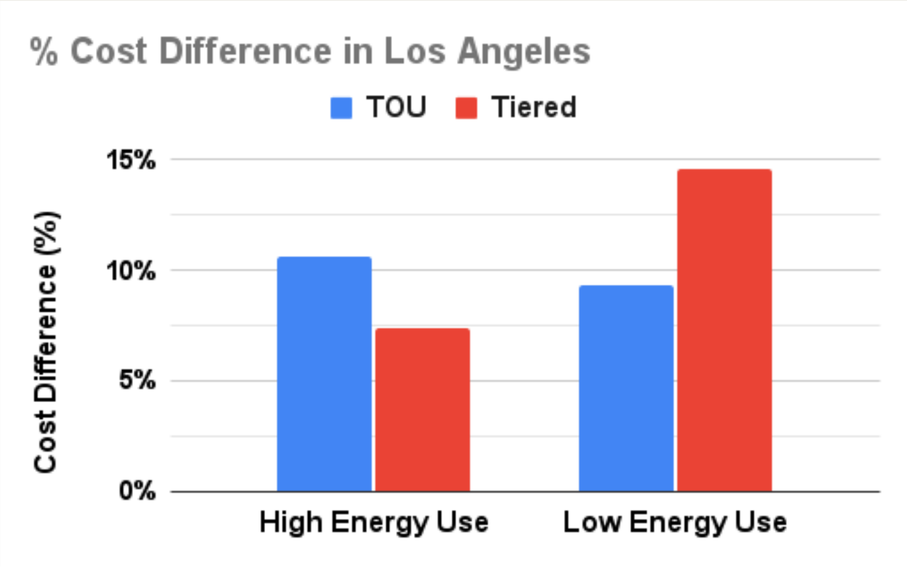
LA's Gas Rates

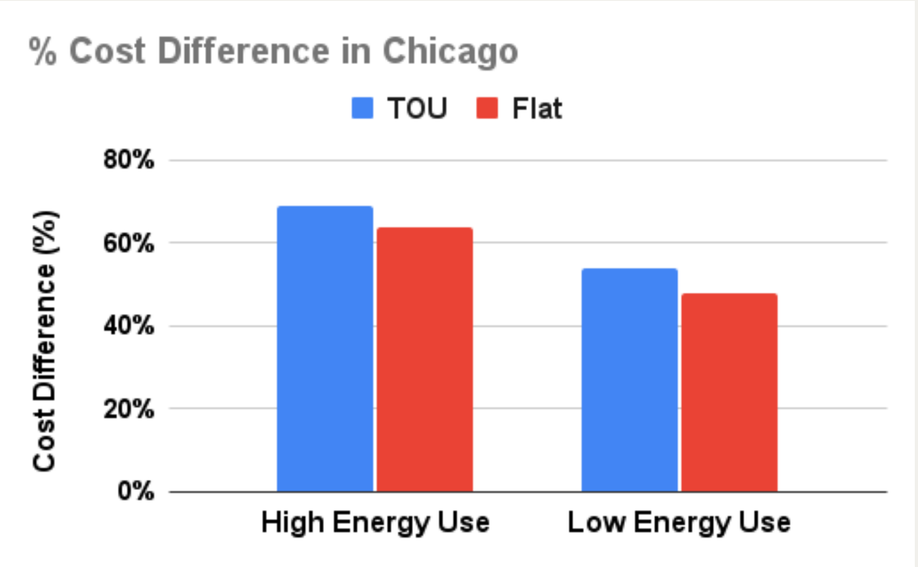
Total Consumption Charge		Base Charge
First 80 therms	$1.54 / therm	$4.69 / month
Over 80 therms	$1.99 / therm	$4.69 / month

