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AGENDA

1. Overview
2. Objectives
3. Methods
4. Results
5. Conclusions
6. Recommendations

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Overview and Objectives

- Approximately 17% of CT residential units are classified as multifamily
- In 2017, EEB sponsored a RASS for SF and MF residences

In light above the above, study objectives were to:

1. Estimate the number of MF units in Connecticut, as well as key characteristics.
2. Collect detailed information on key energy-consuming systems and weatherization characteristics to allow in-depth analysis of MF systems.
3. Based on the above, estimate the technical potential savings if all systems were converted to high-efficiency alternatives in MF units statewide.

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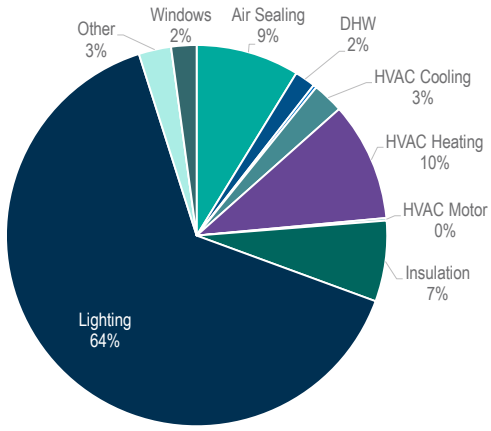
CT Multifamily Snapshot

- Primarily served by four programs: HES, HES-IE, SBEA, and C&I Retrofit
- In 2017, nearly two-thirds of source Btu savings came from lighting upgrades
- MF upgrades comprised about 30% and 43% of HES electric and gas savings, respectively



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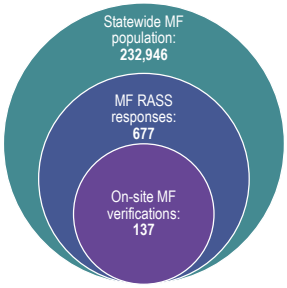
METHODS – SAMPLING



- RASS administered by NMR to a sample of SF and MF Eversource and UI electric customers
- Due to slow MF response rate, MF customers were oversampled
  - Challenging to differentiate MF customers from SF in utility databases
- 20% of RASS respondents volunteered for an on-site visit

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METHODS – DATA COLLECTION

- ERS field engineers visited 137 apartments in Summer 2018
  - ✓ Comprehensive inventory of energy-using equipment
  - ✓ Verify RASS responses
  - ✓ Collect common area characteristics as possible: central systems, envelope
  - ✓ Conduct demographic and behavioral survey
- Since RASS validation was the focus of the study, data collection emphasized in-unit characteristics
- For consistency with NMR's SF study, same iPad software was used

End Use \ Parameter	Technology Type	Qualitative Notes	Fuel type	Location	Wattage / Size	Quantity	Vintage	Capacity	Efficiency / Rating	Make/Model	ENERGY STAR Qualification	Controls Method	Notes
Lighting	✓			✓	✓	✓						✓	Inventoried stored bulbs, marked bulbs for future study
Appliances	✓		✓		✓	✓	✓	✓	✓	✓	✓		Focus on ENERGY STAR-eligible equipment
Mechanical equipment	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	Central and in-unit HVAC systems, thermostats
Water heating	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	System characteristics, flow devices
Weatherization	✓	✓					✓		✓				Wall insulation, windows and doors, air sealing
Electronics	✓			✓									Entertainment/IT hubs for APS potential
Renewables / Transportation	✓	✓			✓								Solar on rooftop, EV charging stations

