Chicago Energy Efficiency Planning and Analysis, and Integrated Retrofit Strategy Validation in Single Family Homes

Elevate Energy
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Project Summary

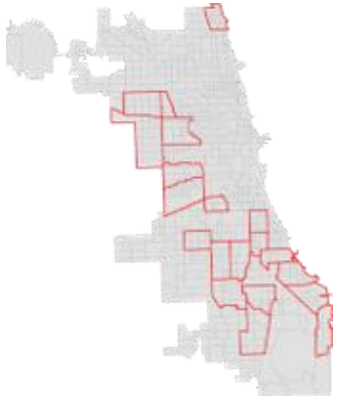
Objective and outcome

To pair advanced technology planning and analysis with consumption data and local building characteristics and typology to develop a scalable, community-wide **Chicago single family (incl 2–4-unit) residential retrofit roadmap.**

A demonstration project proving that with the right **whole-building energy retrofit packages**, in specific Chicago **housing types**, in geographic priority areas, homes can achieve at least **50% energy savings**.

392k

323k



110k

Team and Partners

- **Elevate Energy**
- **National Renewable Energy Laboratory**
- **City of Chicago**
- **ComEd**

Stats

Performance Period: June 2020 to May 2024

DOE budget: $537,640 Cost Share: $137,500

Phase 1: Modeling

Phase 2: Proof of Concept (fieldwork)

Phase 3: Validation and Summary

Problem

- **Need for deep retrofits**
- 1,064,635 Chicago households earn ≤80% area median income (54% of households)
- Annual avg. utility costs (gas + electric) for Chicago single family households: $2,717 ($1,396+ $1,321)[1]
- Annual gas bills have been rising rapidly and are expected to increase by 60% over the next 10 years[2]
- Gas usage and costs are higher in Chicago 1382 therms ($1,396) compared to surrounding states: IL, IN, MI, OH, and WI annual avg. 811 therms ($1,044).
- Zip codes with higher gas burdens and higher rates of disconnection tend to be lower income areas
- **Are there whole-building energy retrofit packages for specific Chicago housing types, where homes can achieve at least 50% energy savings?**

Data Source: Elevate Energy 2020 analysis of Chicago and Cook County energy use analysis published 2014.

[1] Based on median gas cost of $1,396, regional average electricity use (from 2015 EIA Residential Energy Consumption Survey), and ComEd electricity rates

[2] Illinois Commerce Commission v. People Gas, October 2016, ICC Docket No. 16-0376

Alignment and Impact

- Median year of construction is 1957 82% built before energy codes
- Median home size= 1,313 sf
- Energy use is higher than national samples (2009 and 2015 RECS)
  - 1,382 therms annually (1.05 therms/sf)
  - 8,697 kWh annually (6.62 kWh/sf)
- High savings potential starting with air sealing & insulation.