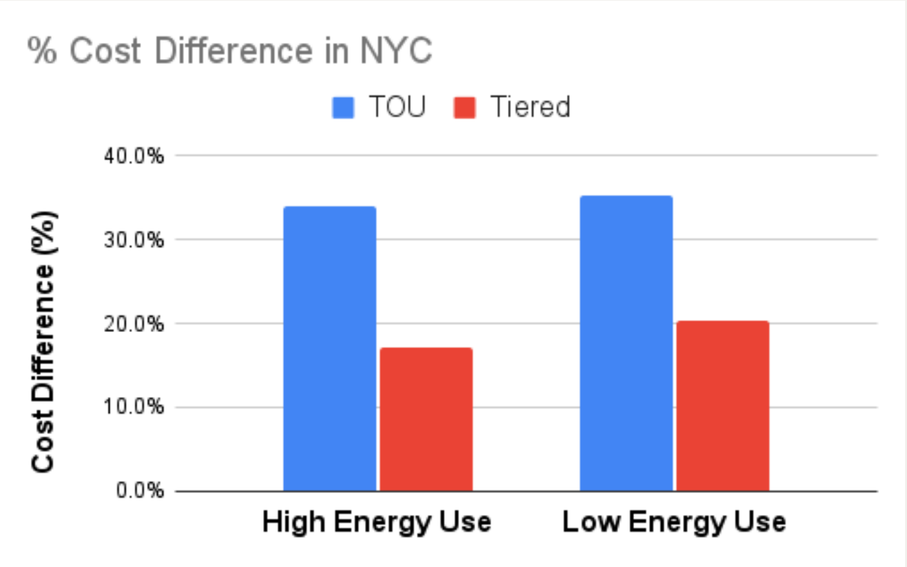
*Based on Jan 2023 rates



Rate Structure : Time-of-Use Rates



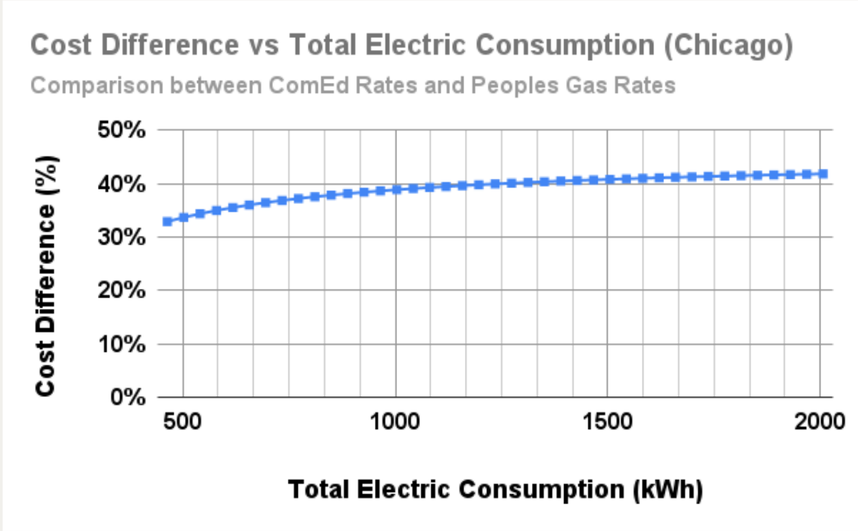


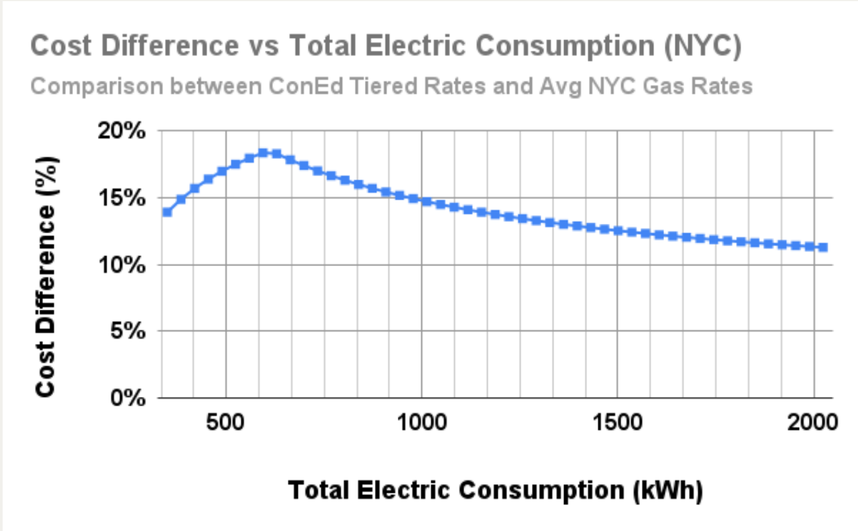


*TOU = Time-of-Use

Rate Structure : Impact on Energy Costs

- Time-of-Use rates save the most money in most cases.
