Beyond Efficiency: The Multifaceted Impacts of Induction Cooktops, Heat Pumps, and Battery Systems

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Background – Strategic Electrification in MA

Massachusetts Program Administrators (PAs) Energy Efficiency Programs

- **2018:** *Green Communities Act* amended, allowing for strategic electrification
- **2019-2021 three-year plan:** Energy optimization programs introduced
- **2021:** *Climate Act* legislation, new mandates for GHG emissions reductions
  - **2022-2024 Plans:** Electrification became one of the top priorities
  - **2025-2027 Plans:** Default solution for all residential customers

Overview of Paper

Findings from 4 recent studies to quantify NEIs that accrue to program participants from residential electrification efforts:

- Heat pumps displacing fossil fuel heating systems and/or adding cooling to homes
- All-electric residential new construction (RNC)
- Induction stovetops replacing gas stovetops
- Battery storage measures
  - Strategic electrification & energy optimization program for low- and moderate-income residential customers

NEIs focused on health, comfort, safety and resilience (battery storage)

Methodology

Slightly different approach for each study:

Study	Research Approach	Description of Approach
Residential Heat Pump NEIs	Bottom-up quantification of individual NEIs	Literature review, secondary data, and survey of program participants
All-Electric RNC NEIs	Bottom-up quantification of individual NEIs	Literature review and secondary data
Induction Stovetop NEIs	Bottom-up quantification of individual NEIs	Literature review and secondary data
Battery Storage NEIs	Top-down quantification of all NEIs as a whole	Building modeling, outage data analysis, and literature review

Literature Review & Algorithm Development

Semi-structured literature and data search

Applied across multiple research databases

Documented the link between electrification measure & an NEI

Quantified the financial implications (i.e, health care costs, productivity losses)

Estimated population sizes

Calculated the overall household benefit of the electrification measure

Example Algorithm

Heat Related Mortality Risk NEI (Added Cooling from HPs)

- Adding air conditioning ➔ reduces negative health impacts from heat stress
- Program intervention: mini-split HP replacing fossil fuel-fired heating system w/out cooling

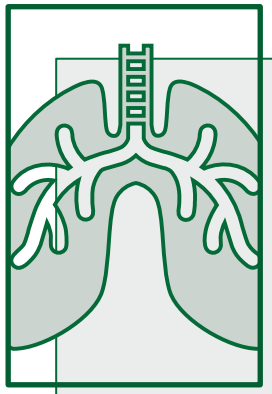
Heat Related Mortality Risk NEI Algorithm

	Input	Value	Source
a	Total MA population (2020)	6,984,723	U.S. Census Bureau
b	Number of homes in MA (Occupied, 2020)	2,749,225	U.S. Census Bureau
c	Annual heat related death rate in NY (2010-2019)	0.00228%	NYC Environmental Health 2021
d	Estimated annual heat related deaths in MA state	159	**a * c**
e	Percentage of households with AC in Massachusetts	87%	U.S. EIA 2023
f	Percentage of households without AC in MA	13%	U.S. EIA 2023
g	Excess risk reduction in heat related mortality due to AC	0.09	Sera, F. et al. 2020
h	($) VSL (avoided death), adjusted to 2022	$10,491,655	U.S. EPA (2006), adjusted for inflation using Consumer Price Index (https://www.bls.gov/data/inflation_calculator.htm)

Heat Related Mortality Risk NEI Algorithm, Cont'd

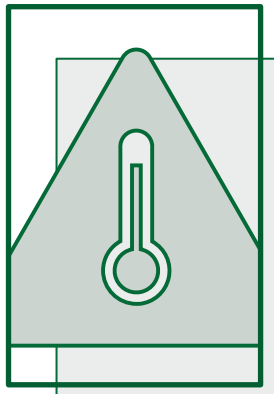
	Input	Value	Source
i	Number of heat related deaths in MA due to not using AC	14.31	**d * g**
j	Value of heat-related deaths avoided due to AC (MA)	$150,135,583	**h * i**
k	Annual Heat related mortality impact per home without AC	$420.21	**j / (b * f)**
l	Mini-split HP with a fossil fuel-fired pre-retrofit heating system (no cooling baseline)	30%	Distribution of Counterfactual Baseline Cooling Types from Guidehouse 2021.
m	% of Mini-split HP installations with added cooling that meet 50% of the home's overall cooling load	74%	Guidehouse and Ridgeline 2024.
NEI Value:			
Annual NEI estimate per home due to MSHP (Delivered Fuel Baseline)		**$93.28**	**k * l * m**