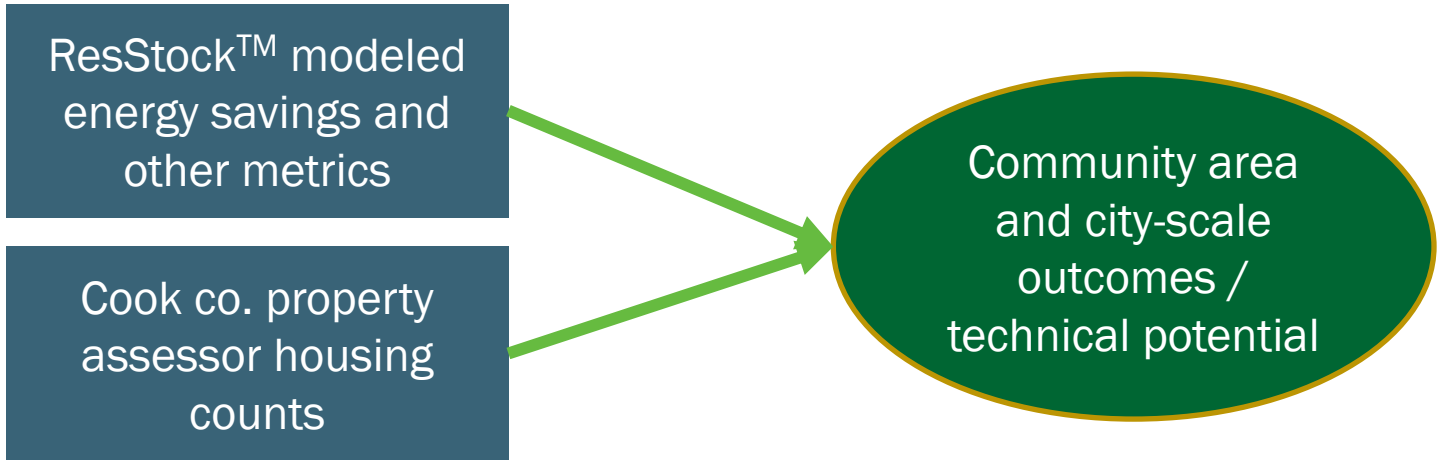
Alignment and Impact

- Develop a Chicago-specific single family retrofit prioritization strategy
- What are the retrofit packages that can achieve deep energy savings (>50%) in Chicago homes?
- What would be the energy use, utility bill, and carbon impacts from installing these retrofit packages city-wide?
- How can Chicago prioritize and achieve deep energy savings in a short timeframe, across the Chicago neighborhoods that need it most?
- Methodology: an important first step was to calibrate NREL's ResStock™ to local housing stock
  - Worked with NREL to expand and calibrate ResStock™ with Chicago 2–4-unit buildings, to represent an additional residential building stock
  - This allowed ResStock™ to model over 75% of Chicago's residential buildings, using the five predominant building types

Approach

City-Scale Analysis

- Identify all priority housing type buildings
- Apply ResStock™ modeled outcomes for various retrofit packages
  - Comprehensive – building envelope energy efficiency (air sealing and insulation) + heat pump HVAC (central or mini-split) + heat pump water heater + LED lighting
  - Comprehensive – with higher efficiency natural gas HVAC (not used due to less than 50% savings)
  - Full electrification – comprehensive plus induction stove and heat pump clothes dryer
- Aggregate up by summing outcomes for all priority housing type buildings in geography
- The results showed both energy savings and cost savings are possible, due in part to the unique natural gas rate structure in Chicago, as well as the existing building conditions



Approach – Count and % of Chicago Residential Building Stock

Single family Pre-1942
Frame construction
83,028 (19.0%)

Baseline:
1,350-2,300 therms
7,320-11,500 kWh

Savings potential:
60-80%
$500-1,500

Single family Pre-1942
Masonry/brick construction
60,993 (13.9%)

Baseline:
1,230-2,110 therms,
7,470-11,980 kWh

Savings potential:
53-77%
$200-1,300

Single family 1942-1978
Masonry/brick construction
82,256 (18.8%)

Baseline:
840-1,530 therms,
6,690-10,220 kWh

Savings potential:
46-72%
$200-900

Approach - Count and % of Chicago Residential Building Stock

2-4 flat Pre 1942 frame
43,812 (10.0%)

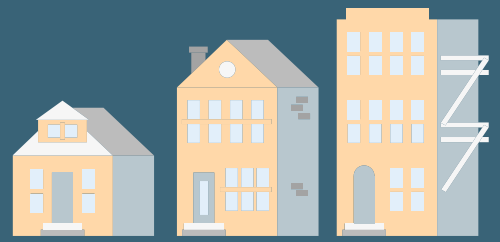
Baseline (per unit):
942-1,340 therms
5,310-7,920 kWh

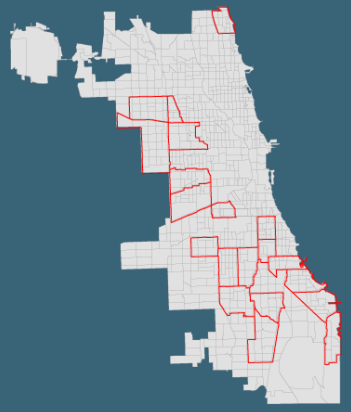
Savings potential (per unit):
57-76%
$200-900

2-4 flat Pre-1942 masonry
63,732 (14.5%)

Baseline (per unit):
860-1,240 therms
5,430-8,400 kWh

Savings potential (per unit):
50-72%
$0-700





392k **323k** **110k**

Chicago Annual Savings Potential

≥ 59% MBTUs

$130 – >$300 million ($400 – $1,000 per building)