- Tiered electricity rates in NYC and LA disincentivize high electric consumption, increasing costs.
- NYC's gas rates decrease with higher usage, incentivizing gas consumption.
- Out of all 3 cities, Chicago had the highest percentage of savings!





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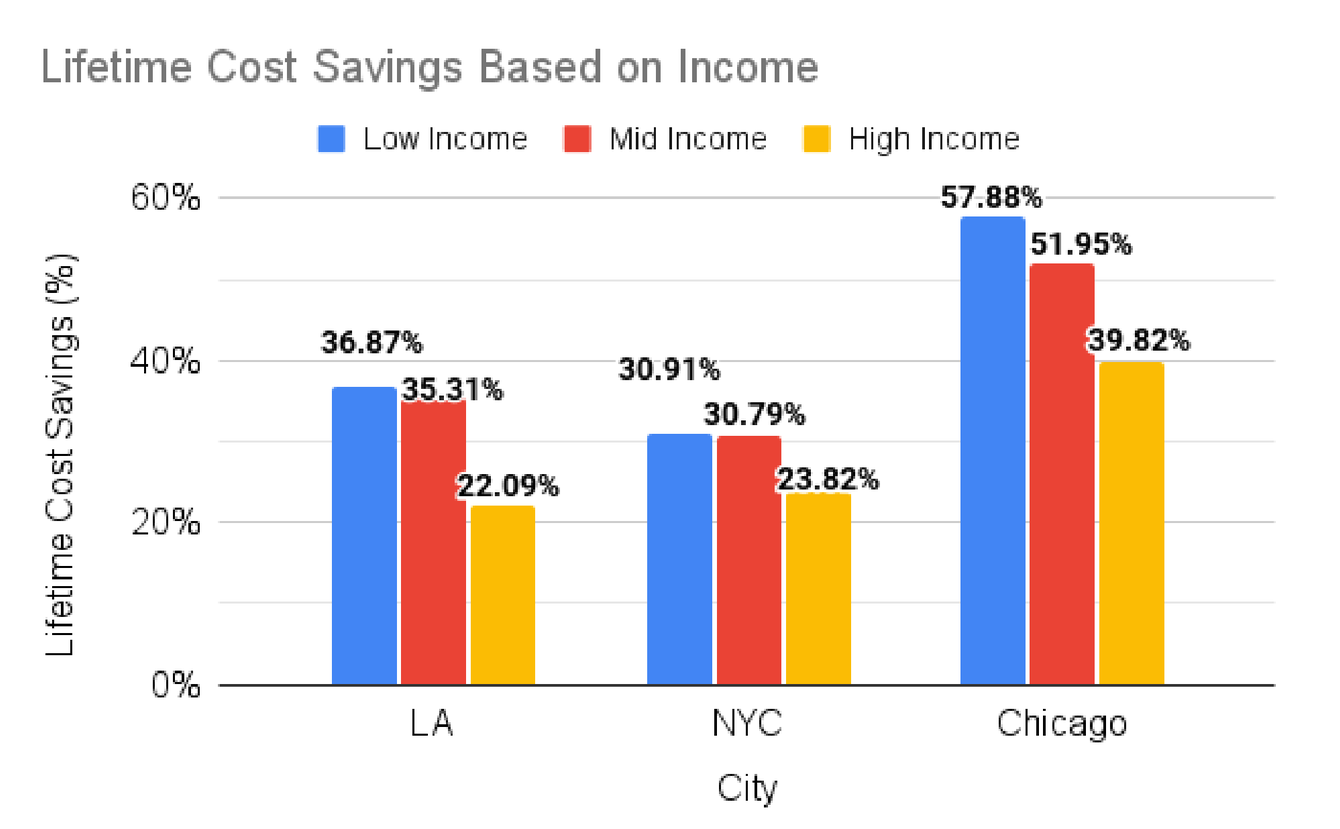
Energy Costs Model

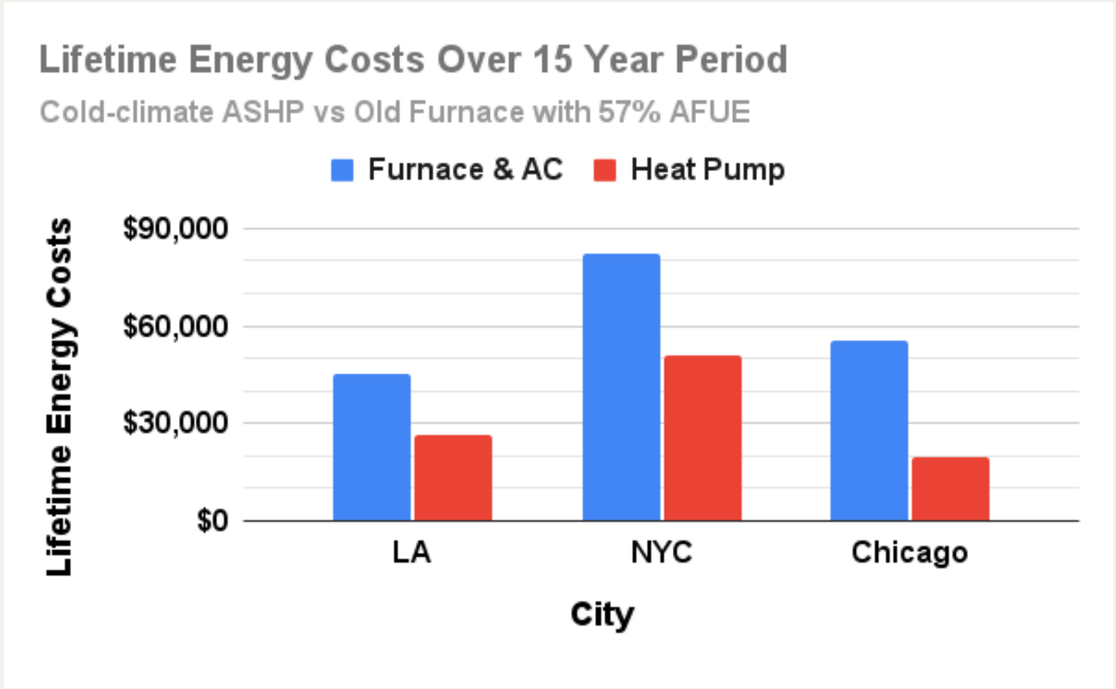
Results

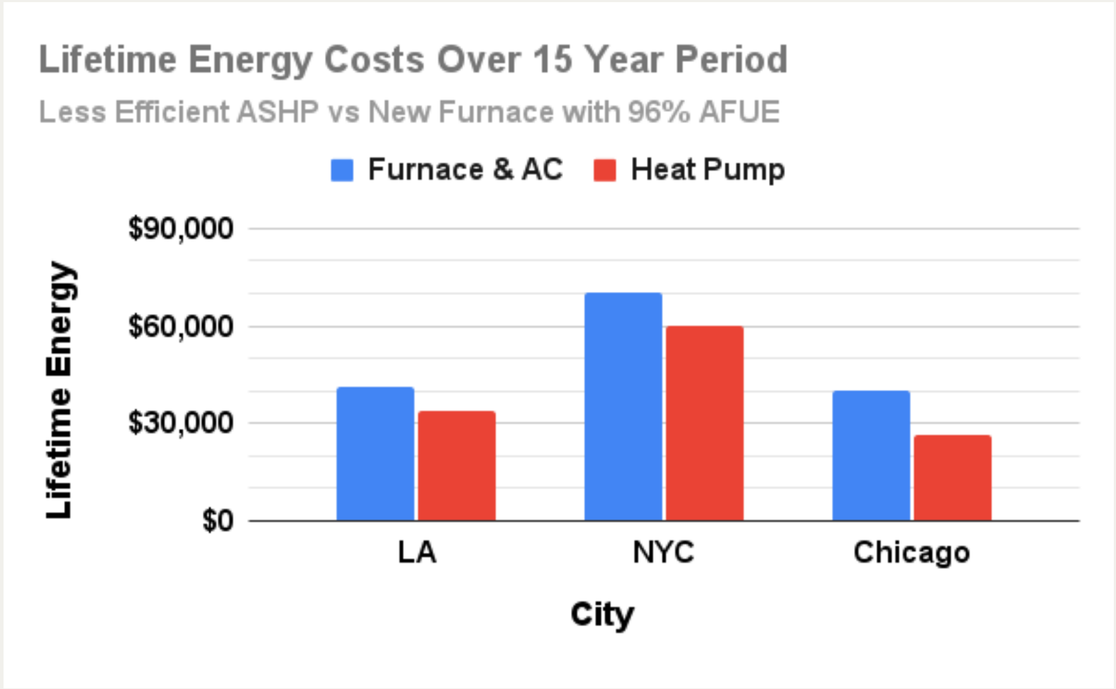


In all cities, heating electrification financially benefits **low-income households** the most.

Energy Costs Model

Results





By replacing old furnaces with cold-climate ASHPs, **low-income households can save up to $35K within 15 years**!

Less efficient ASHPs are still **more cost-effective** over the 15 year period than new highly efficient furnaces.

*ASHP = Air Source Heat Pump

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Inflation Reduction Act & Federal Tax credit

Eligibility Requirements

Ducted

South: All heat pumps that have earned the ENERGY STAR label

North: Heat pumps designated as ENERGY STAR Cold Climate that have an EER2 > 10

Ductless (mini-splits)