Residential Heat Pump NEIs



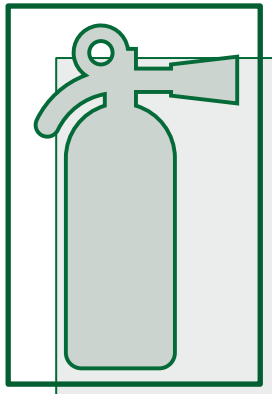
Indoor Air Quality (IAQ)

- Fossil fuel combustion ➔ multiple byproducts that pose health hazards, such as carbon monoxide (CO) and nitrogen dioxide (NO_2).
  - Reduce risks of CO poisoning & respiratory illnesses



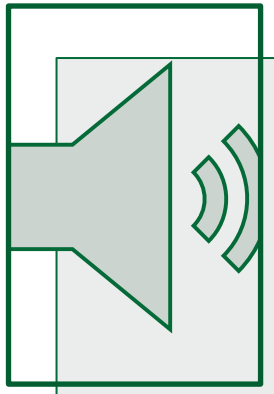
Thermal Stress NEIs

- Added cooling ➔ decrease in heat related mortality risks & negative impacts on cognitive function



Avoided Fires

- Replacing furnaces and boilers with heat pumps ➔ avoided home fires
  - Value of avoided building losses and avoided medical costs from fire-related injuries
    - Analysis of data from the National Fire Incident Reporting System (NFIRS)



Thermal Comfort, Noise and Equipment Maintenance

- Adapted from a Connecticut study - contingent valuation approach to monetize heat pump NEIs

Residential Heat Pump NEIs

NEI Description	Annual per Home NEI ($)
Reduced non-fire related CO poisoning deaths by displacing combustion furnaces (IAQ)	$0.34
Reduced respiratory illness symptoms by displacing natural gas furnaces with pilot lights (IAQ)	$14.14
Heat-related mortality risk (thermal stress)	$37.82 to $115.06 (varies by HP installation)
Productivity gains due to reduced cognitive impacts from extreme heat (thermal stress)	$6.91 to $21.03 (varies by HP installation)
Avoided home fires (fire risk)	$0.01 to $0.03 (varies by HP installation)
Thermal Comfort, summer (participant survey)	$69.43
Thermal Comfort, winter (participant survey)	$88.05
Noise Reduction (participant survey)	$73.25

Induction Stovetop NEIs Explored

Asthma-related impacts

Non-asthma health impacts

Avoided fires and burns

Negative health-related impacts associated with pacemakers

Costs for induction-compatible cookware

Natural Gas Leakage and GHG emissions

Induction Stovetop NEIs, Final Values

Non-Energy Impact	Value
Childhood asthma prevention, occupant lifetime (annual)	$4.73
Childhood asthma symptom reduction (annual)	$51.45
Adult asthma symptom reduction (annual)	$49.77
Lower respiratory tract symptom reduction (annual)	$88.26
COPD-related hospitalization reduction (annual)	$0.28
Total annual NEIs per home	**$194.49**
NEI for partial cookware replacements (one-time)	-$19.37
NEI for full cookware replacements (one-time)	-$38.41

Battery Storage NEIs: Quantifying Resilience for Homes

Top-Down Approach:

Quantity (kWh) of lost load avoided because of battery storage

- Building modeling and detailed outage data

Cost per incidence: value of lost load (VoLL)

- The estimated cost of lost load per kWh
  - The average price per kWh that customers would be willing to pay to avoid the disruption of electricity supply

Multiplying the two yields the monetized resilience NEI estimate for battery storage

- Avoided lost load * VoLL

Study Approach: Quantifying Resilience NEIs from Battery Storage

1. Determine an appropriate VoLL for the study population

2. Estimate typical annual outages for study population
   a. Determine the timing and length of each outage and the probability of a customer being affected by it
   b. Estimate annual kWh of lost load