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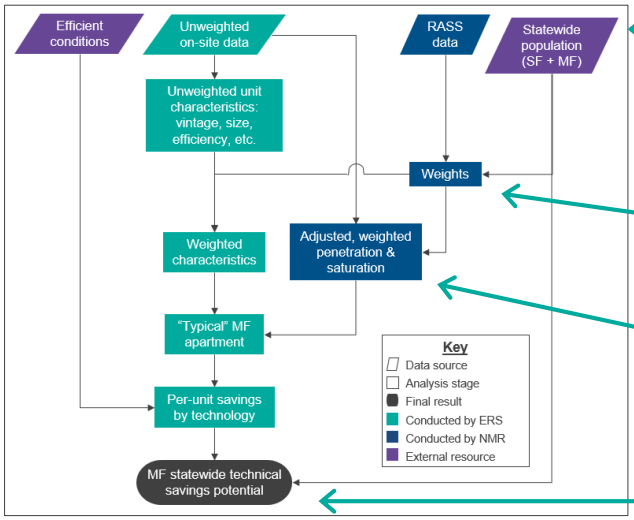
METHODS – ANALYSIS



Tax assessor databases, census data scraped to characterize CT population

Weights developed so that RASS represents statewide population

Adjustment factors developed when comparing RASS and on-site data

Typical apartment extrapolated statewide, compared with efficient conditions = technical savings potential

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UNIT-LEVEL RESULTS: GENERAL

Per-unit occupancy and square footage by segments of interest – 137 participants

Segment		*n*	Number of Occupants	Number of Bedrooms	Square Footage
Income	Low-Income	40	1.89*	1.63	834
	Non-Low-Income	97	1.61*	1.52	949
Tenure	Own	40	1.45*	1.49	941
	Rent	97	1.88*	1.62	860
Statewide		**137**	**1.79**	**1.59**	**876**

Building size and configuration by vintage – 137 participants

Building Vintage	Campus			Single Building		
	n	Average Floors	Average Count of Units	*n*	Average Floors	Average Count of Units
Pre-1939	1	1.0	16.0	13	2.8	22.2
1940-1979	14	2.0	19.0	15	3.8	44.1
1980-1999	10	2.9	38.3	2	4.0	39.1
2000-2009	8	1.6	64.3	5	4.4	27.6
2010 or later	24	4.1	75.4	40	4.4	69.1
Indeterminate	2	1.2	20.9	3	2.6	20.8

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Unit-Level: Weatherization

- Limitations in assessing weatherization due to inaccessible common spaces
- Blower door testing in MF buildings is extremely difficult – more qualitative approach used
- Three primary Wx categories assessed: wall insulation, windows, air sealing
- Weatherization analysis aligns with 2014 SF Wx study assumptions:

Measure	Weatherization Standard	Typical Weatherization Upgrade
Above grade walls	R-11	2x4 framing - R-12 2x6 framing - R-19 Other - R-20
Windows	U-0.50 (Double pane or single pane with storm windows)	U-0.20

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Weatherization, cont'd

Building Vintage	*n*	Meets Air Sealing Standard	Meets Window Standard	Meets AGW Standard
Pre-1939	15	45%	92%	47%
1940–1979	29	80%	90%	56%
1980–1999	12	100%	100%	84%
2000–2009	13	100%	100%	73%
2010 or later	64	100%	99%	82%
Total	**133**	**82%**	**95%**	**70%**

Share of units meeting weatherization standard by measure type

Shares by income category

Building Vintage	*n*	Meets Air Sealing Standard	Meeting Window Standard	Meets AGW Standard
Income assisted	40	85%	94%	72%
Market rate	97	76%	95%	65%
Total	**137**	**89%**	**95%**	**70%**

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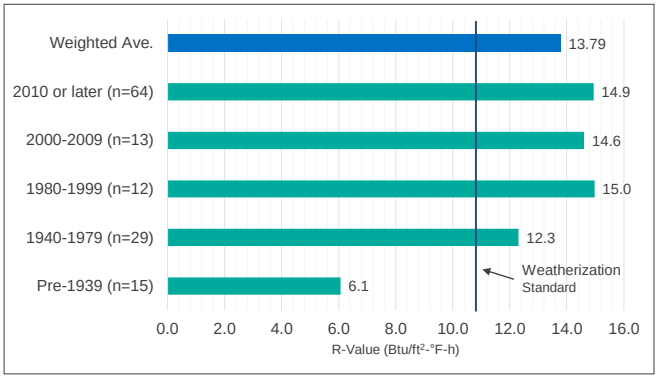
Weatherization: Wall Insulation