South: ENERGY STAR certified heat pumps with

SEER2 > 16

EER2 > 12

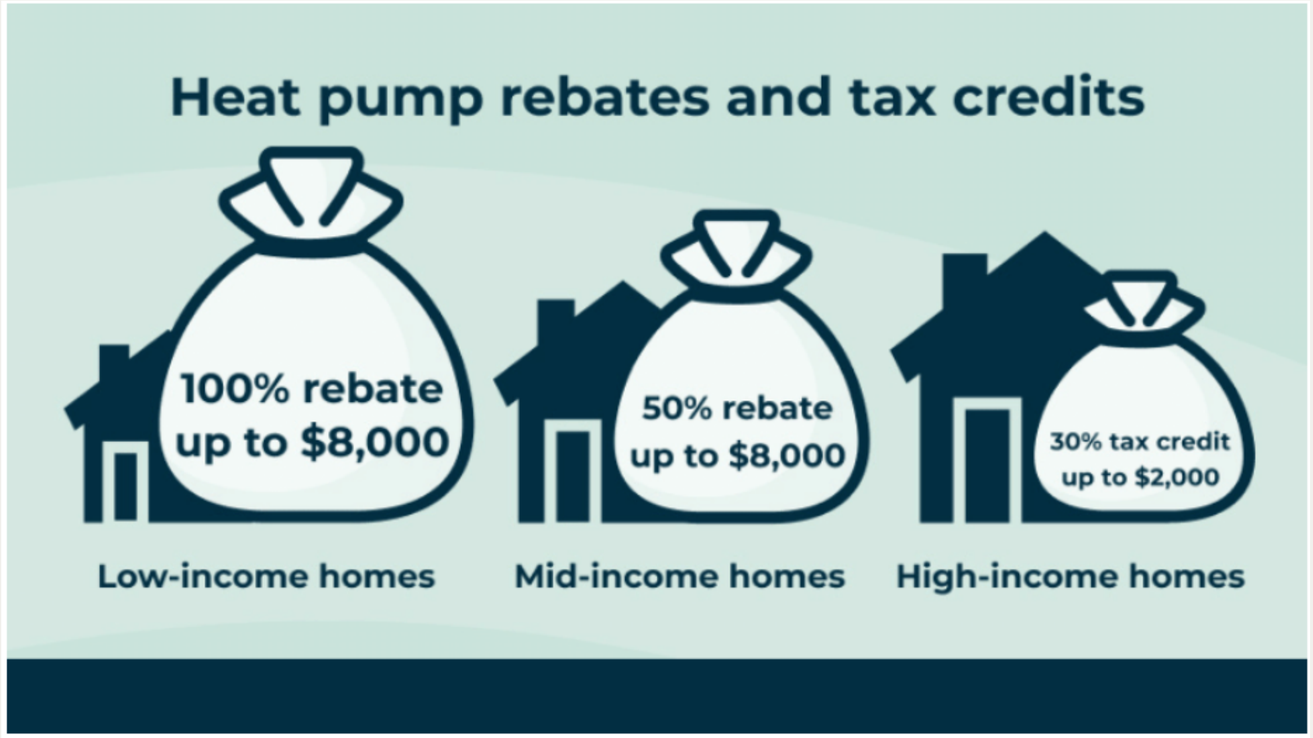
HSPF2 > 9

North: ENERGY STAR Cold Climate heat pumps with

SEER2 > 16

EER2 > 9

HSPF2 > 9.5



Source: EnergyStar.Gov

NYC Local Rebates

System Type	Rebate Amount	
Cold Climate Air Source Heat Pump	90-120% ("full load") of heating load < 300,000 BTUH	$1,000- $1,400 per 10,000 BTUH
Air Source Heat Pump Water Heater	< 120 gallons	$700 per unit
	> 120 gallons	$80 per MMBTU annual energy savings
BONUS for Cold Climate Air Source: Heat Pump + Water Heater installation	N/A	$250

*BTUH- British Thermal Units per Hou
**MMBTU- Millions of British Thermal Units

Source: HeatSmartCNY

Los Angeles Local Rebates

System Type	Rebate Amount	
Central or Split Air Conditioner	15 SEER	$100/Ton
	≥16 SEER	$120/Ton
Central Heat Pump	≥8.5 HSPF, ≥15 SEER	$100 - $120 per ton
AC Optimization	Replace gas HVAC w/ electric heat pump (HP)	Single Family: $3000/HP Multifamily: $2000/HP

*SEER- Seasonal Energy Efficiency Ratio
**HSPF- Heating Seasonal Performance Factor

Source: LADWP HP and AC Rebate

Chicago Local Rebates

System Type	Rebate Amount	
Air Source Heat Pump	≥ 16 SEER/15.2 SEER2	Discount upto: $1400
	Equipment must be installed by a Service Provider to qualify for discounts.	
Mini- Split Heat Pump	≥ 17 SEER, ≥ 9.5 HSPF ≥ 16.1 SEER2, ≥ 9 HSPF2	Discount upto: $1000
	Equipment eligibility verified via the AHRI	
NOTE: Contractor must be enrolled in ComEd Energy Efficiency Service Provided network (EESP)		
*SEER- Seasonal Energy Efficiency Ratio **HSPF- Heating Seasonal Performance Factor		

Source: EPA Illinois and ComEd Energy

Recommended action
Toward Fair and Efficient Energy Pricing

- Phasing out tiered rates can promote building electrification.
- Time-of-use pricing can encourage off-peak consumption.
- Dynamic and location-based pricing can reflect real-time costs and reduce grid strain and meet diverse customer needs.

Limitations and Research Gaps

Energy Costs	GHG Emissions
• Hourly temperature fluctuations vs TOU rates • Effect of electrification on gas price death spiral • More specific ASHP installation and unit costs	• Methane leakage • Hourly temperature fluctuations vs COP

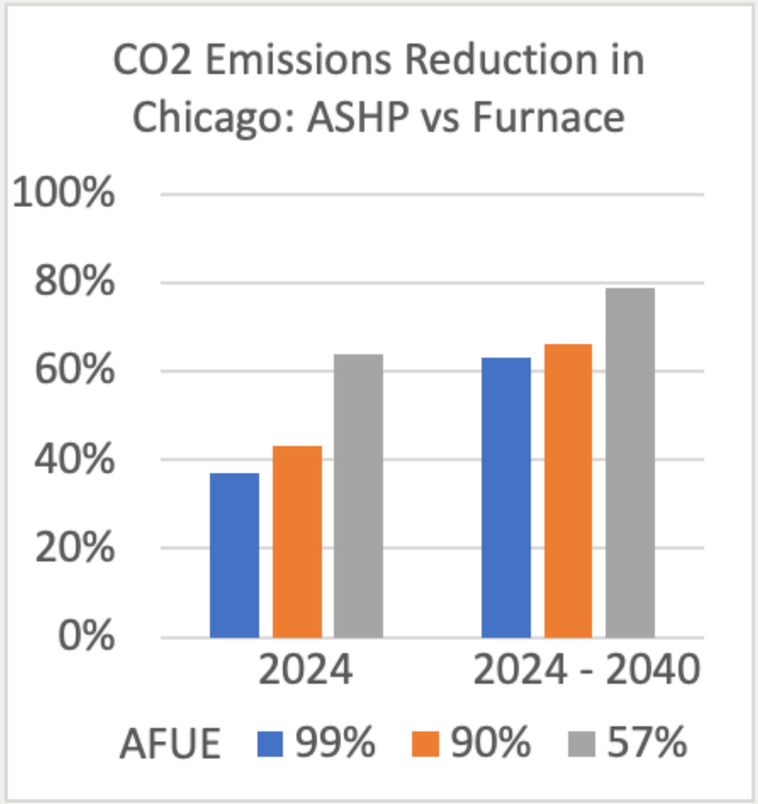
*TOU = Time-of-Use
*ASHP = Air Source Heat Pump
*COP = Coefficient of Performance

