Cost-Effectiveness of Active Demand Response for Residential End-Uses (MA21DR01-E-Res End Use ADR Cost Effectiveness)

Prepared for:

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Executive Summary

Study Scope and Approach

To inform the direction of the Massachusetts Program Administrator's (MA PAs) residential electric active demand reduction (ADR) programs, Guidehouse estimated relative potential and cost-effectiveness of ADR for DR-enabled appliances. For each combination of appliance, enabling device, and DR strategy listed in Table 1, this study provides estimates of:

1) Potential savings per unit during the summer peak period;
2) Current and forecasted market saturation data;
3) Approximate incremental costs for summer DR;
4) Measure-level benefit-cost ratios.

As shown in Table 1, this report considers a range of residential appliances and multiple enablement strategies for each appliance type. The previous Cost-Effectiveness of DR for Residential End-Uses Study, conducted during 2018 and finalized in 2019, was conducted for National Grid alone and covered a broader range of residential end-uses.[1] For this 2021 update, with input from the MA PAs and Massachusetts Energy Efficiency Advisory Council (EEAC), Guidehouse included a subset of measures included in the 2019 report.

This study also provides updated literature review findings related to proven and potential DR enablement technologies, and the program designs of relevant utility programs, along with challenges encountered (as available). The updated literature findings can be found in the "Technology Landscape" and "Program Summaries" subsections in Chapter 3. This report includes chapters for each appliance type listed in Table 1.

The measure-level benefit-cost ratios (BCRs) included in the report reflect potential demand reductions based on end-use metering data associated with weekdays for which the maximum daily temperature was equal to or greater than 90°F.[2] The BCR estimates are at the measure-level only as they do not include administration and marketing costs, among other program-level costs.[3] This means the BCRs at the measure-level in this report are overestimates for how they may contribute to a complete program BCR. Program-level costs are needed to run a program but measure-level TRC results are quite useful in determining the composition of program that could be cost-effective. It is also important to note that the cost-effectiveness analysis conducted for this study does not reflect bundling of EE and DR efforts.

[1] Navigant Consulting, Inc. "Cost-Effectiveness of Electric Demand Response for Residential End-Uses." April 19, 2019 (https://ma-eeac.org/wp-content/uploads/Cost-Effectiveness-of-DR-for-Residential-End-Uses-Final-Report-2019-04-18.pdf)

[2] All non-holiday weekdays in the summers of 2017 - 2019 for which Boston, Massachusetts had a maximum temperature of equal to or greater than 90°F. In 2017, there were 3 such days: June 12, June 13, July 20. In 2018, there were 14 such days: July 3, July 5, July 9, July 10, July 17, August 2, August 6, August 7, August 16, August 28, August 29, August 30, and September 5, September 6. In 2019, there were 8 such days: July 17, July 19, July 29, July 30, July 31, August 19, August 22, September 23.

[3] BCRs for bring-your-own-device (BYOD) measures also do not include the incremental cost associated with Wi-Fi enabled equipment.

Table 1. Combinations of DR-Enabled Appliances

Appliance	Enabling Device[4,5, 6]	DR Strategy[7]
Room Air Conditioner	Smart appliance	Temperature setback
	Simple timer plug	Direct load control (DLC)
	Smart plug	Temperature setback
Dehumidifier	Smart appliance	DLC
	Simple timer plug	DLC
	Smart plug	DLC
Heat Pump Water Heater	Smart appliance	DLC
	Simple timer switch	DLC
	Smart switch	DLC
Electric Resistance Water Heater	Smart appliance	DLC
	Simple timer switch	DLC
	Smart switch	DLC
Pool Pump	Smart appliance	DLC
	Simple timer switch	DLC
	Smart switch	DLC

Source: List compiled collaboratively by the MA PAs and Guidehouse.

Summary Results

For each appliance, enabling technology, and DR strategy combination, Table 2 contains potential unit impact estimates, potential DR program size in 2022 and 2024 (the start year and end year of this study's benefit-cost analysis), and BCRs reflecting the total resource cost (TRC) test over the 2022 to 2024 period (meaning, BCRs reflect the benefits and costs incurred during the 3-year period associated with those who are enrolled during that period). Additionally, the Appendix includes a similar table (Table 41) but with two columns of BCRs: the first reflects BCRs with customer sign-up and ongoing/annual incentives included as costs in the TRC test (as reflected in Table 2 as well); the second column reflects BCRs with customer sign-up and ongoing/annual incentives excluded as costs from the TRC test. Incentives are a transfer payment. The second column allows readers to see the effect of the transfer payment on the BCR. In reviewing the second column, it is important to note that customer participation is highly dependent on the incentive structure. Accordingly, if the program operated without offering incentives, the participation rate would likely be reduced significantly. This is not reflected in the BCR estimates reported in Table 41.

Benefits from each DR program option analyzed represent the avoided costs associated with avoided generation capacity, avoided transmission and distribution capacity, and reliability benefits. Costs included in the benefit-cost analysis are measure-level costs—in other words, costs that depend on the number of enrolled devices. From the analysis, Guidehouse excludes DR portfolio/program-wide costs from the benefit-cost analysis—or costs that would be shared

[4] "Smart appliance" refers to appliances with built-in Wi-Fi / DR capability.
[5] All switches (Wi-Fi and Simple) refer to in-line switches that must be installed by an electrician.
[6] "Simple" refers to mechanical.
[7] In this report, direct load control (DLC) refers to the strategy of the program automatically shutting off the appliance for the duration of a DR event. Temperature setback refers to the strategy of increasing the temperature setpoint of a Wi-Fi thermostat to shut off the connected HVAC unit's compressor periodically during peak hours. Temperature setback employed by DR programs typically ranges from 1° to 4°. For the purposes of this study, a 3° temperature setback was assumed for Room Air Conditioners where a temperature setback is the DR strategy.

with other DR initiatives, such as program setup costs, annual DR management system (DRMS) license fees, administration costs, and marketing costs. This means the BCRs at the measure-level in this report are overestimates for how they may contribute to a complete program BCR.

Table 2. Potential Unit Impacts[8], Program Size, and Benefit-Costs (TRC, 2022-2024)

Appliance	Enabling Device	DR Strategy	Estimated Unit Impacts[9] (kW)	Potential Units Enrolled in MA Statewide (2022)	Potential Units Enrolled in MA Statewide (2024)	BCR w/ Customer Incentives Included (TRC, 2022-2024)[10]
Room Air Conditioner	Smart appliance	Temperature setback	0.13	17,880	78,300	0.7
	Simple switch	DLC	0.09	150,286	594,984	0.5
	Smart switch	Temperature setback	0.09	150,286	594,984	0.2
Dehumidifier	Smart appliance	DLC	0.15	10,362	45,378	0.7
	Smart appliance	DLC	0.08	69,323	229,880	0.6
	Smart appliance	DLC	0.10	69,323	229,880	0.3
Heat Pump Water Heater	Simple plug	DLC	0.10	406	1,780	0.5
	Simple plug	DLC	0.10	2,719	9,015	0.2
	Smart appliance	DLC	0.10	2,719	9,015	0.1
Electric Resistance Water Heater	Simple switch	DLC	0.16	3,454	15,126	0.8
	Smart plug	DLC	0.16	23,108	76,627	0.3
	Smart plug	DLC	0.16	23,108	76,627	0.2
Pool Pump	Smart switch	DLC	0.65	2,709	11,864	3.2
	Simple switch	DLC	0.65	21,748	72,119	1.4
	Smart switch	DLC	0.65	21,748	72,119	0.9

The BCR estimates are at the measure-level only as they do not include administration and marketing costs, among other program-level costs. *This means the BCRs at the measure-level in this report are overestimates for how they may contribute to a complete program BCR.*
Source: Guidehouse analysis based on multiple data sources, reference footnotes.

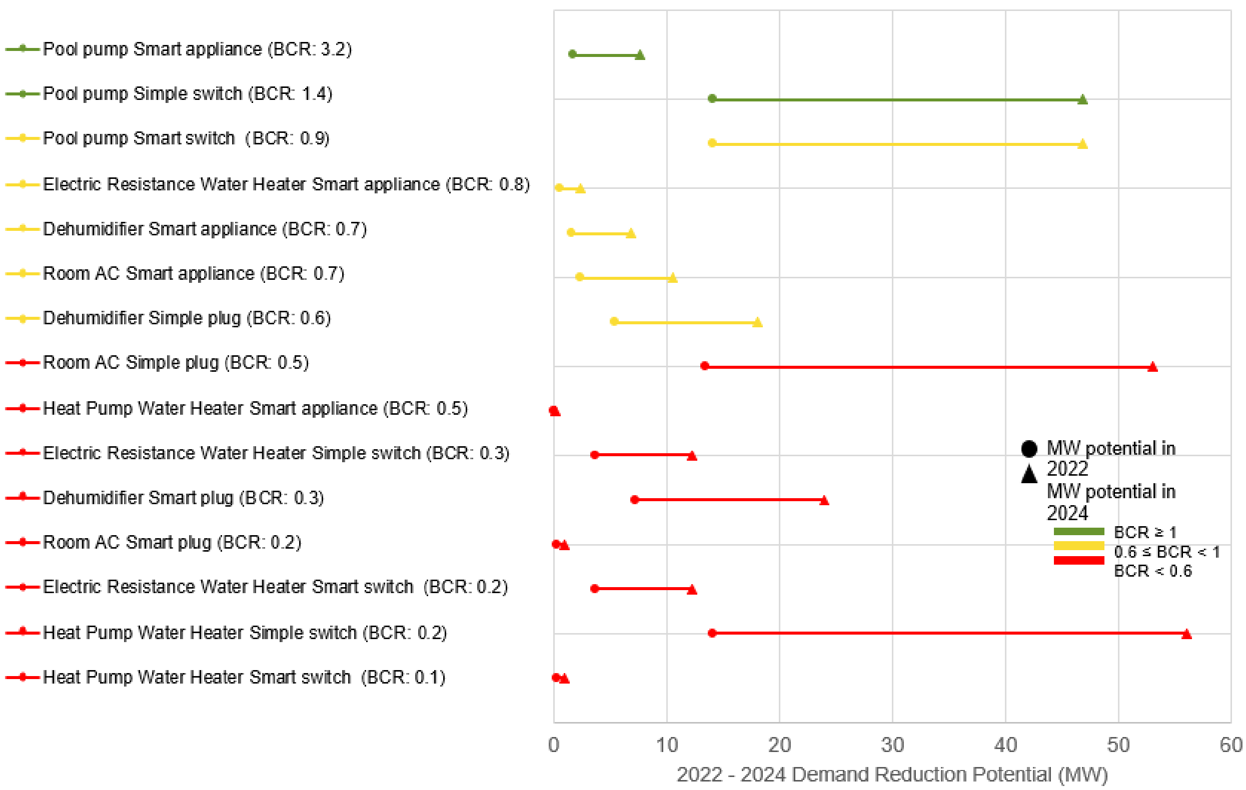
Figure 1 displays the results of the benefit-cost analysis (TRC, 2022 to 2024) for each appliance type and enablement strategy, as well as the associated demand reduction (MW) potential in 2022 and in 2024 program years.

[8] Net of derating factors associated with event participation, Wi-Fi connectivity, DR enablement strategy, and first-year in-service rate.

[9] Potential impacts used for calculating BCRs are based on end-use metering for the hottest 2017-2019 summer days; i.e., all non-holiday weekdays in the summers of 2017 - 2019 for which Boston, Massachusetts had a maximum temperature of equal to or greater than 90°F.

[10] Some costs were not included in the BCR calculation such as program administration, setup costs, and software costs. Inclusion of these costs would reduce BCRs. See Section 2.4 for more details.

Figure 1. Benefit-Costs (TRC, 2022-2024) and Demand Reduction (MW) Potential (Customer Incentives Included)



Source: Guidehouse analysis

Key Findings

This section provides a summary of findings for each appliance type. Findings reflect measure-level benefit-cost analysis for the period of 2022 through 2024 using the TRC test.

- **Room Air Conditioners:** Due to lower peak coincident load than central air conditioners, room air conditioners are associated with relatively low BCRs (0.7, 0.5 and 0.2, for built-in, simple plug and Wi-Fi plug enablement strategies, respectively, when including customer incentives in the TRC test). DR program potential in 2022 is estimated to be 2 MW, 13 MW, and 12 MW for the built-in, simple plug and Wi-Fi plug options, respectively. By 2024, MW potential is estimated to be 11 MW, 53 MW and 48 MW for the built-in, simple plug and Wi-Fi plug options, respectively. Similar to other end-uses where plugs and smart appliances are DR enablement options, for room air conditioners, plug-based enablement is associated with higher costs, lower per unit potential (due to higher derating factors) and higher near-term MW potential than DR enablement through an already Wi-Fi enabled product (i.e. built-in).
- **Dehumidifiers:** Dehumidifiers can provide an estimated 0.08 to 0.15 kW of peak demand impact per device, associated with a projected peak reduction in 2024 of around

20 MW for a Wi-Fi plug, 18 MW for a simple timer plug, and 7 MW for smart dehumidifiers with built-in DR capability. When including customer incentives as costs in the TRC test, Guidehouse finds that potential demand impacts do not outweigh costs associated with DR programs for dehumidifiers, estimating BCRs of 0.3, 0.6, and 0.7 for programs using Wi-Fi plugs, simple plugs and built-in dehumidifiers, respectively.[11]

- **Water Heaters:** The cost-effectiveness of water heaters varies greatly depending on the type and the DR-enabling technology. This study showed that currently, no DR-enabling technologies result in a water heater DR measure that is cost-effective. Through this analysis it appears that the only technology combination that could be cost effective in the future is controlling electric water heaters through built-in DR capability (when customer incentives are included in the TRC test). It appears that controlling heat pump water heaters through the same means would not be cost effective due to their lower average load. The PAs offer energy efficiency incentives to customers to encourage them to use the more efficient heat pump water heaters. Offering a demand response incentive only to new electric resistance water heaters could confuse customers, and decrease the adoption of heat pump water heaters, which provide savings year-round, not just for demand response events. Whereas, offering DR incentives to both electric resistance and heat pump water heaters in an effort to remove the conflict of interest may result in a program that is not cost-effective, since the majority of smart water heaters are heat pump water heaters.
- **Pool Pumps**: Pool pumps are found to have the greatest per-unit impact of the appliances considered in this study (0.65 kW). As a result, DR will likely be cost-effective for programs featuring smart pool pumps (i.e., pool pumps with Wi-Fi built-in) and simple mechanical switches. The BCR for the Wi-Fi switch option was estimated to be just under 1 (0.9). One advantage of DR for pool pumps is that it is assumed to be less of an inconvenience to participants – in contrast to some other end-uses – and, therefore, the rate of opt-out is assumed to be low. However, the low penetration of smart/built-in pool pumps in MA (the option with the highest BCR) shows that the MW benefit in 2024 remains modest at 8 MW. This lower benefit may not be able to support the upfront cost IS/IT, administration, and marketing cost to set up a pool pump program targeting smart pool pumps alone. These upfront costs are not included in the BCR estimates; see Section 2.4 for more details.