Wall insulation R-value by vintage

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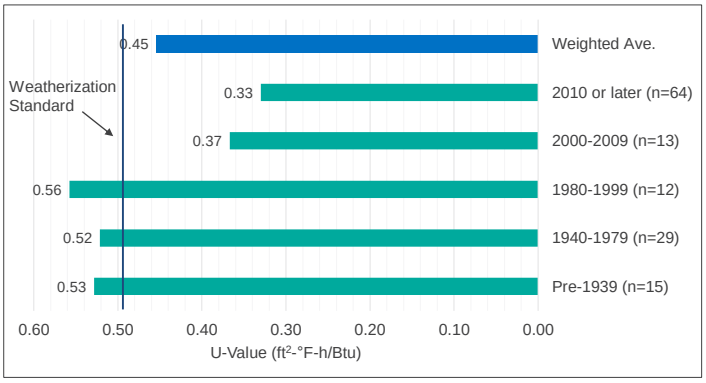
Weatherization: Windows



Window U-value by vintage

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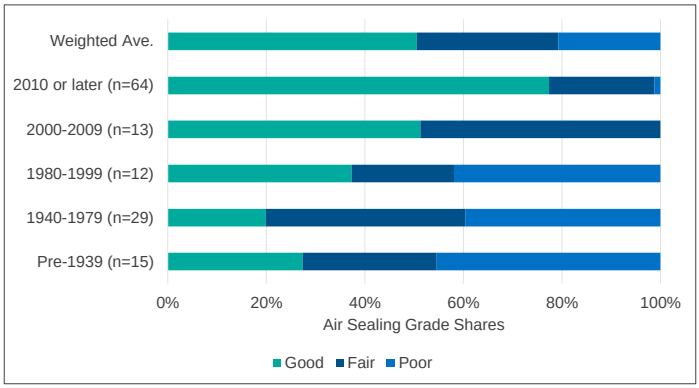
Weatherization: Air Sealing



Air sealing grades by vintage

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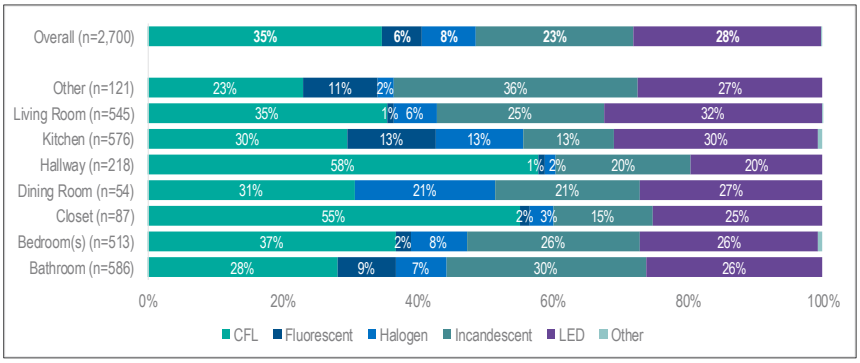
Unit-Level Results: Lighting



Lighting socket saturation by type and location within 137 tenant units

Comparison of socket saturations in low-income vs. non-low-income apts.

Technology	Low-Income	Non-Low-Income	Statewide
n	40	97	137
CFL*	40%	27%	34%
Fluorescent*	7%	4%	6%
Halogen	7%	9%	8%
Incandescent*	19%	28%	23%
LED	26%	30%	27%
Other	1%	2%	2%

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UNIT-LEVEL RESULTS: APPLIANCES

Per-unit saturation and ENERGY STAR qualification by appliance type

Appliance	Average Qty in Unit	Share E.S. Qualified	Share Not E.S. Qualified	Indeterminate
Refrigerator	**1.04**	41%	32%	27%
Dishwasher	**0.72**	64%	21%	14%
Clothes Washer	**0.50**	50%	38%	12%
Clothes Dryer	**0.48**	9%	83%	8%

Statistically significant differences observed for:

- ❑ **Income assistance**: dishwasher rated kWh, washer/dryer location, washer efficiency
- ❑ **Tenure (own vs. rent):** refrigerator cubic feet, dishwasher rated kWh, washer efficiency
- ❑ **Utility**: refrigerator rated kWh, washer/dryer location

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UNIT-LEVEL RESULTS: COOLING

RASS Category	On-Site Inventoried Cooling System Type	System Type Penetration
AC - Room Air Conditioner	Room Air Conditioner	46.0%
AC - Central Air/ASHP	ASHP	7.0%
	Central Air-packaged	4.4%
	Central Air-split	26.7%
AC - MSHP	Ductless mini split	0.5%
AC - No cooling	None	0.8%
Not addressed in RASS[b]	Chiller	3.0%
	Cooling tower	2.6%
	GSHP-closed loop	0.4%
	GSHP-open loop	0.1%
	Packaged roof-top unit	0.3%
	PTAC	3.1%
	PTHP	1.0%
	WSHP	4.0%
Total		**100.0%**

Distribution of cooling systems by type

Average efficiency ratings by system type

Cooling System Type	*n*	Average SEER or SEER-Equivalent
ASHP	10	12.3
Central air-packaged	5	10.7
Central air-split	22	12.9
Chiller	1	11.4
Ductless mini split	2	19.0
GSHP-closed loop	3	14.4
Packaged roof-top unit	1	13.0
PTAC	11	14.8
PTHP	8	9.4
Room air conditioner	31	11.8
WSHP	22	14.2
Total	**116**	**12.8**

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UNIT-LEVEL RESULTS: HEATING

Heating System Type	Low Income	Non-Low Income	Statewide
Natural gas - furnace	21%	37%	28%
Electric baseboard*	35%	19%	28%
Natural gas - boiler	19%	14%	17%
Central (ducted) air source heat pump	7%	8%	8%
Fuel oil - boiler	5%	3%	4%
Other[a]	17%	24%	20%
Total	**103%**	**106%**	**104%**

* Denotes statistically significant difference at the 90% confidence interval.

[a] No individual share is greater than 4%. Predominant technologies include heat pumps, fireplaces, and other fuel-fired furnaces.

Distribution of heating systems by type, fuel, income classification

Average efficiencies by heating system type

Heating System Type	*n*	Average Efficiency	Efficiency Unit
Multi-Unit Systems			
Boiler (forced hot water)	15	0.92	AFUE
Boiler (hydro-air)	3	0.94	AFUE
Single-Unit Systems			
ASHP	8	7.40	HSPF
Combination DHW and space heat	7	0.95	AFUE
Electric baseboard	14	1.00	COP
Furnace	21	0.88	AFUE
GSHP	8	4.34	COP
WSHP	22	4.91	COP

[a] An additional 71 systems were identified that could not be fully characterized for efficiency. At facilities in which the mechanical equipment was inaccessible, field staff identified equipment types based on distribution systems, building plans, and discussion with site staff.

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UNIT-LEVEL RESULTS: HOT WATER

DHW System Type	Low-Income	Non-Low-Income	Statewide
Electric - Standard	51%	43%	46%
Natural Gas - Standard	19%	22%	21%
Natural Gas - Tankless	8%	24%	17%
Natural Gas - Indirect	9%	5%	7%
Electric - Tankless	3%	3%	3%
Fuel Oil - Standard	2%	3%	3%
Other[a]	10%	7%	9%
Total[b]	**100%**	**107%**	**105%**

[a] No individual share >2%. Predominant other technologies included natural gas - combined, propane - standard, propane – tankless, and fuel oil - indirect. No HPWHs were found.

[b] Percentages do not sum to 100% due to statewide weighting, adjustment of RASS data from on-site verifications, and the possibility of more than one DHW system per apartment.