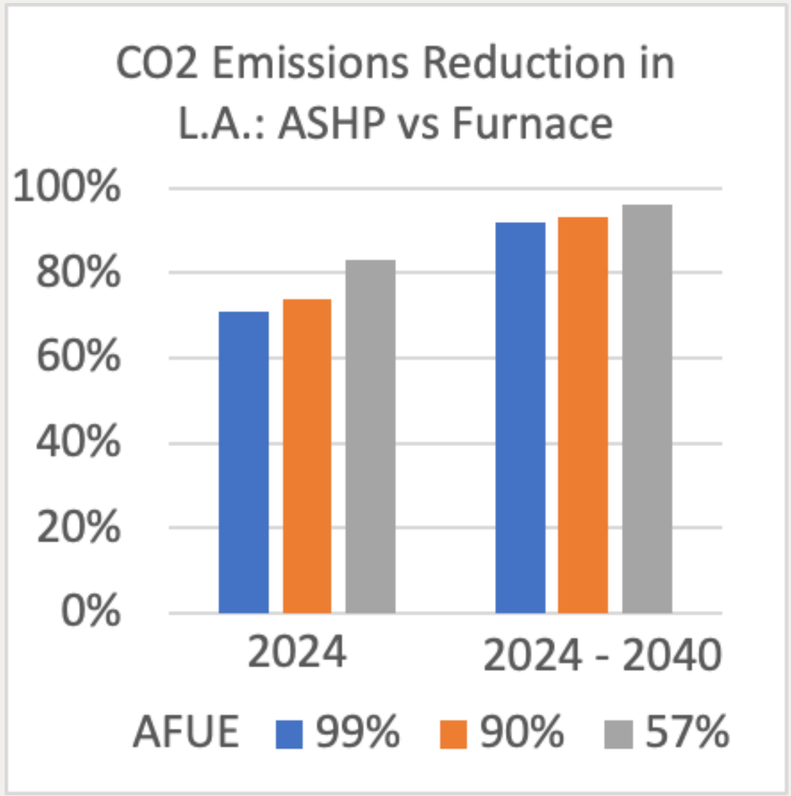
Back-up slides

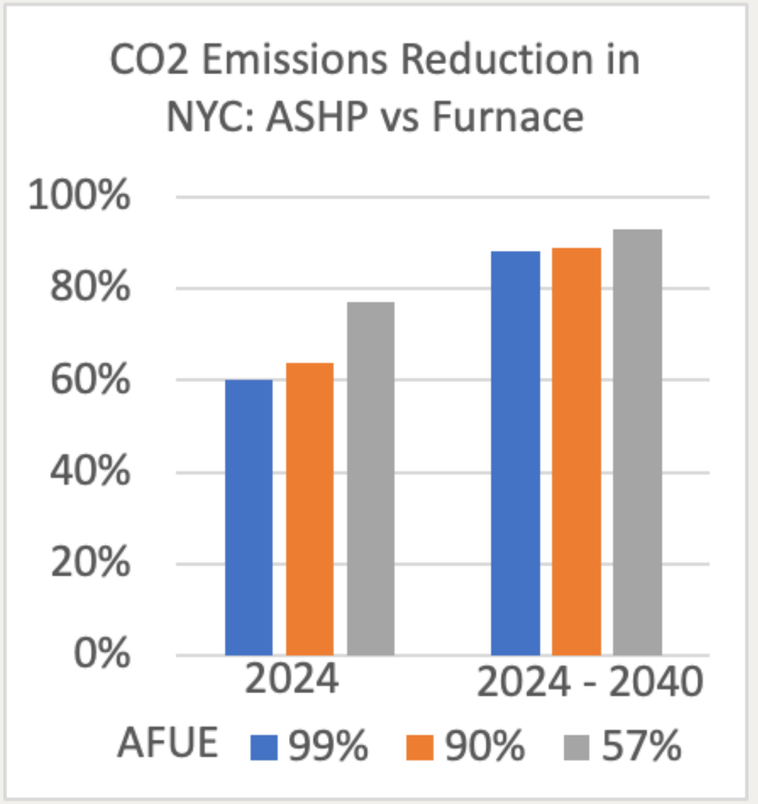
ASHP Specifications

Label	Brand	Model	Ducting Config	Heating Capacity @ 47°F (Btu/h)	COP @ 47°F	Tax Credit Eligibility	SEER
Cold Climate	Samsung	FJM Max Heat	multizone non-ducted	22,000	4.5	North & South	23
Conventional	Mitsubishi Electric	M-Series	multizone non-ducted	22,000	3.9	South	20
Less Efficient	Lennox	Lennox Real	multizone non-ducted	20,000	3.6	No	19

CO2 emissions: ASHP vs Furnace







CO2 emissions: HPWH vs Gas Boiler