[11] As detailed in the RES 1 Comprehensive Report from January 2019, the MA Baseline Study found that there is a high amount of variability across households in usage of dehumidifiers during peak periods. More than 25% of dehumidifiers were not in use at all during peak times, but the top 25% have a mean peak of greater than 0.5 kW. For this reason, the report proposes that the PAs consider targeting certain dehumidifier users for a summer DR program.

1. Study Scope

To inform the direction of the Massachusetts Program Administrator's residential electric active demand reduction (ADR) programs, Guidehouse estimated relative potential and cost-effectiveness of ADR for DR-enabled appliances. For each of the appliance, enabling device, and DR strategy combinations listed in Table 1, this study provides estimates of:

1) Potential savings per unit during the summer peak period;
2) Current and forecasted market saturation data;
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As shown in Table 1, this report considers a range of residential appliances and multiple enablement strategies for each appliance type. The previous Cost-Effectiveness of DR for Residential End-Uses Study, finalized in 2019 and conducted for National Grid alone, covered a broader range of residential end-uses. For this 2021 update, with input from the MA PAs and EEAC, Guidehouse included a subset of measures included in the 2019 report.

This study also provides updated literature review findings related to proven and potential DR enablement technologies, and the program designs of relevant utility programs, along with challenges encountered. The updated literature review findings can be found in the "Technology Landscape" and "Program Summaries" subsections in Chapter 3.

The measure-level benefit-cost ratios (BCRs) included in the report reflect potential demand reductions based on end-use metering data associated with weekdays for which the maximum daily temperature was equal to or greater than 90°F.[12] The BCR estimates are at the measure-level only as they do not include administration and marketing costs, among other program-level costs. This means the BCRs at the measure-level in this report are overestimates for how they may contribute to a complete program BCR. Program-level costs are needed to run a program but measure-level TRC results are quite useful in determining the composition of program that could be cost-effective. It is also important to note that the cost-effectiveness analysis conducted for this study does not reflect bundling of EE and DR efforts.

[12] All non-holiday weekdays in the summers of 2017 - 2019 for which Boston, Massachusetts had a maximum temperature of equal to or greater than 90°F. In 2017, there were 3 such days: June 12, June 13, July 20. In 2018, there were 14 such days: July 3, July 5, July 9, July 10, July 17, August 2, August 6, August 7, August 16, August 28, August 29, August 30, and September 5, September 6. In 2019, there were 8 such days: July 17, July 19, July 29, July 30, July 31, August 19, August 22, September 23.

Table 1-1. Combinations of DR-Enabled Appliances

Appliance	Enabling Device[13,14, 15]	DR Strategy[16]
Room Air Conditioner	Smart appliance	Temperature setback
	Simple timer plug	Direct load control (DLC)
	Wi-Fi plug	Temperature setback
Dehumidifier	Smart appliance	DLC
	Simple timer plug	DLC
	Wi-Fi plug	DLC
Heat Pump Water Heater	Smart appliance	DLC
	Simple timer switch	DLC
	Wi-Fi switch	DLC
Electric Resistance Water Heater	Smart appliance	DLC
	Simple timer switch	DLC
	Wi-Fi switch	DLC
Pool Pump	Smart appliance	DLC
	Simple timer switch	DLC
	Wi-Fi switch	DLC

Source: List compiled collaboratively by the MA PAs and Guidehouse.

[13] "Smart appliance" refers to appliances with built-in Wi-Fi / DR capability.
[14] All switches (Wi-Fi and Simple) refer to in-line switches that must be installed by an electrician.
[15] "Simple" refers to mechanical.
[16] In this report, direct load control (DLC) refers to the strategy of the program automatically shutting off the appliance for the duration of a DR event. Temperature setback refers to the strategy of increasing the temperature setpoint of a Wi-Fi thermostat to shut off the connected HVAC unit's compressor periodically during peak hours. Temperature setback employed by DR programs typically ranges from 1° to 4°. For the purposes of this study, a 3° temperature setback was assumed for Room Air Conditioners where a temperature setback is the DR strategy.

2. Study Approach

This final report includes chapters for each appliance type listed in Table 1-1. Each chapter contains the following subsections: 1) DR Context, 2) Potential Impact Per Device, 3) Total Achievable Impact, 4) Benefit-Cost Analysis.

Error! Reference source not found. provides a summary of data sources used for this study b y chapter subsection. The literature review conducted for this study involved updating the 2018/2019 literature review findings through web research, review of publicly available evaluation reports, and email exchanges and discussions with technology vendors.

Table 2-1. Study Data Sources

Chapter Subsection	Contents / Components	Data Sources
1) DR Context	DR enablement technologies on the market and the vendors providing them	Literature Review
	DR programs that have tested the technologies	Literature Review
2) Potential Impact Per Device	Potential per-unit peak impact	MA Baseline Study End-Use Metering for 2017-2019
	Derating factors	Literature Review
3) Total Achievable Impact	Current saturation	MA Baseline Study Saturation Survey for 2019
	Forecasted enrollment	Literature Review
4) Benefit-Cost Analysis	Total benefits	2021 Avoided Supply Cost Study[17]
	Total costs	PA consensus on program costs

Source: Guidehouse.

The following is an outline of the subsections contained in each appliance chapter.

2.1 DR Context

This section provides a discussion of the appliance and options for DR-enablement. This includes a summary of proven and potential second-generation technologies utilized in order to make each appliance type DR-enabled. For a given appliance, peak demand reduction enabling technologies may include a Wi-Fi plug, Wi-Fi inline switch, Wi-Fi thermostat, and/or smart appliance (built-in DR capabilities). For appliances where a Wi-Fi plug or Wi-Fi switch technology was considered, a simple mechanical timer plug, or switch was also analyzed. For second-generation DR-enabling technologies, major technology manufacturers are documented, along with each manufacturers' relevant DR program involvement.

This section also describes possible DR strategies employed to achieve peak load reductions (e.g., 3° temperature setpoint, direct load curtailment, delayed defrost, etc.).[18]

This section also summarizes the program designs of relevant utility programs, along with challenges encountered, where this information is publicly available. Additionally, where we came across this information, this section highlights the non-energy benefits noted by other utilities related to DR for the end-uses considered in this study.

[17] Avoided Energy Supply Components in New England: 2021 Report (Published March 15, 2021).

[18] For each appliance and DR-enabling device, benefit-cost analysis results will be based on an assumed DR strategy.

2.2 Potential Impact Per Device

Guidehouse constructed average daily load shapes for each appliance type using end-use metering data from the MA Residential Baseline Study for the 2017-2019 summer periods. For each appliance type, Guidehouse reports the average load coincident with peak hours of 2 p.m. to 5 p.m. for all non-holiday weekdays in the summers of 2017 - 2019 for which Boston, Massachusetts had a maximum temperature of equal to or greater than 90°F.

2.3 Total Achievable Impact

In this section, Guidehouse summarizes findings from the MA Baseline Study Saturation Survey related to the statewide installed base of the appliances considered in this study. This section also contains Guidehouse's assumptions related to customers' willingness to enroll in a DR program, ramp rate, and program participation in years following participants' first year of a DR program (i.e., the likelihood that customers will continue to participate in a program after year 1).

2.4 Benefit-Cost Analysis

Combining research on achievable unit impacts and program costs, Guidehouse performed a measure-level benefit-cost analysis, using the MA Total Resource Cost (TRC) Test, for each appliance and DR-enabling device combination. For these analyses, Guidehouse calculated the net-present value of annual benefits and costs for the period from 2022 to 2024.

Table 2-2. Total Resource Cost (TRC) Test, Benefits and Costs

Benefits	Costs
• Avoided Generation Capacity • Avoided T&D Capacity • Reliability benefits	• Technology enablement cost (non-BYO only), including pre-programming fee for Simple timer plugs • OEM Fee per device per year (excluding Simple timer plugs/switches) • DRMS Fee per device per year (excluding Simple timer plugs/switches) • Customer incentives

Source: Guidehouse

In converting unit kilowatt impacts to monetary benefits, Guidehouse used avoided cost assumptions from the 2021 Avoided Energy Supply Cost (AESC) Study. Avoided costs related to avoided generation capacity, avoided transmission and distribution (T&D) capacity, and reliability benefits represent the total avoided costs resulting from DR. Avoided generation capacity costs used in the benefit-cost models for this report range from 174 $/kW-year in 2022 to 183 $/kW-year in 2024[19]. Avoided T&D capacity costs and reliability benefits used for this report stay at approximately 111 $/kW-year between 2022 and 2024. These avoided costs are in real dollars and are discounted using the inflation-adjusted discount rate of 0.21%.

Guidehouse assumes no net-energy savings (for any appliance/DR device combination). This is because energy consumption is assumed to be shifted (not lowered) in response to DR participation. Therefore, avoided costs of energy estimated for this report are assumed to be zero.

[19] Avoided generation costs include DRIPE benefits of 121 $/kW in 2022 and 125 $/kW in 2024.

Guidehouse gathered available information on DR program costs from each of the PAs. For the purposes of this study, costs such as program setup costs, DR management system (DRMS) annual license fees, program administration, and marketing costs which are/would be shared with other DR programs (both residential and commercial and industrial) are not included as costs in the appliance-specific benefit-cost ratio.

Costs included in the benefit-cost analysis are measure-level costs—in other words, costs that depend on the number of enrolled devices. Measure-level costs include upfront device costs for non-bring-your-own device (BYOD) programs (i.e., technology enablement costs). The programs for which Guidehouse included device costs in the total resource cost (TRC) test include those featuring smart plugs, simple timer plugs, smart switches, and simple timer switches. The device cost for smart and simple switches includes the cost of installation, since the assumption is that an electrician would be required to install these devices.[20] For smart appliance (built-in) DR programs, Guidehouse does not include any device cost in the TRC test. For BYOD programs, Guidehouse's analysis assumes that an increasing percentage of the installed stock for a given end-use will be Wi-Fi enabled based on forecasts of the penetration of smart appliances by Navigant Research (now Guidehouse Insights). Beyond the likely increase in market adoption by these Wi-Fi enabled appliances, Guidehouse acknowledges the possibility that some customers may choose to purchase Wi-Fi enabled appliances rather than non-Wi-Fi enabled equipment to participate in the PAs programs. However, an estimate of the incremental cost associated with Wi-Fi enabled equipment is not included in the analysis nor share of customers purchasing Wi-Fi enabled equipment to participate in these potential offerings. As a result, the BCR estimates presented herein may overstate BCRs for BYOD programs. Further understanding adoption of Wi-Fi enabled appliances, and the rationale of customers for their purchase, could be an area of future research if any of these BYOD offerings become full program offerings in the future.

Other costs included in the benefit-cost analysis include per device original equipment manufacturer (OEM) and DRMS fees. Additionally, customer incentives are included in the TRC test as a cost (to the utility). However, included in the Appendix of this report is a table (Table A-1) showing measure-level TRC results with and without customer incentives. The measure-level TRC with customer incentives excluded does not account for the participation drop-off that would occur if the utility were to not offer customer incentives.

For simple timer plug and switch options, no per device OEM and DRMS fee is included. However, a pre-programming fee per device is included.

As with the avoided costs, these costs are discounted using the inflation-adjusted discount rate of 0.21%.

[20] One smart water heater controller manufacturer (Aquanta) spoke about the opportunity for self-installation.