2.5M metric tons CO_2-equivalent

Solar offset of ≥ 30% of post-retrofit electricity use

+ Air conditioning

+ Improved respiratory health

+ Improved thermal resilience

+ Home value & household wealth

+ Prioritized investment in the communities that need it most

Approach

- Deep energy savings (>50%) can be achieved in the Chicago housing stock with off-the-shelf measures and technologies, and help reduce energy costs and energy burdens
- Heat pumps, with air sealing and insulation, are a major driver of energy savings
- Retrofit packages with high efficiency natural gas heating equipment, either forced air or boiler, did produce energy savings, but they did not meet the >50% energy savings
- Additional benefits amplify the impact:
  - Climate resilience: heat pumps add efficient cooling in homes that don't have it (~77% of Chicago's 1–4-unit buildings lack central A/C)
  - Improved indoor air quality with less natural gas burned
  - Increased thermal resilience in case of power outages, due to air sealing and insulation
- Adding solar would offset ≥30% of post-retrofit electricity use, reducing utility provided electricity and increasing annual cost savings

Approach

- Electrification with heat pumps can drive significant energy and cost savings, saving Chicagoans $ millions per year.
- And savings will increase as gas prices go up

Technical potential for packages assuming installation in all applicable Chicago homes from the 5 priority building types

	% Energy Savings (annual MBTUs)			Utility Bill Savings (annual)		
	City-wide mean	Per-building mean	Interquartile range	City-wide mean	Per-building mean	Interquartile range
Comprehensive energy efficiency + heat pump	62%	61%	59% - 63%	$217 million	$670 (19%)	$130-305 million
Full electrification	66%	66%	64% - 66%	$442 million	$750 (21%)	$160-333 million

Approach

- Long-term, electrification will have big climate benefits as the electric grid gets cleaner:

Technical potential for packages assuming installation in all applicable Chicago homes from the 5 priority building types. Average annual carbon savings, projected to 2028-2032 grid conditions.

	City-wide carbon savings (metric tons CO_2e)		Per-building carbon savings (metric tons CO_2e)	
	Mean	Interquartile range	Mean	Interquartile range
Comprehensive energy efficiency + heat pump	2.5 million	1.4 – 3.5 million	8	4 – 11
Full electrification	2.6 million	1.4 – 3.7 million	8	4 – 11

- Heat pumps will provide needed cooling: Only 23% of Chicago 1-4 buildings have central A/C

Approach

- To retrofit all the housing types that can most benefit from energy upgrades by 2035, Chicago will need to retrofit ~30,000 buildings per year

