Electricity Consumption and Peak Demand Scenarios for New England

Steven Nadel
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529 14th Street NW, Suite 600, Washington, DC 20045
Phone: (202) 507-4000 • Twitter: @ACEEEDC
Facebook.com/myACEEE • aceee.org

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About the Author

Steven Nadel has been ACEEE's executive director since 2001. He has worked in the energy efficiency field for more than 30 years and has over 200 publications. His current research interests include utility sector energy efficiency programs and policies, state and federal energy and climate change policy, and appliance and equipment efficiency standards. He joined ACEEE in 1989 and previously served as deputy director of the organization and director of ACEEE's Utilities and Buildings programs.

Prior to ACEEE, Steve planned and evaluated energy efficiency programs for New England Electric, a major electric utility; directed energy programs for the Massachusetts Audubon Society, the state's largest environmental organization; and ran energy programs for a community organization working on housing rehabilitation in the poorest neighborhoods of New Haven, Connecticut. Steve earned a master of science in energy management from the New York Institute of Technology and a master of arts in environmental studies and a bachelor of arts in government from Wesleyan University.

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Executive Summary

In the United States, electricity consumption has been approximately flat in recent years. Increased energy efficiency (EE) efforts have contributed to this lack of consumption growth, even as the US economy has expanded. Looking forward, further energy efficiency gains are likely. In addition, a variety of other trends will affect future electricity consumption and peak demand, including:

- Accelerating use of distributed power generation such as photovoltaic (PV) systems on the customer side of the meter
- Growing use of electric vehicles (EVs)
- The possible expanded use of electric heat pumps (HPs) to replace space and water heating equipment that burns fossil fuels, driven in part by the desire to reduce greenhouse gas emissions, assuming that the power comes from clean generation

The pace of these different trends is hard to predict, and given the uncertainties, any prediction made today is likely to be wrong. That said, it is useful to get a sense of how these trends might affect electricity consumption and peak demand, so we can begin to plan for the future while recognizing the large uncertainties involved. In this paper, rather than forecast the future, we explore three possible scenarios that help to define the range of potential outcomes, without taking a position on which scenario is most likely. As a first step, we focus on one region, New England, although in the future we hope to look at other regions as well. Our three scenarios are:

1. *Business as usual*. We use the reference case from the just released *2016 Annual Energy Outlook* (AEO) prepared by the Energy Information Administration (EIA), a branch of the US Department of Energy (DOE). We used this forecast rather than the forecast from the New England regional Independent System Operator (ISO-NE) because the EIA forecast extends to 2040, while ISO-NE goes only to 2025.
2. *Accelerated*, with significantly enhanced programs and policies to promote EE, PV, EV, and HP.
3. *Aggressive*, pushing the boundaries of the levels of EE, PV, EV, and HP that could be achieved.

New England electricity sales in the three scenarios are compared in figure ES1. This figure also shows the ISO-NE forecast to 2025. In the AEO reference case, electricity sales decline over the 2015–2018 period and then rise slowly over the balance of the analysis period. Sales in 2040 are 1.0% higher than 2015 sales. In the accelerated and aggressive cases, sales decline over the 2015–2030 period but then increase over the subsequent decade. In the accelerated and aggressive cases, sales in 2040 are 2.1% lower and 9.7% lower, respectively, than sales in 2015. In both of these scenarios, sales decline due to efficiency and PV, only partially offset by growth in EVs and heat pumps. The impacts of energy efficiency on sales are greater than the impacts of PV. Heat pumps and EVs both increase sales, with heat pumps having the larger effect relative to the reference case.

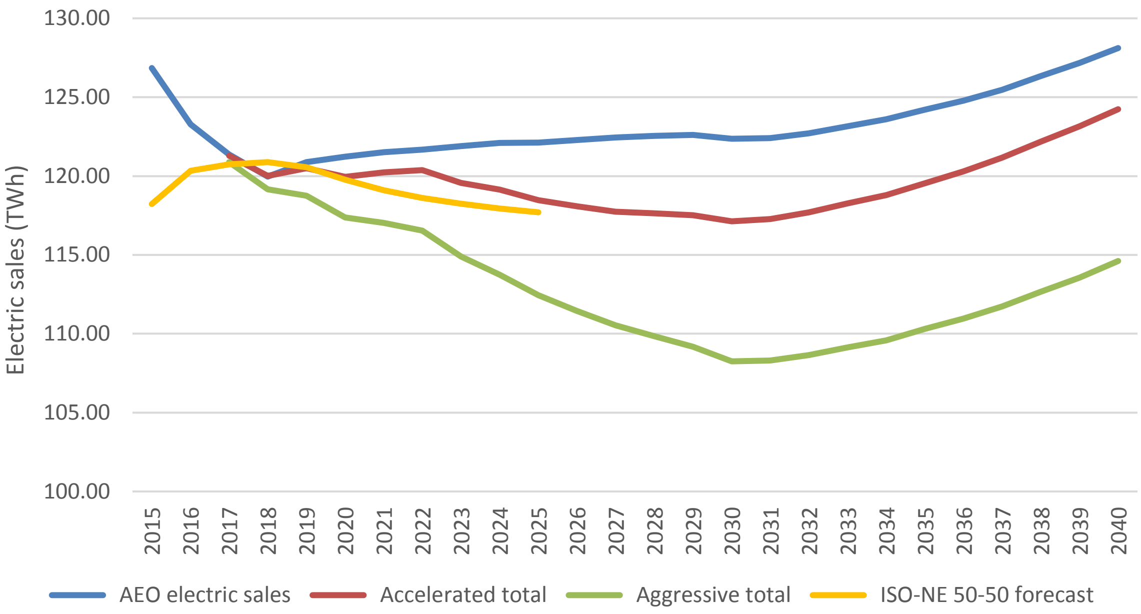

Figure ES1. Electricity sales in the three scenarios, 2015–2040 plus ISO-NE forecast for 2015–2025. The ISO-NE forecast is adjusted to eliminate transmission and distribution losses.

We also examined trends in summer and winter peak demand. In the reference case, both summer and winter peak demand modestly increase. ISO-NE also predicts gradually rising peak demand. In our accelerated scenarios, summer peak demand declines and winter peak demand modestly grows. The decline in summer peak demand is larger in the aggressive case, driven by energy efficiency savings and, secondarily, by photovoltaics. In the accelerated scenario, summer peak declines until about 2030 and then levels off before starting modest growth, reflecting the impact of EVs and heat pumps (we assume that a significant share of heat pump growth occurs in homes lacking central air-conditioning, as adding air-conditioning to a home can be a significant consumer motivator). The increase in winter peak demand is driven by growth in EVs and heat pumps. In the aggressive scenario, by 2040, summer peak demand is only a little higher than winter peak demand. And the trends are such that the winter peak could surpass the summer peak in the 2040s.

Of course, other scenarios are also possible, such as one that combines our more aggressive EV and heat pump scenarios with lower levels of efficiency and PV. This scenario would result in higher sales and higher summer peaks. The annual rates of efficiency savings shown in the accelerated and aggressive scenarios have been achieved in several of the New England states, although there is uncertainty about how many years these increased savings rates can be maintained. The levels of PV, EV, and heat pumps are more speculative and are subject to large uncertainty.

Both the ISO-NE forecast and our scenarios illustrate the importance of incorporating energy efficiency as well as PV into load forecasts. If EE and PV were not included, forecasts would be much higher, resulting in extra costs for ratepayers if the grid was designed to serve these higher loads. Our scenarios illustrate the importance of also including EVs and heat pumps in long-term forecasts. While the impacts of these technologies are moderate over the next 10 years (the period covered by the ISO-NE load forecast), for longer time frames these technologies could become increasingly important.

At this point it is probably premature to put too much weight on these long-term scenarios for resource planning. However these scenarios do point out two possibilities that resource planners should keep in mind. First, it is possible that kWh sales and summer peak demand will no longer grow. Existing power plants will retire and may need to be replaced, and the grid will also need investment to replace aging equipment and address growth in some fast-expanding regions, but significant growth in sales and resource needs above present levels are unlikely over the next 25 years. Second, over the longer term (post 2040), electricity sales could grow beyond current levels if EVs and heat pumps take off, and it is possible that the region will become winter-peaking during this period.

We are entering a dynamic period with substantial uncertainty for long-term electricity sales and peaks. Trends in energy efficiency, PV, EV, and heat pump impacts need to be carefully observed and analyzed over the next few years. Resource planners should be sure to incorporate these emerging trends into their long-term forecasting and planning. Such observations and analysis should provide greater clarity to resource planners and help to keep energy consumption, energy costs, and energy sector emissions down while continuing to grow the New England economy.

Introduction

In the United States in recent years, electricity consumption has been approximately flat, even as our population and economy have grown (see figure 1). Analysis by ACEEE (Nadel and Young 2014) and others credits energy efficiency savings for much of the difference between actual consumption and what consumption would have been if it grew in parallel with our economy.[1]

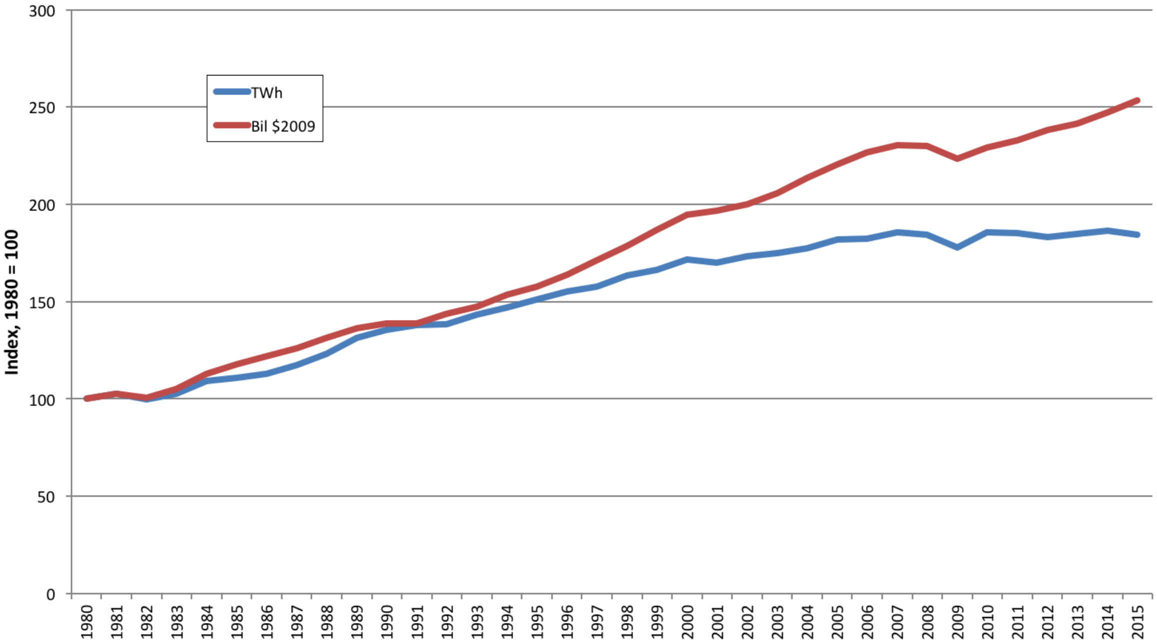

Figure 1. US electricity sales and GDP, 1980–2015. ***Source:*** **ACEEE analysis using data from EIA 2016b.**

Looking forward, further energy efficiency gains are likely, as noted in a recent ACEEE analysis (Molina, Nowak, and Kiker 2016). In addition, a variety of other trends will affect future electricity consumption and peak demand, including:

- Accelerating use of distributed power generation on the customer side of the meter.[2] In particular, power produced by customer-owned or leased photovoltaic (PV) systems has been growing rapidly (e.g., 17% per year average growth in residential PV over the 2012–2015 period).[3]

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[1] See, for example, www.eia.gov/todayinenergy/detail.cfm?id=20031.

[2] We focus on PV on the customer side of the meter as this affects the power demand a utility needs to serve. The utility meets this customer demand using a wide array of resources, including renewable energy projects that the utility may own or contract for.

[3] Derived by ACEEE from tables 10.2a and A6 in EIA 2016b.

- Growing use of electric vehicles (EVs), with several new, moderate-cost models that can go 200 miles between charges about to enter the market.[4] Recent analyses by MIT (Heywood and MacKenzie 2015) and several northeastern environmental organizations (Rushlow et al. 2016) suggest that these trends can be accelerated, noting that electric vehicles generally use less energy than the most efficient gasoline-powered vehicles (including hybrids) and can also reduce greenhouse gas emissions, provided the power comes from low-emissions generation.[5]
- The possible expanded use of electric heat pumps (HPs) to replace space and water heating equipment that burns fossil fuels (mostly natural gas, propane, and fuel oil), driven in part by a desire to reduce greenhouse gas emissions, assuming that the power comes from clean generation. A recent ACEEE paper (Nadel 2016a) explores this issue. Recent progress on high-efficiency heat pumps for use in cold climates expands the opportunity to use heat pumps to replace fuel oil, propane, and in some cases natural gas.[6]

EVs and HPs are more efficient than their fossil-fueled alternatives (EPRI and NRDC 2015; Nadel 2016a). Energy efficiency (EE) can be used to downsize heat pump and PV systems, which lowers their cost and also lowers the energy use of heat pumps. From just an electricity perspective, some of these trends (EE and PV) reduce the amount of power needed from the electric grid, while others (EVs and HPs) increase electricity use even as they decrease total energy use (electricity plus fossil fuels). Furthermore, all of these trends can reduce US greenhouse gas emissions, helping to mitigate the severity of global climate change.[7] And increased use of EE, PV, and HP provides local jobs and contributes to local economic development.[8]

The pace of these different trends is hard to predict, and given the uncertainties, any prediction made today is likely to be wrong. That said, it is useful to explore how these trends might affect electricity consumption and peak demand in the future so we can begin to factor these possible impacts into electric system planning discussions, while recognizing the large uncertainties involved.

This paper is an initial attempt to address this need. It is written for the use of energy system planners as well as policymakers and other interested parties who care about system planning issues. Rather than forecast the future, we explore three possible scenarios that define a range of potential outcomes, without judging which scenario is most likely. As a

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[4] For example, the Chevrolet Bolt and the Tesla Model 3.

[5] See www.afdc.energy.gov/vehicles/electric_emissions.php and EPRI and NRDC 2015.

[6] See www.neep.org/initiatives/high-efficiency-products/emerging-technologies/ashp/cold-climate-air-source-heat-pump. Also see Johnson 2013.

[7] Of course, greenhouse gas emissions also depend on how electricity is generated. In the United States overall, greenhouse gas emissions per kWh are declining due to decreased use of coal and increased use of renewable energy, although these effects are partly offset by increased natural gas use and the closing of several nuclear power plants.

[8] See aceee.org/fact-sheet/ee-job-creation.

first step, we focus in this paper on one region, New England, although in the future we hope to also look at other regions.

We chose New England for this initial analysis for three reasons: (1) all of these trends are active in the region; (2) New England policymakers are particularly interested in reducing greenhouse gas emissions and encouraging these trends; and (3) good data are available for New England.[9] Our results may be broadly indicative for regions in the northern part of the country with old infrastructure and relatively compact development. However differences between regions mean that specific conclusions cannot be drawn for other areas of the country. For instance, findings for New England will not apply in the South or in areas where driving distances are vastly greater.

New England is already very aggressively pursuing energy efficiency. Four of the New England states (Massachusetts, Vermont, Rhode Island, and Connecticut) are in the top 10 in ACEEE's most recent *State Energy Efficiency Scorecard* (Gilleo et al. 2015), and the other two (Maine and New Hampshire) are in the top 20. The New England Independent System Operator (ISO-NE), which runs the electric grid in the region, actively incorporates both energy efficiency and PV in its 10-year load forecast, shown in figure 2. As a result, ISO-NE is forecasting modestly declining electric sales. On the other hand, more of these sales are occurring during peak hours, and therefore ISO-NE predicts modestly growing peak demand through 2025, the last year of its forecast.

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[9] Use of natural gas to generate power is increasing in the region, replacing some coal, oil, and nuclear generation. Regional planners are interested in strategies that can help keep regional greenhouse gas emissions on a downward trajectory.

Figure 2. ISO-NE forecast. *Source:* ISO New England 2016b.

For our analysis, we look at longer-term possibilities using three scenarios:

1. *Business as usual*. We use the reference case from the just released *2016 Annual Energy Outlook* (AEO) prepared by the Energy Information Administration (EIA), a branch of the US Department of Energy (DOE).[10] We used this forecast rather than the forecast from ISO-NE because the EIA forecast extends to 2040, while ISO-NE goes only to 2025. Also, using the AEO will make it easier to adapt our methodology to other regions later. However we do show the ISO-NE forecast through 2025 in the presentation of our results.
2. *Accelerated*, with significantly enhanced programs and policies to promote EE, PV, EV, and HP.
3. *Aggressive*, pushing the boundaries of the levels of EE, PV, EV, and HP that could be achieved.[11]

From an energy efficiency and climate change perspective, these latter scenarios are desirable, given that the New England electric grid primarily uses cleaner power than do many other regions of the country.[12]

Methodology

For our analysis, we used the 2016 AEO as our foundation. We used the AEO reference case, which includes the Clean Power Plan.[13] This analysis covers the 2014–2040 period. The AEO reference case includes assumptions about future penetration of EE programs, PV, EV, and HP. We use these as our starting points, adding to the AEO reference case for our accelerated and aggressive scenarios. EIA has not been entirely clear about how it incorporates energy efficiency in its forecasts, except explicitly stating in 2015 that at the national level about 0.5% energy efficiency savings is included in its reference forecast (EIA 2015). This was based on estimated utility program savings in recent years. Given this statement, we assumed the same method was employed in the 2016 forecast. We find that over the past five years, utility sector efficiency programs have achieved about 0.5% per year efficiency savings nationwide (consistent with EIA 2015) and about 1.5% per year efficiency savings in New England.[14] In its 2016 reference case, EIA estimates that at the national level over the 2014–2040 period, electricity production from PV systems at customer homes and facilities will increase by an average of 8.6% per year, while the

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[10] As noted later, we used New England–specific tables within this forecast.

[11] Even greater penetration of these technologies may be possible if the region truly decides to pull out all the stops.

[12] In 2015, 49% of ISO-NE's power came from natural gas, 30% from nuclear, 16% from hydro and other renewables, and only 6% from coal and oil (www.iso-ne.com/static-assets/documents/2016/02/NE_Power_Grid_2015-2016_Regional_Profile.pdf).

[13] Specifically, we used tables 2.1, 39.1 and 55.5.

[14] ACEEE estimates 0.53% average efficiency savings in the United States and 1.47% in New England over the past five years, using state-specific estimates of energy efficiency program savings by year from ACEEE's annual *State Energy Efficiency Scorecard* (Gilleo et al. 2015).

number of EVs on the road will increase by an average of 4.2% per year.[15] The number of homes heated with HPs will increase 2.3% per year (relative to an annual increase of only 0.8% in the number of homes) (EIA 2016a). In table 1, below, we summarize New England data in the AEO.

For our accelerated case, we increased annual energy efficiency savings to 2.0% per year, up from the 1.47% per year weighted average for New England over the past five years. Three New England states (Massachusetts, Rhode Island, and Vermont) regularly exceed 2% per year, and the other three (Connecticut, Maine and New Hampshire) are ramping up their savings (Gilleo et al. 2015). For residential PVs, in our accelerated case we estimate that by 2040, 50% of the available roof area in the region will be covered by PVs. As discussed later, this is a moderate increase relative to the AEO reference case. Available roof area by state comes from the National Renewable Energy Laboratory (Lopez et al. 2012). For EVs, we ramp up to 20% of the passenger vehicle stock by 2040.[16] And for HPs for space heating, we assume that by 2040, 15% of homes that currently use natural gas, propane, or fuel oil as their primary fuel will switch to HPs.[17] For HPs, since conversions have barely begun, the uncertainties are probably greater than for EE, PV, and EV. Given these uncertainties, as well as a desire to keep the analysis from getting too complicated, we did not include additional use of electric heat pump water heaters in our scenarios.[18]

For our aggressive case we further ramp up our assumptions. We take EE to 2.5% per year (Massachusetts and Rhode Island have been exceeding this level) and PV to 80% of the available roof area by 2040.[19] We ramp up EVs to 33% of the vehicle stock by 2040 (on the

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[15] We include plug-in hybrid vehicles as well as all-electric vehicles.

[16] An MIT analysis estimates roughly 13% penetration by 2040 for the United States (Haywood and MacKenzie 2015), but we estimate New England could be above the US average. Our scenario is not quite as aggressive as one recently proposed by some northeast environmental groups (Rushlow et al. 2016).

[17] This estimate is an educated guess. In New England, more than 40% of homes are heated with fuel oil and additional homes are heated with propane. Both fuels can present good opportunities to switch to heat pumps. In addition, more than half of homes with heat distribution systems use steam or hot water; many of these can instead be heated with ductless heat pumps. Thus, there are many good opportunities to use cold-climate-optimized heat pumps in New England (Neme 2016). Furthermore, Vermont, in part 3 of its 2015 renewable portfolio standard, establishes a 12% "energy transformation" standard by 2032. "Energy transformation" means a net reduction in fossil fuel consumption by utility customers and includes air- and ground-source heat pumps as well as energy efficiency measures. See legislature.vermont.gov/assets/Documents/2016/Docs/ACTS/ACT056/ACT056%20Act%20Summary.pdf.

[18] Inclusion of heat pump water heaters would increase electricity demand in the latter years of our analysis to some extent. Because water heaters generally have substantial storage capacity for hot water, there are also good opportunities to use demand response strategies to help manage the contribution of heat pump water heaters to summer and winter peak demand.

[19] While 80% of available roof area may sound high, the NREL estimates we use may be conservative. For example, as shown in table 1, the 50% penetration of available roof area by 2040 assumption we use for the accelerated case is very similar to the reference case.

road to 50% by 2050, as predicted by Lovins [2011]) and ramp up heat pump conversions to 30% in 2040.[20]

For all scenarios, we estimated kWh sales per year. These are sales by the utilities in the region and *do not* include electricity generation that is used on site but *do* include distributed generation that is provided to the grid by customer-owned power systems. We also estimated peak summer and winter peak electric demand by year using the ratio of annual kWh sales to summer and winter peak demand by year from the most recent ISO-NE load forecast (ISO-NE 2016a).[21] For this peak analysis, we assume that both the summer and the winter peaks occur at 6 p.m. The winter peak in New England currently occurs about then. The summer peak presently occurs a little earlier (e.g., the 2015 summer peak was at 5 p.m.), but as PV generation rises, ISO-NE expects the peak to shift later (ISO-NE, 2016b). For both alternative cases, deviations from the reference case begin in 2017. For 2016, all three cases are the same.

Table 1 compares some key inputs for New England for the three scenarios. Detailed assumptions are documented in Appendix A.

Table 1. Comparison of key drivers for the three scenarios

	Reference case		Accelerated scenario		Aggressive scenario	
Variable	2025	2040	2025	2040	2025	2040
Incremental annual energy efficiency savings	1.47%[1]	1.47%[1]	2.0%	2.0%	2.5%	2.5%
Electric generation from PV (TWh)[2]	3.56[2]	12.73	4.77	12.76	7.64	20.37
EV % of passenger vehicle stock	3.7%[1]	8.4%[1]	7.5%	20%	9.1%[3]	33%
Share of residential fossil systems converted to heat pumps	1%[1]	6%[1]	3%	15%	5%	30%

[1] ACEEE estimates derived from EIA 2016a. [2] By way of comparison, the ISO-NE 2016 forecast estimates 2.96 TWh from PV in 2025 (ISO-NE 2016a). [3] 2025 goal in Rushlow et al. (2016) study.

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[20] Also an educated guess. This results in a similar heat pump penetration in 2030 as the Acadia Center estimates as achievable in a forthcoming report (J. Howland, Acadia Center, personal communication, June 23, 2016). It is also a similar order of magnitude to a heat pump scenario examined by the Vermont Electric Power Company (and summarized in Neme 2016).

[21] For this ratio, we used the ISO-NE 50/50 forecast, which is based on a normal weather year and not an extreme weather year. This forecast extends to 2025. We used the average annual rate of change in these ratios over the 2015–2025 period to estimate these ratios out to 2040.

Scenario Results

In this section we discuss differences between the three scenarios in electricity sales and summer and winter peak demand.

ELECTRICITY SALES

New England electricity sales in the three scenarios are compared in figure 3.[22] This figure also shows the ISO-NE forecast, which extends to 2025.[23] In the AEO reference case, electricity sales decline over the 2015–2018 period and then rise slowly over the balance of the analysis time frame. 2040 sales are 1.0% higher than 2015 sales. The decline in the early years is driven by the commercial sector, while the increase in the latter years is driven by the commercial and transportation sectors. By comparison, the ISO-NE forecast predicts a significant rise in sales in 2016 and then is essentially level over the 2016–2019 period before declining gradually over the next six years. By 2017 the AEO reference case and ISO-NE forecasts are fairly similar, with the ISO-NE forecast tending to track our accelerated scenario in the 2018–2025 period.[24]

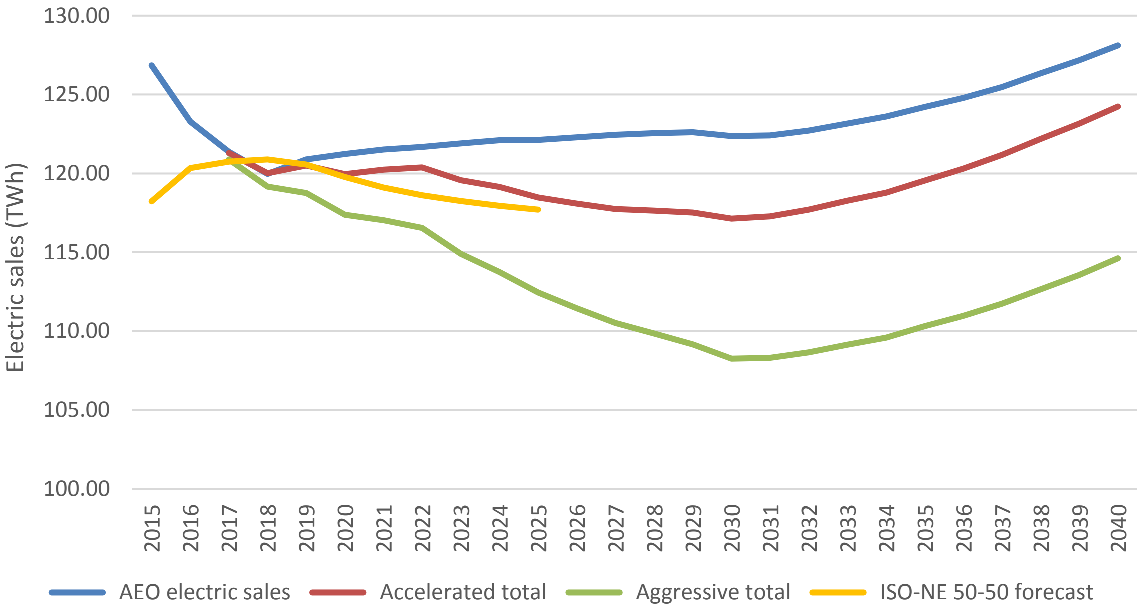

Figure 3. Electricity sales in the three scenarios, 2015–2040, plus ISO-NE forecast for 2015–2025. The ISO-NE forecast is adjusted to eliminate T&D losses.

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[22] This figure shows trends for the overall New England region. Results will likely differ to some extent by state and for subregions.

[23] To enable comparisons between the two forecasts, we reduce the ISO-NE forecast by 6%, as suggested by ISO-NE staff, to adjust for the fact that the ISO-NE forecast includes transmission and distribution (T&D) losses while the AEO numbers we use do not.

[24] AEO predicts sales of 122.1 TWh in 2025 and 128.1 TWh in 2040. ISO-NE predicts 125.2 TWh in 2025, the last year of its forecast. If we subtract 6% T&D losses from the ISO-NE forecast, then its 2025 forecast of sales is 117.7 TWh. We did not do a detailed comparison of the AEO and ISO-NE forecasts.

In the accelerated case, sales decline by 7.7% over the 2015–2030 period but then increase by 6.1% over the subsequent decade. Sales in 2040 are 2.1% lower than sales in 2015. Reasons for these changes are illustrated in figure 4. Enhanced energy efficiency efforts cause a substantial decline in sales; photovoltaics cause a smaller decline. Heat pumps and EVs both increase sales, with heat pumps having the larger effect relative to the reference case.

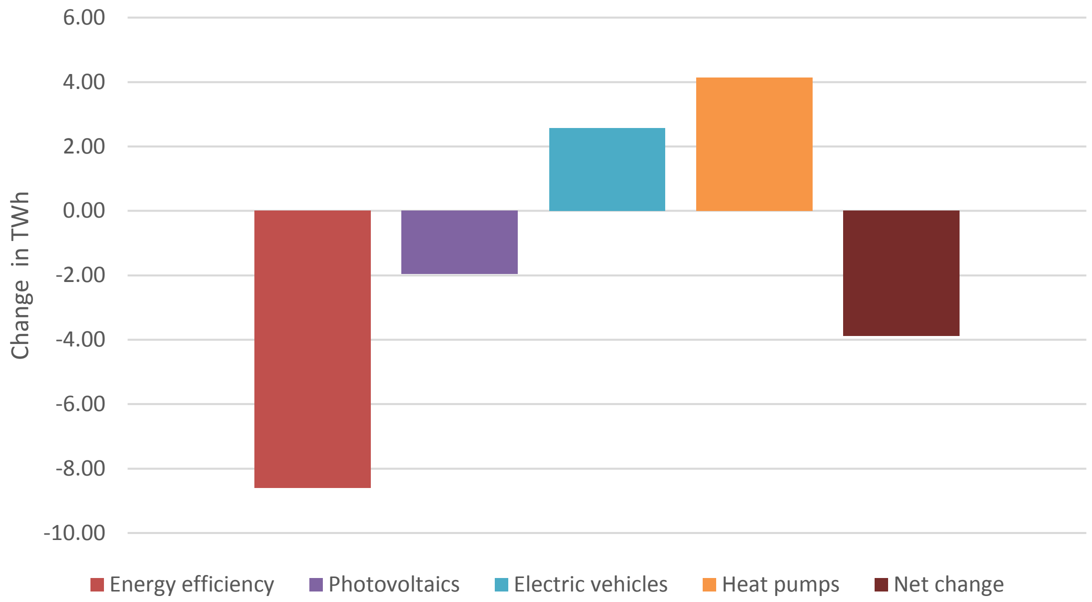

Figure 4. Changes in electricity sales in the accelerated case relative to the reference case in 2040

In the aggressive case, sales decline by 14.7% over the 2015-2030 period, but then increase by 5.9% over the subsequent decade. Sales in 2040 are 9.7% lower than sales in 2015. Relative to the accelerated case, the decline in the aggressive case over the 2015–2030 period is nearly twice as large, while in the 2030–2040 period, sales growth is similar in the accelerated and aggressive scenarios. Figure 5 compares the reference and aggressive scenarios for 2040. Sales decline due to efficiency and PV, only partially offset by growth in EVs and heat pumps. Relative to figure 4, the impact of PVs in decreasing sales is particularly notable.

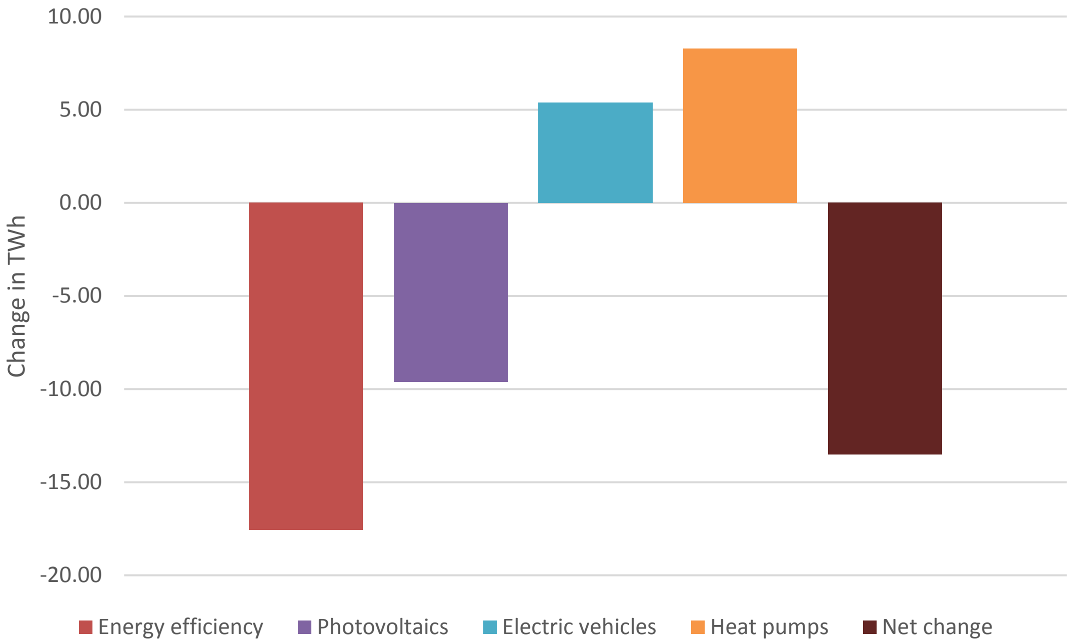

Figure 5. Changes in electricity sales in the aggressive case relative to the reference case in 2040

PEAK DEMAND

Trends in peak demand are shown in figures 6 and 7. These estimates are very approximate as our calculations of peak impact use a variety of simple ratios, as explained in the Methodology and Appendix A.[25] These estimates should be considered indicative and are far from definitive.

Summer peak demand trends in our three scenarios are illustrated in figure 6. In the reference case, both summer and winter peak demand modestly increase. As noted earlier, ISO-NE also predicts gradually rising peak demand (see figure 2), although the ISO-NE estimate for 2016 is higher due to its higher kWh forecast and also due to the fact that figure 2 is based on extreme weather (what grid operators need to plan for) and not average weather.[26] In our accelerated and aggressive scenarios, summer peak demand declines and winter peak demand modestly grows. The decline in summer peak demand is larger in the aggressive case, driven by energy efficiency savings and secondarily by photovoltaics. In the accelerated scenario, summer peak declines until about 2030 and then levels off before

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[25] For example, these estimates do not consider the impact of increased demand response activities or storage, both of which could have a substantial effect on peak demands. Storage could include utility-owned storage, customer-owned in-building storage, and use of electric vehicle batteries during periods when a car is parked and plugged in. These estimates implicitly assume that energy efficiency programs have about the same percentage impact on peak demand as they do on energy consumption.

[26] For example, for the 2025 summer peak, ISO-NE estimates 29,781 MW with extreme weather (10% probability) and 27,122 MW with average weather.

starting modest growth, reflecting the impact of EVs and heat pumps (we assume that a significant share of heat pump growth occurs in homes lacking central air-conditioning as adding air-conditioning to a home can be a significant consumer motivator). The increase in winter peak demand is driven by growth in EVs and heat pumps. In the aggressive scenario, by 2040, summer peak demand is only a little higher than winter peak demand. And the trends are such that the winter peak could surpass the summer peak in the 2040s.[27] Contributions toward the changes in 2040 summer and winter peak demand in the aggressive case are shown in figure 8.

It should be noted that even if peak demand declines overall, some investments in the grid will likely be needed to accommodate areas with above-average growth and also to replace aging equipment.

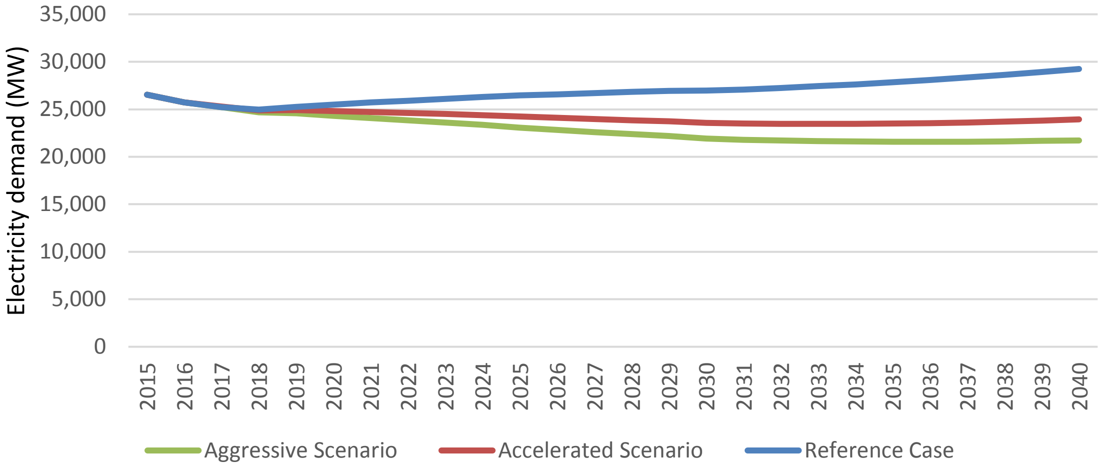

Figure 6. Estimated summer peak demand by year for each of the three scenarios

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[27] New England had a winter peak until about 1990 (ISO-NE 2016c), and then growing use of air-conditioning made the summer peak higher. And Vermont is now winter peaking when the impact of PV is included (J. Howland, Acadia Center, personal communication, June 23, 2016). Also, it should be noted that the summer peak can be reduced through demand response strategies such as cycling air conditioners off. While demand response strategies can also be used to reduce the winter peak, it is unclear if consumers will respond in the same way on very cold days as they respond on very hot days. If consumers do not respond as much in the winter, this could contribute to a higher winter peak.

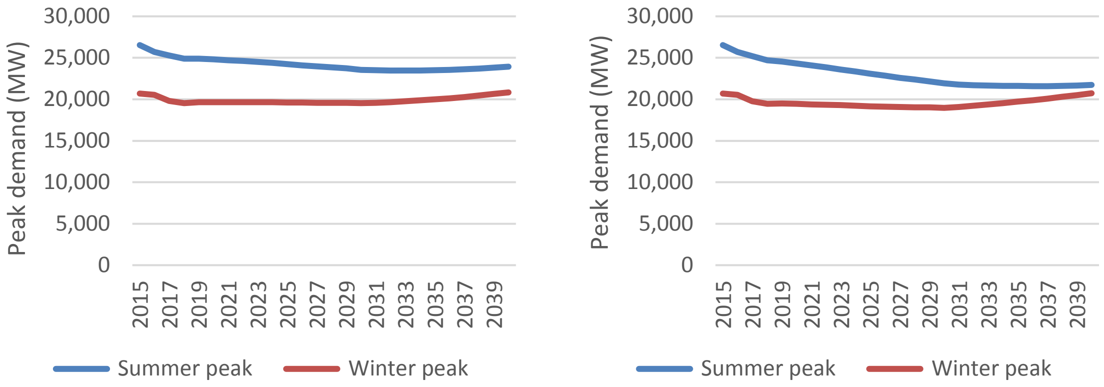

Figure 7. Peak demand trends. Accelerated scenario is on the left, aggressive scenario on the right.

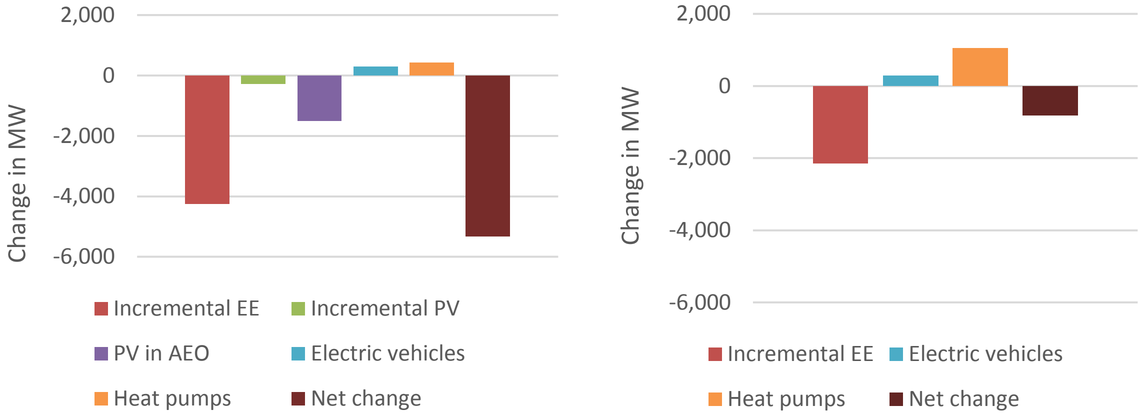

Figure 8. Changes in 2040 summer (left) and winter (right) peak demand in the aggressive scenario relative to the reference scenario. PV is not listed under winter since the winter peak occurs after the sun goes down.

Charts comparing 2030 kWh sales and peak demand to the reference case can be found in Appendix B.

Discussion and Conclusions

The scenarios presented here are highly approximate. The intent is to paint a picture of what *could* happen, not what *will* happen. In the reference case, electricity sales are very similar in 2015 and 2040, with some decline in the first 15 years due in particular to energy efficiency and photovoltaic systems, and then growth in the final decade as electric vehicles and heat pumps become more common. In the accelerated and aggressive scenarios, these trends become more pronounced, with larger declines in the first 15 years and more significant growth in the final 10 years. Still, sales are lower in 2040 in the accelerated and aggressive scenarios than in the reference case as more aggressive energy efficiency and gains in PV more than offset the additional growth in EVs and heat pumps. These results illustrate the power of energy efficiency to keep consumption and emissions down. From a peak demand perspective, the New England region remains summer peaking in all three scenarios, but summer peak declines in both the accelerated and aggressive scenarios and grows only modestly in the reference scenario. In the aggressive scenario a winter peak might happen in the 2040s.

Of course, other scenarios are also possible, such as combining our more aggressive EV and heat pump scenarios with lower levels of efficiency and PV. Such scenarios would result in higher sales and higher summer peaks.

Thus far, the rate of efficiency savings shown in the accelerated and aggressive scenarios has been achieved in several of the New England states, although there is uncertainty about how many years these increased savings rates can be maintained.[28] The levels of PV, EV, and heat pump penetration are more speculative and are subject to large uncertainty.

We recommend close observation over the next few years of PV, EV, and heat pump trends. Such observation can help to identify whether the reference, accelerated, or aggressive scenario is most likely to happen. Such observation can also lead to refinements of these scenarios.

Both the ISO-NE forecast and our scenarios illustrate the importance of incorporating energy efficiency as well as PV into load forecasts. As figure 2 shows, if EE and PV were not included, forecasts would be much higher, resulting in extra costs for ratepayers if the grid is designed to serve these higher loads. Our scenarios illustrate the importance of also including EVs and heat pumps in long-term forecasts. While the impacts of these technologies are moderate over the next 10 years (the period covered by the ISO-NE load forecast), for longer time frames these technologies could become increasingly important.

At this point it is probably premature to put too much weight on these long-term scenarios for resource planning. However these scenarios do point out two possibilities that resource planners should keep in mind. First, it is possible that kWh sales and summer peak demand will no longer grow. Existing power plants will retire and may need to be replaced, but significant growth in sales and resource needs above present levels are unlikely over the next 25 years. Second, over the longer term (post 2040), electricity sales could grow beyond current levels if EVs and heat pumps take off, and it is possible that the region will become winter peaking during this period.

We are entering a dynamic period with substantial uncertainty for long-term electricity sales and peaks. Trends in energy efficiency, PV, EV, and heat pump impacts need to be carefully observed and analyzed over the next few years. Resource planners should be sure to incorporate these emerging trends into their long-term forecasting and planning. Such observations and analysis should provide greater clarity to resource planners and help to keep energy consumption, energy costs, and energy sector emissions down while continuing to grow the New England economy.

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[28] Some reviewers of a draft of this paper thought the levels of efficiency we modeled could be sustained, but others questioned how long these levels of annual savings could endure. The long-term potential for sustained energy efficiency savings is explored further in Nadel 2016b.

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Appendix A. Detailed Analysis

Table A1. Accelerated case

A1. Accelerated case	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**
Electricity sales (TWh)																											
Residential	47.18	47.54	46.93	47.25	47.39	47.29	46.54	46.05	45.63	45.24	44.97	44.53	44.23	44.02	43.90	43.79	43.54	43.42	43.42	43.46	43.51	43.66	43.80	43.95	44.14	44.35	44.57
Commercial/Other	53.06	53.08	49.87	47.32	45.04	45.44	45.96	46.17	46.24	46.21	46.25	46.29	46.45	46.64	46.89	47.09	47.07	47.16	47.35	47.58	47.79	48.09	48.35	48.66	49.03	49.43	49.83
Industrial	27.47	25.78	25.94	26.21	26.93	27.50	28.02	28.52	28.94	29.47	29.80	30.11	30.33	30.40	30.29	30.18	30.12	30.10	30.14	30.25	30.38	30.47	30.60	30.76	31.03	31.22	31.50
Transportation	0.34	0.46	0.54	0.58	0.61	0.65	0.71	0.78	0.87	0.97	1.07	1.18	1.28	1.38	1.47	1.56	1.64	1.72	1.79	1.86	1.92	1.98	2.04	2.09	2.13	2.17	2.21
Total Sales	128.05	126.85	123.28	121.37	119.96	120.89	121.23	121.52	121.67	121.89	122.10	122.11	122.29	122.45	122.55	122.62	122.36	122.41	122.70	123.15	123.60	124.20	124.78	125.46	126.34	127.18	128.11
ISO-NE 50-50 forecast	119.49	118.23	120.33	120.73	120.88	120.56	119.76	119.09	118.61	118.24	117.94	117.70															
Efficiency																											
Efficiency in base			1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%
Additional efficiency (total 2%)				0.18%	0.35%	0.53%	0.53%	0.53%	0.53%	0.53%	0.53%	0.53%	0.53%	0.53%	0.53%	0.53%	0.53%	0.53%	0.53%	0.53%	0.53%	0.53%	0.53%	0.53%	0.53%	0.53%	0.53%
Incremental efficiency savings (TWh)				0.22	0.43	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.62	0.62	0.62	0.62	0.62	0.61	0.61	0.61	0.61	0.61	0.62	0.62	0.62	0.62	0.63
Annual efficiency savings (TWh)				0.22	0.63	1.23	1.80	2.34	2.86	3.34	3.80	4.24	4.65	5.04	5.40	5.75	6.08	6.39	6.69	6.97	7.23	7.48	7.73	7.96	8.18	8.40	8.60
Remaining sales (TWh)				121.15	119.33	119.65	119.43	119.18	118.82	118.55	118.30	117.88	117.64	117.41	117.14	116.86	116.28	116.01	116.01	116.18	116.37	116.72	117.05	117.50	118.15	118.78	119.51
Photovoltaics (TWh)																											
Ramp-up to 50% of tech poten			0	0.53	1.06	1.59	2.12	2.65	3.18	3.71	4.24	4.77	5.30	5.83	6.36	6.89	7.42	7.96	8.49	9.02	9.55	10.08	10.61	11.14	11.67	12.20	12.73
Subtract PV already in AEO				0.38	0.77	1.16	1.54	1.96	2.35	2.72	3.12	3.56	4.04	4.53	5.02	5.51	6.03	6.54	7.06	7.57	8.10	8.62	9.12	9.58	10.02	10.40	10.76
Net PV				0.15	0.29	0.43	0.58	0.69	0.83	1.00	1.13	1.21	1.26	1.30	1.35	1.38	1.39	1.42	1.43	1.44	1.45	1.46	1.49	1.56	1.65	1.80	1.97
Electric vehicles (cars and light trucks)																											
Sales share in AEO	0.55%	1.00%	0.98%	1.08%	1.83%	2.56%	3.67%	4.97%	6.57%	7.34%	8.22%	9.03%	8.64%	8.48%	8.39%	8.53%	8.51%	8.52%	8.52%	8.56%	8.51%	8.43%	8.40%	8.36%	8.24%	8.23%	8.23%
Stock share based on sales 5 years earlier				0.38%	0.36%	0.55%	1.00%	0.98%	1.08%	1.83%	2.56%	3.67%	4.97%	6.57%	7.34%	8.22%	9.03%	8.64%	8.48%	8.39%	8.53%	8.51%	8.52%	8.52%	8.56%	8.51%	8.43%
Stock share with aggressive promotion				0.83%	1.67%	2.50%	3.33%	4.17%	5.00%	5.83%	6.67%	7.50%	8.33%	9.17%	10.00%	10.83%	11.67%	12.50%	13.33%	14.17%	15.00%	15.83%	16.67%	17.50%	18.33%	19.17%	20%
Multiplier relative to AEO				2.19	4.63	4.54	3.34	4.26	4.62	3.19	2.60	2.04	1.68	1.40	1.36	1.32	1.29	1.45	1.57	1.69	1.76	1.86	1.96	2.05	2.14	2.25	2.37
AEO EV electricity use (TWh)				0.24	0.25	0.31	0.37	0.44	0.53	0.63	0.73	0.84	0.94	1.04	1.13	1.22	1.30	1.38	1.45	1.52	1.58	1.64	1.70	1.75	1.79	1.83	1.87
Additional TWh from aggressive promotion				0.29	0.89	1.10	0.86	1.43	1.92	1.37	1.18	0.88	0.64	0.41	0.41	0.39	0.38	0.62	0.83	1.05	1.20	1.42	1.62	1.84	2.05	2.29	2.56
Heat pumps																											
Oil, propane & NG residential space heating energy use (q			0.331	0.332	0.329	0.323	0.318	0.314	0.311	0.308	0.305	0.303	0.300	0.298	0.295	0.292	0.290	0.288	0.285	0.283	0.280	0.278	0.275	0.273	0.271	0.269	0.267
Before conversion, weatherization reduces load 20%					0.263	0.258	0.254	0.251	0.248	0.246	0.244	0.242	0.240	0.238	0.236	0.234	0.232	0.230	0.228	0.226	0.224	0.222	0.220	0.219	0.217	0.215	0.214
% converted to heat pumps				0.00%	0.25%	0.50%	0.75%	1%	1.5%	2%	2.5%	3%	3.50%	4%	4.75%	5.5%	6.25%	7.0%	7.75%	8.5%	9.25%	10%	11%	12%	13%	14%	15%
Electricity consumption from HP conversions (TWh)					0.08	0.17	0.24	0.32	0.48	0.63	0.78	0.93	1.08	1.22	1.44	1.65	1.86	2.07	2.27	2.47	2.67	2.86	3.12	3.38	3.63	3.88	4.13
Summary (TWh)																											
AEO electric sales	128.05	126.85	123.28	121.37	119.96	120.89	121.23	121.52	121.67	121.89	122.10	122.11	122.29	122.45	122.55	122.62	122.36	122.41	122.70	123.15	123.60	124.20	124.78	125.46	126.34	127.18	128.11
Reduction from additional efficiency				-0.22	-0.63	-1.23	-1.80	-2.34	-2.86	-3.34	-3.80	-4.24	-4.65	-5.04	-5.40	-5.75	-6.08	-6.39	-6.69	-6.97	-7.23	-7.48	-7.73	-7.96	-8.18	-8.40	-8.60
Remaining electric sales				121.15	119.33	119.65	119.43	119.18	118.82	118.55	118.30	117.88	117.64	117.41	117.14	116.86	116.28	116.01	116.01	116.18	116.37	116.72	117.05	117.50	118.15	118.78	119.51
Reduction for PV				-0.15	-0.29	-0.43	-0.58	-0.69	-0.83	-1.00	-1.13	-1.21	-1.26	-1.30	-1.35	-1.38	-1.39	-1.42	-1.43	-1.44	-1.45	-1.46	-1.49	-1.56	-1.65	-1.80	-1.97
Addition for EVs				0.29	0.89	1.10	0.86	1.43	1.92	1.37	1.18	0.88	0.64	0.41	0.41	0.39	0.38	0.62	0.83	1.05	1.20	1.42	1.62	1.84	2.05	2.29	2.56
Addition for HPs				0	0.08	0.17	0.24	0.32	0.48	0.63	0.78	0.93	1.08	1.22	1.44	1.65	1.86	2.07	2.27	2.47	2.67	2.86	3.12	3.38	3.63	3.88	4.13
Revised total				121.29	120.01	120.49	119.95	120.24	120.38	119.56	119.13	118.48	118.09	117.75	117.64	117.52	117.13	117.28	117.69	118.26	118.78	119.54	120.30	121.17	122.18	123.15	124.24
Net change				-0.08	0.05	-0.40	-1.28	-1.28	-1.30	-2.33	-2.97	-3.64	-4.20	-4.70	-4.90	-5.10	-5.24	-5.13	-5.01	-4.89	-4.81	-4.67	-4.47	-4.29	-4.15	-4.02	-3.88
Summer Peak (MW, 6pm)																											
Ratio peak to sales		0.209176	0.208602	0.207865	0.208121	0.20881	0.210254	0.211666	0.21295	0.214184	0.215402	0.216607	0.217365	0.218126	0.218889	0.219655	0.220424	0.221196	0.22197	0.222747	0.223526	0.224309	0.225094	0.225882	0.226672	0.227466	0.228262
Peak from sales in AEO		26535	25717	25228	24967	25242	25490	25721	25910	26107	26301	26451	26581	26710	26824	26933	26972	27076	27236	27431	27627	27860	28086	28340	28637	28928	29244
Savings from incremental EE				114	-6	-213	-508	-793	-1057	-1309	-1555	-1793	-1973	-2149	-2321	-2488	-2649	-2808	-2968	-3128	-3286	-3445	-3602	-3761	-3922	-4082	-4245
Remaining electric sales				25342	24961	25029	24982	24929	24854	24798	24746	24658	24608	24560	24503	24445	24323	24267	24268	24303	24341	24415	24484	24579	24715	24846	24999
Reduction for incremental PV				-21	-41	-61	-82	-96	-117	-139	-157	-169	-177	-182	-188	-193	-195	-198	-199	-202	-203	-204	-208	-217	-231	-252	-275
Reduction for PV in AEO				-53	-107	-162	-215	-274	-328	-379	-435	-497	-564	-633	-701	-770	-842	-913	-986	-1058	-1131	-1204	-1273	-1338	-1399	-1452	-1503
Watts per vehicle at 6 pm				0.565	0.560	0.555	0.550	0.540	0.530	0.520	0.510	0.500	0.490	0.480	0.470	0.460	0.450	0.435	0.420	0.405	0.390	0.375	0.360	0.345	0.330	0.315	0.300
Addition for EVs				22	61	89	102	134	161	164	165	152	131	100	100	96	94	134	162	186	202	220	236	249	262	272	283
Addition for HPs				0	7	14	21	28	42	57	71	85	99	113	135	156	177	198	220	241	262	283	312	340	368	397	425
Total		26535	25717	25291	24882	24911	24809	24721	24614	24500	24389	24228	24098	23959	23849	23734	23558	23488	23464	23470	23472	23512	23550	23613	23716	23811	23929
Net change				62	-85	-332	-681	-1001	-1297	-1607	-1912	-2223	-2484	-2751	-2975	-3200	-3414	-3588	-3772	-3961	-4156	-4349	-4536	-4727	-4921	-5117	-5315
Approx PV nominal system MW				370	741	1111	1481	1852	2222	2593	2963	3333	3704	4074	4444	4815	5185	5555	5926	6296	6666	7037	7407	7778	8148	8518	8889
Winter Peak (GW, 6pm)																											
Ratio peak to sales		0.163151	0.166701	0.166133	0.164715	0.16479	0.165052	0.165255	0.165359	0.165412	0.165445	0.165454	0.165686	0.165918	0.16615	0.166383	0.166615	0.166849	0.167082	0.167316	0.167551	0.167785	0.16802	0.168255	0.168491	0.168727	0.168963
Peak from sales in AEO		20696	20551	20163	19760	19921	20010	20082	20120	20162	20201	20204	20262	20317	20361	20401	20388	20423	20501	20605	20709	20840	20965	21110	21286	21458	21647
Savings from incremental EE				-397	-291	-399	-525	-638	-735	-821	-900	-972	-1068	-1160	-1249	-1335	-1416	-1496	-1573	-1649	-1723	-1797	-1868	-1939	-2009	-2079	-2148
Remaining electric sales				19766	19469	19522	19485	19444	19385	19342	19301	19232	19193	19156	19112	19066	18972	18928	18928	18955	18985	19043	19097	19171	19277	19379	19498
Reduction for PV				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Addition for EVs				22	61	89	102	134	161	164	165	152	131	100	100	96	94	134	162	186	202	220	236	249	262	272	283
Addition for HPs				0	21	42	62	81	121	160	198	236	273	309	364	418	472	524	575	626	676	725	791	856	921	984	1047
Total		20696	20551	19788	19552	19653	19649	19659	19667	19665	19664	19619	19597	19565	19576	19580	19538	19585	19665	19767	19862	19988	20123	20276	20460	20635	20828
Net change				-376	-208	-268	-361	-423	-453	-497	-537	-585	-665	-752	-785	-821	-850	-838	-836	-838	-846	-852	-842	-834	-827	-823	-818

Notes to Table A1

- The major assumptions are discussed in the text.
- For annual efficiency savings, we assume that 5% of prior-year savings are lost each year. This is based on a 10-year average measure life, with some measures lasting longer and some ending sooner (Molina 2014). Half of the measures are in place and saving after 10 years, an average loss of 5% per year.
- For electric vehicles, we estimate that the share of EVs in the vehicle stock is equivalent to the share of EV sales five years earlier. In other words, the EV share in the stock lags the EV share in sales, since less than 10% of vehicles are replaced each year. We estimate the energy use of EVs beyond those included in the AEO by calculating a ratio of EV stock in our accelerated and aggressive cases to the EV stock in the AEO and multiplying EV energy use in the AEO by this ratio. Assumptions on EV miles traveled and miles/kWh are part of the AEO, and we implicitly use these same assumptions.
- We assume that transportation electricity use in 2012 was all due to public transportation and that subsequent growth in electricity used for transportation is due to EVs. This is a simplification that makes modeling much easier.
- Before or when homes are converted to heat pumps, we assume that energy efficiency measures are employed to reduce heating energy needs by 20%, allowing a smaller heat pump system.
- Heat pump performance is based on a prototype cold-climate heat pump tested over several winters in New Haven, Connecticut (Johnson 2013). We assume that, on average, the fossil fuel systems being replaced have a 90% annual fuel utilization efficiency (AFUE). In New England, 71% of homes have air-conditioning and 29% do not (EIA 2013). We assume that 75% of the homes that convert to heat pumps do not have air-conditioning before the conversion, while 25% do have air conditioning. The 75% that add air-conditioning use an average of 332 kWh per year for air-conditioning (average use of New England homes with air-conditioning, per EIA 2013).
- We convert the kWh produced by PV systems into peak demand by dividing kWh by 1,074 kWh produced per kW of system capacity (from ISO-NE 2016b) and then multiplying by 15%, where 15% is an estimate of the load factor of PV systems at 6 p.m. on a very hot day. (ISO-NE 2016b estimates this to be just over 20% when 8,000 MW of PV is installed, but we reduce this to 15% because some of the effect of PV on peak load is already reflected in the impact of PV on lowering kWh sales.)
- For EVs, we estimate that the average vehicle draws 600 W for charging at 6 p.m., ramping down to 300 W by 2040. These figures come from Hostick et al. 2012 (p. K-11) and presume that smart charging during off-peak hours gradually becomes more common. We multiply this estimate of W/EV by the number of EVs, which we estimate by multiplying the incremental EV stock share (relative to the AEO (EIA 2016a)) by the number of vehicles in the stock. This latter figure we estimate by multiplying the number of new vehicles sold each year (from the AEO) by the average age of vehicles on US roads (from www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_01_26.html_mfd).
- For heat pumps, winter peak is estimated for 6 p.m. using the EPRI Load Shape Library 3.0 (loadshape.epri.com/). We convert the annual kWh for winter space heating and summer air-conditioning (only for homes previously without air-conditioning) into peak kW using these load shapes. For winter, the EPRI load shape shows a ratio for the Northeast of 0.5711 kW at 6 p.m. to 2,286 annual kWh (these figures are both per 1 kW of load). For summer, the ratio is 1 kW of peak load per 560.7 of AC kWh.

Table A2. Aggressive case

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Efficiency																											
Efficiency in base			1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%	1.47%
Additional efficiency (total 2.5%)				0.34%	0.69%	1.03%	1.03%	1.03%	1.03%	1.03%	1.03%	1.03%	1.03%	1.03%	1.03%	1.03%	1.03%	1.03%	1.03%	1.03%	1.03%	1.03%	1.03%	1.03%	1.03%	1.03%	1.03%
Incremental efficiency savings (TWh)				0.42	0.83	1.23	1.24	1.25	1.25	1.25	1.25	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.27	1.27	1.28	1.28	1.29	1.30	1.31
Annual efficiency savings (TWh)				0.42	1.23	2.41	3.53	4.60	5.62	6.59	7.51	8.39	9.23	10.03	10.78	11.50	12.19	12.84	13.46	14.04	14.61	15.15	15.67	16.17	16.65	17.12	17.57
Remaining sales (TWh)				120.95	118.73	118.48	117.70	116.92	116.06	115.30	114.59	113.72	113.06	112.43	111.76	111.11	110.17	109.57	109.25	109.10	108.99	109.05	109.11	109.29	109.68	110.06	110.54
Photovoltaics (TWh)																											
Ramp-up to 80% of tech poten			0	0.85	1.70	2.55	3.39	4.24	5.09	5.94	6.79	7.64	8.49	9.33	10.18	11.03	11.88	12.73	13.58	14.43	15.27	16.12	16.97	17.82	18.67	19.52	20.37
Subtract PV already in AEO				0.38	0.77	1.16	1.54	1.96	2.35	2.72	3.12	3.56	4.04	4.53	5.02	5.51	6.03	6.54	7.06	7.57	8.10	8.62	9.12	9.58	10.02	10.40	10.76
Net PV				0.47	0.93	1.39	1.86	2.28	2.74	3.22	3.67	4.08	4.45	4.80	5.16	5.52	5.85	6.19	6.52	6.85	7.18	7.50	7.85	8.24	8.65	9.12	9.61
Electric vehicles (cars and light trucks)																											
Sales share in AEO	0.55%	1.00%	0.98%	1.08%	1.83%	2.56%	3.67%	4.97%	6.57%	7.34%	8.22%	9.03%	8.64%	8.48%	8.39%	8.53%	8.51%	8.52%	8.52%	8.56%	8.51%	8.43%	8.40%	8.36%	8.24%	8.23%	8.23%
Stock share based on sales 5 years earlier				0.38%	0.36%	0.55%	1.00%	0.98%	1.08%	1.83%	2.56%	3.67%	4.97%	6.57%	7.34%	8.22%	9.03%	8.64%	8.48%	8.39%	8.53%	8.51%	8.52%	8.52%	8.56%	8.51%	8.43%
Stock share with aggressive promotion				1.0%	2.0%	3.0%	4.0%	5.1%	6.1%	7.1%	8.1%	9.1%	10.2%	11.4%	12.7%	14.1%	15.6%	17.3%	19.0%	20.8%	22.5%	24.2%	25.9%	27.6%	29.4%	31.1%	32.8%
Multiplier relative to AEO				2.66	5.62	5.51	4.05	5.17	5.60	3.87	3.16	2.48	2.05	1.74	1.73	1.71	1.73	2.00	2.25	2.47	2.63	2.85	3.04	3.24	3.43	3.65	3.89
AEO EV electricity use (TWh)				0.24	0.27	0.31	0.37	0.44	0.53	0.63	0.73	0.84	0.94	1.04	1.13	1.22	1.30	1.38	1.45	1.52	1.58	1.64	1.70	1.75	1.79	1.83	1.87
Additional TWh from aggressive promotion				0.40	1.26	1.41	1.12	1.83	2.44	1.80	1.58	1.25	0.99	0.76	0.82	0.87	0.95	1.38	1.81	2.24	2.59	3.03	3.47	3.92	4.36	4.85	5.40
Heat pumps																											
Oil, propane & NG residential space heating energy use (q			0.331	0.332	0.329	0.323	0.318	0.314	0.311	0.308	0.305	0.303	0.300	0.298	0.295	0.292	0.290	0.288	0.285	0.283	0.280	0.278	0.275	0.273	0.271	0.269	0.267
Before conversion, weatherization reduces load 20%					0.263	0.258	0.254	0.251	0.248	0.246	0.244	0.242	0.240	0.238	0.236	0.234	0.232	0.230	0.228	0.226	0.224	0.222	0.220	0.219	0.217	0.215	0.214
% converted to heat pumps				0.0%	0.25%	0.75%	1.25%	1.75%	2.5%	3.25%	4%	5%	6%	7%	8%	9%	10%	12%	14%	16%	18%	20%	22%	24%	26%	28%	30%
Electricity consumption from HP conversions (TWh)					0.08	0.25	0.41	0.56	0.79	1.02	1.25	1.55	1.85	2.14	2.42	2.70	2.98	3.55	4.10	4.65	5.19	5.72	6.24	6.76	7.27	7.77	8.27
Summary (TWh)																											
AEO electric sales		126.85	123.28	121.37	119.96	120.89	121.23	121.52	121.67	121.89	122.10	122.11	122.29	122.45	122.55	122.62	122.36	122.41	122.70	123.15	123.60	124.20	124.78	125.46	126.34	127.18	128.11
Reduction from additional efficiency				-0.42	-1.23	-2.41	-3.53	-4.60	-5.62	-6.59	-7.51	-8.39	-9.23	-10.03	-10.78	-11.50	-12.19	-12.84	-13.46	-14.04	-14.61	-15.15	-15.67	-16.17	-16.65	-17.12	-17.57
Remaining electric sales				120.95	118.73	118.48	117.70	116.92	116.06	115.30	114.59	113.72	113.06	112.43	111.76	111.11	110.17	109.57	109.25	109.10	108.99	109.05	109.11	109.29	109.68	110.06	110.54
Reduction for PV				-0.47	-0.93	-1.39	-1.86	-2.28	-2.74	-3.22	-3.67	-4.08	-4.45	-4.80	-5.16	-5.52	-5.85	-6.19	-6.52	-6.85	-7.18	-7.50	-7.85	-8.24	-8.65	-9.12	-9.61
Addition for EVs				0.40	1.26	1.41	1.12	1.83	2.44	1.80	1.58	1.25	0.99	0.76	0.82	0.87	0.95	1.38	1.81	2.24	2.59	3.03	3.47	3.92	4.36	4.85	5.40
Addition for HPs				0	0.08	0.25	0.41	0.56	0.79	1.02	1.25	1.55	1.85	2.14	2.42	2.70	2.98	3.55	4.10	4.65	5.19	5.72	6.24	6.76	7.27	7.77	8.27
Revised total				120.88	119.15	118.75	117.37	117.03	116.55	114.90	113.75	112.44	111.45	110.52	109.85	109.17	108.25	108.31	108.64	109.14	109.59	110.30	110.96	111.74	112.66	113.56	114.60
Net change				-0.49	-0.82	-2.14	-3.86	-4.48	-5.13	-6.99	-8.35	-9.67	-10.84	-11.93	-12.70	-13.45	-14.11	-14.10	-14.06	-14.00	-14.01	-13.90	-13.82	-13.73	-13.68	-13.61	-13.51
Summer Peak (MW, 6pm)																											
Ratio peak to sales		0.209	0.209	0.208	0.208	0.209	0.210	0.212	0.213	0.214	0.215	0.217	0.217	0.218	0.219	0.220	0.220	0.221	0.222	0.223	0.224	0.224	0.225	0.226	0.227	0.227	0.228
Peak from sales in AEO		26535	25717	25228	24967	25242	25490	25721	25910	26107	26301	26451	26581	26710	26824	26933	26972	27076	27236	27431	27627	27860	28086	28340	28637	28928	29244
Savings from incremental EE				71	-131	-459	-869	-1264	-1634	-1989	-2332	-2663	-2932	-3193	-3446	-3691	-3926	-4157	-4384	-4609	-4829	-5048	-5264	-5478	-5693	-5906	-6120
Remaining electric sales				25299	24836	24783	24621	24457	24276	24118	23969	23788	23649	23517	23378	23242	23046	22919	22852	22822	22798	22812	22823	22862	22943	23022	23123
Reduction for incremental PV				-65	-130	-194	-259	-318	-383	-450	-513	-569	-621	-671	-721	-771	-817	-865	-910	-957	-1003	-1048	-1097	-1151	-1209	-1274	-1342
Reduction for PV in AEO				-53	-107	-162	-215	-274	-328	-379	-435	-497	-564	-633	-701	-770	-842	-913	-986	-1058	-1131	-1204	-1273	-1338	-1399	-1452	-1503
Watts per vehicle at 6pm				0.565	0.560	0.555	0.550	0.540	0.530	0.520	0.510	0.500	0.490	0.480	0.470	0.460	0.450	0.435	0.420	0.405	0.390	0.375	0.360	0.345	0.330	0.315	0.300
Addition for EVs				30	78	114	132	172	205	215	222	215	203	185	202	215	235	301	352	398	435	471	503	531	558	577	596
Addition for HPs				0	7	21	35	50	71	92	113	142	170	198	227	255	283	340	397	453	510	567	623	680	737	793	850
Total		26535	25717	25212	24685	24564	24315	24086	23841	23596	23357	23078	22838	22597	22385	22172	21906	21782	21705	21659	21609	21598	21579	21584	21631	21666	21725
Net change				-17	-283	-679	-1175	-1636	-2070	-2511	-2944	-3373	-3744	-4113	-4440	-4762	-5067	-5294	-5531	-5773	-6018	-6262	-6507	-6756	-7006	-7262	-7519
Approx. PV nominal system MW				593	1185	1778	2370	2963	3555	4148	4741	5333	5926	6518	7111	7703	8296	8889	9481	10074	10666	11259	11851	12444	13037	13629	14222
Winter Peak (MW, 6pm)																											
Ratio peak to sales		0.163	0.167	0.166	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.166	0.166	0.166	0.166	0.167	0.167	0.167	0.167	0.168	0.168	0.168	0.168	0.168	0.169	0.169
Peak from sales in AEO		20696	20551	20163	19760	19921	20010	20082	20120	20162	20201	20204	20262	20317	20361	20401	20388	20423	20501	20605	20709	20840	20965	21110	21286	21458	21647
Savings from incremental EE				-431	-389	-591	-806	-1006	-1185	-1351	-1506	-1651	-1816	-1974	-2127	-2273	-2413	-2547	-2678	-2804	-2927	-3047	-3164	-3278	-3391	-3502	-3611
Remaining electric sales				19733	19371	19330	19204	19076	18935	18812	18695	18554	18446	18342	18234	18128	17975	17876	17824	17800	17781	17792	17801	17831	17895	17956	18036
Reduction for PV				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Addition for EVs				30	78	114	132	172	205	215	222	215	203	185	202	215	235	301	352	398	435	471	503	531	558	577	596
Addition for HPs				0	21	63	103	142	201	259	317	393	468	541	614	685	755	898	1040	1178	1315	1449	1581	1712	1841	1968	2095
Total		20696	20551	19763	19471	19507	19439	19390	19341	19286	19234	19162	19117	19069	19050	19028	18965	19075	19216	19376	19531	19713	19885	20074	20294	20501	20726
Net change				-400	-289	-414	-571	-692	-779	-876	-967	-1043	-1145	-1248	-1311	-1373	-1423	-1348	-1286	-1228	-1178	-1126	-1079	-1036	-992	-957	-920

All notes from table A1 also apply to table A2.

Appendix B. Comparison of 2030 Sales and Peak Demand to the Reference Case

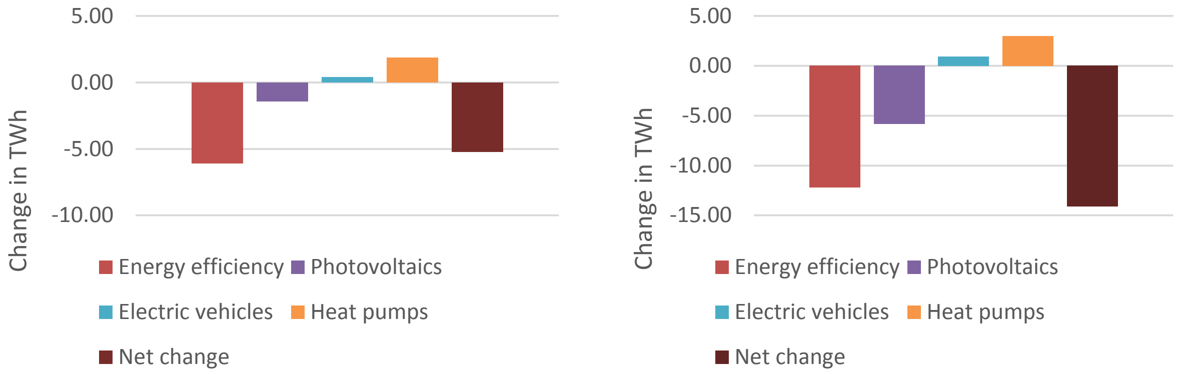

Figure B1. Comparison of 2030 sales in the accelerated scenario (left) and the aggressive scenario (right) to the reference case

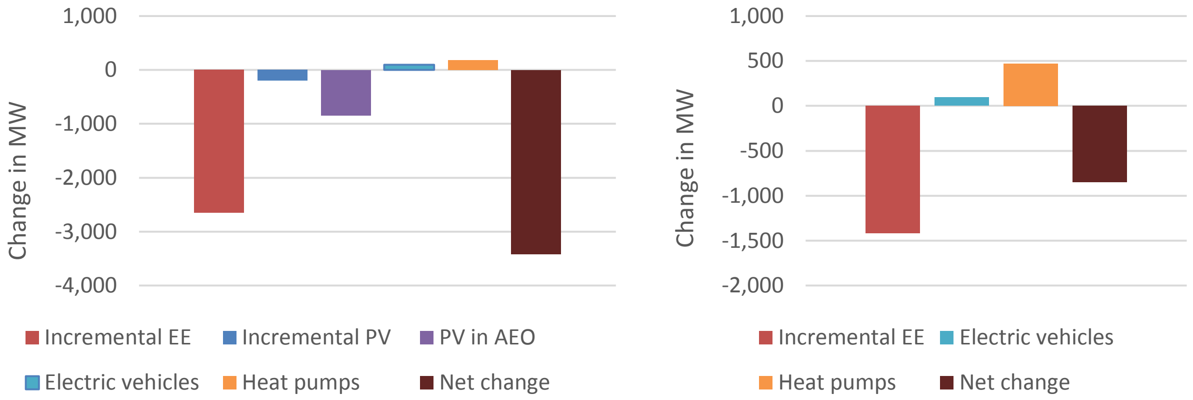

Figure B2. Comparison of 2030 summer (left) and winter (right) peak demand in the accelerated scenario to the reference case.

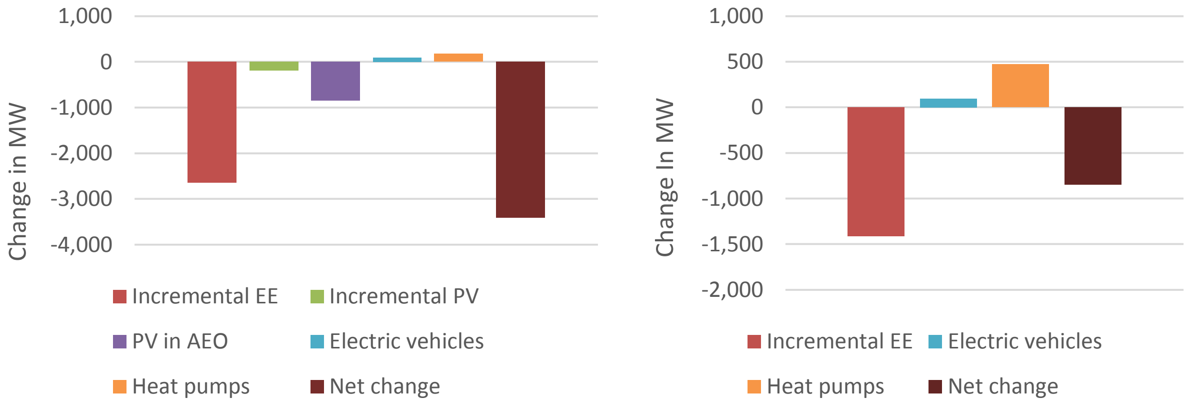

Figure B3. Comparison of 2030 summer (left) and winter (right) peak demand in the aggressive scenario to the reference case.