Distribution by DHW fuel and type among income categories

DHW efficiencies by system type

DHW System Type	*n*	Average Efficiency
Multiple Units	**12**	**71.3%**
Indirect w/storage tank	4	88.4%
Storage, stand alone	7	66.0%
Single Unit	**69**	**91.2%**
Combination appliance	13	93.7%
Indirect w/storage tank	2	82.1%
Instantaneous	6	94.4%
Storage, stand alone	48	90.7%
Total	**81**	**87.6%**

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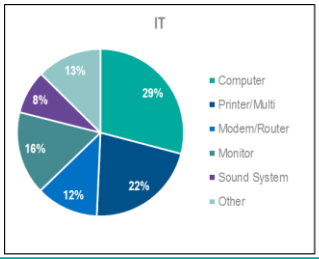
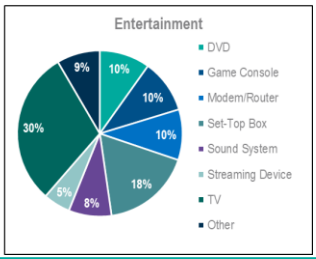
Unit-Level Results: Electronics

Advanced power strip potential from entertainment or IT hubs

Metric	Entertainment	IT
A – Average hubs per MF dwelling	1.55	0.64
B – Average devices per hub	3.11	3.19
C – Estimated annual consumption per hub (kWh)	351	345
D – Total annual consumption per MF dwelling (kWh) (A × C)	544	222
E – High-end Tier 1 APS annual savings	12.5%	15.8%
F – High-end Tier 1 APS annual savings per MF unit (kWh) (D × E)	68	35
G – Low-end Tier 1 APS annual savings in MF apartments (kWh)	77	





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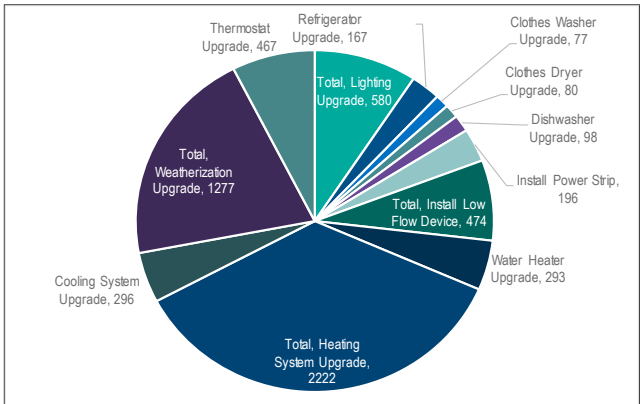
Statewide Results

Development	Multifamily Housing Units	5–9 Building Units	10–19 Building Units	20+ Building Units
Fairfield County	25,782	6,432	3,540	15,811
Hartford County	45,676	16,676	10,309	18,691
Litchfield County	17,991	5,252	4,216	8,523
Middlesex County	22,798	7,971	5,481	9,345
New Haven County	50,701	14,322	10,798	25,580
New London County	16,430	5,961	4,030	6,439
Tolland County	28,440	8,277	5,978	14,184
Windham County	25,128	7,647	5,591	11,890
Total	**232,946**	**72,538**	**49,943**	**110,464**

Count of multifamily units by county, building size (U.S. Census)

Statewide source BBtu technical savings potential per year by measure category (all fuels)



Total statewide technical potential savings of 6,226 BBtu/yr would result in an estimated 25% reduction in billed energy consumption and $350 in savings per year per apartment.

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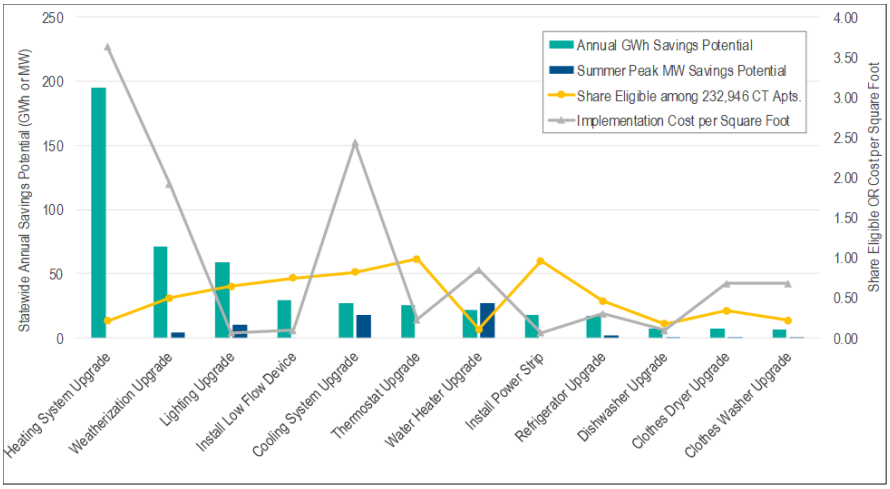
Statewide Results – Electric