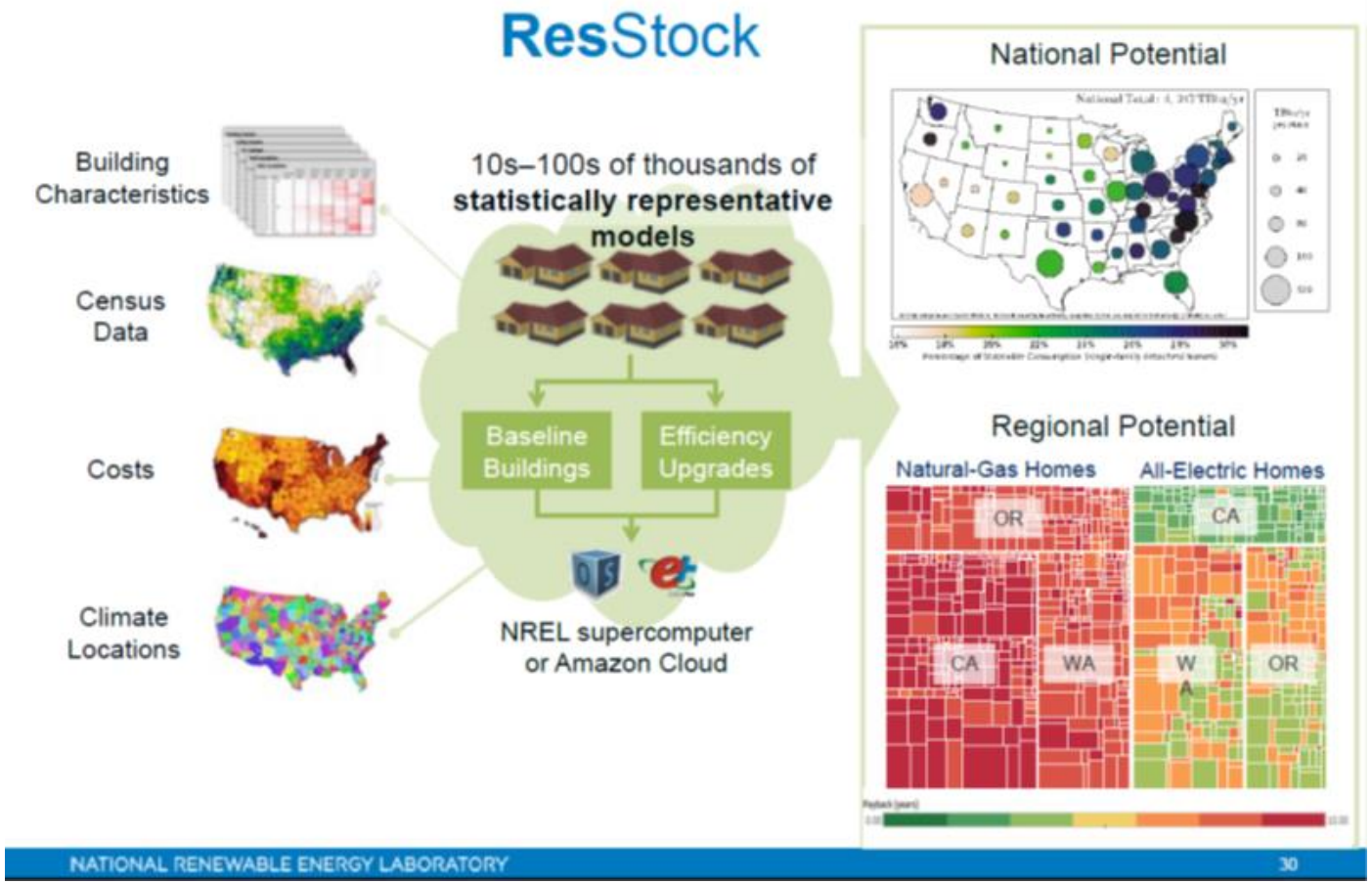
	Year 1 (2022)	Year 2 (2023)	Year 3 (2024)	Year 4 (2025)	Year 5 (2026)	Year 6 (2027)	Year 7 (2028)	Year 8 (2029)	Year 9 (2030)	Year 10 (2031)	Year 11 (2032)	Year 12 (2033)	Year 13 (2034)	Year 14 (2035)
Annual total (buildings)	500	2,500	10,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000
Priority community or household <80% AMI	450 (90%)	2250 (90%)	8000 (80%)	24000 (80%)	21000 (70%)	21000 (70%)	18000 (60%)	18000 (60%)	18000 (60%)	18000 (60%)	12000 (40%)	12000 (40%)	12000 (40%)	12000 (40%)
Anywhere	50 (10%)	250 (10%)	2000 (20%)	6000 (20%)	9000 (30%)	9000 (30%)	12000 (40%)	12000 (40%)	12000 (40%)	12000 (40%)	18000 (60%)	18000 (60%)	18000 (60%)	18000 (60%)
Cumulative total (buildings)	500	3,000	13,000	43,000	73,000	103,000	**133,000**	163,000	193,000	223,000	253,000	283,000	313,000	343,000

For comparison, New York State is proposing to upgrade 200,000 buildings per year to achieve 2050 carbon goals[1]