3. Determine the lost load the battery system will help avoid during outages
   a. Develop seasonal customer load profiles
   b. Estimate the kWh of electricity supplied by the battery system during each outage

4. Annual resilience NEI value: multiply the estimated annual kWh supplied by the battery system during outages by VoLL

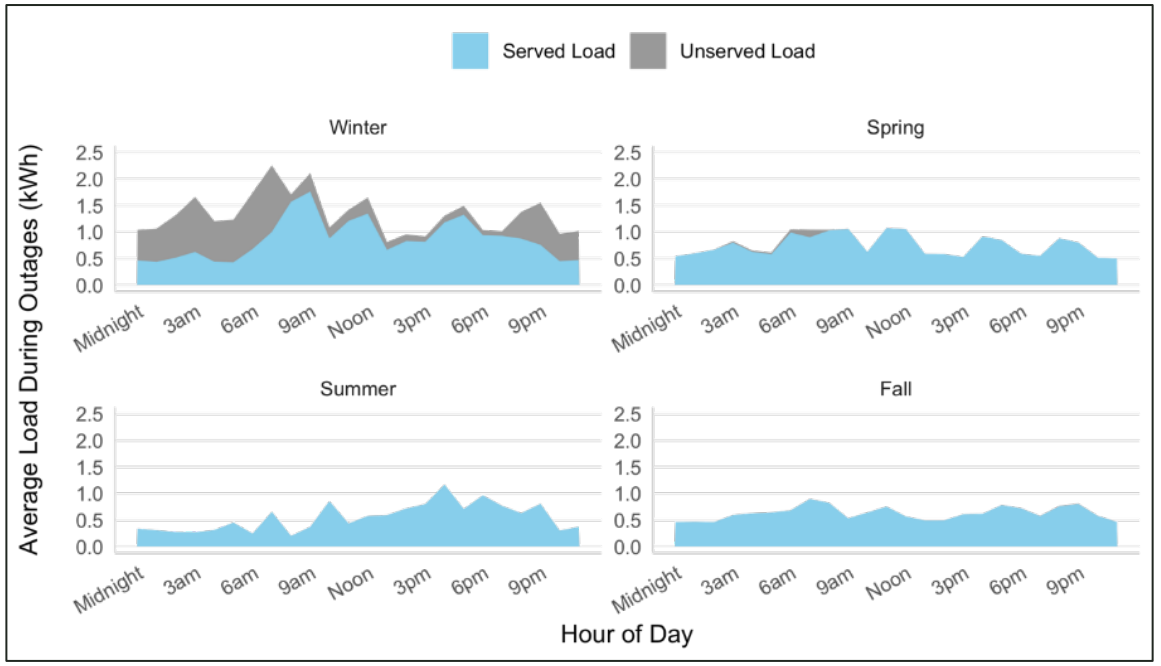
Quantified Resilience NEIs from Battery Storage

1. VoLL: 2021 Self-Generation Incentive Program (SGIP) Energy Storage Market Assessment Study (Verdant Associates 2022)

2. Annual outages: Massachusetts Dept. of Public Utilities (DPU), 2020 through 2022

3. Seasonal customer load profiles & kWh supplied by the battery system: BEopt energy modeling software

4. Annual resilience NEI: *NEI per Home per Outage = $VoLL\_{CVEO}$($/kWh) * Total kWh supplied by the battery system during the outage * The probability of the home being affected by the outage*



** Seasonal Critical Load Profile and Average Load Supplied by a 2-Battery System, Small Detached CVEO Home*

Total Annual Resilience NEI per Home ($)	
$162.08 (home with one battery)	**$181.00** (home with two batteries)

Conclusions

1. Residential electrification measures offer a wide array of important co-benefits beyond energy efficiency

2. NEI studies illustrate the value of leveraging existing research and secondary data
   - Chaining algorithmic inputs from the literature
   - Battery resilience NEIs also entails using building energy modeling and outage data to produce a top-down estimate

3. Periodically reassess the NEIs, given ongoing research on the impacts of global climate change and the health effects of fossil fuel combustion in homes

Thank You

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Link to Our Study: