



**Memo to:** Massachusetts Program Administrators  
Attention:  
Jaclyn Rambarran, Eversource  
Brian Greenfield, Eversource

**Prepared By:** Emmeline Luck, DNV  
Chad Telarico, DNV  
Laengheng Khoun, DNV  
Naikaj Pandya, DNV  
Indukumar Packrisamy, DNV  
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**Copied to:**  
Will Gorrissen, Cadeo  
Doug Bruchs, Cadeo

## IMPACT SHAPE FINAL BRIEF

This final brief accompanies the final impact shape spreadsheet and is intended to explain the methodology behind the updated calculations, present the results, and describe how they might be applied.

### 1 INTRODUCTION

This brief explains the methodology behind impact shape calculations to be used for the BCR model for the planning cycle beginning in 2025 and presents results. We describe what data was used for each category and raise opportunities for input from the PAs regarding which data should be leveraged. This update supplements data from the legacy tool created by DNV in 2018.

### 2 METHODOLOGY

DNV has retained all data from the original tool developed in 2018. In addition, DNV collected new data from internal and external sources, namely from custom electric impact evaluation studies, a library of load shapes, Cadeo's Massachusetts Commercial Energy Optimization Model, and the National Renewable Energy Laboratory.

#### 2.1 Internal data analysis

##### 2.1.1 Impact evaluation 8,760 data

To supplement the existing data from the legacy load shapes tool, DNV compiled data from Massachusetts Custom Electric evaluations from 2016 to 2022. DNV focused on non-lighting measures since the existing tool has an extensive data set for lighting measures. DNV compiled data from 36 Massachusetts custom electric sites that performed on-site metering (full M&V with operational adjustments) and used an 8,760-hour analysis approach.

- **Impacted categories:** Lighting (indoor), Lighting (outdoor), Lighting (indoor controls), Lighting (outdoor controls), Cooling, Compressed Air, Refrigeration, Industrial process

##### 2.1.2 DNV load shape library

Some measure categories warranted further research based on available data, so the team drew upon DNV's load shape library for Foodservice and Water Heating. This library borrows savings shapes from external sources, including the End Use Load and Consumer Assessment Program (ELCAP) administered by the Regional Technical Forum (RTF), and from the National Renewable Energy Laboratory (NREL) ComStock database. For this project, we used NREL for everything except Cooking and Industrial, which NREL did not model. The RTF load shapes include ELCAP, but also other sources, including California studies collected by RTF.

- **Impacted categories:** Foodservice, Water Heating

#### 2.2 Massachusetts commercial energy optimization model output

The original legacy load shape tool did not include any heat pump measures. To generate savings shapes for the various heat pump categories included in this study, the DNV team leveraged Cadeo and their recently completed MA



Energy Optimization (EO) Model Update.<sup>1</sup> This model was recently updated using the PAs' existing small commercial EO model to develop improved prescriptive heat pump impacts for a variety of equipment types, displaced fuel, and displacement scenarios. For this study, Cadeo produced 8,760 baseline and efficient savings profiles for each of these scenarios from which savings shapes and relevant impact factors could be derived.

- **Impacted categories:** Heating (HP), Heating (ER), Heating & Cooling (HP), Heating & Cooling (ER+AC)

## 2.3 National Renewable Energy Laboratory (NREL)

NREL has developed ComStock, a database of building characteristics from DOE's Commercial Prototype Building Models and Commercial Reference Building. Through various data collections, the building characteristics include simulated energy consumption by end use for each of the building models in the NREL sample. DNV used this database (filtered for the state of MA) for developing the savings shape for electric water heating measures and to corroborate the savings shapes developed from the internal data and the EO models.

- **Impacted categories:** Lighting (indoor), Lighting (outdoor), Heating (HP), Heating (ER), Heating & Cooling (HP), Heating & Cooling (ER+AC)

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<sup>1</sup> Cadeo Group. *Energy Optimization Model Update* developed for the MA Program Administrators. November 1, 2023. [https://ma-eeac.org/wp-content/uploads/MA22C10-Energy-Optimization-Model-Update-Report\\_FINAL\\_01NOV2023\\_ForEEACWebsite.pdf](https://ma-eeac.org/wp-content/uploads/MA22C10-Energy-Optimization-Model-Update-Report_FINAL_01NOV2023_ForEEACWebsite.pdf)

**Table 2-1. Methodology by measure category**

Measure category	Average vintage of data	Number of profiles	Final data source(s)	What's included
<b>Cooling</b>	2012	116	MA Custom Electric data and legacy tool	Chillers, AHUs, other unitary equipment
<b>Compressed Air</b>	2015	85	MA Custom Electric data and legacy tool	Air compressors
<b>Industrial Process</b>	2019	12	MA Custom Electric data and legacy tool	Thermoformer, extruders, process furnaces, and other industrial equipment
<b>Refrigeration</b>	2017	36	MA Custom Electric data and legacy tool	Walk-ins, reach-in cases, and standalone fridges
<b>Foodservice</b>	N/A	4	RTF	Cooking equipment modeled savings profiles from Restaurant (70% wt.), Healthcare (15% wt.), and Lodging (15% wt.)
<b>Water Heating</b>	N/A	5	NREL	Electric water heater modeled savings profiles from Medium Office (35% wt.), Quick Serve Restaurant (20% wt.), Large Hotel (15% wt.), Hospital (15% wt.), and Primary School (15% wt.)
<b>Lighting (indoor)</b>	2011	75	Data from legacy tool and NREL check	All indoor lighting types including fluorescent and LED
<b>Lighting (outdoor)</b>	2014	10	Data from legacy tool and NREL check	All outdoor lighting types including fluorescent and LED
<b>Lighting (indoor controls)</b>	2011	230	Data from legacy tool	Combined both indoor and outdoor lighting controls
<b>Lighting (outdoor controls)</b>	2011	230	Data from legacy tool	Combined both indoor and outdoor lighting controls



**Table 2-2. Heat pump categories**

Measure Name	Baseline Equipment has Cooling (Y/N)	Baseline Equipment Heating Fuel	Annual Electrical Savings (kWh)	Summer		Winter		Load Factor converting Annual kWh to Max kW	Summer kW CF	Winter kW CF
				On-Peak	Off-Peak	On-Peak	Off-Peak			
Heating and Cooling (ER + AC)	Yes	Electric	118,777	6%	1%	54%	38%	0.0011	0.0705	0.1039
Heating and Cooling (HP)	Yes	Natural Gas	-35,428	-14%	1%	41%	73%	0.0026	-0.0785	0.0347
Heating (ER)	No	Electric	79,846	-14%	-11%	74%	50%	0.0015	-0.1026	0.1029
Heating (HP)	No	Natural Gas	-88,549	22%	15%	23%	40%	0.0012	0.2025	0.0359

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<sup>2</sup> Note: A check against NREL values was also applied to the heat pump analysis.

<sup>3</sup> Note: Please see APPENDIX A for details on heat pump measures included in the above categories.

### 3 RESULTS

Table 3-1 presents the impact shape results for each measure category of interest. Each shape includes the following savings factors:

- Summer % on-peak kWh savings: June – September, non-holiday weekdays, 7 am – 11 pm
- Summer % off-peak kWh savings: June – September, all other hours
- Winter % on-peak kWh savings: October – May, non-holiday weekdays, 7 am – 11 pm
- Winter % off-peak kWh savings: October – May, all other hours
- Load factor converting Annual kWh to Max kW (LF)
- Summer kW coincidence factor (SCF): June – August, non-holiday weekdays, 1 pm – 5 pm
- Winter kW coincidence factor (WCF): December – January, non-holiday weekdays, 5 pm – 7 pm

These savings factors are to be applied using the program Annual kWh savings as the basis for calculating the following savings impacts via the BCR model:

- Summer on-peak kWh savings = Annual kWh savings x Summer % on-peak kWh savings
- Summer off-peak kWh savings = Annual kWh savings x Summer % off-peak kWh savings
- Winter on-peak kWh savings = Annual kWh savings x Winter % on-peak kWh savings
- Winter off-peak kWh savings = Annual kWh savings x Winter % off-peak kWh savings
- Summer kW savings = Annual kWh savings x LF x SCF
- Winter kW savings = Annual kWh savings x LF x WCF

For heat pump categories, the weights used in Table 2-2 above are all equal at the EO tool measure-level. The weights come to either approximately 11% or 12.5% each because the PTHP measure only displaces electric baselines. The EO model has differing weights by unique combination of baseline HVAC type, counterfactual HVAC type, building types, climate etc., that all get rolled up to the EO tool measure level. Please see APPENDIX A for the updated EO tool heat pump measure level results.

Table 3-1. Impact shape data by measure category

Measure Categories	Summer on-peak kWh savings (%)	Winter on-peak kWh savings (%)	Summer off-peak kWh savings (%)	Winter off-peak kWh savings (%)	Load Factor converting Annual kWh to Max kW (LF)	Summer kW CF (SCF)	Winter kW CF (WCF)
Cooling	38%	19%	29%	14%	0.000759	59%	5%
Compressed Air	17%	32%	16%	34%	0.000258	70%	64%
Industrial Process	22%	23%	24%	31%	0.000725	55%	4%
Refrigeration	15%	31%	17%	37%	0.000200	68%	72%
Foodservice	28%	28%	22%	22%	0.000192	80%	82%
Water Heating	16%	37%	14%	33%	0.000258	54%	56%
Interior Lighting	23%	41%	12%	24%	0.000237	88%	71%
Exterior Lighting	13%	26%	19%	42%	0.000231	32%	86%
Lighting Controls	22%	41%	11%	25%	0.003417	32%	22%
Heat pumps: Heating and Cooling (ER + AC) <i>With cooling, Electric baseline</i>	6%	54%	1%	38%	0.0011	7.05%	10.39%
Heat pumps: Heating and Cooling (HP) <i>With cooling, Natural Gas baseline</i>	-14%	41%	1%	73%	0.0026	-7.85%	3.47%
Heat pumps: Heating (ER) <i>Without cooling, Electric baseline</i>	-14%	74%	-11%	50%	0.0015	-10.26%	10.29%
Heat pumps: Heating (HP) <i>Without cooling, Natural Gas baseline</i>	22%	23%	15%	40%	0.0012	20.25%	3.59%



## APPENDIX A. HEAT PUMP MEASURES

Demand Impact Measure Name	EO Tool Measure Name	Measure Equipment	Baseline Equipment has Cooling (Y/N)	Baseline Equipment Heating Fuel	Displacement Type	Weight	Summer		Winter		Load Factor converting Annual kWh to Max kW	Summer kW CF	Winter* kW CF
							Off-Peak	On-Peak	Off-Peak	On-Peak			
Heating and Cooling (ER + AC)	Air Source Heat Pump+Partial+Electric+Yes	Air Source Heat Pump	Yes	Electric	Partial	0.11111	8%	5%	48%	39%	0.0012	0.0707	0.0679
Heating and Cooling (ER + AC)	Air Source Heat Pump+Full+Electric+Yes	Air Source Heat Pump	Yes	Electric	Full	0.11111	5%	3%	47%	44%	0.0013	0.0416	0.0813
Heating and Cooling (HP)	Air Source Heat Pump+Partial+Natural Gas+Yes	Air Source Heat Pump	Yes	Natural Gas	Partial	0.12500	60%	83%	-65%	22%	-0.0025	-0.1984	0.1484
Heating and Cooling (HP)	Air Source Heat Pump+Full+Natural Gas+Yes	Air Source Heat Pump	Yes	Natural Gas	Full	0.12500	-246%	-343%	572%	117%	0.0184	-0.1123	0.1777
Heating and Cooling (ER + AC)	Minisplit - Multi-zone+Partial+Electric+Yes	Minisplit - Multi-zone	Yes	Electric	Partial	0.11111	10%	-2%	67%	25%	0.0012	0.0935	0.0347
Heating and Cooling (ER + AC)	Minisplit - Multi-zone+Full+Electric+Yes	Minisplit - Multi-zone	Yes	Electric	Full	0.11111	7%	-1%	63%	31%	0.0009	0.0918	0.0601
Heating and Cooling (HP)	Minisplit - Multi-zone+Partial+Natural Gas+Yes	Minisplit - Multi-zone	Yes	Natural Gas	Partial	0.12500	-15%	8%	26%	81%	0.0030	-0.0683	0.0125
Heating and Cooling (HP)	Minisplit - Multi-zone+Full+Natural Gas+Yes	Minisplit - Multi-zone	Yes	Natural Gas	Full	0.12500	-8%	5%	27%	77%	0.0021	-0.0560	0.0290
Heating and Cooling (ER + AC)	Minisplit - Single-zone+Partial+Electric+Yes	Minisplit - Single-zone	Yes	Electric	Partial	0.11111	6%	2%	52%	39%	0.0011	0.0644	0.0906
Heating and Cooling (ER + AC)	Minisplit - Single-zone+Full+Electric+Yes	Minisplit - Single-zone	Yes	Electric	Full	0.11111	4%	2%	50%	44%	0.0008	0.0612	0.1406
Heating and Cooling (HP)	Minisplit - Single-zone+Partial+Natural Gas+Yes	Minisplit - Single-zone	Yes	Natural Gas	Partial	0.12500	-88%	59%	-25%	154%	0.0015	-0.9008	-0.1964
Heating and Cooling (HP)	Minisplit - Single-zone+Full+Natural Gas+Yes	Minisplit - Single-zone	Yes	Natural Gas	Full	0.12500	-36%	24%	6%	106%	0.0056	-0.0955	-0.0153
Heating and Cooling (ER + AC)	Variable Refrigerant Flow+Partial+Electric+Yes	Variable Refrigerant Flow	Yes	Electric	Partial	0.11111	11%	-2%	65%	25%	0.0014	0.1070	0.1537
Heating and Cooling (ER + AC)	Variable Refrigerant Flow+Full+Electric+Yes	Variable Refrigerant Flow	Yes	Electric	Full	0.11111	8%	-1%	63%	30%	0.0011	0.0992	0.2310
Heating and Cooling (HP)	Variable Refrigerant Flow+Partial+Natural Gas+Yes	Variable Refrigerant Flow	Yes	Natural Gas	Partial	0.12500	3%	5%	39%	52%	0.0017	-0.0133	0.0291
Heating and Cooling (HP)	Variable Refrigerant Flow+Full+Natural Gas+Yes	Variable Refrigerant Flow	Yes	Natural Gas	Full	0.12500	2%	3%	38%	57%	0.0015	-0.0098	0.0443