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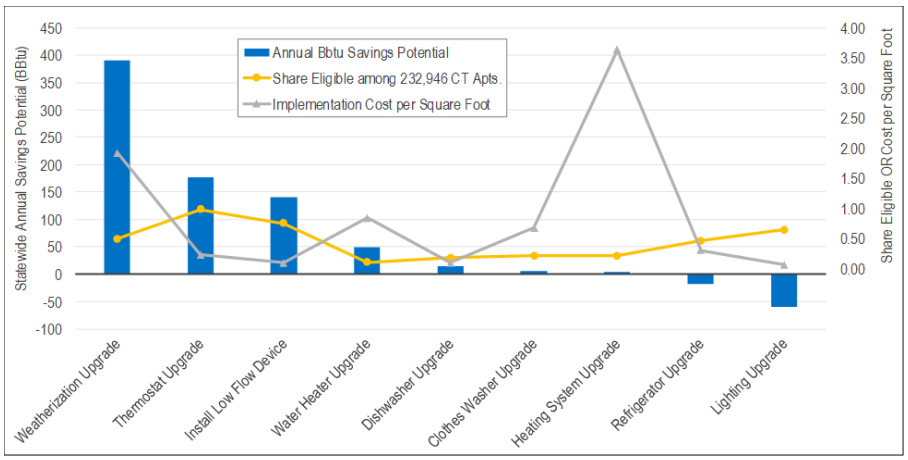
Statewide Results – Gas



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Key Findings in MF Units

- Converting electric heat to air-source heat pumps offers the most promising energy savings opportunity, and more so for carbon emissions reduction
- LED saturation (27% overall) indicates significant remaining opportunity
- Nearly all MF customers in the state would benefit from smart thermostat installation– currently 2% penetration
- 50% of MF units would benefit from at least one weatherization measure
  - Caveat: building envelope could not be fully assessed (common area limitations)
  - Older buildings present better opportunities
  - Results by income classification not significantly different
- Other measure findings:
  - Appliance and window AC upgrades offer modest savings potential
  - Only 4% of apartments contained an advanced power strip per on-site verification
  - Low-flow DHW savings opportunities are prevalent

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Recommendations for MF Programs

- Pursue deeper penetration of **low-cost** and **low-barrier measures** that offer significant savings potential: LED lighting, smart thermostats, low-flow devices, and advanced power strips.

- **High-impact** measure categories – in particular, electric heating system upgrades and weatherization measures – should be further assessed for feasibility in Connecticut MF buildings.
  - **Heating system upgrades** would be most impactful for low-income tenants
  - **Weatherization** measures are most needed in older buildings.
  - Such high-impact opportunities require more disruptive retrofits, higher capital commitment, and a dedicated contractor base.

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Recommendations for Future Research

- A similar baseline and savings opportunity study should be conducted among MF properties with **common areas** as the research focus.
  - This study's focus was tenant units, primarily to validate RASS responses.
  - Since the HES and HES-IE often work with property managers, a sample of property representatives should be targeted in such a study.
- A follow-up, global **economic or achievable potential study** should be conducted in Connecticut and should address the MF sector distinctly using this study's research as a starting point.
- Given focus on carbon emissions reduction, we recommend that further research be conducted on **strategic electrification** opportunities in Connecticut.
  - With the preponderance of electric resistance and oil space-heating in MF units, such a study should emphasize the MF customer sector.

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Roundtable

- Questions? Comments?
- Final report soon to be posted on Energize CT website

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