Table 2-3. Technology Enablement Costs (per Device)

Enablement Technology	Costs	Assumptions
Smart Plug	$70 (RACs); $50 (dehumidifiers)	Based on cost of ThinkEco smartAC kit for RACs and modlet BN for dehumidifiers. Although there are other smart plugs on the market, none have been tested for DR, with the exception of ThinkEco and Rainforest. The cost of Rainforest is $128.98, including a required external device.
Simple Timer Plug[21]	$15	$10 is the average cost for mechanical timer plugs, based on web research. Guidehouse assumed an additional $5 for device activation (setup of timer settings).
Smart Switch	$305	Based on cost of Aquanta and Armada Power controllers ($150) and assuming an installation cost of $155 (based on a 2015 PNNL study).
Simple Timer Switch	$205	Based on cost of Nsi Industries indoor/outdoor mechanical switch ($50) and assuming an installation cost of $155 (based on a 2015 PNNL study).
BYOD	$0	N/A

Table 2-4. OEM and DRMS, Fees (per Device)

Enablement Technology	Costs	Assumptions
Smart Plug	$30	Annual OEM ($10) fee per device based on costs incurred by National Grid NY for coolControl pilot in 2017. Annual DRMS fee ($20) per device is based on cost incurred by National Grid MA for Wi-Fi thermostat DLC in 2017.
Simple Timer Plug	$0	N/A
Smart Switch	$30	Annual OEM ($10) fee per device based on costs incurred by National Grid NY for coolControl pilot in 2017. Annual DRMS fee ($20) per device is based on cost incurred by National Grid MA for Wi-Fi thermostat DLC in 2017.
Simple Timer Switch	$0	N/A
BYOD	$30	Annual OEM ($10) fee per device based on costs incurred by National Grid NY for coolControl pilot in 2017. Annual DRMS fee ($20) per device is based on cost incurred by National Grid MA for Wi-Fi thermostat DLC in 2017.

[21] Guidehouse did find some timer switches with a backup battery, but these are electronic (not mechanical) and run from $100-$130, An example offered by Intermatic: https://www.1000bulbs.com/product/3398/ELEC-EH10.html?gclid=EAIaIQobChMImePM2ZbC8AIVpYJbCh1TrgyZEAQYAyABEgIOevD_BwE#detail-tabs

Table 2-5. Customer Sign-Up Incentives (per Device)

Enablement Technology	Costs	Assumptions
Smart Plug	$25	Consistent with current Wi-Fi thermostat (BYOT) DR programs in MA.
Simple Timer Plug	$25	Consistent with current Wi-Fi thermostat (BYOT) DR programs in MA.
Smart Switch	$25	Consistent with current Wi-Fi thermostat (BYOT) DR programs in MA.
Simple Timer Switch	$25	Consistent with current Wi-Fi thermostat (BYOT) DR programs in MA.
BYOD	$25	Consistent with current Wi-Fi thermostat (BYOT) DR programs in MA.

Table 2-6. Customer Annual Incentives (per Device)

Enablement Technology	Costs	Assumptions
Smart Plug	$20	Consistent with current Wi-Fi thermostat (BYOT) DR programs in MA.
Simple Timer Plug	$20	Consistent with current Wi-Fi thermostat (BYOT) DR programs in MA.
Smart Switch	$20	Consistent with current Wi-Fi thermostat (BYOT) DR programs in MA.
Simple Timer Switch	$20	Consistent with current Wi-Fi thermostat (BYOT) DR programs in MA.
BYOD	$20	Consistent with current Wi-Fi thermostat (BYOT) DR programs in MA.

3. Study Findings

Findings related to each appliance type are discussed in the chapters below.

3.1 Room Air Conditioners

3.1.1 DR Context

3.1.1.1 Technology Landscape

Room air conditioners (RACs) can be DR-enabled either indirectly through a smart plug, such as those offered by ThinkEco, or directly if the RAC itself is Wi-Fi enabled, such as some models offered by Frigidaire, Friedrich, LG, and others (see Table 3-1). Based on our research, there has been a significant increase in smart RAC models available on the market since the time of the 2018/2019 report.

There are also devices currently on the market, such as offerings by AirPatrol, Sensibo, Cielo, Ambi Climate, and Flair, that can enable most remote-controlled RACs via an infrared controller and can be utilized much like a smart thermostat through smartphone apps. These devices are easy to install, according to manufacturer claims, with costs ranging from $70 to $150.

Popular DR strategies used for RACs are cycling and setpoint adjustment. CPS Energy in Texas used a combination of these strategies for its ThinkEco pilot program, cycling the RAC off for the first 10 minutes and then increasing the setpoint by 3° after that. For the bulk system, the cycle times were randomized to best reduce peak load overall.

Table 3-1. DR-Enabling Device Market

OEMs	DR-Enabled Product	Tested in DR Context?	Example Utility Partners
Smart Plugs			
ThinkEco^	Modlet / smartAC kit	Yes	National Grid NY, CPS Energy, United Illuminating, Con Edison
Belkin	Wemo Smart Plug	No	
TP-Link	Smart plug	No	
Rainforest	Smart plug	Yes	Eversource CT
iHome	Smart plug	No	
Wi-Fi Controllers[22]			
Sensibo	Sensibo Sky, Sensibo Air	Yes	Powercor Australia (w/ mini-splits, not RACs)[23], Cape Light Compact (w/ mini-splits, not RACs),[24] Green Mountain Power (w/ mini-splits, not RACs)[25]
Cielo	Breez Plus	No	

[22] Guidehouse did not model benefits and costs for RACs in conjunction with Wi-Fi controllers.

[23] https://www.powercor.com.au/energy-partner/

[24] In 2018, Cape Light Compact tested the use of Sensibo devices to enable ductless mini-splits for DR. Evaluation findings indicated that, on average, only a little over 10% of mini-splits enabled with Sensibo devices were successfully signaled and curtailed during control events. https://ma-eeac.org/wp-content/uploads/CLC-2018-Smart-AC-Savings-Program-Evaluation-Report-2019-01-28-FINAL_.pdf

[25] Green Mountain Power's eControl program features Sensibo program for heat pumps/ductless mini-splits.

AirPatrol	Wi-Fi AC controller	No	
Ambi Climate	Ambi Climate 2, Ambi Climate Mini	No	
Flair	Flair Puck	No	
Myasa (Available in May 2021)	Mysa Smart Thermostat for Air Conditioners	No	
Built-In			
Frigidaire	Cool Connect models and various others	Yes	Con Edison, Eversource CT, National Grid NY
Freidrich	Kühl models	Yes	Con Edison, National Grid NY, CPS Energy
GE/Haier	Comfort Mobile models and various others	Yes	Eversource CT
LG	SmartThinQ models and various others	Yes	Con Edison, Eversource CT
Arctic King/Midea	Various models	Yes	Eversource CT
Toshiba	Various models	Yes	Eversource CT
Emerson	Quiet Kool	No	

Source: Guidehouse Research Leaderboard: Residential Demand Response (2017); Web research
^Ranked as a "Challenger" in the DR space by Guidehouse Research (Scoring strongest to weakest: Leaders, Contenders, Challengers, Followers)

3.1.1.2 Program Summaries

Con Edison runs the Residential Smart AC program (originally called the CoolNYC pilot), a DR program targeting customers with RACs in New York City. Prior to 2020, the program included two DR-enablement pathways – those with non-smart RACs received a ThinkEco smart plug (smartAC kit) and those with an AC with built-in Wi-Fi could enroll through a BYOD pathway. For the smart plug pathway, the program initially found success with its customer self-install option by leveraging a "Try-it" strategy that changed the eligibility requirements to ensure that customers could install the devices and would only get to keep them if they were installed correctly, and by introducing a points program that rewarded the quick installation of devices. However, in 2020, Con Edison closed the smartAC kit pathway of the program, but continues to accept new enrollments in the BYOD pathway.[26]

In their room AC pilot with ThinkEco, CPS Energy found that while 793 of the 820 ThinkEco Wi-Fi plugs installed in 2016 were online (97%), just 35% (287 devices) of the SmartAC kits provided in the previous year were online.[27] Since RAC units are typically uninstalled for the winter, they found that most people did not plug the AC unit back in with the Wi-Fi plug. While built-in DR-enabled RACs solve this problem, they are generally more expensive and have less penetration in the market. United Illuminating saw similar results in its RAC DR pilot from 2016 – 2018. The company determined that this pilot was not cost-effective, citing as factors the low installation and reinstallation rates of the smart plugs with the window Room A/C unit and the

[26] https://www.coned.com/en/save-money/rebates-incentives-tax-credits/rebates-incentives-tax-credits-for-residential-customers/smart-air-conditioners

[27] Frontier Associates LLC, *Evaluation, Measurement & Verification of CPS Energy's FY 2016 DSM Programs*, June 2016, https://www.sanantonio.gov/portals/0/files/sustainability/Environment/CPSFY2016.pdf.

cost of continual customer engagement to reinstall the smart plug with the Room A/C in subsequent cooling seasons.[28]

Another limitation to DR for RACs is that RAC load is associated with relatively low peak coincident load (compared to central ACs). A Con Edison residential room AC impact evaluation report that in fact 50% of rebated RACs are installed in a bedroom, and therefore are likely used mostly at night.[29] Relatedly, due to their lower capacities (relative to central ACs), RACs are likely used more on an as needed basis to cool a proximal space than to cool on a consistent schedule. Findings from the MA Baseline Study support this. For RACs, the MA Baseline Study calculated a System Peak[30] coincidence factor of 0.45 and an On-Peak[31] coincidence factor of 0.18.[32]

3.1.2 Potential Impact Per Device

Table 3-2, Table 3-3, and Table 3-4 contain the average coincident load results for RACs from the metering conducted as part of the MA Baseline Study for all summer weekdays (All Days) and weekdays for which the maximum temperature was greater than or equal to 90°F (Hottest Days) for the smart plug, simple timer plug, and smart RAC (built-in) technologies, respectively. The size of the metering sample for RACs was 128 units.

For each RAC's technology option, Guidehouse used the Hottest Days' impact as final potential peak demand reduction value for BCR purposes. After applying a derating factor, potential load reduction during the peak period associated with the Hottest Days scenario for the smart plug, simple timer plug, and smart RACs options is 0.09 kW, 0.09 kW, and 0.13 kW, respectively. Below the tables, we provide more information about the derating factors assumed for RACs.

Table 3-2. Unit Impact Metrics for RACs with Smart Plug

	Smart Plug, Temperature Setback			
Source	Analysis Year	Average Coincident Load	Derating	kW/Appliance During Peak
MA Baseline Study End-Use Metering – All Days	2017-2019	0.10	0.37	0.04
MA Baseline Study End-Use Metering – Hottest Days	2017-2019	0.25	0.37	**0.09**
Potential Peak Demand Impact per Device				**0.09**

Source: Guidehouse analysis of MA Baseline Study End-Use Metering data for 2017-2019.

[28] 2019-2021 Conservation & Load Management Plan, submitted by Eversource Energy, United Illuminating, Connecticut Natural Gas Corporation, and Southern Connecticut Gas, November 19, 2018.

[29] Energy & Resources Solutions, *Con Edison EEPS Programs – Impact Evaluation of Residential Room Air Conditioner Program* October 10, 2013.

[30] The MA Baseline Study defines summer system peak as the 2-hour period on a non-holiday weekday in June, July, or August with the highest average ISO-NE system peak load. The weather-normalized summer system peak was derived from model simulations using the previous 15 years of weather data, and the year that resulted in the median demand was selected.

[31] The MA Baseline Study defines summer On-Peak equivalent to the ISO-NE summer on-peak definition: all hours 1 p.m.-5 p.m. on non-holiday weekdays in June, July, and August. This is weather normalized the same way as summer system peak.

[32] *Massachusetts Residential Baseline Study – 2019 Comprehensive Report, March 31, 2020.*

Table 3-3. Unit Impact Metrics for RACs with Simple Timer Plug

		Simple Plug, DLC		
Source	**Analysis Year**	**Average Coincident Load**	**Derating**	**kW/Appliance During Peak**
MA Baseline Study End-Use Metering – All Days	2017-2019	0.10	0.35	0.03
MA Baseline Study End-Use Metering – Hottest Days	2017-2019	0.25	0.35	**0.09**
Potential Peak Demand Impact per Device				**0.09**

Source: Guidehouse analysis of MA Baseline Study End-Use Metering data for 2017-2019.

Table 3-4. Unit Impact Metrics for RACs with Built-in DR Capability

		Smart Appliance, Temperature Setback		
Source	**Analysis Year**	**Average Coincident Load**	**Derating**	**kW/Appliance During Peak**
MA Baseline Study End-Use Metering – All Days	2017-2019	0.10	0.53	0.05
MA Baseline Study End-Use Metering – Hottest Days	2017-2019	0.25	0.53	0.13
Potential Peak Demand Impact per Device				**0.13**

Source: Guidehouse analysis of MA Baseline Study End-Use Metering data for 2017-2019.

The derating factors listed in Table 3-5,

Table 3-6, and Table 3-7 are based on information provided in cost-effectiveness reports relating to Con Edison's CoolNYC program (though Guidehouse assumes a 95% connectivity rate based on 2019 Wi-Fi thermostat evaluation findings for the PAs[33]). Results for CoolNYC showed an average 30% opt-out rate (i.e., 70% participation rate).[34] Additionally, for the smart plug strategy, Guidehouse assumed a first-year in-service rate of 60%, consistent with the rate Con Edison achieved in 2018.[35] Guidehouse assumed a slightly lower first year in-service rate of 50% for the simple timer plug option due to the fact that the program will not be able to verify installation.

[33] https://ma-eeac.org/wp-content/uploads/2019-Residential-Wi-Fi-Thermostat-DLC-Evaluation-Report-2020-04-01-with-Infographic.pdf

[34] Consistent with the opt-out rate of the CoolNYC pilot in 2015. As of 2018, the program experienced higher opt-out rates (60-70%) during each event, attributed to the fact that, although BYOD participants were notified with two emails leading up to an event, one the day ahead of time and one two hours before the event start, there was no notification available while a participant was in their home during the event unless they checked their email.

[35] http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7BA1AA8E42-41EE-4B48-9EB7-4FEE6E462BF7%7D

In addition, for the smart plug and smart RACs options, Guidehouse incorporated an additional derating factor associated with a 3° temperature setback strategy.[36]

For each technology option, these derating factor components were combined and applied to coincident load estimates to estimate potential or achievable impact per unit, as reported above.

Table 3-5. Derating Assumptions, Smart Plug

Derating Factor	Value
Participation Rate per event	0.7[37]
Connectivity	0.95[38]
Additional Derating for Temperature Setback Strategy	0.8[39]
First Year In-Service	0.7[40]
Final Derating Factor	**0.37**

Source: Guidehouse analysis based on multiple data sources, reference footnotes.

Table 3-6. Derating Assumptions, Simple Timer Plug

Derating Factor	Value
Participation Rate per Event	0.7[41]
Connectivity	N/A
Additional Derating for Temperature Setback Strategy	N/A
First Year In-Service	0.5[42]
Final Derating Factor	**0.35**

Source: Guidehouse analysis based on multiple data sources, reference footnotes.

[36] Guidehouse assumed an additional derating factor of 0.8 reflecting the fact that the temperature setback strategy entails a cycling of the air conditioner compressor aimed at maintaining a certain temperature. This additional 0.8 derating factor was based on the 2019 Wi-Fi thermostat evaluation for the Massachusetts PAs and was back calculated from the evaluated total derating factor (0.6) and the combined participation rate and connectivity rate derating factor (0.8).

[37] Based on CoolNYC program average event participation rate across all events in summer 2015; Consolidated Edison Company of New York, Inc., *Program Performance and Cost Effectiveness of Demand Response Programs*, December 1, 2015, 53.

[38] Assuming the same connectivity rate as for Wi-Fi thermostats. https://ma-eeac.org/wp-content/uploads/2019-Residential-Wi-Fi-Thermostat-DLC-Evaluation-Report-2020-04-01-with-Infographic.pdf

[39] Guidehouse assumed an additional derating factor of 0.8 reflecting the fact that the temperature setback strategy entails a cycling of the air conditioner compressor aimed at maintaining a certain temperature. This additional 0.8 derating factor was based on the 2019 Wi-Fi thermostat evaluation for the Massachusetts PAs and was back calculated from the evaluated total derating factor (0.6) and the combined participation rate and connectivity rate derating factor (0.8).

[40] CoolNYC 2015 installation rate for first-year enrollees based on 2015 incentive structure (up from 40% in 2013); Consolidated Edison Company of New York, Inc., *Program Performance and Cost Effectiveness of Demand Response Programs*, December 1, 2015, 53.

[41] Based on CoolNYC program average event participation rate across all events in summer 2015; Consolidated Edison Company of New York, Inc., *Program Performance and Cost Effectiveness of Demand Response Programs*, December 1, 2015, 53.

[42] Assumed to be slightly lower than smart plug first-year in-service rate due to the fact that installation cannot be verified by program.

Table 3-7. Derating Assumptions, Smart RAC

Derating Factor	Value
Participation Rate per Event	0.7[43]
Connectivity	0.95[44]
Additional Derating for Temperature Setback Strategy	0.8[45]
First Year In-Service	N/A
Final Derating Factor	**0.53**

Source: Guidehouse analysis based on multiple data sources, reference footnotes.

3.1.3 Total Achievable Impact

Table 3-8 contains relevant saturation statistics from the MA Baseline Study Saturation Survey and Navigant Research reports. The results show that there were approximately 3.3 million RACs in the Electric PAs's Massachusetts territory as of 2020. The number of smart RACs (with built-in DR-enablement) is currently assumed to be small but growing (approximately 7% of installed RACs in 2020, growing to 13% by 2024).[46] This information serves as a basis for estimating total impacts (benefits) on a program level. Additionally, it provides context for the feasibility of program expansion in coming years.

[43] Based on CoolNYC program average event participation rate across all events in summer 2015; Consolidated Edison Company of New York, Inc., *Program Performance and Cost Effectiveness of Demand Response Programs*, December 1, 2015, 53.

[44] Assuming the same connectivity rate as for Wi-Fi thermostats. https://ma-eeac.org/wp-content/uploads/2019-Residential-Wi-Fi-Thermostat-DLC-Evaluation-Report-2020-04-01-with-Infographic.pdf

[45] Guidehouse assumed an additional derating factor of 0.8 reflecting the fact that the temperature setback strategy entails a cycling of the air conditioner compressor aimed at maintaining a certain temperature. This additional 0.8 derating factor was based on the 2019 Wi-Fi thermostat evaluation for the Massachusetts PAs and was back calculated from the evaluated total derating factor (0.6) and the combined participation rate and connectivity rate derating factor (0.8).

[46] Based on forecasted smart appliance penetration for North America. Navigant Research, *Market Data: Smart Appliance with Hub Percent Penetration, World Markets: 2019-2028*, 2019.

Table 3-8. Saturation and Estimated Enrollment in Massachusetts Electric PA Territory

	2022	2024
Average Number of RACs/Customer	1.32[47]	1.32
Approximate Number of RACs[48]	3,300,000	3,300,000
Approximate Number of Smart RACs (i.e., built-in)[49]	300,000	450,000
Estimated Devices Enrolled in DR Program with Simple Timer Plug	150,000	600,000
Estimated Devices Enrolled in DR Program with Wi-Fi Plug	150,000	600,000
Estimated Smart RAC Devices Enrolled in DR Program	18,000	80,000

Source: Guidehouse estimates based on multiple data sources, reference footnotes within table and in-text below.

Two other factors impact the total peak demand reduction achievable on a program level: customers' willingness to sign up for a DR program (i.e., discretionary factor) and customers' likelihood of continued program participation following the first year of participation (i.e., persistence factor). Based on a review of available literature, Guidehouse assumed that 30% of customers with smart RACs (with built-in Wi-Fi) would be willing to enroll in a program in which their AC use would be automatically curtailed or temperature setpoint adjusted by the PAs.[50] For plug-based options, Guidehouse assumed a slightly lower willingness cap of 20%.[51] Guidehouse assumed a 5-year ramp rate to reach the willingness cap. The BCA model assumes the program would begin in 2021 and reach steady state enrollment in 2025.[52]

A persistence factor of 90% is assumed for smart RAC participant, consistent with the 2019 Wi-Fi thermostat DLC program evaluation findings related to attrition.[53] However, a persistence factor of 30% is assumed for smart plug and simple timer plug participants, reflecting the fact that a segment of returning participants will forget to reconnect their RAC with the plug provided by the program every season.[54]

[47] From MA Baseline Study Saturation Survey results for MA statewide (*Appendix B-3 MA Statewide Saturation Results 2020-03-31.xls*).

[48] Based on MA Electric PA Allocation for 2020 and forecasted growth in households in Massachusetts from Metropolitan Planning Council (MAPC), https://www.mass.gov/files/documents/2018/11/20/dot-board-mtg-13-MAPC-Modeling-2018Nov19.pdf.

[49] Based on forecasted smart appliance penetration for North America. Navigant Research, *Market Data: Smart Appliance with Hub Percent Penetration, World Markets: 2019-2028*, 2019.

[50] This is based on current enrollment of Wi-Fi thermostats in the PAs BYOT programs (~30,000) as a percent of central ACs in MA (estimated to be ~84,000), which is approximately 36%.

[51] Based on willingness to participate in DLC for single-family households under a "low" incentive scenario of $9/month as measured through a survey effort conducted by Xcel Energy as part of their 2014 DR market potential study. *Demand Response Market Potential in Xcel Energy's Northern States Power Service Territory,* April 2014.

[52] This is in line with industry best practice assumptions. In the current MA potential studies, a 3-year or 5-year ramp rate is assumed.

[53] https://ma-eeac.org/wp-content/uploads/2019-Residential-Wi-Fi-Thermostat-DLC-Evaluation-Report-2020-04-01-with-Infographic.pdf

[54] Consolidated Edison Company of New York, *Report on Program Performance and Cost Effectiveness of Demand Response Programs*, December 1, 2015.

3.1.4 Benefit-Cost Analysis

Table 3-9 shows the estimated net-present value of total benefits and costs, according to the Total Resources Cost (TRC) test, for the 2022 to 2024 timeframe, based on expected program size over this period. Results for both the smart plug and smart appliance DR-enablement strategies are provided. Results show a benefit-cost ratio of 0.2, 0.5, and 0.7 for the smart plug, simple timer plug, and smart RAC options, respectively.

Although none of these options passes the cost-effectiveness test, it is evident that a smart plug-based program is a less cost-effective option than a program featuring cheaper mechanical timer plugs or a program targeting RACs with built-in DR capability. This is due to the added costs of smart plugs.[55]

Table 3-9. TRC Test Benefits and Costs, 2022-2024

	Smart Plug, Temperature Setback		
	Total Impact (Benefit) (Millions)	Total Costs (Millions)	Benefit-Cost Ratio
RACs - Smart Plug	$35.9	$155.0	0.2

The BCR estimates are at the measure-level only as they do not include administration and marketing costs, among other program-level costs. This means the BCRs at the measure-level in this report are overestimates for how they may contribute to a complete program BCR..
Source: Guidehouse analysis

	Simple Timer Plug, DLC		
	Total Impact (Benefit) (Millions)	Total Costs (Millions)	Benefit-Cost Ratio
RACs - Simple timer plug	$33.9	$64.0	0.5

Table Ibid.
Source: Guidehouse analysis

	Smart Appliance, Temperature Setback		
	Total Impact (Benefit) (Millions)	Total Costs (Millions)	Benefit-Cost Ratio
RACs - Smart Appliance	$6.3	$9.3	0.7

Table Ibid.
Source: Guidehouse analysis

55 In the future, more customers may have their own smart plugs, and the program's cost-effectiveness would improve.

3.2 Dehumidifiers

3.2.1 DR Context

3.2.1.1 Technology Landscape

A 2016 paper for ACEEE jointly authored by Cadmus and Eversource shared the results of a technical demonstration undertaken by Eversource MA and CT which explored a variety of home appliances and their potential savings when enrolled in demand response programs.[56] The results found that heavy-use dehumidifiers have the second-highest potential energy and demand savings of home appliances(following pool pumps) when coupled with wireless switches. Heavy-use dehumidifiers showed more than 2x the annual energy expenditure than average dehumidifiers. The paper ultimately recommended that dehumidifier DR programs focus on plumbed dehumidifiers, which are likely to run continuously (since they do not need to be emptied), and, thus, more likely to be heavy-users.

Another factor that affects demand response potential is whether or not the dehumidifier has an automatic humidistat – a feature that will automatically adjust the dehumidifier's operation to achieve/maintain a desired humidity level. A recent analysis conducted as part of the MA Baseline study in 2020 found that dehumidifiers that are plumbed and do not have a humidistat are the heaviest users, while dehumidifiers that are not plumbed and have a humidistat are the lowest users.[57]

Based on preliminary findings from the MA Baseline study's current saturation survey, approximately half of residential dehumidifiers in MA are plumbed and half require buckets to be emptied.[58]

Dehumidifiers can be DR-enabled through smart plugs that ultimately allow users to control their devices via their smart phones. The smart plug industry is quickly expanding with current leaders including ThinkEco, Belkin, and Kasa. In addition to smart plugs, many companies, such as Honeywell, SoleusAir, LG, and Frigidaire, have begun manufacturing dehumidifiers with built-in DR capability. Guidehouse was not able to identify any DR program offerings targeting smart dehumidifiers.

Table 3-10 provides a summary of the DR-enabling technologies currently available on the market for dehumidifiers.

Table 3-10. DR-Enabling Device Market

OEMs	DR-Enabled Product	Tested in DR Context?	Example Utility Partners
Smart Plugs			
ThinkEco^	Modlet	Yes	United Illuminating, National Grid NY
Belkin	Wemo Smart Plug	No	
Kasa	Smart Wi-Fi Power Outlet	No	
Rainforest	Smart plug	No	
iHome	ISP6X SmartPlug	No	

[56] https://www.aceee.org/files/proceedings/2016/data/papers/12_630.pdf

[57] This analysis was presented internally to the MA PAs and EEAC by Guidehouse in 2020. There are no public-facing materials associated with this analysis.

[58] These results are preliminary and have not yet been published or shared with the PAs. Preliminary weights were applied.

Built-in		
Honeywell	Various	No
SoleusAir	Various	No
Frigidaire	Various	No
LG	Various	No
Ivation	Various	No
Emerson	Quiet Cool	No

Source: Guidehouse Research Leaderboard: Residential Demand Response (2017); Web research
^Ranked as a "Challenger" in the DR space by Guidehouse Research (Scoring strongest to weakest: Leaders, Contenders, Challengers, Followers)

3.2.1.2 Program Summaries

National Grid New York offered the ThinkEco modlet and smartAC kit as a direct-install measure for the coolControl program for customers in the Village of Kenmore. However, the ThinkEco portion of the program was discontinued after two years in hopes of making the overall program more cost-effective. Those who had received the kits prior to 2018 were still allowed to participate, but no new kits were installed.[59]

United Illuminating expanded its Smart AC program in 2019 to include smart plugs for dehumidifiers. UI offered smartAC kits from ThinkEco that could be used for either RACs or dehumidifiers. With this setup, the DR strategy was to shut off the device during peak periods. At this time, it appears the program is no longer being implemented (for dehumidifiers or RACs).

The programs outlined above were targeting portable dehumidifiers (not specifically plumped dehumidifiers). Portable dehumidifiers generally have the capability to be plumbed.

3.2.2 Potential Impact Per Device

Table 3-11, Table 3-12, and Table 3-13 contain the average coincident load results for dehumidifiers from the metering conducted as part of the MA Baseline Study for all summer weekdays (All Days) and weekdays for which the maximum temperature was greater than or equal to 90°F (Hottest Days) for the smart plug, simple timer plug, and smart dehumidifier (Built-In) technologies, respectively. The size of the metering sample for dehumidifiers was 95 units.