Demand Impact Measure Name	EO Tool Measure Name	Measure Equipment	Baseline Equipment has Cooling (Y/N)	Baseline Equipment Heating Fuel	Displacement Type	Weight	Summer		Winter		Load Factor converting Annual kWh to Max kW	Summer kW CF	Winter* kW CF
							Off-Peak	On-Peak	Off-Peak	On-Peak			
Heating and Cooling (ER + AC)	Packaged Terminal Heat Pump+Full+Electric+Yes	Packaged Terminal Heat Pump	Yes	Electric	Full	0.11111	5%	1%	49%	46%	0.0009	0.0630	0.0961
Heating (ER)	Air Source Heat Pump+Partial+Electric+No	Air Source Heat Pump	No	Electric	Partial	0.11111	-9%	-3%	63%	49%	0.0016	-0.0755	0.0659
Heating (ER)	Air Source Heat Pump+Full+Electric+No	Air Source Heat Pump	No	Electric	Full	0.11111	-5%	-2%	56%	51%	0.0016	-0.0442	0.0793
Heating (HP)	Air Source Heat Pump+Partial+Natural Gas+No	Air Source Heat Pump	No	Natural Gas	Partial	0.12500	35%	10%	34%	20%	0.0012	0.3707	0.0987
Heating (HP)	Air Source Heat Pump+Full+Natural Gas+No	Air Source Heat Pump	No	Natural Gas	Full	0.12500	25%	7%	40%	29%	0.0009	0.3230	0.1767
Heating (ER)	Minisplit - Multi-zone+Partial+Electric+No	Minisplit - Multi-zone	No	Electric	Partial	0.11111	-22%	-20%	105%	36%	0.0020	-0.1249	0.0262
Heating (ER)	Minisplit - Multi-zone+Full+Electric+No	Minisplit - Multi-zone	No	Electric	Full	0.11111	-13%	-12%	85%	40%	0.0013	-0.1211	0.0505
Heating (HP)	Minisplit - Multi-zone+Partial+Natural Gas+No	Minisplit - Multi-zone	No	Natural Gas	Partial	0.12500	23%	20%	17%	41%	0.0012	0.1969	0.0144
Heating (HP)	Minisplit - Multi-zone+Full+Natural Gas+No	Minisplit - Multi-zone	No	Natural Gas	Full	0.12500	17%	15%	19%	48%	0.0011	0.1649	0.0310
Heating (ER)	Minisplit - Single-zone+Partial+Electric+No	Minisplit - Single-zone	No	Electric	Partial	0.11111	-17%	-14%	77%	54%	0.0017	-0.1107	0.0890
Heating (ER)	Minisplit - Single-zone+Full+Electric+No	Minisplit - Single-zone	No	Electric	Full	0.11111	-11%	-9%	65%	55%	0.0011	-0.1049	0.1386
Heating (HP)	Minisplit - Single-zone+Partial+Natural Gas+No	Minisplit - Single-zone	No	Natural Gas	Partial	0.12500	25%	33%	2%	41%	0.0010	0.2558	-0.0619
Heating (HP)	Minisplit - Single-zone+Full+Natural Gas+No	Minisplit - Single-zone	No	Natural Gas	Full	0.12500	18%	24%	8%	49%	0.0024	0.0808	-0.0134
Heating (ER)	Variable Refrigerant Flow+Partial+Electric+No	Variable Refrigerant Flow	No	Electric	Partial	0.11111	-44%	-42%	141%	45%	0.0029	-0.1726	0.1708
Heating (ER)	Variable Refrigerant Flow+Full+Electric+No	Variable Refrigerant Flow	No	Electric	Full	0.11111	-24%	-23%	103%	44%	0.0017	-0.1522	0.2455
Heating (HP)	Variable Refrigerant Flow+Partial+Natural Gas+No	Variable Refrigerant Flow	No	Natural Gas	Partial	0.12500	24%	15%	26%	36%	0.0010	0.2452	0.0323
Heating (HP)	Variable Refrigerant Flow+Full+Natural Gas+No	Variable Refrigerant Flow	No	Natural Gas	Full	0.12500	18%	11%	28%	43%	0.0009	0.1870	0.0482
Heating (ER)	Packaged Terminal Heat Pump+Full+Electric+No	Packaged Terminal Heat Pump	No	Electric	Full	0.11111	-15%	-12%	66%	61%	0.0013	-0.1282	0.0972

Note: A couple of EO tool measures displacing natural gas show a reduced peak demand in the winter. This reflects a relatively low heating load during the peak demand period in some of the simulated cases combined with significant fan savings from decoupling the ventilation which allows the zone fans to cycle in the program case.