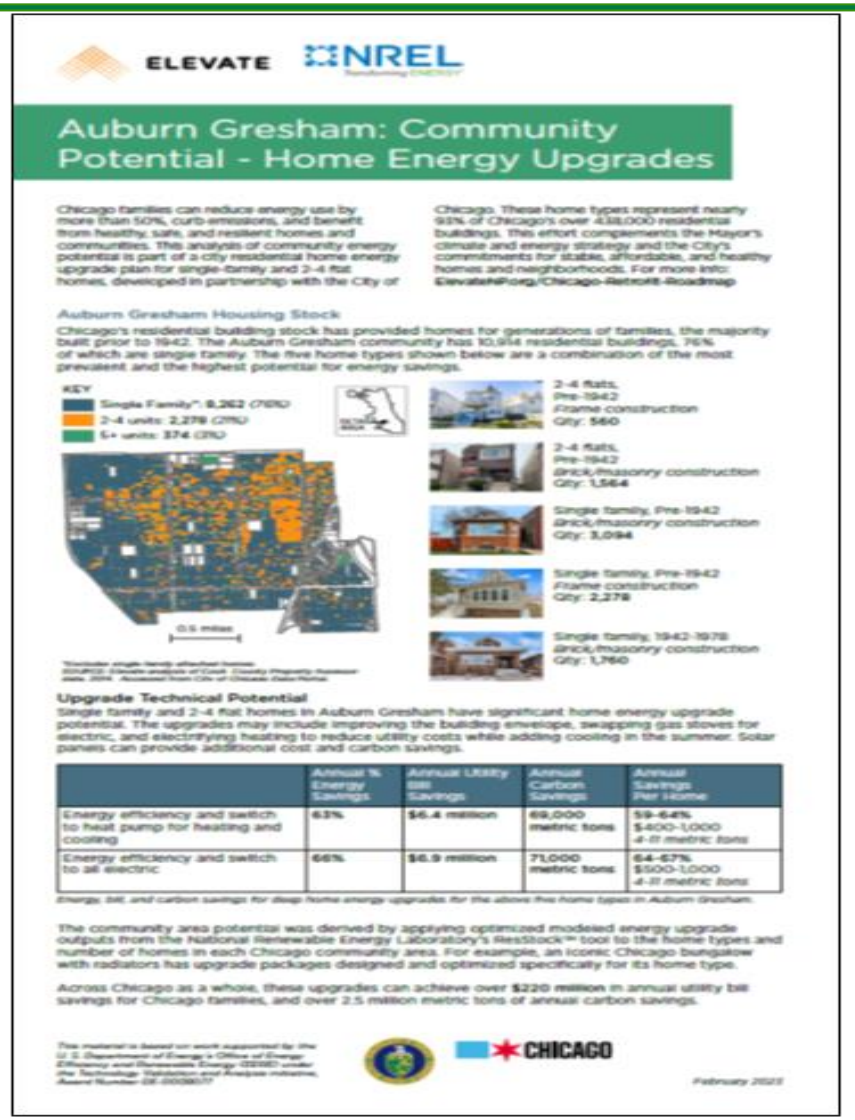
[1] NYSERDA Carbon Neutral Roadmap presentation, June 15, 2021, https://www.nyserda.ny.gov/All-Programs/Carbon-Neutral-Buildings

Progress and Future Work

First Phase - Modeling w/Community Profiles - Complete



https://www.nrel.gov/docs/fy22osti/83575.pdf



https://www.elevatenp.org/wp-content/uploads/2023-Chicago-Community-Area-Profiles-Auburn-Gresham-1.pdf

Progress and Future Work

Second Phase - Proof of Concept - Nearing Completion

Single family Pre-1942
Frame construction
Full electrification

Single family Pre-1942
Frame construction
Comprehensive

Single family Pre-1942
Masonry/brick construction
Comprehensive

2-4 flat Pre-1942
Masonry/brick construction
Comprehensive

Single family Pre-1942
Masonry/brick construction
Full electrification

Progress and Future Work

Second Phase - Proof of Concept - Nearing Completion

Single family 1942-1978
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2-4 flat Pre 1942
Frame construction
Full electrification

2-4 flat Pre 1942
Masonry/brick construction
Full electrification

Single family 1942-1978
Masonry/brick construction
Full electrification

Progress and Future Work

Third Phase – Validation and Summary - Starting and Preliminary

- Indoor air quality and energy monitoring equipment installed
- Data collection
- Final report (some preliminary lessons learned)
  - Home infrastructure upgrades
  - Unrelated code violations
  - Implementation knowledge and installation time
  - Homeowner reluctance to switch from natural gas
  - Solar could be crucial to achieve cost savings
  - Induction stoves and heat pump water heaters and clothes dryers can be expensive and difficult to fit in to existing conditions

The Future – Unanswered questions

- Funding for retrofit work?
- Workforce – availability and equity?
- Funding for existing conditions remediation?
- Energy burden shift on multi-family units?

Thank You

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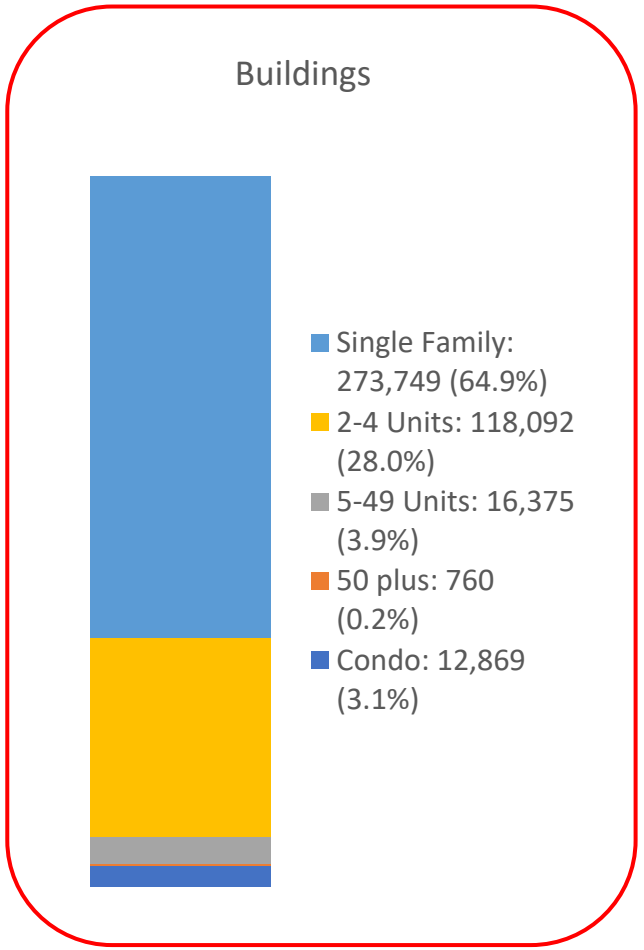
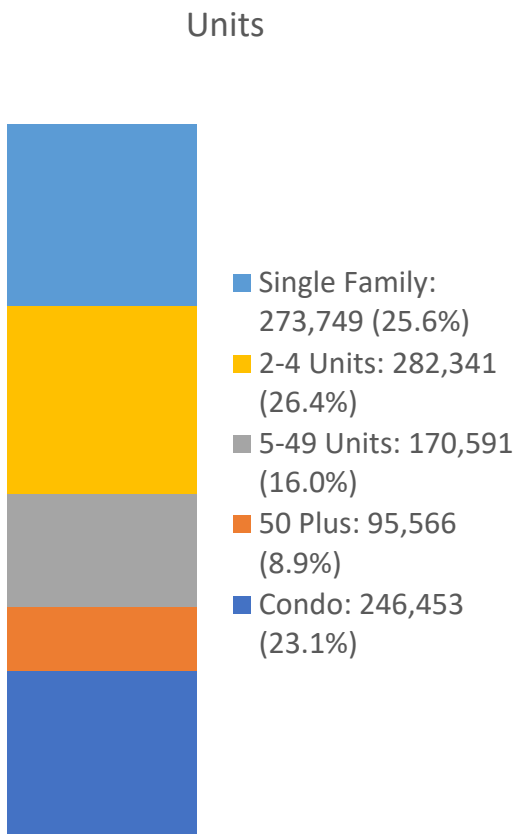
REFERENCE SLIDES

The Chicago Housing Stock

SF and 2-4 unit: 92.9%



TOTAL = 438,054

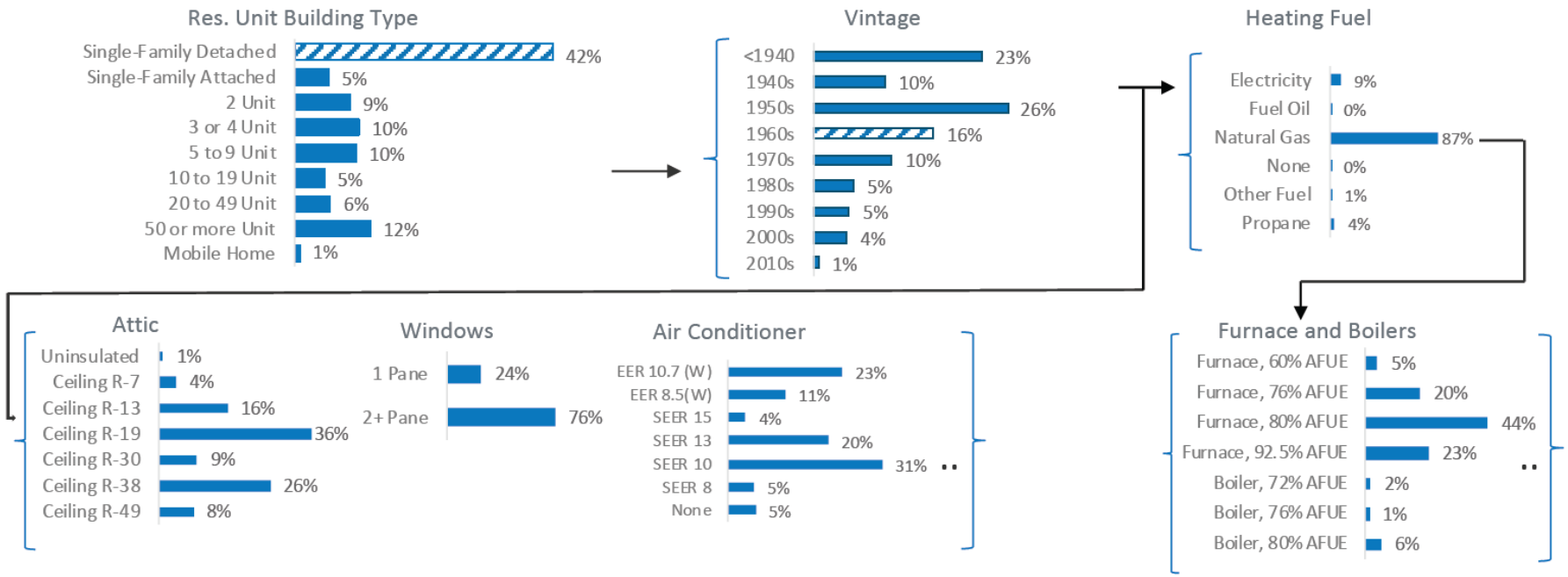


TOTAL = 1,068,700

Source: Elevate Energy Analysis 2019 of Cook County property assessor data 2014.
Percentages don't add up to 100% because subcategory totals do not include row houses / single-family attached buildings.

Chicago Housing Stock – Cook County Assessor Data – used in ResStock™

Conditional Probability Distributions



NREL | 25

Source: NREL calibration of ResStock™

Measure Packages

Comprehensive

- **Air sealing and insulation**
- **Higher-Efficiency upgrades to existing heating and cooling equipment**
- **Domestic water heater conversion to tankless water heater**
- **LED lighting**
- Rooftop Solar Photovoltaic (PV) potential *

Comprehensive + heat pump:

- **Air sealing and insulation**
- **Conversion of heating and cooling equipment to electrically fueled heat pump(s)**
- **Domestic water heater conversion to tankless water heater**
- **LED lighting**
- Rooftop Solar Photovoltaic (PV) potential *

Electrification:

- **Air sealing and insulation**
- **Conversion of heating and cooling equipment to electrically fueled heat pump(s)**
- **Domestic water heater conversion to electrically fueled heat pump water heater**
- **Clothes dryer conversion to electrically fueled heat pump clothes dryer**
- **Conversion of non-electric stove to induction**
- **LED lighting**
- Rooftop Solar Photovoltaic (PV) potential *

* Energy savings results do not include savings from solar

Project Execution

	FY2020				FY2021				FY2022				FY2023				FY2024			
Planned budget $537,640																				
Spent budget $487,745																				
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Past Work																				
ResStock calibration																				
ResStock City-scale model scenarios created																				
Technology packages identified																				
Create data visualization plan																				
Develop selection and recruitment plan for field validation																				
Recruit cadidate homes																				
Create community profiles																				
Installation of retrofit packages																				
Current/Future Work																				
Monitoring results																				
Analyze field data results																				
Final Technical Report																				

- Go/no-go decision points were May 2021 and May 2022, and in May 2022 a one-year extension was approved.
- Early slipped milestones did not affect the May 2021 go/no-go decision. But Covid-19 did affect the remainder of the milestones schedule (from both an in-home safety perspective as well as an equipment and workforce availability). This resulted in the one-year extension request for the project completion from May 2023 to May 2024.

Team

Lawrence Kotewa, Elevate Energy, Chief Engineer, Principal Investigator
Lucas Kappel, Elevate Energy, Strategist, Energy & Sustainability II, Project Manager
Rachel Schue, Elevate Energy, Principal Director, Research and Innovation

Janet Reyna, NREL
Lixi Liu, NREL

Angela Tovar, City of Chicago

Steven Labarge, ComEd

There are many others at Elevate Energy, NREL, the City of Chicago and ComEd that are involved in the success of the project

There are also many others that were involved in the success of the project, that either left their companies or transitioned to different roles at their companies