For each dehumidifier technology option, Guidehouse used the Hottest Days' impact as final potential peak demand reduction value for BCR purposes. After applying a derating factor, potential load reduction during the peak period associated with the Hottest Days scenario is 0.10 kW, 0.08 kW, and 0.15 kW for the smart plug, simple timer plug, and smart dehumidifier options, respectively. Below the tables, we provide more information about the derating factors assumed for dehumidifiers.

[59] https://www.nationalgridus.com/media/pdfs/bus-ways-to-save/dynamic_load_filing.pdf

Table 3-11. Unit Impact Metrics for Dehumidifiers with Smart Plug

		Smart Plug, DLC		
Source	**Analysis Year**	**Average Coincident Load**	**Derating**	**kW/Appliance During Peak**
MA Baseline Study End-Use Metering – All Days	2017-2019	0.15	0.6	0.09
MA Baseline Study End-Use Metering – Hottest Days	2017-2019	0.17	0.6	**0.10**
Potential Peak Demand Impact per Device				**0.10**

Source: Guidehouse analysis of MA Baseline Study End-Use Metering data for 2017-2019.

Table 3-12. Unit Impact Metrics for Dehumidifiers with Simple timer plug

		Simple Plug, DLC		
Source	**Analysis Year**	**Average Coincident Load**	**Derating**	**kW/Appliance During Peak**
MA Baseline Study End-Use Metering – All Days	2017-2019	0.15	0.5	0.07
MA Baseline Study End-Use Metering – Hottest Days	2017-2019	0.17	0.5	**0.08**
Potential Peak Demand Impact per Device				**0.08**

Guidehouse analysis of MA Baseline Study End-Use Metering data for 2017-2019.

Table 3-13. Unit Impact Metrics for Efficient Dehumidifiers with Built-in DR Capability

		Smart Appliance, DLC		
Source	**Analysis Year**	**Average Coincident Load**	**Derating**	**kW/Appliance During Peak**
MA Baseline Study End-Use Metering – All Days	2017-2019	0.15	0.9	0.13
MA Baseline Study End-Use Metering – Hottest Days	2017-2019	0.17	0.9	**0.15**
Potential Peak Demand Impact per Device				**0.15**

Guidehouse analysis of MA Baseline Study End-Use Metering data for 2017-2019.

The derating factors listed in the above tables are based on multiple sources. Table 3-14, Table 3-15, and Table 3-16 list the components of the derating factors assumed for a dehumidifier DR program utilizing smart plugs, simple time plugs and smart dehumidifiers, respectively.

Together, these factors make up the derating factor, which is applied to coincident load estimates in order to estimate potential or achievable impact per unit.

Table 3-14. Derating Assumptions, Smart Plug

Derating Factor	Value
Participation Rate per Event	0.9[60]
Connectivity	0.95[61]
Additional Derating for Temperature Setback Strategy	N/A
First Year In-Service	0.7[62]
Final Derating Factor	**0.6**

Source: Guidehouse analysis based on multiple data sources, reference footnotes.

Table 3-15. Derating Assumptions, Simple Timer Plug

Derating Factor	Value
Participation Rate per Event	0.9[63]
Connectivity	N/A
Additional Derating for Temperature Setback Strategy	N/A
First Year In-Service	0.5[64]
Final Derating Factor	**0.5**

Source: Guidehouse analysis based on multiple data sources, reference footnotes.

[60] Guidehouse assumes that dehumidifiers would be associated with fewer event opt outs than room air conditioners. Therefore, Guidehouse assumed a participation rate of 90% for dehumidifiers, somewhat higher than that assumed for room air conditioners (70%).

[61] Assuming the same connectivity rate as for Wi-Fi thermostats. https://ma-eeac.org/wp-content/uploads/2019-Residential-Wi-Fi-Thermostat-DLC-Evaluation-Report-2020-04-01-with-Infographic.pdf

[62] CoolNYC 2015 installation rate for first-year enrollees based on 2015 incentive structure (up from 40% in 2013); Consolidated Edison Company of New York, Inc., *Program Performance and Cost Effectiveness of Demand Response Programs*, December 1, 2015, 53.

[63] Guidehouse assumes that dehumidifiers would be associated with fewer event opt outs than room air conditioners. Therefore, Guidehouse assumed a participation rate of 90% for dehumidifiers, somewhat higher than that assumed for room air conditioners (70%).

[64] Assumed to be slightly lower than smart plug first-year in-service rate due to the fact that installation cannot be verified by program.

Table 3-16. Derating Assumptions: Smart Dehumidifier

Derating Factor	Value
Participation Rate per Event	0.9[65]
Connectivity	0.95[66]
Additional Derating for Temperature Setback Strategy	N/A
First Year In-Service	N/A
Final Derating Factor	**0.9**

Source: Guidehouse analysis based on multiple data sources, reference footnotes.

3.2.3 Total Achievable Impact

Table 3-17 contains relevant saturation statistics from the MA Baseline Study Saturation Survey. The results show that there were approximately 1.2 million dehumidifiers in the Electric PA's Massachusetts territory as of 2020, 7% of which are estimated to be smart dehumidifiers. This information serves as a basis for estimating total impacts (benefits) on a program level. Additionally, it provides context for the feasibility of program expansion in coming years. Based on a Guidehouse Insights (formerly Navigant Research) report on growth projections of smart appliances, Guidehouse estimates that the number of smart dehumidifiers will be approximately 170,000 by 2024.[67]

[65] Guidehouse assumes that dehumidifiers would be associated with fewer event opt outs than room air conditioners. Therefore, Guidehouse assumed a participation rate of 90% for dehumidifiers, somewhat higher than that assumed for room air conditioners (70%).

[66] Assuming the same connectivity rate as for Wi-Fi thermostats. https://ma-eeac.org/wp-content/uploads/2019-Residential-Wi-Fi-Thermostat-DLC-Evaluation-Report-2020-04-01-with-Infographic.pdf

[67] Based on forecasted smart appliance penetration for North America. Navigant Research, *Market Data: Smart Appliance with Hub Percent Penetration, World Markets: 2019-2028*, 2019.

Table 3-17. Saturation and Estimated Enrollment in Massachusetts Electric PA Territory

	2022	2024
Average Number of Dehumidifiers/Customer	0.38[68]	0.38
Approximate Number of Dehumidifiers[69]	1,260,000	1,280,000
Approximate Number of Smart Dehumidifiers[70]	120,000	170,000
Estimated Devices Enrolled in DR Program with a Simple Timer Plug	70,000	230,000
Estimated Devices Enrolled in DR Program with a Wi-Fi Plug	70,000	230,000
Estimated Smart Dehumidifier Devices Enrolled in DR Program	10,500	45,000

Source: Guidehouse estimates based on multiple data sources, reference footnotes within table and in-text below.

Two other factors impact the total peak demand reduction achievable on a program level: customers' willingness to sign up for a DR program (i.e., discretionary factor) and customers' likelihood of continued program participation following the first year of participation (i.e., persistence factor). Based on a review of available literature, Guidehouse assumed that 30% of customers with smart dehumidifiers (same percentage assumed as for RACs) would be willing to enroll in a program in which their dehumidifiers use would be automatically delayed by the PAs.[71] For plug-based options, Guidehouse assumed a slightly lower willingness cap of 20%.[72] Guidehouse assumed a 5-year ramp rate to reach the willingness cap The BCA model assumes the program would begin in 2021 and reach steady state enrollment in 2025.[73]

For smart dehumidifiers, a persistence factor of 90% is assumed (i.e., same as for smart RACs and consistent with the 2019 Wi-Fi thermostat DLC program evaluation findings related to attrition).[74] A persistence factor of 75% is assumed for the smart plug and simple timer plug options, an estimate in between the persistence rates used for Central Air Conditioners (CACs) (99%) and plug options for RACs (30%). Guidehouse assumes that many dehumidifiers in the northeast will remain plugged in all year round.

[68] From MA Baseline Study Saturation Survey results for MA statewide (*Appendix B-3 MA Statewide Saturation Results 2020-03-31.xls*).

[69] Based on MA Electric PA Allocation for 2020 and forecasted growth in households in Massachusetts from Metropolitan Planning Council (MAPC), https://www.mass.gov/files/documents/2018/11/20/dot-board-mtg-13-MAPC-Modeling-2018Nov19.pdf.

[70] Based on forecasted smart appliance penetration for North America. Navigant Research, *Market Data: Smart Appliance with Hub Percent Penetration, World Markets: 2019-2028*, 2019.

[71] This is based on current enrollment of Wi-Fi thermostats in the PAs BYOT programs (~30,000) as a percent of central ACs in MA (estimated to be ~84,000), which is approximately 36%.

[72] Based on willingness to participate in DLC for single-family households under a "low" incentive scenario of $9/month as measured through a survey effort conducted by Xcel Energy as part of their 2014 DR market potential study. *Demand Response Market Potential in Xcel Energy's Northern States Power Service Territory,* April 2014.

[73] This is in line with industry best practice assumptions. In the current MA potential studies, a 3-year or 5-year ramp rate is assumed.

[74] https://ma-eeac.org/wp-content/uploads/2019-Residential-Wi-Fi-Thermostat-DLC-Evaluation-Report-2020-04-01-with-Infographic.pdf

3.2.4 Benefit-Cost Analysis

Table 3-49 shows the estimated net-present value of total benefits and costs, according to the TRC test, for the 2022 to 2024 timeframe, based on expected program size over this period. This results in benefit-cost ratios of 0.3, 0.6, and 0.7 for the smart plug, simple timer plug, and built-in smart dehumidifier options, respectively.

Given the lack of supporting data to inform the persistence factor for dehumidifiers, Guidehouse conducted a sensitivity analysis to look at how different persistence factors would impact BCRs for dehumidifiers. The results of this analysis are included in the Appendix (Table A-2).

Table 3-18. TRC Test Benefits and Costs, 2022-2024[75]

	Smart Plug, DLC		
	Total Impact (Benefit) (Millions)	Total Costs (Millions)	Benefit-Cost Ratio
Dehumidifiers - Smart Plug	$15.7	$49.6	0.3

The BCR estimates are at the measure-level only as they do not include administration and marketing costs, among other program-level costs. This means the BCRs at the measure-level in this report are overestimates for how they may contribute to a complete program BCR..
Source: Guidehouse analysis

	Simple timer plug, DLC		
	Total Impact (Benefit) (Millions)	Total Costs (Millions)	Benefit-Cost Ratio
Dehumidifiers – Simple timer plug	$11.8	$20.4	0.6

Table Ibid.
Source: Guidehouse analysis

	Smart Appliance, DLC		
	Total Impact (Benefit) (Millions)	Total Costs (Millions)	Benefit-Cost Ratio
Dehumidifiers - Smart Appliance	$4.0	$5.4	0.7

Table Ibid.
Source: Guidehouse analysis

[75] Given the lack of supporting data to inform the persistence factor for dehumidifiers, Guidehouse conducted a sensitivity analysis to look at how different persistence factors would impact BCRs for dehumidifiers. The results of this analysis are included in the Appendix (Table A-2).

3.3 Water Heaters

3.3.1 DR Context

3.3.1.1 Technology Landscape

Along with thermostat-controlled AC systems, water heaters have been the most widely adopted appliance for DR programs. In the US, direct load control pilots for water heaters have been operating since the 1990s, with numerous active programs currently in place around the country. The main DR strategy for water heaters is to turn off the water heater entirely for the duration of the event. Utilities like Arizona Public Service, Great River Energy, Duke, Hawaiian Electric (HECO), Baltimore Gas & Electric, Florida Power and Light (FPL), and Eversource Connecticut have had or currently have demand response pilots or programs of this type, with some, like Duke, finding that DR for both electric resistance and heat pump water heaters is cost-effective.[76]

Programs mainly utilize DR-enabled switches to control electric water heaters, which has historically required utilities to bear the cost of the switch and installation. Aquanta, Armada Power, and Shifted Energy are leaders in this space, offering a new generation smart controller, compatible with Nest thermostats, that allows for Nest-like control of water heater settings directly from the user's smart phone. Aquanta advertises that self-installation is possible for many homeowners and that the process does not require any electrical knowledge or special equipment. The process is expected to take about 15 minutes and is equated to the difficulty of installing a new lighting fixture. Armada Power does not recommend that customers attempt to install their own smart controllers, but the company has created guides for contractor installment and estimates that the installation process takes 15 minutes or less.

Water heater manufacturers are becoming DR enablement players as well. Some manufacturers currently offer add-on Wi-Fi enabling devices, for example, Rheem markets heat pump water heaters (HPWHs) with an optional $49 external device that connects the water heater to Wi-Fi. Rheem's EcoNet and GE's ConnectPlus add-on devices for HPWHs were recently tested by WEC and Efficiency Vermont in their 2019-2020 water heater direct load control demonstration (more below). According to a white paper relating to this pilot, "both Rheem and GE support the hardware and the back-end application programming interfaces required to connect to the devices remotely. At the time of the pilot, these HPWH manufacturers were the only manufacturers supporting commercially available hardware and software for flexible load management."[77]

Additionally, Rheem, A.O. Smith, and Richmond, are a few prominent brands that produce water heaters with built-in DR capabilities.

There have been some recent policy moves in some states supporting the use of water heaters for DR. In 2020, the Washington State Legislature passed new legislation[78] mandating that all Electric Water Heaters installed, sold, or offered for sale, lease, or rent (after January 2021)

[76] George Gurlaskie, *Heat Pump Water Heaters for Demand Response*, February 2016. http://aceee.org/sites/default/files/pdf/conferences/hwf/2017/Gurlaskie_Session7A_HWF17_2.28.17.pdf

[77] https://www.efficiencyvermont.com/Media/Default/docs/white-papers/2019-RD-DR-Final-Report.pdf

[78] http://lawfilesext.leg.wa.gov/biennium/2019-20/Pdf/Bills/House%20Bills/1444-S2.pdf#page=1

must include technology for demand response. California is currently considering a similar proposal.

A 2019 paper authored by Christiana O. Onabola of the University of Northern British Columbia[79] discusses the concerns regarding demand response programs for water heaters and their potential to increase the risk of Legionnaires Disease. A paper by the Technology Collaboration Programme on Heat Pumping Technologies by IEA (HPT TCP), and Heat Pump Centre asserts that water heaters should be researched more for their connection to legionella, yet that single-family residential water heaters carry a much lower risk than commercial water heaters, like those in hotels and hospitals. According to this study, water heaters have an even lower probability of cultivating an environment for legionella growth when water is maintained at or below 20°C (68°F) or above 50°C (122°F).[80] The paper also references a finding from a German study which states that the water can be kept below 50°C, and maintain a low risk for legionella, if there is less than 3 liters within the heater. It is important to note that OSHA standards recommend that water heater temperatures never go below 60°C (140°F) to fully minimize the risk of spreading legionella. Yet, at the same time the large non-profit and advocacy group, Legionella.org, cautions customers to consider the potential for scalding if water is temperatures over 55°C (131°F).

Aquanta, Armada Power, and Shifted Energy have all conducted their own research on the risks of Legionnaires Disease with domestic hot water heaters in the context of demand response. The manufacturers have found that there is a low risk for legionella spread for numerous reasons, including the nature of domestic piping, distribution, and cooling systems. Typically, larger buildings' water systems have the highest risk for legionella growth due to the high probability that there will be stagnant water and poorly maintained piping.[81]

[79] https://sustain.ubc.ca/sites/default/files/2018-21%20Health%20and%20safety%20aspects%20of%20residential%20water%20heaters_Onabola.pdf

[80] https://heatpumpingtechnologies.org/annex46/wp-content/uploads/sites/53/2020/10/hpt-an46-03-task-1-legionella-and-heat-pumps-1.pdf

[81] https://www.cdc.gov/legionella/wmp/overview/growth-and-spread.html#:~:text=Certain%20groups%20of%20people%20are,disease%20or%20weakened%20immune%20systems.

Table 3-19. DR-Enabling Device Market

OEMs	DR-Enabled Product	ERWHs/HPWHs	Tested in DR Context?	Example Utility Partners
External Controller				
Aquanta	Smart Controller	Not compatible with HPWHs	Yes	Green Mountain Power (GMP), Con Edison, Portland General Electric (PGE)[82], Gas Technology Institute/Minnesota Center for Energy and Environment (CEE) (not specific to DR)
Emerson	75A01-100	Both	Yes	Duke Florida, Habersham Electric Membership Corporation, Timpmont REMC
Packetized Energy	Mello	Both	Yes	Efficiency Vermont / Washington Electric Co-op Inc. (WEC)
Shifted Energy	Smart Controller	Both	Yes	Hawaiian Electric Company, City of Longmont
Armada Power	LCS2400	Not compatible with HPWHs	Yes	AEP Ohio[83]
SkyCentrics	CTA-2045 USNAP Wi-Fi Modules	Both	Yes	City of Fort Collins
Carina	WISE	Both	Yes	TVA
Rheem	EcoNet	Both	Yes	Efficiency Vermont / WEC
GE	ConnectPlus	Not compatible with HPWHs (GE products only)	Yes	Efficiency Vermont / WEC
Built-In				
Rheem	Performance Platinum, ProTerra	Both	Yes	Arizona Public Service (APS), United Illuminating
A.O. Smith	Various	Both	No	
Richmond	Various	ERWH	No	

Source: Guidehouse Research Leaderboard: Residential Demand Response (2017); Web research
^Ranked as a "Challenger" in the DR space by Guidehouse Research (Scoring strongest to weakest: Leaders, Contenders, Challengers, Followers)

3.3.1.2 Program Summaries

BGE's Water Heater Control program involved direct load control of participants' electric water heaters via one-way switches. This involved two appointments for the customer; first, for the switch installation by a qualified BGE contractor, and then, a second for the local government's inspection. Participants received a $6.25 bill credit every month between November and February. Customer participation in the Electric Water Heater Program has been limited, with only approximately 23,000 customers having enrolled since the program's implementation. Customer feedback has indicated that the multiple appointments necessary for enrollment, coupled with the minimal monthly bill credits, makes them unlikely to enroll in the program. Additionally, customers are resistant to having a county/city inspector in their homes.

[82] https://edocs.puc.state.or.us/efdocs/HAQ/um1827haq143510.pdf
[83] https://plma.memberclicks.net/assets/resources/Guidehouse%20Insights_ArmadaPowerWhitePaper.pdf

Furthermore, the costs of the program exceed the benefits by nearly 40%. The Total Resource Cost ("TRC") equals 0.73. This program ended for all customers on April 1, 2021.[84]

From 2017 to 2020, Green Mountain Power of Vermont partnered with Aquanta for their eSmartwater program. If customers chose to enroll, they were given an Aquanta controller for $.99 per month to install on their ERWHs. As of October 2018, GMP reported contracts signed with 240 customers with an aggregate demand of 103.92 kW.[85] In GMP's 2018 Integrated Resource Plan, it was estimated that the program would eventually yield 3 MWs of controllable capacity.[86] Aquanta CEO, Matt Carlson, estimates that customers will save 10-30% of water heating electricity if they take advantage of demand response opportunities that become available through their device.[87]

In 2019, Con Edison installed 200 Aquanta water heater controllers in Westchester, NY to test the energy efficiency and gas demand response potential of the devices.[88] The impact is currently being evaluated for the 2019-2020 program years and the full assessment is expected to be available by the end of Q2 2021.

In partnership with Gas Technology Institute, Minnesota CEE conducted a state-funded pilot to validate the field performance and energy savings of the Aquanta controller and assess the energy and non-energy related benefits. Cited non-energy benefits include the fact that the smartphone application associated with the Aquanta controller provides users with the ability to control their water heater usage remotely and receive message alerts on water heater activity including maintenance reminders and leak detection.[89]

Efficiency Vermont and Washington Electric Co-op partnered on a two-year project (2019-2020) named PowerShift, which sought to demonstrate the potential of water heaters to bring flexible load management to Vermonters. The demonstration utilized Vermont-based Packetized Energy Technologies's (PET's) external controller switch, Mello, for enrolled ERWH with their Nimble dashboard software to manage the load. For the enrolled HPWHs, the demonstration tested a different technology, leveraging Virtual Peaker with a distributed energy platform to remotely control the units. The water heater controls strategy focused on the ability for water heaters to avoid using energy during forecasted peak times without disrupting the hot water service for members. Events were called 1-5 times per month. For ERWHs, peaks were avoided by using PET's "Peak Crusher" algorithm to reduce load during events. For HPWHs, tanks were preheated to 140° F starting 3 hours before a forecasted peak, and during events, temperatures were turned down to 120° F. All events were 2 hours long. A preliminary assessment of the demonstration found that, after some initial challenges with the technologies being tested, including some data quality issues related to the PET solution, the technologies proved to successfully enable load management. A final assessment of the demonstration project, expected in the first half of 2021, will document the cost-effectiveness of the program. [90]

Arizona Public Service began running its Reserve Rewards program in 2019, as part of its larger Rewards program, where 226 customers (in targeted areas) were given a full rebate for a

[84] https://www.bge.com/MyAccount/MyBillUsage/Documents/Electric/BGE%20Semi-Annual%20EmPOWER%20Maryland%20Report%20(Q1-Q2%202019).pdf
[85] https://greenmountainpower.com/wp-content/uploads/2019/04/2018-11-08-GMP-Responses-to-DPS-Discovery-R2.pdf
[86] https://greenmountainpower.com/wp-content/uploads/2019/03/IRP-Innovative-Customer-Programs.pdf
[87] https://www.greentechmedia.com/articles/read/green-mountain-powers-latest-distributed-energy-play-grid-smart-water-heate
[88] http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7BA1D97B04-2685-43EE-8217-FDA296374995%7D
[89] https://www.mncee.org/resources/projects/field-study-of-intelligent,-networked,-retrofittab/
[90] https://www.efficiencyvermont.com/Media/Default/docs/white-papers/2019-RD-DR-Final-Report.pdf

Wi-Fi-enabled Ruud (Rheem) heat pump water heater, on the condition of their participation in the demand response program.[91] APS evaluates the Reserve Rewards program in coordination with Cool Rewards (a smart thermostat DR program) and Storage Rewards (a battery storage program), and reports that the three programs saved 5,453,606 MWh in 2019 – which equates to avoiding 1,927 million pounds of CO_2.[92]

Shifted Energy is a Hawaii-based company that partners with Hawaii Electric (HECO) to enable DR on 35,000 + water heaters, thus creating 15 MW of controllable peak demand across Hawaii. The controllers are unique in that instead of connecting to Wi-Fi, they enabled through low-frequency cellular signals. HECO compensates customers for their participation with a small bill credit each month, and the controllers are free to install. HECO is using the Shifted Energy controller as part of its strategy to power Hawaii through 100% renewable energy by 2045. Events are called to the controllers approximately 50 – 100 times per year. This program is no longer recruiting new customers.

United Illuminating partnered with the Energy Hub platform and Rheem to administer a smart HPWH pilot for its income-eligible customers. United Illuminating provided free home energy assessments and Rheem HPWH heaters to eligible customers, those customers then participated in the demand response events.[93]

The City of Fort Collins Municipal Utility offers eligible customers with an ERWH or HPWH, a free A.O. Smith water heater (either an ERWH or HPWH, depending on the customer's original type of water heater) with an external controller which enables remote adjustment by Fort Collins through their Peak Partners Water Heater program. The Peak Partners program uses the SkyCentrics CTA-2045 controller, specifically designed for A.O. Smith Water Heaters. The utility offers three levels of participation: basic energy savings, default energy savings, and aggressive energy savings. The programs delay water heater energy consumption by 1, 2.5, or 4 hours, respectively. In its marketing, the program informs customers that there are benefits to the community by lowering carbon output and peak energy usage.[94] The City of Fort Collins Peak Partners Water Heater program contributes to the 3 MWh saved through DR for their wholesale energy provider, Platte River Power Authority.[95]

The Bonneville Power Administration has led many of the DR initiatives in the Pacific Northwest. In 2018, the organization partnered with Pacific Gas and Electric and eight other utilities to commission a regional study of CTA-2045.[96] At the time it was completed, this was the largest smart water heater pilot ever implemented and the first large demonstration of HPWHs participating in DR events. There were more than 600 events across the 220-day study, with no advance notice to customers. Overall, the program saw success in how it was perceived by customers. 80% of customers were very satisfied with the pilot. 94% of customers would be very likely or somewhat likely to a join a program based on this technology in the future, whereas the projected economic model assumed 26.5%. And lastly, most, if not all of the eight utilities found the experience favorable.

[91] https://www.aps.com/en/About/Sustainability-and-Innovation/Technology-and-Innovation/Reserve-Rewards

[92] http://s22.q4cdn.com/464697698/files/doc_downloads/performance_summary/2020/Pinnacle_West_Capital_Corporation_-_CDP_Climate_Change_Questionnaire_2020_-_20200826185826.pdf

[93] https://info.energyhub.com/blog/united-illuminating-der-program

[94] https://www.peakpartnersfortcollins.com/smart_water_heater_program

[95] https://www.prpa.org/wp-content/uploads/2020/10/IRP_10.8_spread.pdf

[96] https://www.bpa.gov/EE/Technology/demand-response/Documents/20181118_CTA-2045_Final_Report.pdf

Portland General Electric partnered with Bonneville Power Administration (BPA), again, and the Pacific Northwest National Laboratory (PNNL) on a pilot program where customers were required to be located within a specific geographical area (within the range to receive a strong signal from KINK 101.9 MHz – a local radio station).[97] The DLC events were then implemented through a device that could receive this radio signal, and Wi-Fi was used to record usage data at the households. Customers could participate in this pilot with either an ERWH or HPWH. Each household could receive up to $250 for their participation in the pilot. The program is currently being evaluated for cost effectiveness.

3.3.2 Potential Impact Per Device

Table 3-20 and Table 3-21 contain the average coincident load results for water heaters from the metering conducted as part of the MA Baseline Study for all summer weekdays (All Days) and weekdays for which the maximum temperature was greater than or equal to 90°F (Hottest Days). The size of the metering sample for HPWHs and electric resistance water heaters (ERWHs) was 29 and 37 units, respectively.

Guidehouse used the Hottest Days' impact as final potential peak demand reduction value for BCR purposes. After applying a derating factor, potential load reduction during the peak period associated with the Hottest Days scenario is 0.10 kW and 0.16 kW for HPWHs and ERWHs, respectively, regardless of the enabling technology (since all options are assumed to have the same derating factor).

Table 3-20. Unit Impact Metrics for HPWHs

	Smart Switch/Simple Timer Switch/Smart Appliance, DLC			
Source	**Analysis Year**	**Average Coincident Load**	**Derating**	**kW/ Appliance During Peak**
MA Baseline Study End-Use Metering – All Days	2017-2019	0.12	0.9	0.10
MA Baseline Study End-Use Metering – Hottest Days	2017-2019	0.11	0.9	**0.10**
Potential Peak Demand Impact per Device				**0.10**

Source: Guidehouse analysis of MA Baseline Study End-Use Metering data for 2017-2019.

[97] https://assets.ctfassets.net/416ywc1laqmd/6rUSjxANzOOyqHkj8MClhY/8f8b4f13068a2b238e9ab320240c553d/Sched_003.pdf

Table 3-21. Unit Impact Metrics for ERWHs

	Smart Switch/Simple Timer Switch/Smart Appliance, DLC			
Source	**Analysis Year**	**Average Coincident Load**	**Derating**	**kW/ Appliance During Peak**
MA Baseline Study End-Use Metering – All Days	2017-2019	0.19	0.9	0.17
MA Baseline Study End-Use Metering – Hottest Days	2017-2019	0.18	0.9	**0.16**
Potential Peak Demand Impact per Device				**0.16**

Source: Guidehouse analysis of MA Baseline Study End-Use Metering data for 2017-2019.
The derating factors listed in the above tables are based on the 2018 impact evaluation of BPA's CTA-2045 Water Heater Demonstration.[98] Table 3-22 lists the components of the derating factors assumed for water heater DR programs. The derating factor is assumed to be the same regardless of whether the appliance is a HPWH or ERWH and regardless of the DR-enablement scenario (smart switch, simple timer switch, built-in).

The final derating factor is applied to coincident load estimates in order to estimate potential or achievable impact per unit.

Table 3-22. Derating Assumptions, Water Heaters

Derating Factor	Value
Participation Rate per Event	0.96[99]
Connectivity Rate	0.95[100]
Additional Derating for Temperature Setback Strategy	N/A
First Year In-Service	N/A
Final Derating Factor	**0.9**

Source: Guidehouse analysis based on multiple data sources, reference footnotes.

3.3.3 Total Achievable Impact

The following tables contain relevant saturation statistics from the MA Baseline Study Saturation Survey for HPWHs and ERWHs. The results show that there were approximately 50,000 HPWHs in the Electric PAs's Massachusetts territory as of 2020, 3,500 of which were Wi-Fi enabled (either built-in or through the add-on device offered by the water heater OEM that makes the unit Wi-Fi enabled). For ERWHs, the results show that there were approximately 415,000 ERWHs in the Electric PAs's Massachusetts territory as of 2020, 30,000 of which were

[98] https://www.bpa.gov/EE/Technology/demand-response/Documents/Demand%20Response%20-%20FINAL%20REPORT%20110918.pdf

[99] https://www.bpa.gov/EE/Technology/demand-response/Documents/Demand%20Response%20-%20FINAL%20REPORT%20110918.pdf

[100] Assuming the same connectivity rate as for Wi-Fi thermostats. https://ma-eeac.org/wp-content/uploads/2019-Residential-Wi-Fi-Thermostat-DLC-Evaluation-Report-2020-04-01-with-Infographic.pdf

Wi-Fi enabled. Estimates of the growth rate for smart water heaters are based on Navigant Research findings.[101]

Table 3-23. Saturation and Estimated Enrollment in Massachusetts Electric PA Territory, HPWHs

	2022	2024
Average Number of HPWHs/ Customer	0.02[102]	0.02
Approximate Number of HPWHs[103]	50,000	50,000
Approximate Number of Smart HPWHs[104]	4,700	6,500
Estimated Devices Enrolled in DR Program with a Simple Timer Switch	2,700	9,000
Estimated Devices Enrolled in DR Program with a Wi-Fi Switch	2,700	9,000
Estimated Smart Devices Enrolled in DR Program	400	1,800

Source: Guidehouse estimates based on multiple data sources, reference footnotes within table and in-text below.

Table 3-24. Saturation and Estimated Enrollment in Massachusetts Electric PA Territory, ERWHs

	2022	2024
Average Number of ERWHs/ Customer	0.17[105]	0.17
Approximate Number of ERWHs[106]	420,000	426,000
Approximate Number of Smart ERWHs[107]	40,000	56,000
Estimated Devices Enrolled in DR Program with a Simple Timer Switch	23,000	77,000
Estimated Devices Enrolled in DR Program with a Wi-Fi Switch	23,000	77,000
Estimated Smart Devices Enrolled in DR Program	3,500	15,000

[101] Based on forecasted smart appliance penetration for North America. Navigant Research, *Market Data: Smart Appliance with Hub Percent Penetration, World Markets: 2019-2028*, 2019.

[102] From MA Baseline Study Saturation Survey results for MA statewide (*Appendix B-3 MA Statewide Saturation Results 2020-03-31.xls*).

[103] Based on MA Electric PA Allocation for 2020 and forecasted growth in households in Massachusetts from Metropolitan Planning Council (MAPC), https://www.mass.gov/files/documents/2018/11/20/dot-board-mtg-13-MAPC-Modeling-2018Nov19.pdf.

[104] Based on forecasted smart appliance penetration for North America. Navigant Research, *Market Data: Smart Appliance with Hub Percent Penetration, World Markets: 2019-2028*, 2019.

[105] From MA Baseline Study Saturation Survey results for MA statewide (*Appendix B-3 MA Statewide Saturation Results 2020-03-31.xls*).

[106] Based on MA Electric PA Allocation for 2020 and forecasted growth in households in Massachusetts from Metropolitan Planning Council (MAPC), https://www.mass.gov/files/documents/2018/11/20/dot-board-mtg-13-MAPC-Modeling-2018Nov19.pdf.

[107] Based on forecasted smart appliance penetration for North America. Navigant Research, *Market Data: Smart Appliance with Hub Percent Penetration, World Markets: 2019-2028*, 2019.

Source: Guidehouse estimates based on multiple data sources, reference footnotes within table and in-text below.

Two other factors impact the total peak demand reduction achievable on a program level: customers' willingness to sign up for a DR program (i.e., discretionary factor) and customers' likelihood of continued program participation following the first year of participation (i.e., persistence factor). Guidehouse assumed that 30% of customers with smart water heaters would be willing to enroll in a program in which their water heater's heating resistance elements are controlled by the PAs.[108] For switch-based options, Guidehouse assumed a slightly lower willingness cap of 20%.[109] These assumptions may represent a lower bound given that customers may be more inclined to accept adjustments to their water heating than they would to their cooling on a hot day. Guidehouse assumed a 5-year ramp rate to reach the willingness cap. The BCA model assumes the program would begin in 2021 and reach steady state enrollment in 2025.[110]

A persistence factor of 90% is assumed (i.e., consistent with the 2019 Wi-Fi thermostat DLC program evaluation findings related to attrition).[111]

3.3.4 Benefit-Cost Analysis

For HPWHs and ERWHs, respectively, Table 3-25 and Table 3-26 show the estimated net-present value of total benefits and costs, according to the TRC test, for the 2022 to 2024 timeframe, based on expected program size over this period. For HPWHs and ERWHs, results for both the retrofit (smart switch and simple timer switch) and smart appliance DR-enablement strategies are provided. For HPWH programs, results show benefit-cost ratios ranging from 0.1 to 0.5 for DR programs. For ERWHs, results range from 0.2 to 0.8 for DR programs. Benefit-cost ratios associated with HPWHs are lower due to the lower average coincident demand (due to HPWHs being more efficient) than ERWHs. Additionally, the retrofit (inline switch/controller) options are less cost-effective for both HPWHs and ERWHs due to the per unit costs of the switch and installation (regardless of whether Wi-Fi or simple mechanical timer).

Although none of the DR-enabling technologies for water heaters have been found to be cost-effective, ERWHs with built-in DR capability are closest. Controlling heat pump water heaters through the same means is further off due to the lower average load of HPWHs. The PAs offer energy efficiency incentives to customers to encourage them to use the more efficient heat pump water heaters. Offering a demand response incentive only to electric resistance water heaters could confuse customers, and decrease the adoption of heat pump water heaters, which provide savings year-round, not just for demand response events. Whereas, offering DR incentives to both electric resistance and heat pump water heaters in an effort to remove the conflict of interest may result in a not cost-effective program, especially since the majority of smart water heaters are heat pump water heaters.

[108] This is based on current enrollment of Wi-Fi thermostats in the PAs BYOT programs (~30,000) as a percent of central ACs in MA (estimated to be ~84,000), which is approximately 36%.

[109] Based on willingness to participate in DLC for single-family households under a "low" incentive scenario of $9/month as measured through a survey effort conducted by Xcel Energy as part of their 2014 DR market potential study. *Demand Response Market Potential in Xcel Energy's Northern States Power Service Territory,* April 2014.

[110] This is in line with industry best practice assumptions. In the current MA potential studies, a 3-year or 5-year ramp rate is assumed.

[111] https://ma-eeac.org/wp-content/uploads/2019-Residential-Wi-Fi-Thermostat-DLC-Evaluation-Report-2020-04-01-with-Infographic.pdf

Table 3-25. TRC Test Benefits and Costs, 2022-2024 - HPWHs

	Smart Switch, DLC		
	Total Impact (Benefit) (Millions)	Total Costs (Millions)	Benefit-Cost Ratio
HPWHs – Smart Switch	$0.6	$4.5	0.1

The BCR estimates are at the measure-level only as they do not include administration and marketing costs, among other program-level costs. This means the BCRs at the measure-level in this report are overestimates for how they may contribute to a complete program BCR..
Source: Guidehouse analysis

	Simple Timer Switch, DLC		
	Total Impact (Benefit) (Millions)	Total Costs (Millions)	Benefit-Cost Ratio
HPWHs – Simple Timer Switch	$0.6	$2.8	0.2

Table Ibid.
Source: Guidehouse analysis

	Smart Appliance, DLC		
	Total Impact (Benefit) (Millions)	Total Costs (Millions)	Benefit-Cost Ratio
HPWHs – Smart Appliance	$0.1	$0.2	0.5

Table Ibid.
Source: Guidehouse analysis

Table 3-26. TRC Test Benefits and Costs, 2022-2024 - ERWHs

	Smart Switch, DLC		
	Total Impact (Benefit) (Millions)	Total Costs (Millions)	Benefit-Cost Ratio
ERWHs – Smart Switch	$8.0	$37.9	0.2

Table Ibid.
Source: Guidehouse analysis

	Simple Timer Switch, DLC		
	Total Impact (Benefit) (Millions)	Total Costs (Millions)	Benefit-Cost Ratio
ERWHs – Simple Timer Switch	$8.0	$24.0	0.3

Table Ibid.
Source: Guidehouse analysis

	Smart Appliance, DLC		
	Total Impact (Benefit) (Millions)	Total Costs (Millions)	Benefit-Cost Ratio
ERWHs -Smart Appliance	$1.4	$1.8	0.8

Table Ibid.
Source: Guidehouse analysis

3.4 Pool Pumps

3.4.1 DR Context

3.4.1.1 Technology Landscape

Pool pumps can either have built-in connectivity or can be controlled with plugs or inline switches. Inline switches are the most common control mechanism.

Though ENERGY STAR has outlined the requirements for its “connected” label, it considers this an optional component of the overall certification. There are currently two pool pumps on the market that meet the ENERGY STAR “connected” certification, and both are manufactured by Pentair Aquatic Systems.

For the 2018/2019 Cost-Effectiveness of ADR for Residential End-Uses study, Guidehouse leveraged survey data from the 2017 MA Residential Baseline Study, which found that there are no plug-in pool pumps in National Grid’s Massachusetts jurisdiction. Therefore, Guidehouse excluded a plug-based option from the BCR analysis for the 2018/2019 study. For this current study, we continue to exclude a plug-based option from the BCR analysis under the assumption that plug-in pool pumps represent a marginal share of pool pumps in Massachusetts. Additionally, the 2017 MA Baseline Study Saturation Survey revealed that, for the respondents with smart pool pumps (built-in Wi-Fi capability), the majority were single-speed pool pumps (as opposed to multi-speed). For this reason, Guidehouse used the same impact assumptions for all DR-enablement strategies considered in the following sections (i.e., smart switch, simple timer switch, built-in). For this current study, we continue to follow this approach.

Table 3-27. DR-Enabling Device Market

OEMs	DR-Enabled Product	Proven in DR Context?	Example Utility Partners
Smart Plug			
iDevices	Smart Plug	No	
Shifted Energy	Smart Plug		
Smart Switch			
Aclara	LCT [pictured]	Yes	FPL, Duke
Zodiac	Aqualink	No	
Hayward	AquaConnect	No	
Built-In			
Pentair	EasyTouch, IntelliTouch	No	

Source: Guidehouse analysis based on web research

3.4.1.2 Program Summaries

Pool pumps have long been a target of residential DR programs. Largely, these programs have focused on solutions for a suite of home products. In Florida, Duke Energy's Energy Wise[112] and FPL's FPL On Call[113] programs require that a device be installed in the home to control numerous appliances, including pool pumps. Customers are then rewarded with bill credits in exchange for the utility turning off these appliances during peak energy events. FPL pays $3 per month for full control over connected pool pumps.

Similarly, Louisville Gas & Electric (LG&E) administers the Demand Conservation program, a program where customers can install a switch on their pool pumps (and/or on several other household devices). If the customer participates in the event, they are awarded a $5 credit per device installed at the end of the season.[114]

In 2018, the Australian Renewable Energy Agency (ARENA) devoted $1.91 million (USD) to the Pooled Energy Project.[115] This initiative focuses on connecting pools to demand response technology through a third-party implementer. So far, the program reports that typical users see a 60% reduction in pool-related energy costs. The program has developed its own sensors that are installed on pool pumps, chlorinators, and heaters. In addition to electricity use, the program monitors pool chemicals and sends alerts to customers. The trial is aiming to enroll 5,000 participants – the savings from which could "power a small town". The Pooled Energy Project claims that the automation of pool pumps creates the opportunity to save money on maintenance and reduce overall pool chemical use.[116]

3.4.2 Potential Impact Per Device

Table 3-28 contains the average coincident load results for pool pumps from the metering conducted as part of the MA Baseline Study for all summer weekdays (All Days) and weekdays for which the maximum temperature was greater than or equal to 90°F (Hottest Days). The size of the metering sample for pool pumps was 20 units.[117]

Guidehouse used the Hottest Days' impact as the final potential peak demand reduction value for BCR purposes. After applying a derating factor, potential load reduction during the peak period associated with the Hottest Days scenario is 0.61 kW, regardless of the enabling technology (since all options are assumed to have the same derating factor).

Table 3-28. Unit Impact Metrics for Pool Pumps

	Smart Switch/Simple Timer Switch/Smart Appliance, DLC

[112] https://www.duke-energy.com/home/products/energywise-home.
[113] https://www.fpl.com/save/programs/on-call.html
[114] https://lge-ku.com/demand-conservation
[115] https://pooledenergy.com.au/
[116] https://pooledenergy.com.au/how-it-works/swimming-pool-chemicals/
[117] Baseline Study Saturation Survey results from 2017 suggest that the majority of smart pool pumps are single speed. Therefore, Guidehouse assumed the same unit impacts for switch versus smart pool pump options.

Source	Analysis Year	Average Coincident Load	Derating	kW/ Appliance During Peak
MA Baseline Study End-Use Metering – All Days	2017-2019	0.61	0.95	0.54
MA Baseline Study End-Use Metering – Hottest Days	2017-2019	0.68	0.95	**0.62**
Potential Peak Demand Impact per Device				**0.62**

Source: Guidehouse analysis of MA Baseline Study End-Use Metering data for 2017-2019.
Guidehouse assumed that event participation for pool pump owners would be close to 100%. Guidehouse assumed the connectivity rate to be the same as that for Wi-Fi thermostats in MA.[118]

Together, these factors make up the derating factor, which is applied to coincident load estimates in order to estimate potential or achievable impact per unit.

Table 3-29. Derating Assumptions

Derating Factor	Value
Participation Rate per event	1
Connectivity	0.95[119]
Additional Derating for Temperature Setback Strategy	N/A
First Year In-Service	N/A
Final Derating Factor	**0.95**

Source: Guidehouse analysis based on multiple data sources, reference footnotes.

3.4.3 Total Achievable Impact

The figure below contains relevant saturation statistics on pool pump saturation from the MA Baseline Study Saturation Survey. The results show that there were approximately 195,000 pool pumps in the Electric PAs's Massachusetts territory as of 2020, and 14,000 were Wi-Fi enabled. Estimates of the growth rate for smart pool pumps are based on Navigant Research forecasts.[120]

Table 3-30. Saturation and Estimated Enrollment in Massachusetts Electric PA Territory

	2022	2024
Average Number of Pool Pumps (PPs)/Customer	0.08[121]	0.08

[118] Assuming the same connectivity rate as for Wi-Fi thermostats. https://ma-eeac.org/wp-content/uploads/2019-Residential-Wi-Fi-Thermostat-DLC-Evaluation-Report-2020-04-01-with-Infographic.pdf

[119] Assuming the same connectivity rate as for Wi-Fi thermostats. https://ma-eeac.org/wp-content/uploads/2019-Residential-Wi-Fi-Thermostat-DLC-Evaluation-Report-2020-04-01-with-Infographic.pdf

[120] Based on forecasted smart appliance penetration for North America. Navigant Research, *Market Data: Smart Appliance with Hub Percent Penetration, World Markets: 2019-2028*, 2019.

[121] From MA Baseline Study Saturation Survey results for MA statewide (*Appendix B-3 MA Statewide Saturation Results 2020-03-31.xls*).

	2022	2024
Approximate Number of PPs[122]	200,000	200,000
Approximate Number of Smart PPs[123]	19,000	26,000
Estimated Devices Enrolled in DR Program with a Simple Timer Switch	20,000	70,000
Estimated Devices Enrolled in DR Program with a Wi-Fi Switch	20,000	70,000
Estimated Smart Pool Pump Devices Enrolled in DR Program	3,000	12,000

Source: Guidehouse estimates based on multiple data sources, reference footnotes within table and in-text below.

Two other factors impact the total peak demand reduction achievable on a program level: customers' willingness to sign up for a DR program (i.e., discretionary factor) and customers' likelihood of continued program participation following the first year of participation (i.e., persistence factor). Since pool pump operation does not impact customer comfort or convenience, Guidehouse assumed that 50% of customers with smart pool pumps would be willing to enroll in a program in which their pool pumps are controlled by the PAs. For switch-based options, Guidehouse assumed a slightly lower willingness cap of 40%. Guidehouse assumed a 5-year ramp rate to reach the willingness cap. The BCA model assumes the program would begin in 2021 and reach steady state enrollment in 2025.[124] A persistence factor of 90% is also assumed.

3.4.4 Benefit-Cost Analysis

Table 3-31 shows the estimated net-present value of total benefits and costs according to the TRC test for the 2022 to 2024 timeframe based on expected program size over this period. Results for the smart switch, simple timer switch, and smart appliance DR-enablement strategies are provided. Results show a benefit-cost ratio of 0.9, 1.9, and 3.2 for the smart switch, simple timer switch, and smart appliance options, respectively. These ratios indicate that a pool pump DR program, in any form, may be worth pursuing.

Given the lack of supporting data to inform the discretionary factor for pool pumps, Guidehouse conducted a sensitivity analysis to look at how different discretionary factors would impact BCRs for pool pumps. The results of this sensitivity analysis appear in the Appendix (Table A-3).

[122] Based on MA Electric PA Allocation for 2020 and forecasted growth in households in Massachusetts from Metropolitan Planning Council (MAPC), https://www.mass.gov/files/documents/2018/11/20/dot-board-mtg-13-MAPC-Modeling-2018Nov19.pdf.

[123] Based on forecasted smart appliance penetration for North America. Navigant Research, *Market Data: Smart Appliance with Hub Percent Penetration, World Markets: 2019-2028*, 2019.

[124] This is in line with industry best practice assumptions. In the current MA potential studies, a 3-year or 5-year ramp rate is assumed.

Table 3-31. TRC Test Benefits and Costs, 2022-2024[125]

	Smart Switch, DLC		
	Total Impact (Benefit) (Millions)	Total Costs (Millions)	Benefit-Cost Ratio
Pool Pumps - Smart Switch (50% discretionary factor)	$30.7	$35.6	0.9

The BCR estimates are at the measure-level only as they do not include administration and marketing costs, among other program-level costs. This means the BCRs at the measure-level in this report are overestimates for how they may contribute to a complete program BCR..

Source: Guidehouse Analysis

	Simple Switch, DLC		
	Total Impact (Benefit) (Millions)	Total Costs (Millions)	Benefit-Cost Ratio
Pool Pumps – Simple Switch	$30.7	$22.6	1.4

Table Ibid.

Source: Guidehouse Analysis

	Smart Appliance, DLC		
	Total Impact (Benefit) (Millions)	Total Costs (Millions)	Benefit-Cost Ratio
Pool Pumps - Smart Appliance	$4.6	$1.4	3.2

Table Ibid.

Source: Guidehouse Analysis

[125] Given the lack of supporting data to inform the discretionary factor for pool pumps, Guidehouse conducted a sensitivity analysis to look at how different discretionary factors would impact BCRs for pool pumps. The results of this sensitivity analysis appear in the Appendix (Table A-3).

3.5 Appendix

Table 41. Potential Unit Impacts[126], Program Size, and Benefit-Costs (TRC, 2022-2024) – Two BCR Scenarios

Appliance	Enabling Device	DR Strategy	Estimated Unit Impacts[127] (kW)	Potential Units Enrolled in MA Statewide (2022)	Potential Units Enrolled in MA Statewide (2024)	BCR w/ Customer Incentives Included (TRC, 2022-2024)[128]	BCR w/ Customer Incentives Excluded (TRC, 2022-2024)[129]
Room Air Conditioner	Smart appliance	Temperature setback	0.13	17,880	78,300	0.7	1.4
	Simple switch	DLC	0.09	150,286	594,984	0.5	2.3
	Smart switch	Temperature setback	0.09	150,286	594,984	0.2	0.3
Dehumidifier	Smart appliance	DLC	0.15	10,362	45,378	0.7	1.6
	Smart appliance	DLC	0.08	69,323	229,880	0.6	2.9
	Smart appliance	DLC	0.10	69,323	229,880	0.3	0.5
Heat Pump Water Heater	Simple plug	DLC	0.10	406	1,780	0.5	1.0
	Simple plug	DLC	0.10	2,719	9,015	0.2	0.3
	Smart appliance	DLC	0.10	2,719	9,015	0.1	0.2
Electric Resistance Water Heater	Simple switch	DLC	0.16	3,454	15,126	0.8	1.7
	Smart plug	DLC	0.16	23,108	76,627	0.3	0.4
	Smart plug	DLC	0.16	23,108	76,627	0.2	0.2
Pool Pump	Smart switch	DLC	0.65	2,709	11,864	3.2	6.9
	Simple switch	DLC	0.65	21,748	72,119	1.4	1.8
	Smart switch	DLC	0.65	21,748	72,119	0.9	1.0

The BCR estimates are at the measure-level only as they do not include administration and marketing costs, among other program-level costs. This means the BCRs at the measure-level in this report are overestimates for how they may contribute to a complete program BCR.
Source: Guidehouse analysis based on multiple data sources, reference footnotes.

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[126] Net of derating factors associated with event participation, Wi-Fi connectivity, DR enablement strategy, and first-year in-service rate.

[127] Potential impacts used for calculating BCRs are based on end-use metering for the hottest 2017-2019 summer days; i.e., all non-holiday weekdays in the summers of 2017 - 2019 for which Boston, Massachusetts had a maximum temperature of equal to or greater than 90°F.

[128] Some costs were not included in the BCR calculation such as program administration, setup costs, and software costs. Inclusion of these costs would reduce BCRs. See Section 2.4 for more details.

[129] Ibid.

Table A-2. Dehumidifiers TRC Test Benefits and Costs, 2022-2024[130] - Sensitivity Analysis

	Smart Plug, DLC		
	Total Impact (Benefit) (Millions)	Total Costs (Millions)	Benefit-Cost Ratio
Dehumidifiers - Smart Plug (75% persistence factor)	$15.7	$49.6	0.3
Sensitivity Analysis			
Dehumidifiers – Smart Plug (30% persistence factor)	$15.4	$59.9	0.3
Dehumidifiers - Smart Plug (90% persistence factor)	$15.9	$46.0	0.3

The BCR estimates are at the measure-level only as they do not include administration and marketing costs, among other program-level costs. This means the BCRs at the measure-level in this report are overestimates for how they may contribute to a complete program BCR..

Source: Guidehouse Analysis

	Simple Plug, DLC		
	Total Impact (Benefit) (Millions)	Total Costs (Millions)	Benefit-Cost Ratio
Dehumidifiers - Simple Plug (75% persistence factor)	$11.8	$20.4	0.6
Sensitivity Analysis			
Dehumidifiers - Simple Plug (30% persistence factor)	$11.5	$24.7	0.5
Dehumidifiers - Simple Plug (90% persistence factor)	$11.9	$18.9	0.6

Table Ibid.

Source: Guidehouse Analysis

[130] Given the lack of supporting data to inform the persistence factor for dehumidifiers, Guidehouse conducted a sensitivity analysis to look at how different persistence factors would impact BCRs for dehumidifiers.

	Smart Appliance, DLC		
	Total Impact (Benefit) (Millions)	Total Costs (Millions)	Benefit-Cost Ratio
Dehumidifiers - Smart Appliance (90% persistence factor)	$4.0	$5.4	0.7
Sensitivity Analysis			
Dehumidifiers - Smart Switch (30% persistence factor)	$3.9	$5.9	0.7
Dehumidifiers - Smart Switch (75% persistence factor)	$4.0	$5.5	0.7

Table Ibid.
Source: Guidehouse Analysis

Table A-3. Pool Pumps TRC Test Benefits and Costs, 2022-2024[131] - Sensitivity Analysis

	Smart Switch, DLC		
	Total Impact (Benefit) (Millions)	Total Costs (Millions)	Benefit-Cost Ratio
Pool Pumps - Smart Switch (40% discretionary factor)	$30.7	$35.6	0.9
Sensitivity Analysis			
Pool Pumps - Smart Switch (30% discretionary factor)	$23.0	$26.0	0.9
Pool Pumps - Smart Switch (90% discretionary factor)	$69.1	$80.2	0.9

The BCR estimates are at the measure-level only as they do not include administration and marketing costs, among other program-level costs. This means the BCRs at the measure-level in this report are overestimates for how they may contribute to a complete program BCR..

[131] Given the lack of supporting data to inform the discretionary factor for pool pumps, Guidehouse conducted a sensitivity analysis to look at how different discretionary factors would impact BCRs for pool pumps.

Source: Guidehouse Analysis

	Simple Switch, DLC		
	Total Impact (Benefit) (Millions)	**Total Costs (Millions)**	**Benefit-Cost Ratio**
Pool Pumps – Simple Switch (40% discretionary factor)	$30.7	$22.6	1.4
Sensitivity Analysis			
Pool Pumps - Smart Switch (30% discretionary factor)	$23.0	$17.0	1.4
Pool Pumps - Smart Switch (90% discretionary factor)	$69.1	$50.9	1.4

Table Ibid.
Source: Guidehouse Analysis

	Smart Appliance, DLC		
	Total Impact (Benefit) (Millions)	**Total Costs (Millions)**	**Benefit-Cost Ratio**
Pool Pumps - Smart Appliance (50% discretionary factor)	$4.6	$1.4	3.2
Sensitivity Analysis			
Pool Pumps - Smart Switch (30% discretionary factor)	$2.7	$0.85	3.2
Pool Pumps - Smart Switch (90% discretionary factor)	$8.2	$2.5	3.2

Table Ibid.
Source: Guidehouse Analysis