Acadia Center

EnergyVision 2030

Technical Appendix

Executive Summary

EnergyVision 2030 shows that it is viable for states to redouble efforts in the near-term to support and expand clean energy markets in ways that will put the Northeast (New York, Connecticut, Rhode Island, Massachusetts, Vermont, New Hampshire, and Maine) on track to meet its 2050 emissions targets. The report draws a straight line from today's emissions to the 2050 requirements to determine that in 2030 emissions need to be reduced by approximately 45% of 1990 levels to meet these goals. To understand the specific steps the region needs to take to reach a 45% GHG emissions reduction target – the reductions needed in 2030 for states to meet 2050 requirements – Acadia Center performed modeling analysis using the Long-range Energy Alternatives Planning System (LEAP) to examine the entire energy system of the Northeast. Three scenarios were developed to assess the options that states have to reduce their emissions: (1) a Baseline scenario ("business as usual") that projected emissions in 2030 without any policy changes, (2) the Primary Scenario that will achieve the 45% reduction from 1990 levels, and (3) an Accelerated Scenario that examines options for ambitious states that want to lead the region in reducing emissions. The following is a brief overview of the modeling inputs for each scenario, which are described in detail in this Technical Appendix:

Baseline Scenario

The Baseline Scenario is a "business as usual" or "BAU" forecast for the Northeast that considers no new policy changes. It is based on the Energy Information Administration's 2016 Annual Energy Outlook and forecasts by the New York and New England Independent System Operators, with changes to reflect recent policy actions by states, such as the agreement by MA, CT, and RI to procure additional hydropower and the adoption of the Clean Energy Standard in NY. By 2030, as older power plants like coal, oil, and uneconomic nuclear come offline, wind and solar power increase to the limits set by existing state renewable portfolio requirements (~22% on average excluding hydropower) and related state-initiated purchases of renewable energy. The five large nuclear plants in the region (Millstone Nuclear Power Station in CT, Seabrook Station Nuclear Power Plant in NH, and Ginna Nuclear Power Plant, Nine Mile Point Nuclear Generating Station, and James A. Fitzpatrick Power Plant in NY) remain in operation through 2030, which assumes license renewals for some plants. Beyond power generation, the Baseline Scenario projects that electric vehicles will make up 5% of cars and light trucks by 2030. In residential buildings, heat pumps will make up just 3% of heating stock and average annual energy efficiency will decrease from today's levels to 1%. By modeling this Baseline Scenario, it is clear that the region will not meet the 45% 2030 emission reduction target, nor is it likely to meet the 2050 requirement, without new policy actions, as emissions reductions are only 30% of 1990 levels in 2030.

Primary Scenario

In the Primary Scenario, Acadia Center modeled changes in clean energy market penetration levels to ascertain what incremental additions of clean energy across the key sectors would be needed to reach the 2030 goal of a

45% reduction from 1990 levels. In doing this, Acadia Center increased renewable generation to levels greater than the current state RPSs in New England, while maintaining the recently established Clean Energy Standard in New York. The remaining generation mix was designed to keep nuclear and imported hydropower at the Baseline Scenario levels, with fossil fuel generation dispatched to meet the remaining load. In addition to generation resources, 2000 MW of demand response, 1800 MW of advanced load management, and 4200 MW of energy storage capacity were added to the grid to optimize load. In buildings, electric and natural gas efficiency annual incremental savings goals were increased from the Baseline Scenario to an average of 2.5% and 1.4%, respectively across all states; heat pumps replaced fossil fuels for 13% of residential building heating needs. In transportation, electric vehicles were increased to 17% of cars and light trucks based on state commitments, and 2.5% of medium duty vehicles like box trucks and buses were electrified.

Accelerated Scenario

In the Accelerated Scenario, Acadia Center modeled additional enhancements in clean energy market penetration levels to reach a 50% emissions reduction by 2030, with the goal of providing ambitious states a picture of the emissions reductions from stronger – but still achievable – policy actions. In the Accelerated Scenario, renewable generation was ramped up in both New England and New York beyond the levels in Primary Scenario. As with the Primary Scenario, the remaining generation mix maintained the same level of nuclear and imported hydropower, and fossil fuel generation was dispatched to meet the remaining load. Grid modernization resources were increased to 5000 MW of total demand response, 3000 MW of advanced load management, and 6000 MW of energy storage capacity. Electric and natural gas efficiency annual incremental savings were increased to 2.7% and 1.6% respectively across all states, and heat pumps were increased to replace 16% of fossil fuel in residential building heating. In this Accelerated Scenario, electric vehicles comprised 23% of cars and light trucks, with 5% of medium duty vehicles also being electrified.

Introduction & Purpose

EnergyVision 2030 shows that it is viable for states to redouble efforts in the near-term to support and expand clean energy markets in ways that will put the Northeast (New York, Connecticut, Rhode Island, Massachusetts, Vermont, New Hampshire, and Maine) on track to meet a scientifically directed target of 80% emissions reduction from 1990 levels by 2030. The report draws a straight line from today's emissions to the 2050 requirements, concluding that in 2030 emissions need to be reduced by approximately 45% from 1990 levels. To understand the specific steps the region needs to take to reach this 45% reduction target, Acadia Center performed modeling analysis using the Long-range Energy Alternatives Planning (LEAP) System to examine the entire energy system of the Northeast. Three scenarios were developed to assess the options that states have to reduce their emissions:(1) a Baseline Scenario ("business as usual") that projected emissions in 2030 without any policy changes, (2) the Primary Scenario that will achieve the 45% reduction from 1990 levels, and (3) an Accelerated Scenario that examines options for ambitious states that want to lead the region in reducing emissions. In each scenario, energy system was analyzed by sector: buildings, transportation, industries and electricity generation. Waste and agriculture sector emissions were forecasted outside of the LEAP model based on historical trends. For each sector in the Primary Scenario, combinations of penetration levels of clean energy technologies that will lead to the necessary reductions from 1990 levels were analyzed. In the Primary and Accelerated Scenarios, clean energy technologies and the forecast of their growth are based on literature reviews, commitments made by states, demonstrated achievements and likely technological advances.

Each scenario was constructed using existing data and technology-informed forecasting. This appendix describes the basis for each scenario in detail and shows the resulting emissions outputs from LEAP by sector.

Methodology Overview

Modeling was conducted using the Long-range Energy Alternatives Planning (LEAP) System, supplemented with external modeling as needed. For all three scenarios, top-down projections of energy consumption and production were put into LEAP to generate greenhouse gas (GHG) emissions across all sectors of the economy. Most of the Baseline Scenario inputs were based on the Energy Information Administration's (EIA's) 2016 Annual Energy Outlook (AEO) "Reference Case" fuels consumption forecast and the New York and New England Independent System Operator's electricity forecasts. These projections were then modified for renewable generation based on recently approved state plans or legislation, including the Clean Energy Standard (CES) in NY, a Renewable Portfolio Standard (RPS) increase in Rhode Island, and hydropower import authorizations. For the Primary and Accelerated Scenarios, changes to the baseline consumption were made based on forecasts of clean energy technology penetrations in different sectors. These forecasts were constructed external to the LEAP model and are described in more detail below. The electric generation mix and corresponding fuel consumption required to meet the demand was determined using LEAP's dispatch model, which evaluated solutions for eight different time periods of average seasonal demand. The following sections provide methodology details and data sets for each of the three scenarios: Baseline, Primary, and Accelerated.

Baseline Scenario

Sources & Adjustments

The Baseline Scenario is based primarily on inputs from the AEO "Reference Case," which includes the Clean Power Plan. The transportation sector diesel consumption forecast is based on the EIA AEO 2016 phase 2 standards scenario that includes the impacts of the EPA/DOT fuel efficiency standards for medium and heavy duty vehicles. The transportation sector gasoline consumption forecast in AEO 2016 includes Corporate Average Fuel Economy (CAFÉ) standards established by the EPA and DOT through 2025. The National Energy Modeling System (NEMS) that is the basis for the AEO provides a technology-based bottom-up analysis of energy demand and production, with the exception of the electricity consumption forecast. NEMS generates regional results for New England, which were used directly, while data for New York were dis-aggregated from the NEMS Mid-Atlantic regional output by adjusting them with the ratio of New York and Mid-Atlantic states 2014 consumption data from the EIA State Energy Data System (SEDS) database The electricity consumption forecast for New England is from the 2016 ISO New England (ISO-NE) Capacity, Energy, Loads, and Transmission (CELT) report, and the New York electricity consumption forecast is from the 2016 New York ISO (NYISO) Load and Capacity report ("Gold Book"). These consumption forecasts only extend through 2025, so for the 2026–2030 period, the growth rates from the reports were used to forecast consumption beyond 2025. Acadia Center developed the forecast for electricity generation to meet the forecasted demand using the LEAP dispatch model with heat rate and capacity inputs from Egrid 2012, AEO 2016 fuel prices and capacity projections, and renewables capacity projections developed in-house based on adopted state energy policy. The details of the AEO model, the CELT report and the NYISO Gold Book can be found on the EIA,[1] ISO-NE,[2] and the NYISO[3] websites. The LEAP dispatch model and Acadia Center's modifications to the AEO are described in this section.

Generation

Acadia Center modified the AEO generation forecast to include several state energy system changes not captured: the scheduled closure of Indian Point Nuclear plant in New York,[4] the enactment of the Clean Energy Standard (CES) in New York,[5] the tristate (Massachusetts, Rhode Island, and Connecticut) plan to import

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[1] https://www.eia.gov/outlooks/archive/aeo16/
[2] https://www.iso-ne.com/system-planning/system-plans-studies/celt
[3] http://www.nyiso.com/public/markets_operations/market_data/reports_info/index.jsp
[4] http://www.entergynewsroom.com/latest-news/entergy-ny-officials-agree-indian-point-closure-2020-2021/
[5] https://www.nyserda.ny.gov/All-Programs/Programs/Clean-Energy-Standard

additional hydropower,[6] and the approved Rhode Island Renewable Portfolio Standard (RPS) increase.[7] The following is a description of the generation forecast by resource.

Solar

The Baseline Scenario inputs for the utility-scale solar generation projection were developed for New England to meet the total renewables penetration projected in AEO, which is based on an aggregated RPS, with adjustments made in-house to include the approved Rhode Island RPS increase. The model inputs for New York were developed to meet the approved CES. In the Baseline Scenario, utility scale solar is projected to grow in the Northeast and be 5% of the generation resource mix by 2030. For distributed solar, the inputs were based on distributed solar generation forecasts published by ISO-NE and NYISO, which were modified to reflect the recently adopted RPS increase in Rhode Island and CES in New York. As the ISO reports extend only to 2025, data inputs for 2026–2030 were projected from the published forecasts using the growth rates provided in the reports. The resulting distributed generation represents about 7% of the resource mix in 2030 for the Northeast. Solar hourly generation profiles were constructed for both New England and New York using the NREL PVWatts calculator.[8]

Wind

The Baseline Scenario inputs for the onshore wind generation projection in New England were developed to meet the total renewables penetration projected in AEO, which is based on an aggregated RPS, with adjustments made in-house to include the recent Rhode Island RPS increase. The projections for New York were developed to meet the approved CES. For the Northeast, the Baseline Scenario projected onshore and offshore wind to be approximately 8% and 3% of the resource mix respectively by 2030. Onshore and offshore wind hourly profiles were generated using the NREL EWITS database[9].

Additional Imported Hydro

Imported hydropower generation added between 2015 and 2030 was based on the current tristate procurement in MA, CT, and RI of 10.3 TWh by 2030. In New York, 8 TWh of additional hydropower generation was added by 2030 due to the inclusion of hydropower as an eligible resource to meet the CES requirement. Existing hydropower generation was projected to stay at existing levels based on the AEO forecast.

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[6] Projected additions of hydroelectricity based on 2016 Acadia Center analysis of authorized clean energy procurements in MA, CT and RI, available at: http://acadiacenter.org/wp-content/uploads/2016/08/Acadia-Center_RGGI-Report-2016_Part-II.pdf

[7] http://programs.dsireusa.org/system/program/detail/1095

[8] http://pvwatts.nrel.gov/

[9] https://www.nrel.gov/grid/eastern-wind-data.html

Nuclear

The Baseline Scenario used the AEO forecast for nuclear generation. The New York forecast was adjusted to include the scheduled closing of the Indian Point Nuclear plant in 2021. The Ginna Nuclear Power Plant and Nine Mile Point Nuclear Power plant that have licenses expiring in 2029 are assumed to be relicensed and remain online in the AEO forecast. None of the EnergyVision Scenarios change this assumption.

Other Generation

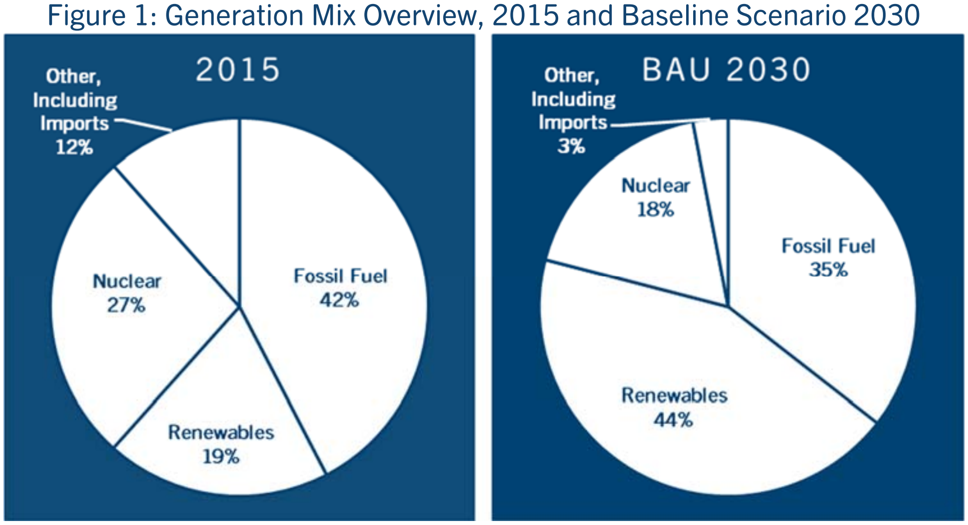
Generation from other resources, such as wood/waste and landfill gas, were taken from the AEO forecast where available and used without modification.

Fossil Fuels Generation

Fossil fuel electric generation by resource is evaluated using an economic dispatch model built in LEAP using Egrid 2012[10] data and K mean-cluster analysis. To simulate power plants in the region, a subgroup of generic power plants was created by grouping similar power plants using the K-Cluster method, based on capacity and heat rate. Capacity was adjusted to represent the whole system based on the weightage of each group. Marginal cost for this representative power plant mix was calculated using fuel price data from AEO. The marginal cost, representative capacity, and heat rates were inserted into the LEAP model. For renewable, nuclear and other generation (which includes landfill gas and wood/waste), marginal cost was kept at zero. A solution was evaluated for 8 different time periods to capture seasonal demand variation, which was based on yearly load shapes inserted into the model. The yearly shapes were developed using the hourly load forecasts from ISO-NE and NYISO, which were adjusted for the hourly profiles of additional solar and wind generation. The dispatch model was used to evaluate the least cost resource mix to meet demand.

An overview of the generation mix in 2015 and 2030 as projected in the Baseline Scenario are shown in Figure 1.

Figure 1: Generation Mix Overview, 2015 and Baseline Scenario 2030



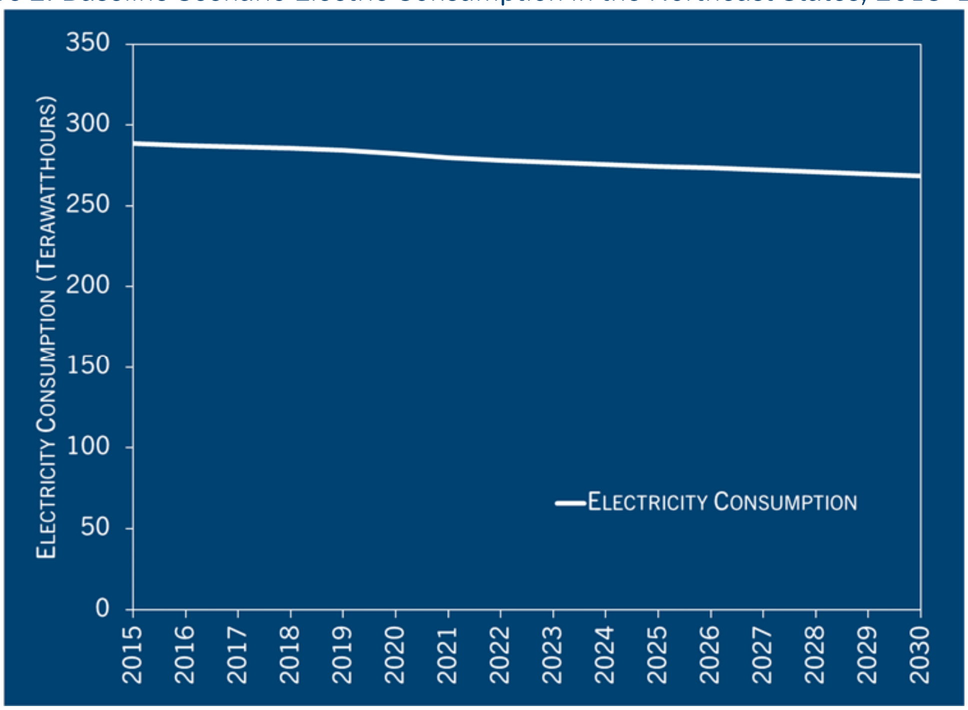
[10] https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid

Buildings

Energy Efficiency

The inputs for electric efficiency in the Baseline Scenario were derived from ISO-NE and NYISO forecasts, which project cumulative electric savings through 2025. The inputs for 2026–2030 were projected from the ISO-NE and NYISO forecasts using the gross and net load trends. The result by 2030 is a 2% cumulative reduction in annual load in New England and 3% cumulative reduction in annual load in New York, which excludes additional DG reductions to apparent load due to the CES requirements in New York. The Baseline Scenario forecast of electric consumption is shown in Figure 2.

Figure 2: Baseline Scenario Electric Consumption in the Northeast States, 2015–2030



Fossil fuel efficiency data comes from state efficiency program administrator annual reports and databases. Efficiency impacts are assumed to be embedded in the AEO fuel consumption forecasts due to their existence in historical data. Natural gas efficiency levels are 0.9% annual incremental in New England and 0.4% annual incremental in New York. Cumulative efficiency is 17% and 8% by 2030 for New England and New York, respectively. The resulting consumption is shown in Figure 3. For delivered fuels efficiency (propane and heating oil), existing levels assumed in the AEO forecast are 0.2% annual incremental efficiency. Cumulative efficiency is 4.7% for New England. For New York, delivered fuel efficiency data is not available and was assumed to be zero. The Northeast baseline consumption for heating oil and propane are shown in Figures 4 and 5.

Figure 3: Baseline Scenario Natural Gas Consumption in Northeast Buildings, 2015–2030

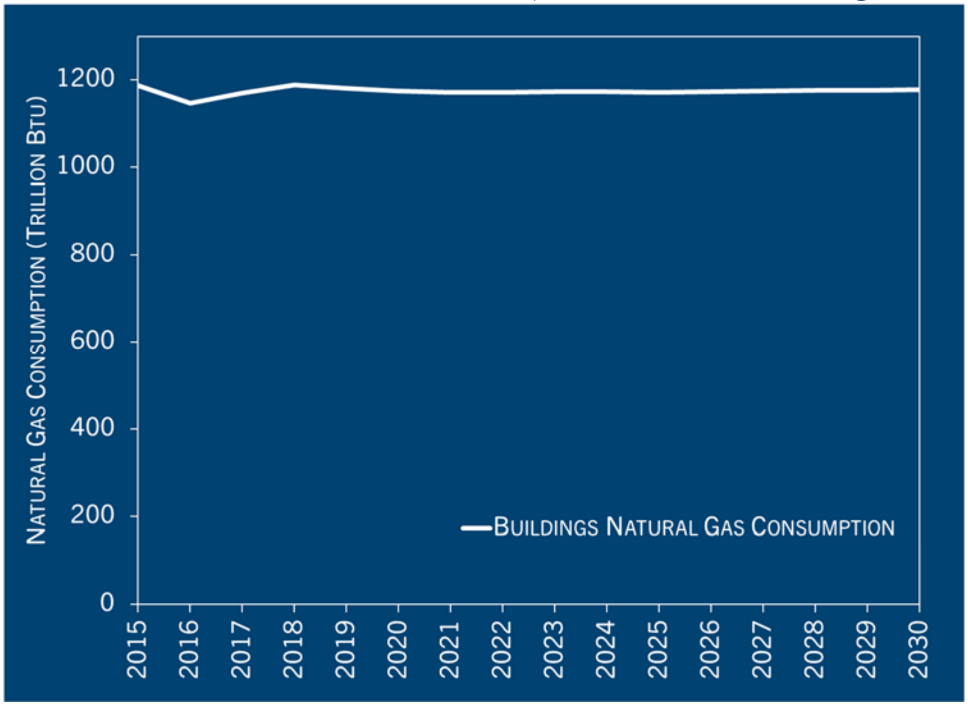


Figure 4: Baseline Scenario Heating Oil Consumption in Northeast Buildings, 2015–2030

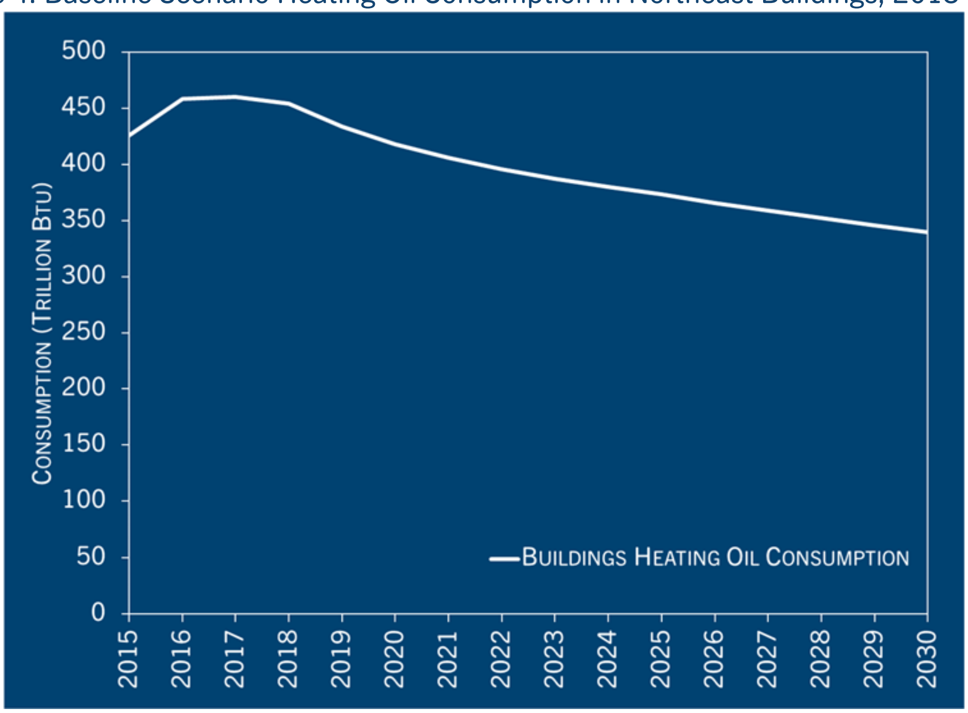
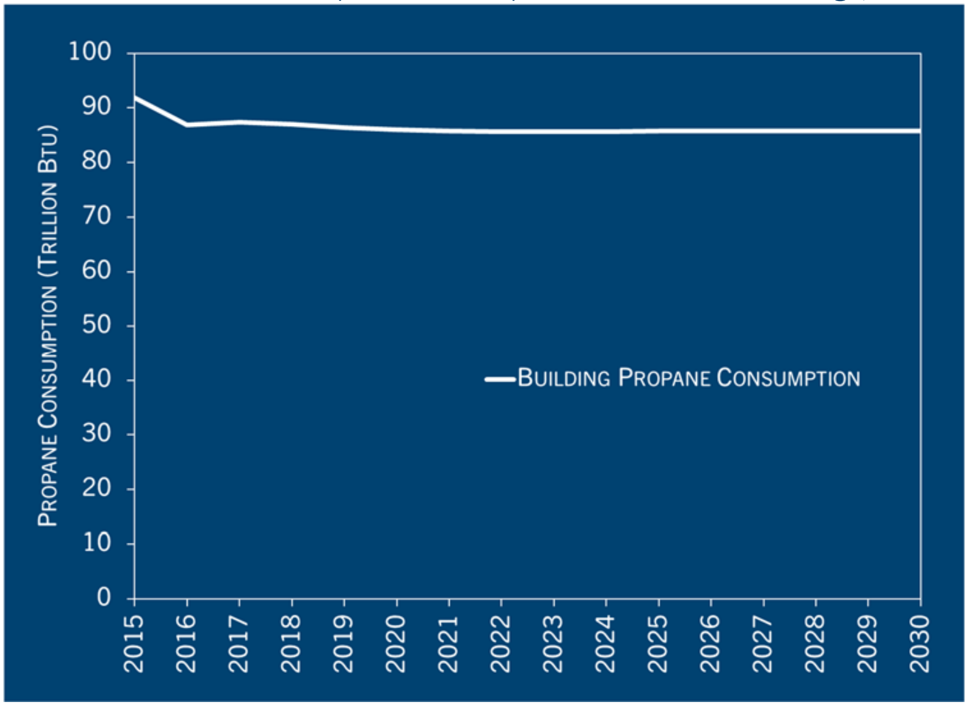


Figure 5: Baseline Scenario Propane Consumption in Northeast Buildings, 2015–2030



Heat Pumps and Water Heaters

Historical data for residential heat pump installations were found in state-level energy efficiency reports. For the Baseline Scenario, Acadia center derived about 1.35% heat pump adoption in fossil fuel-heated homes in the Northeast using national data estimates from AEO. Conversions from electric resistance heating to heat pumps were not included in this figure, as these installations are captured in electric efficiency. The reduced consumption of natural gas, propane, and fuel oil due to the 1.35% conversion to heat pumps was assumed to be included in the AEO forecast. Because the impacts of these heat pumps are included in the baseline, they are not included in the two policy scenarios. No heat pump conversions in commercial buildings were assumed in the Baseline Scenario.

Conversions of fossil fueled residential water heaters to heat pump water heaters were also considered in the modeling. The same penetration rate of 1.35% for space heating conversions was used for converting fossil fuel stock to heat pump water heaters by 2030 in the Baseline Scenario. These conversions were assumed to be included in the AEO forecast. Conversions from electric resistance water heaters to heat pumps are not included in this figure, as these installations are captured in electric efficiency. Because the impacts of these heat pump water heaters are included in the baseline, they are not included in the two policy scenarios. No fossil conversions to solar thermal water heaters, which are included in the policy scenarios, were assumed in the Baseline Scenario.

Transportation

The passenger electric vehicle (EV) adoption in the Baseline Scenario was based on the AEO forecast, which predicts that, by 2030, 3.3% of the light-duty fleet will be comprised of EVs in New England, and 5.1% of the light-duty fleet will be EVs in New York. This percentage of electrification was considered to be included in the AEO forecasts of gasoline consumption, which includes the EPA/DOT Corporate Average Fuel Economy (CAFÉ) standards through 2025, as well as the AEO forecast for electric consumption

Medium duty vehicle electrification beyond phase 2 of the EPA/DOT fuel efficiency standards was also considered in the Primary Scenario, but no electrification was assumed in the Baseline Scenario, which uses the AEO transportation sector diesel consumption as an input.

Figure 6: Baseline Scenario Gasoline Consumption for the Northeast States, 2015–2030

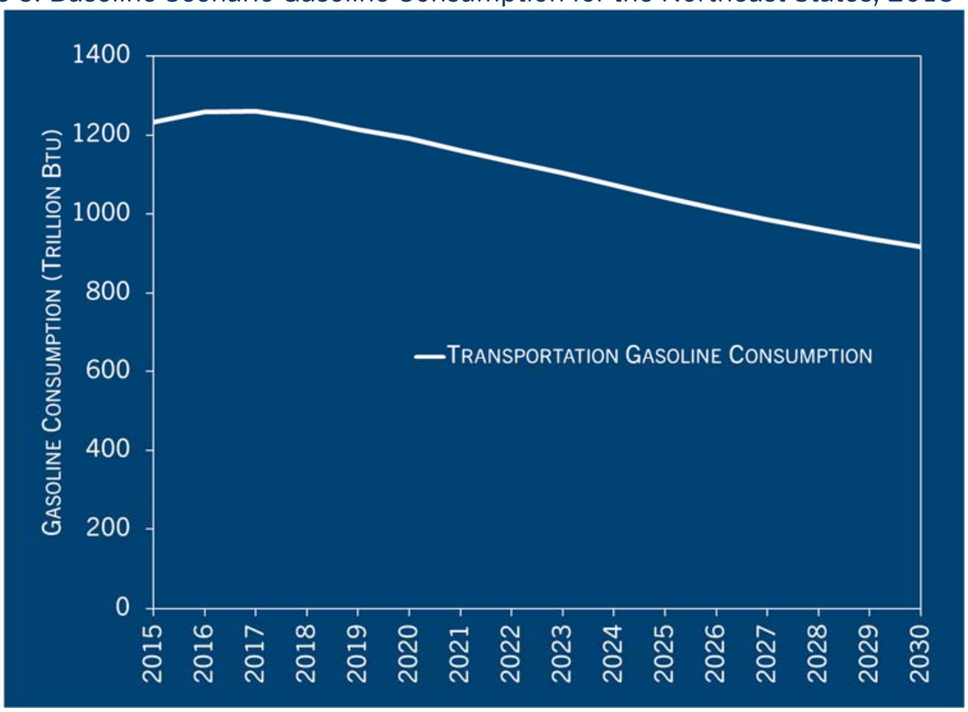
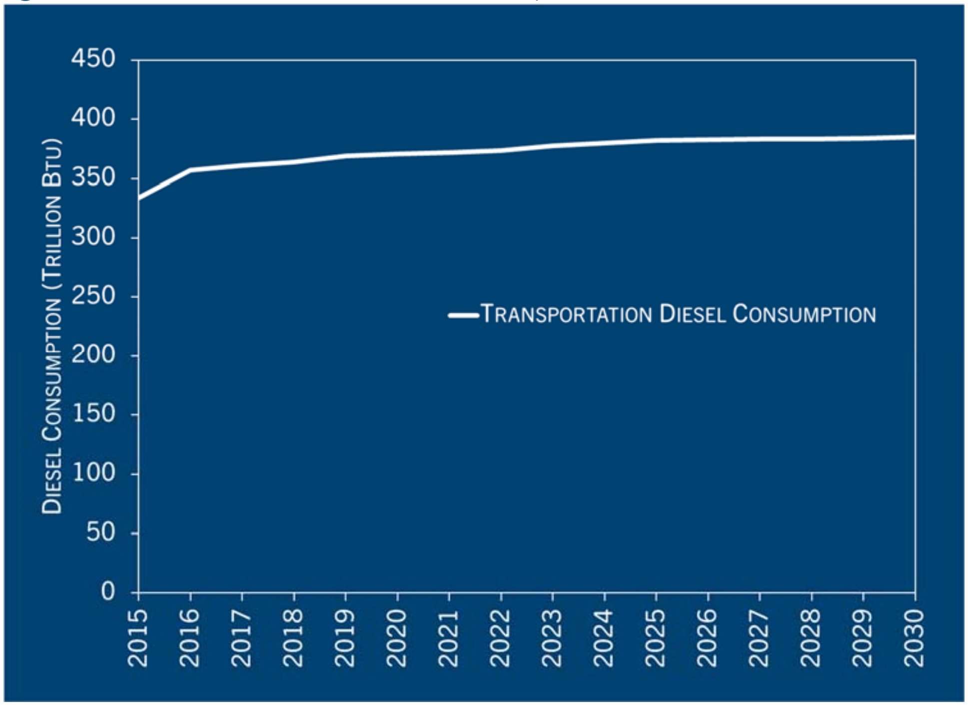


Figure 7: Baseline Scenario Diesel Consumption in the Northeast, 2015–2030



Grid Modernization

The impacts of additional load management were considered in the dispatch analysis to verify that sufficient generator resources were available to meet peak loads. To perform this, the hourly load forecasts from ISO-NE and NYISO were first adjusted for renewable integration using their hourly output to calculate hourly load needed to be met with fossil fuels based generation. Then daily load variation (in MW) was calculated by subtracting daily average load forecasts from the hourly load forecasts. The baseline considered that there will be 1,980 MW of demand response resources on the grid by 2030, which can be used to reduce the peaks in the daily load shape variation. No storage or advanced load management was included in the Baseline Scenario.

Waste and Agriculture Sector Emissions

Emissions were forecasted from 2015 to 2030 based on historical trends.

Results

The emissions outputs from the Baseline Scenario are shown in Figure 8, including historical data from 1990. Emissions are evaluated to be 30% lower than 1990 levels for the Northeast. Table 1 shows historical and Baseline Scenario projections for emissions from 1990 to 2030 by sector and region.

Figure 8: Northeast Historical and Baseline Scenario Emissions Compared to the EnergyVision 2030 Primary Scenario Target

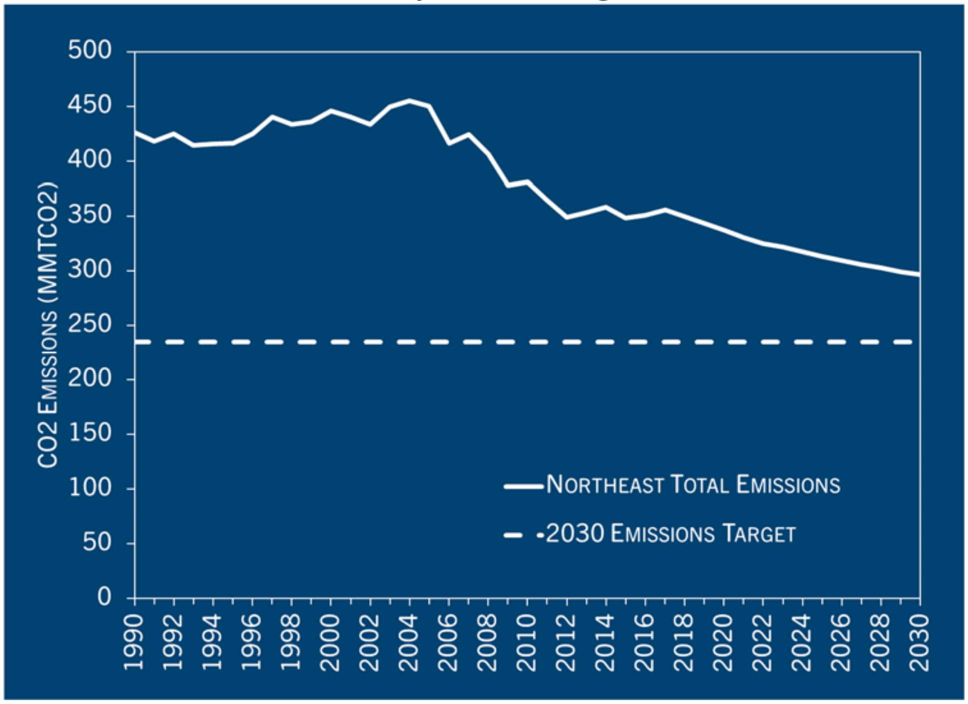


Table 1: Historical and Baseline Emissions, MMTCO2

New England	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Residential	33	32	36	36	35	34	35	34	31	33	36
Commercial	18	18	18	17	18	17	18	19	17	15	17
Transportation	70	68	68	69	69	70	72	74	74	77	78
Industry	14	15	20	18	20	17	17	16	16	16	15
Electric Power	44	44	41	37	37	37	39	48	48	44	43
Total	178	177	183	177	180	175	180	191	186	185	189
Agriculture	3	2	2	3	3	2	2	2	3	3	3
Waste	9	9	9	9	9	9	9	9	8	9	8
Imports	3	3	3	3	3	3	3	3	3	3	3
Final Total'	193	192	198	192	195	189	195	205	200	200	203

New York	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Residential	34	33	37	36	36	35	37	36	32	35	40
Commercial	27	27	28	28	28	27	28	30	28	30	32
Transportation	65	63	62	63	62	64	67	67	67	68	68
Industry	20	20	21	20	21	22	23	23	22	18	17
Electric Power	63	59	54	48	47	51	47	52	56	57	56
Total	210	202	201	196	194	200	202	207	205	208	214
Agriculture	6	6	6	6	6	5	5	5	6	5	6
Waste	16	16	17	18	18	17	17	17	17	17	18
Imports	2	2	3	3	4	4	5	5	5	5	6
Final Total'	233	226	227	222	221	227	230	235	233	236	243

Combined	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Residential	67	65	73	72	71	69	72	69	64	68	76
Commercial	45	45	46	45	46	45	46	49	45	46	49
Transportation	135	131	130	132	131	133	139	141	142	145	146
Industry	34	35	41	39	40	39	40	39	37	34	33
Electric Power	107	103	95	85	85	88	85	101	104	101	99
Total	387	379	385	373	374	374	383	398	391	394	403
Agriculture	8	8	8	8	8	8	8	8	8	8	8
Waste	26	26	26	27	27	26	27	26	25	26	26
Imports	5	5	6	6	7	8	8	8	8	9	9
Final Total'	426	418	425	414	416	416	425	440	433	436	446

Table 1 (continued): Historical and Baseline Emissions, MMTCO2

New England	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Residential	36	34	39	39	37	32	32	32	32	30	30
Commercial	15	15	18	17	16	13	14	14	14	15	15
Transportation	77	79	79	81	81	78	78	75	71	71	70
Industry	15	15	12	13	13	13	12	11	10	10	10
Electric Power	44	44	47	46	48	43	44	40	35	37	31
Total	187	188	195	196	194	178	181	172	162	162	156
Agriculture	2	2	2	2	3	2	2	3	3	2	2
Waste	8	8	8	8	9	8	8	8	7	8	8
Imports	3	2	1	1	1	0	0	1	1	0	0
Final Total'	201	200	205	207	206	190	192	183	172	174	167

New York	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Residential	39	37	40	39	40	33	37	36	33	32	31
Commercial	31	31	33	35	29	26	27	26	25	24	24
Transportation	68	70	74	76	74	75	74	74	72	71	66
Industry	17	15	14	14	15	15	14	14	11	10	11
Electric Power	55	51	52	52	55	46	49	43	34	38	34
Total	209	204	214	216	213	195	201	192	175	175	166
Agriculture	6	6	5	6	6	6	6	6	6	6	6
Waste	18	18	19	20	19	18	17	17	16	17	16
Imports	6	6	6	6	7	7	8	8	9	10	9
Final Total'	239	234	244	248	244	226	232	223	206	207	197

Combined	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Residential	75	71	79	78	76	65	69	68	65	62	61
Commercial	46	47	51	52	45	39	41	40	39	39	39
Transportation	145	148	153	157	155	153	152	148	143	142	136
Industry	32	30	27	27	28	27	26	25	21	20	21
Electric Power	99	95	99	99	103	89	93	83	69	75	65
Total	397	391	408	412	407	373	382	363	337	338	322
Agriculture	8	8	8	8	8	8	8	9	8	8	8
Waste	26	26	26	28	28	27	26	25	23	25	25
Imports	9	8	7	7	7	8	8	9	10	10	10
Final Total'	440	433	449	455	450	416	424	406	378	381	365

Table 1 (continued): Historical and Baseline Emissions, MMTCO2

New England	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Residential	26	28	31	31	28	28	27	27	26	26	26
Commercial	13	15	16	16	17	17	18	17	17	17	17
Transportation	68	70	67	66	68	69	68	68	67	66	65
Industry	10	10	9	8	10	10	10	10	11	11	11
Electric Power	29	27	25	26	26	29	25	24	23	22	17
Total	145	150	148	146	149	153	149	147	144	141	136
Agriculture	2	2	2	2	2	2	2	2	2	1	1
Waste	8	7	7	7	7	7	7	6	6	6	6
Imports	0	1	2	2	2	1	2	2	2	2	2
Final Total'	156	160	159	157	160	162	159	156	154	151	145

New York	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Residential	30	32	36	34	32	33	32	32	31	31	31
Commercial	21	22	22	21	24	25	25	25	24	24	24
Transportation	69	69	73	72	71	72	71	70	69	68	67
Industry	11	10	9	9	9	9	9	10	10	10	10
Electric Power	32	30	30	27	28	27	25	24	23	22	26
Total	163	164	170	162	164	165	163	160	158	156	159
Agriculture	6	5	5	5	5	4	4	4	4	4	3
Waste	16	16	16	15	15	14	14	13	13	13	12
Imports	9	9	8	9	8	10	10	9	8	7	6
Final Total'	194	194	199	191	191	193	191	187	183	179	180

Combined	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Residential	57	61	66	64	60	60	60	59	58	57	56
Commercial	34	38	38	36	41	42	43	42	41	41	41
Transportation	136	139	140	138	140	140	139	138	136	134	132
Industry	20	20	19	17	19	19	20	20	20	21	21
Electric Power	61	57	55	53	54	56	50	48	46	44	44
Total	307	314	319	309	314	318	312	307	302	297	294
Agriculture	8	8	7	7	7	6	6	6	5	5	5
Waste	25	23	23	22	21	21	20	20	19	19	18
Imports	9	10	10	10	9	10	11	11	10	9	7
Final Total'	349	353	358	348	351	355	350	343	337	330	325

Table 1 (continued): Historical and Baseline Emissions, MMTCO2

New England	2023	2024	2025	2026	2027	2028	2029	2030
Residential	25	25	25	25	24	24	24	24
Commercial	17	17	17	17	17	17	17	17
Transportation	64	64	63	62	61	60	59	59
Industry	11	11	11	11	11	11	11	11
Electric Power	18	18	19	19	20	21	21	21
Total	136	135	134	133	133	133	132	131
Agriculture	1	1	1	1	1	1	1	1
Waste	6	6	6	5	5	5	5	5
Imports	2	1	1	1	1	1	1	1
Final Total'	144	143	142	141	140	139	138	137
New York	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Residential	31	30	30	30	30	29	29	29
Commercial	24	24	24	24	24	24	24	24
Transportation	66	66	65	64	63	63	62	61
Industry	10	11	11	11	11	11	11	12
Electric Power	26	26	25	24	25	24	23	22
Total	157	157	155	153	153	151	149	148
Agriculture	3	3	3	2	2	2	2	2
Waste	12	11	11	11	10	10	10	9
Imports	5	3	3	2	0	0	0	0
Final Total'	177	174	172	169	166	163	161	159
Combined	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Residential	56	55	55	54	54	53	53	53
Commercial	41	41	41	41	41	41	41	41
Transportation	131	129	128	126	124	123	121	120
Industry	21	21	22	22	22	22	22	22
Electric Power	44	45	44	43	45	45	44	43
Total	293	292	289	286	286	284	281	279
Agriculture	4	4	4	3	3	3	3	2
Waste	18	17	17	16	16	15	14	14
Imports	6	4	4	4	1	1	1	1
Final Total'	321	317	313	309	306	302	299	296

Primary Scenario

Generation

In the Primary Scenario, renewable generation projections were ramped up in New England above the Baseline Scenario to help achieve 45% emissions reduction below 1990 levels by 2030. Generation in New York remained at the recently adopted CES levels, as in the Baseline Scenario.

Solar

In the Primary Scenario, utility-scale solar generation was projected to be 5.5% of the total generation mix in 2030 for the Northeast. This projected generation is within the bounds of utility-scale solar potential identified in the NREL Economic Potential study. First, a solar capacity forecast was developed, which was then translated into hourly generation profiles for the Northeast using the NREL PVWatts tool. Solar profiles were constructed in PVWatts using the averages of major population centers in New England and New York. This resulted in annual capacity factors for New England and New York of 14.9% and 14.3%, respectively. The projected hourly profile was then used to calculate annual generation and evaluate the yearly load shape.

Distributed solar generation was projected to be 12% of the total generation mix by 2030 for the Northeast. Again, capacity projections were developed, and then translated into hourly generation profiles using the NREL PVWatts tool. As with utility-scale solar, distributed PV hourly generation was used to calculate annual generation.

Wind

The Primary Scenario inputs for onshore and offshore wind generation were projected to be 18% of the total generation mix for the Northeast. This level of generation is within the bound of NREL's Economic Potential study for wind energy. A wind capacity forecast was developed, which was then used to calculate hourly generation profiles using the EWITS tool. This forecast assumes an annual average capacity factor of 33.5% for land-based wind and 40.1% for offshore wind, as an average of site data in the region. Like solar generation, hourly wind generation profiles were used to calculate annual generation and evaluate the yearly load shape.

Additional Imported Hydro, Nuclear, and Fossil Fuel Generation

For these technologies, the model inputs were the same as the Baseline Scenario, except for fossil generation, where the yearly shapes were adjusted for winter and summer average electric efficiency savings, demand response, advance load management, and energy storage, in addition to the hourly profiles of solar and wind generation as in the Baseline Scenario.

Other Generation

Other Generation sources include landfill gas and waste/wood generation. In the Primary Scenario, generation from waste/wood in New England was decreased to the levels in New York due to the uncertainty around the carbon footprint of this resource. Landfill gas generation projections remained the same as the Baseline Scenario.

Figure 9: Primary Scenario Electricity Generation in the Northeast 2015–2030

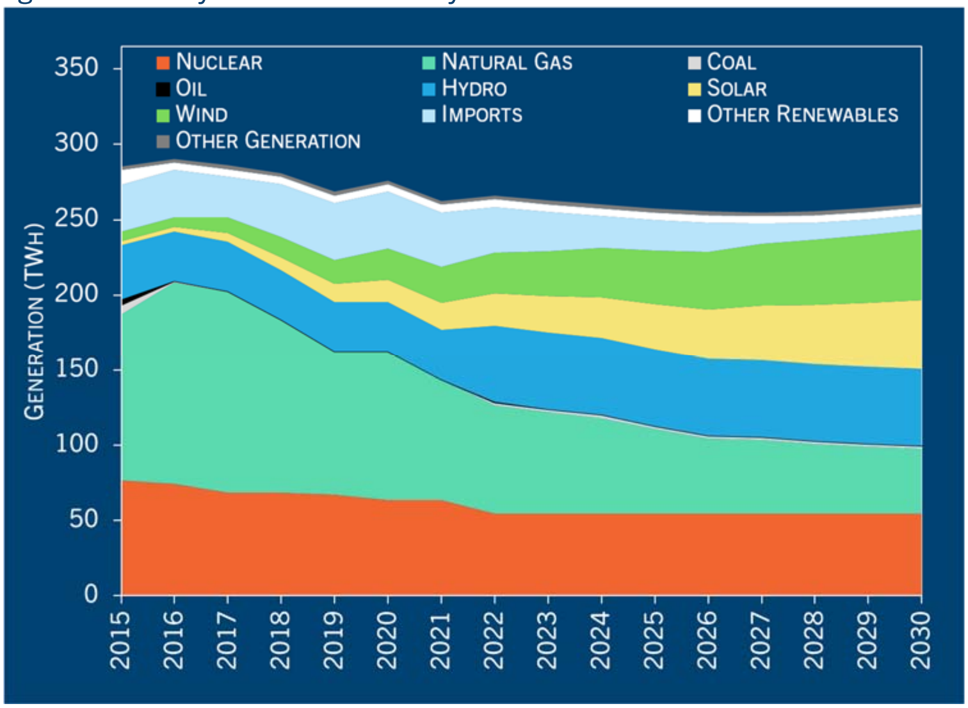
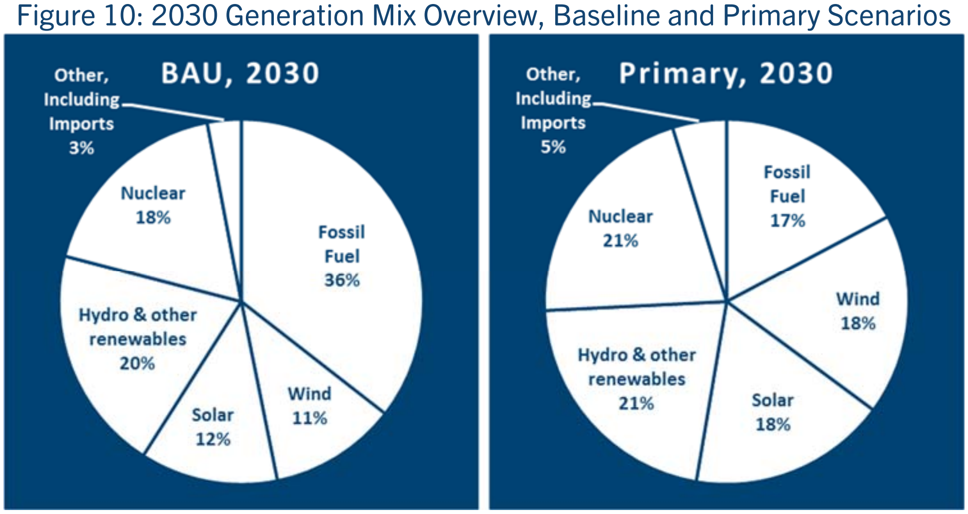


Figure 10: 2030 Generation Mix Overview, Baseline and Primary Scenarios



Buildings

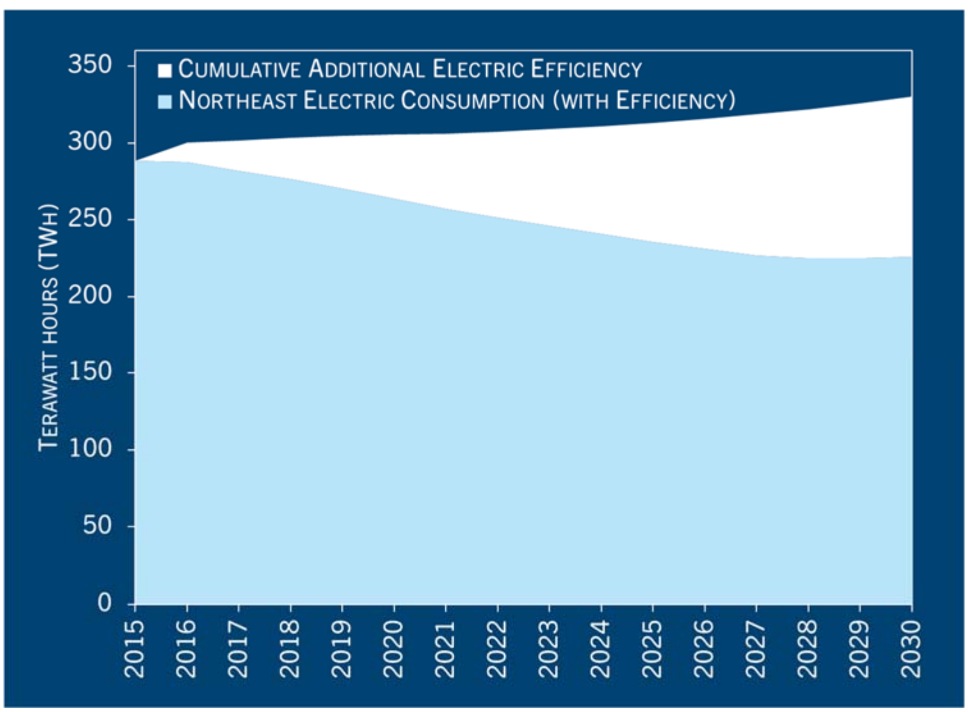
Energy Efficiency

Electric

For the projection of electric efficiency in the Primary Scenario, all states in New England and New York were targeted to achieve similar annual incremental electric efficiency to leading states in the region, or 2.5% annually. In 2016, MA and RI achieved over 3% and 2.7%, respectively, demonstrating that 2.5% annual efficiency is an achievable goal for northeastern states. Installed measure lifespans were set to 11 years for electric efficiency programs, based on the average measure life observed by states in the region. Half of the implemented efficiency was assumed to remain after the duration of an installed measure's life due to anticipated improvements in the future baseline efficiency of products.

To implement electric efficiency in the model, 2016 electric consumption was used as the reference year to calculate savings. The 2016 consumption was multiplied by the cumulative annual energy efficiency percentage to calculate efficiency savings in each year. Efficiency savings were then subtracted from the consumption forecast in each year to get net annual consumption with efficiency.

Figure 11: Primary Scenario Electric Consumption and Cumulative Electric Efficiency, 2015–2030

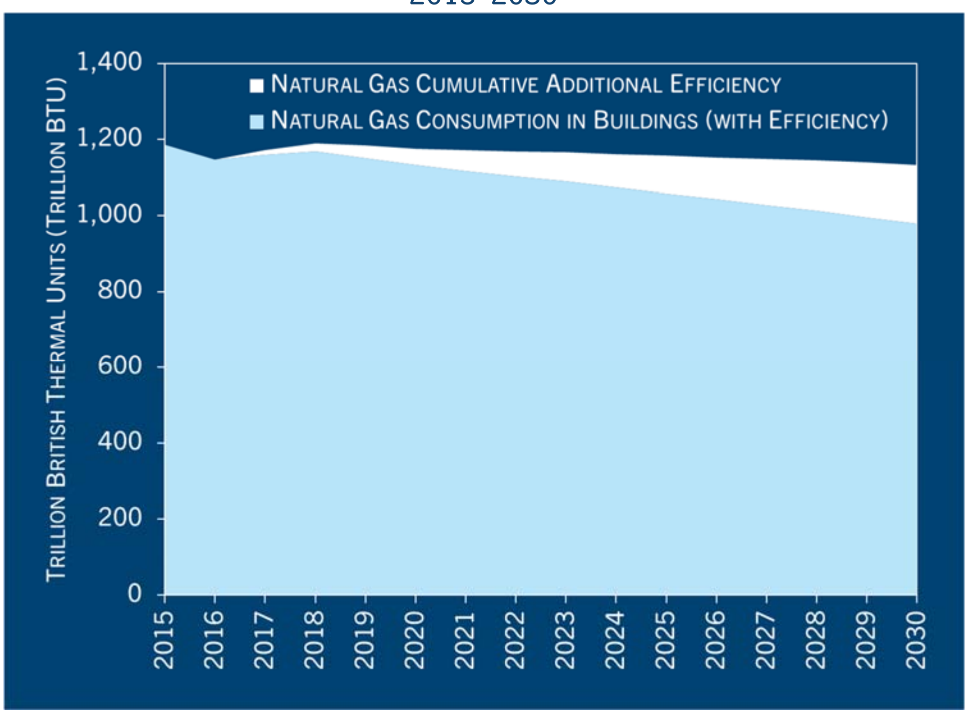


Natural Gas

For natural gas efficiency, the Primary Scenario considered that 0.5% additional annual efficiency would be achieved in New England and 1.0% additional efficiency would be achieved in New York (0.8% for the combined region). Installed measure lifespans were set to 14 years for gas efficiency programs, based on the average of the measure life observed in the Northeast states. As with electric efficiency, half of the implemented efficiency was assumed to remain after the duration of an installed measure's life due to anticipated improvements in the baseline efficiency of products.

The 2016 natural gas consumption from the Baseline Scenario was used as the reference year to implement natural gas efficiency in LEAP. This consumption was multiplied by the annual cumulative efficiency percentage to calculate gas efficiency savings in each year. Then annual efficiency savings were subtracted from annual consumption to get net consumption.

Figure 12: Primary Scenario Natural Gas Consumption and Cumulative Additional Efficiency, 2015–2030

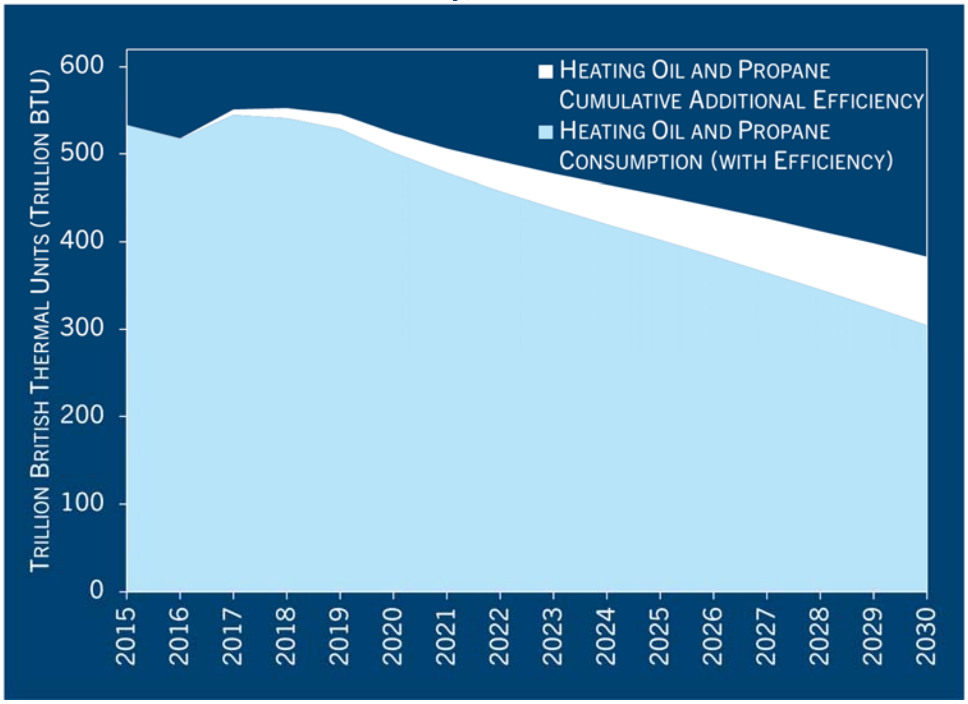


Delivered Fuels

Propane and heating oil efficiency was calculated in a manner similar to natural gas efficiency, except a 1.0% annual additional efficiency was assumed in the Northeast (additional 1.0% in New England, additional 1.2% in

New York). The Baseline Scenario 2016 delivered fuel consumption data from AEO was used as the reference year, which was multiplied by the annual cumulative savings to get savings each year. Annual savings were then subtracted from yearly consumption to get net consumption.

Figure 13: Primary Scenario Propane and Heating Oil Consumption and Cumulative Additional Efficiency, 2015-2030



Heat pumps and Water Heaters

The Primary Scenario inputs for residential heat pumps were based on a bottom-up potential analysis conducted by Acadia Center. The analysis assumed that space heat pump efficiency is 250% in 2015 and increases linearly to 310% in 2030. For winter peak day gas consumption analysis, space heat pump efficiency was considered to be 150% for all years, while the total system efficiency (including heating distribution system losses) of natural gas, propane, and heating oil systems was set to 78%. The heat pump forecast considered that on average the fraction of heat that a heat pump provided in a home with a fossil fuel system is 55% in 2016 and increases to 90% in 2030. The remainder of heat was provided by the existing fossil fuel system. Cumulatively, 13% (14% in New England and 11% in New York) of residential space heating fossil fuel load was converted to heat pumps based on this potential forecast, inclusive of the 1.35% of fossil fuel load conversion that was assumed to be included in the AEO forecast, as described in the Baseline Scenario. Conversions of electric resistance heaters to heat pumps were not included in these figures, as they were accounted for under electric efficiency.

The decrease in residential natural gas, propane, and fuel oil consumption was evaluated by multiplying consumption from the EIA Residential Energy Consumption Survey (RECS) data by the heating load percentage converted for each fuel.[11] Across the Northeast states, household space heating consumption from RECS was 67 MMBTU of natural gas, 53 MMBTU of propane, and 82 MMBTU of fuel oil. The corresponding electricity increase was evaluated by multiplying the fuel consumption decrease with the ratio of fossil fuel system efficiency and heat pump efficiency described above.

Heat pump water heaters were assumed to be installed in a subset of residential homes that installed heat pump heating systems. Importantly, this assumption did not include conversions of fossil fuel hot water systems that occurred without converting home heating to heat pumps. These conversions were not included in this analysis, but would likely lead to a higher number of installations than forecasted. In the Northeast, 11% of fossil fuel water heating load was considered to convert to heat pump water heaters, with 12% of water heating load converting in New England and 10% of water heating load converting in New York.

For residential water heaters, a similar methodology was followed as for space heating heat pumps. Water heat pump efficiency was assumed to increase linearly from 290% in 2015 to 350% in 2030, while the efficiency of natural gas, propane, and heating oil systems was set at 61%, 65% and 55%, respectively, from the AEO 2016 forecast. Annual household fuel consumption for water heating was taken from the EIA RECS: natural gas consumption was 21 MMBTU; propane consumption was 13 MMBTU; and fuel oil consumption was 18 MMBTU.

Solar water heater penetration was projected to increase linearly, replacing 1% of household water heating systems in 2030 based on continuation of the Federal Renewable Investment Tax Credit beyond 2021.To evaluate solar water heaters in the model, the annual consumption for each natural gas, propane, and fuel oil from AEO was multiplied by the annual cumulative percent penetration of solar thermal water heaters to get consumption of each fuel to be replaced.

Commercial heat pump assumptions for the Primary Scenario were based on a bottom-up potential analysis conducted by Acadia Center. Similar efficiency increases were assumed in commercial buildings as for residential buildings. Cumulatively, 5% (7% in New England and 4% in New York) of commercial fossil fuel load was considered to convert to heat pumps. Conversion of electric resistance heaters to heat pumps were not included in this estimate, as they were accounted for under electric efficiency.

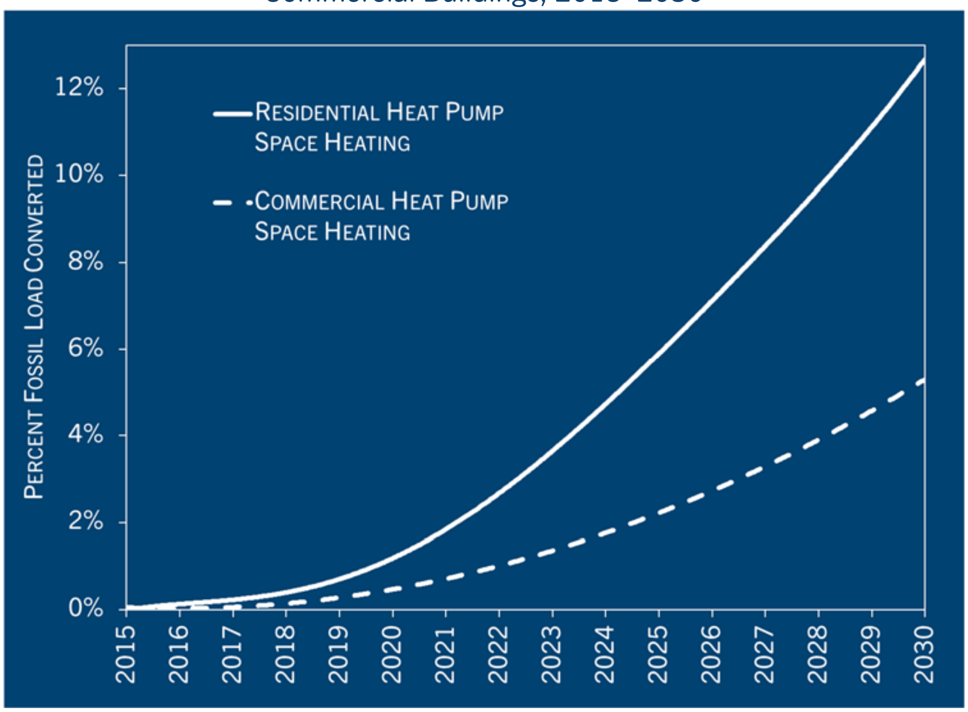
For commercial sector space heat pumps, a forecast of total heated floor-space was developed. It was evaluated in a similar manner to the residential sector, except that the forecasted total floor-space available for electrification was used rather than available units. The forecasted available floor-space was multiplied by annual fuel consumption per floor-space from the EIA Commercial Buildings Energy Consumption Survey (CBECS) to calculate the fossil fuel consumption decrease.[12] EIA CBECS reports annual natural gas consumption per floor-

[11] https://www.eia.gov/consumption/residential/index.php
[12] https://www.eia.gov/consumption/commercial/

space at 36485 BTU/SQFT; annual propane consumption per floor-space at 1901 BTU/SQFT; and annual fuel oil consumption at 33400 BTU/SQFT. The corresponding electricity increase was evaluated by multiplying the fuel consumption decrease by the ratio of fuel equipment system efficiency and heat pump efficiency. Natural gas, propane and fuel oil buildings were evaluated separately.

Fuel consumption reductions due to efficiency changes, residential and commercial sector electrification and solar water heater penetration were added together and subtracted from annual AEO fuel consumption forecast to calculate the net fuel consumption forecast for the Primary Scenario. New electric consumption due to electrification was added to the ISOs' electric consumption forecasts.

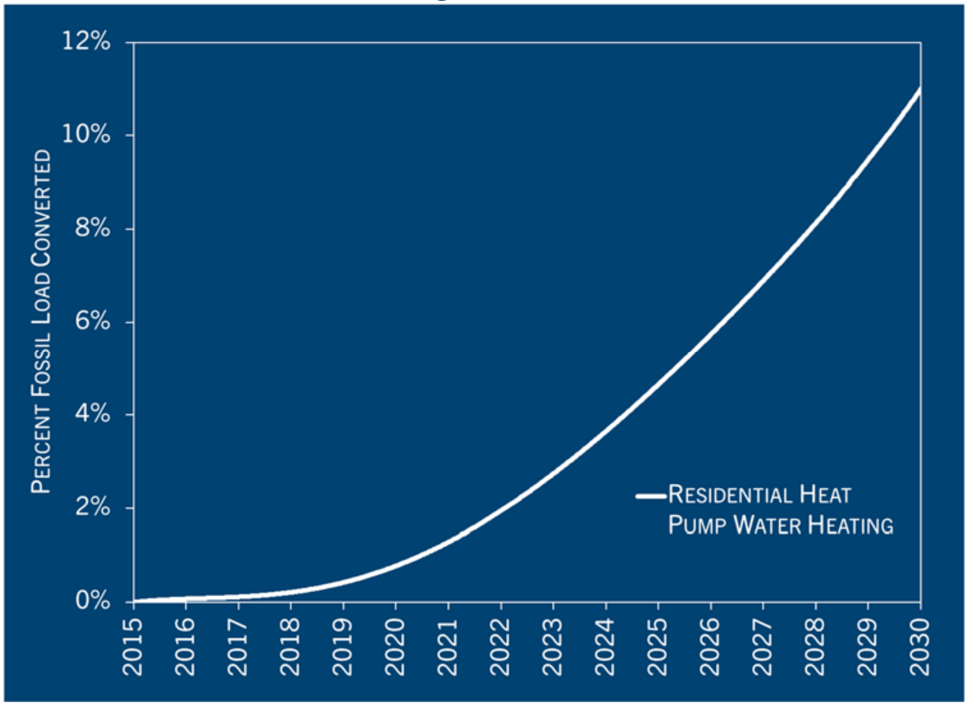
Figure 14: Primary Scenario Percent of Fossil Fuel Load Converted to Heat Pumps in Residential and Commercial Buildings, 2015–2030



	Residential Space Heat Pumps as % of Heating Load					
	New England			New York		
	Oil	Gas	Propane	Oil	Gas	Propane
2016	0.10%	0.06%	0.14%	0.10%	0.04%	0.12%
2017	0.45%	0.18%	0.55%	0.45%	0.12%	0.51%
2018	0.73%	0.33%	0.93%	0.72%	0.22%	0.85%
2019	1.01%	0.52%	1.34%	1.01%	0.34%	1.22%
2020	1.60%	0.97%	2.22%	1.59%	0.66%	2.02%
2021	2.42%	1.65%	3.47%	2.40%	1.17%	3.15%
2022	3.48%	2.54%	5.07%	3.45%	1.85%	4.62%
2023	4.68%	3.47%	6.83%	4.65%	2.57%	6.27%
2024	6.02%	4.43%	8.76%	5.98%	3.32%	8.08%
2025	7.51%	5.41%	10.84%	7.46%	4.10%	10.06%
2026	9.15%	6.43%	13.08%	9.09%	4.92%	12.20%
2027	10.94%	7.49%	15.46%	10.87%	5.78%	14.51%
2028	12.88%	8.56%	17.97%	12.80%	6.66%	16.96%
2029	14.99%	9.66%	20.61%	14.89%	7.58%	19.57%
2030	17.25%	10.80%	23.40%	17.15%	8.53%	22.33%

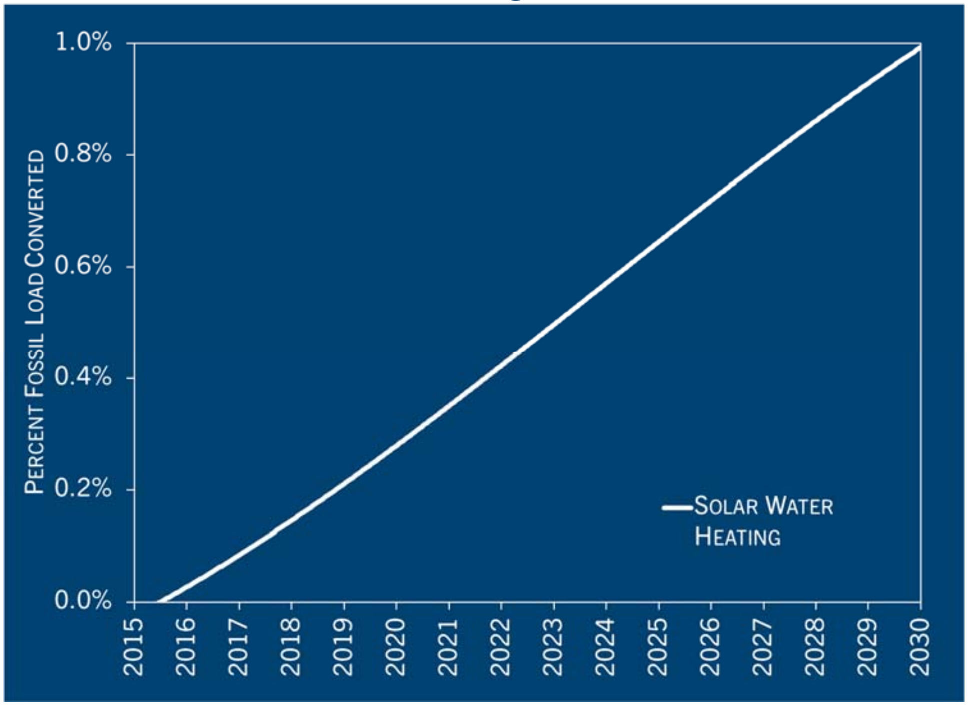
	Commercial Space Heat Pumps as % of Heating Load					
	New England			New York		
	Oil	Gas	Propane	Oil	Gas	Propane
2016	0.06%	0.02%	0.06%	0.05%	0.02%	0.05%
2017	0.25%	0.04%	0.20%	0.24%	0.04%	0.18%
2018	0.48%	0.06%	0.39%	0.47%	0.06%	0.34%
2019	0.78%	0.08%	0.64%	0.74%	0.08%	0.55%
2020	1.26%	0.18%	1.32%	1.17%	0.18%	1.23%
2021	1.80%	0.31%	2.12%	1.66%	0.31%	2.03%
2022	2.43%	0.49%	3.04%	2.23%	0.48%	2.95%
2023	3.16%	0.70%	4.08%	2.88%	0.67%	3.99%
2024	3.98%	0.94%	5.24%	3.60%	0.90%	5.15%
2025	4.89%	1.23%	6.52%	4.41%	1.16%	6.43%
2026	5.90%	1.55%	7.93%	5.30%	1.45%	7.83%
2027	7.01%	1.90%	9.45%	6.27%	1.78%	9.35%
2028	8.22%	2.30%	11.11%	7.34%	2.13%	11.00%
2029	9.53%	2.73%	12.89%	8.49%	2.52%	12.77%
2030	10.98%	3.37%	14.83%	9.75%	3.14%	14.70%

Figure 15: Primary Scenario Percent of Fossil Fuel Load Converted to Heat Pumps in Residential Buildings, 2015-2030



	Residential Water Heat Pumps as % of Heating Load					
	New England			New York		
	Oil	Gas	Propane	Oil	Gas	Propane
2016	0.05%	0.03%	0.07%	0.05%	0.02%	0.06%
2017	0.26%	0.09%	0.29%	0.25%	0.06%	0.27%
2018	0.45%	0.19%	0.53%	0.43%	0.12%	0.48%
2019	0.68%	0.32%	0.80%	0.65%	0.20%	0.72%
2020	1.13%	0.66%	1.39%	1.08%	0.46%	1.24%
2021	1.78%	1.18%	2.26%	1.70%	0.86%	2.03%
2022	2.67%	1.88%	3.42%	2.56%	1.42%	3.10%
2023	3.73%	2.63%	4.76%	3.57%	2.03%	4.33%
2024	4.98%	3.43%	6.27%	4.76%	2.68%	5.74%
2025	6.41%	4.28%	7.96%	6.13%	3.37%	7.33%
2026	8.05%	5.18%	9.84%	7.70%	4.12%	9.11%
2027	9.90%	6.13%	11.89%	9.49%	4.91%	11.09%
2028	11.99%	7.12%	14.12%	11.49%	5.74%	13.25%
2029	14.33%	8.17%	16.54%	13.73%	6.62%	15.60%
2030	16.92%	9.27%	19.16%	16.22%	7.56%	18.17%

Figure 16: Primary Scenario Percent of Fossil Fuel Load Converted to Solar Water Heaters in Residential Buildings, 2015-2030



Transportation

Passenger EVs

In the Primary Scenario, electric vehicles were forecast to grow exponentially from 2015 to 2030 by the factor 1.28^x. The projection approximately aligns with the commitments made by New York and the participating New England states under the Multi-State Zero-Emission Vehicle Memorandum of Understanding through 2025. First, annual gasoline vehicle miles traveled (VMT) were determined using the fuel consumption forecast multiplied by the fuel efficiency forecast, both from the AEO. Then the total number of fossil fuel light-duty vehicles was calculated each year by dividing VMT from AEO by annual VMT per vehicle (assumed to be 12,000). Then electric vehicles as a percentage of total light duty vehicles was calculated. The model considered that 80% of electric vehicles will be fully electric and 20% will be plug-in hybrids that run on 90% electricity and 10% gasoline.

To model the fossil fuel savings from electrification of the light-duty fleet, the projected number of electric vehicles was first multiplied by the annual VMT per vehicle (12,000) to determine electric vehicle VMT. The electric vehicle VMT, which was set to replace fossil fuel VMT, was then divided by average light duty vehicle fuel efficiency data from AEO to calculate the reduction in fossil fuel consumption due to vehicle electrification. Gasoline savings due to the increased fuel efficiency of PHEVs compared to the average light duty vehicle stock was also used to calculate overall fossil fuel decrease due to electric vehicles.

To calculate the associated increase in electricity load due to electric vehicle charging, the electric vehicle VMT was multiplied by an electric vehicle efficiency factor of 0.3 kWh/mile,[13] and the product was added to total electric consumption.

Medium-Duty EVs

The Primary Scenario considered that 2.5% electrification of the medium duty fleet will occur by 2030. The same methodology as described above for passenger EVs was applied to medium duty vehicles, using annual diesel consumption and vehicle fuel efficiency from AEO to calculate fuel reduction and electricity increase. Average annual VMT per vehicle of 20,000 miles from EIA and electric vehicle efficiency of 1.1 kWh/mile[14] was used for the analysis.

VMT

Vehicle miles traveled in the Primary Scenario was calculated by reducing the baseline VMT for light duty vehicles in 2030 by 5%. VMT reductions compared to the baseline were multiplied by fuel efficiency data from AEO to calculate the annual fossil fuel consumption decrease.

Fuel reductions due to VMT reductions and electrification were added together and subtracted from annual AEO fuel consumption forecast to calculate the net fuel consumption forecast for the Primary Scenario. New electric consumption due to electrification was added to the electric consumption forecasts.

[13] https://www.fueleconomy.gov/feg/noframes/38428.shtml
[14] Efficiency was derived from the following vehicle specification: http://www.evi-usa.com/LinkClick.aspx?fileticket=SyZhwUVqNJs%3d&tabid=83

Figure 17: Electric Vehicles as a Percentage of the Passenger Vehicle Fleet in the Primary Scenario

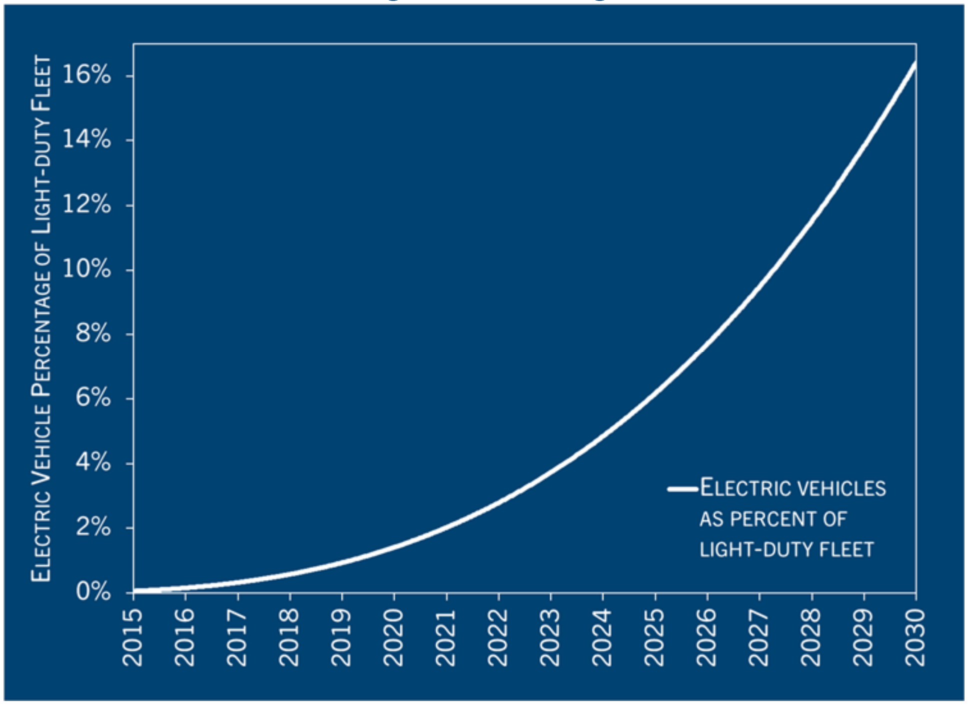


Figure 18: Medium Duty Electric Vehicles as a Percentage of the Fleet in the Primary Scenario

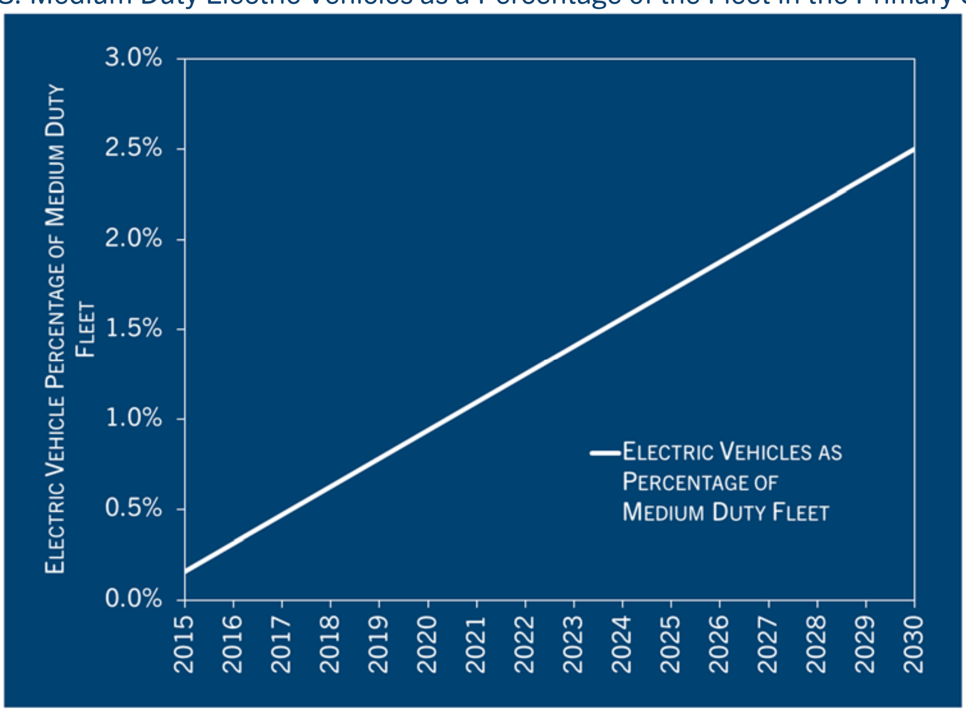
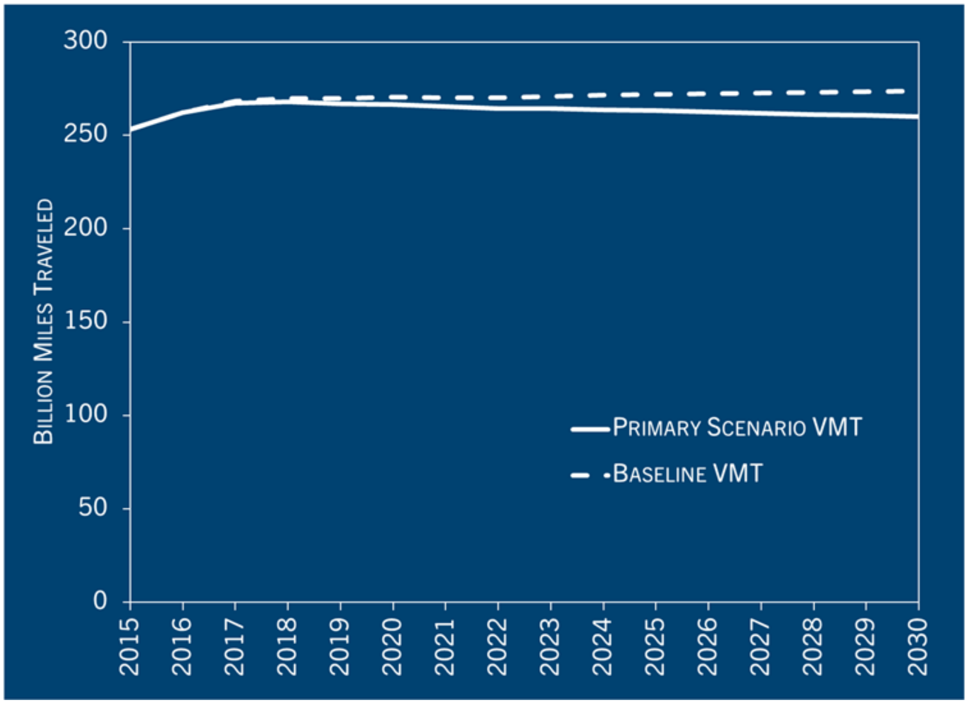


Figure 19: Primary Scenario Vehicle Miles Traveled, 2015–2030



Grid Modernization

The Primary Scenario considers that various load management resources will be available by 2030, including demand response, advanced load management, and energy storage. To model these resources, hourly load from ISO-NE and NYISO was first adjusted with electricity consumption changes due to electrification (in buildings and transportation), efficiency, and renewable energy integration. Daily average load was then subtracted from adjusted hourly load each day to calculate load variation in MWs each day. The peaks in the daily load variations were adjusted with demand response capacity, advanced load management, and energy storage capacity. The Primary Scenario considers that an additional 2,020 MW of demand response resources will be available to reduce peak load by 2030. The Primary Scenario also sets 1,800 MW of advanced load management capacity and 4,200 MW of energy storage capacity to be installed by 2030 to shift and smooth daily load.

Results

The emissions outputs from the Primary Scenario are shown in Figure 20, including historical data from 1990. The data show that the Primary Scenario will meet the target of a 45% reduction from 1990 levels, unlike the Baseline Scenario. Figure 21 shows the contribution of each sector to the reductions in the Primary Scenario compared to the Baseline Scenario. Table 2 shows Primary Scenario projections for emissions from 2015 to 2030 by sector and region.

Figure 20: Historical, Baseline, and Primary Scenario Emissions, 1990–2030

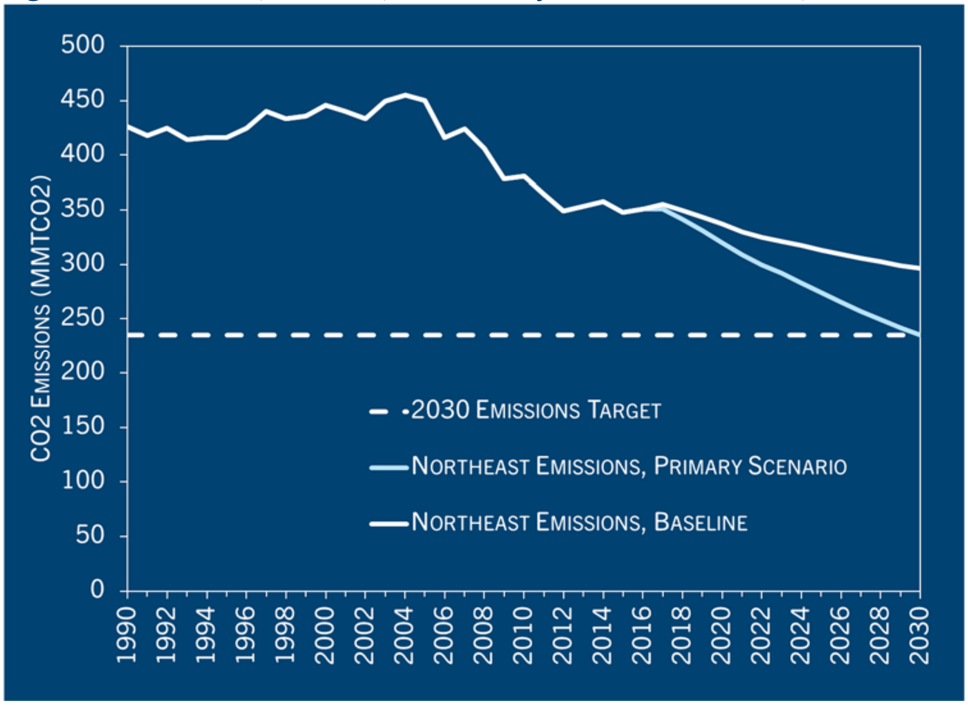


Figure 21: Primary Scenario Emissions Reductions from the Baseline Scenario by Sector

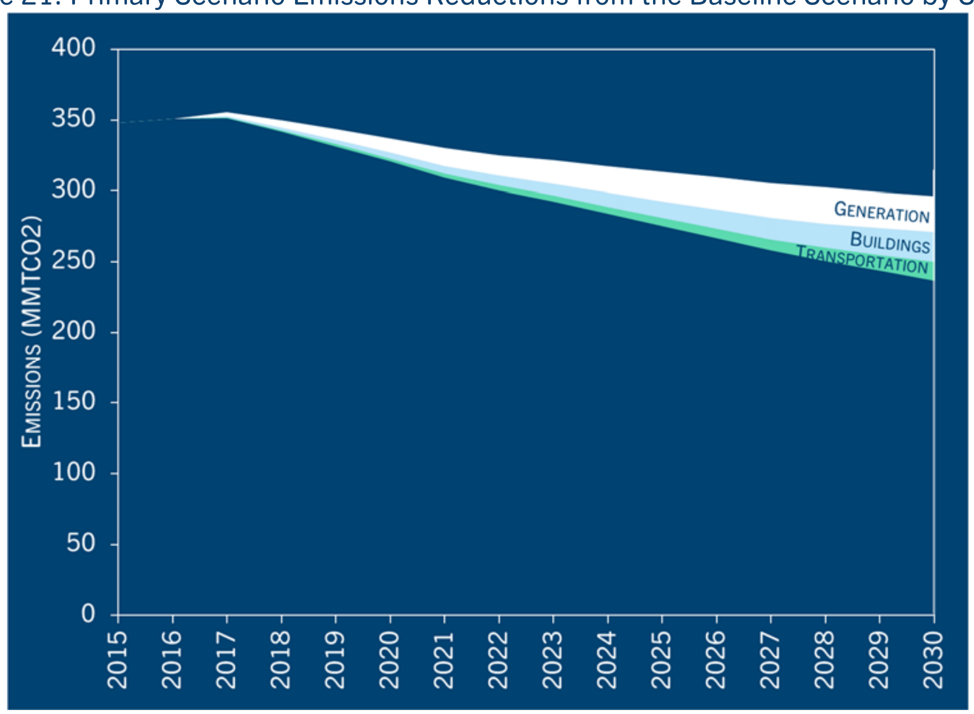


Table 2: Primary Scenario Emissions by Sector, MMTCO2

New England	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Residential	31	28	27	27	26	25	24	24	23	22	21	20	19	18	17	16
Commercial	16	17	17	17	17	17	16	16	16	16	16	16	15	15	15	15
Transportation	66	68	68	68	67	66	65	63	62	61	60	58	57	55	54	52
Industry	8	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Electric Power	26	26	28	22	20	17	14	10	9	8	7	6	6	7	7	7
Total	146	149	151	144	140	135	130	123	121	118	114	111	108	106	103	101
Agriculture	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1
Waste	7	7	7	7	6	6	6	6	6	6	6	5	5	5	5	5
Imports	2	2	1	2	2	2	2	2	2	1	1	1	1	1	1	1
Final Total'	157	160	160	154	150	145	139	132	129	126	122	119	116	113	110	107

New York	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Residential	34	32	32	32	31	30	29	28	27	26	26	25	24	23	22	20
Commercial	21	24	24	25	24	23	23	23	22	22	22	22	21	21	21	21
Transportation	72	71	71	70	69	68	67	66	64	63	62	61	59	58	56	54
Industry	9	9	9	9	10	10	10	10	10	10	10	10	10	10	10	11
Electric Power	27	28	26	23	21	19	17	20	18	18	16	14	14	13	12	11
Total	162	164	163	160	154	150	146	146	143	140	136	131	129	124	121	117
Agriculture	5	5	4	4	4	4	4	3	3	3	3	2	2	2	2	2
Waste	15	15	14	14	13	13	13	12	12	11	11	11	10	10	10	9
Imports	9	8	10	10	9	8	7	6	5	3	3	2	0	0	0	0
Final Total'	191	191	191	187	181	175	169	167	162	157	152	147	141	136	132	128

Combined	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Residential	64	60	60	58	57	55	53	52	50	48	47	45	43	41	39	37
Commercial	36	41	42	42	41	40	39	39	38	38	38	37	37	37	36	36
Transportation	138	140	140	138	136	134	132	129	127	124	122	119	116	113	110	106
Industry	17	19	19	20	20	20	20	20	20	21	21	21	21	21	21	21
Electric Power	53	54	54	45	41	36	31	29	28	26	23	21	20	19	18	18
Total	309	313	314	304	294	285	276	269	263	258	250	242	237	230	224	218
Agriculture	7	7	6	6	6	5	5	5	4	4	4	3	3	3	3	2
Waste	22	21	21	20	20	19	19	18	18	17	17	16	16	15	14	14
Imports	10	9	10	11	11	10	9	7	6	4	4	4	1	1	1	1
Final Total'	348	351	351	341	331	320	309	300	292	283	274	265	257	249	242	235

Accelerated Scenario

The inputs to the Accelerated Scenario were designed to reach a 50% GHG reduction from 1990 levels by 2030. The inputs are described in detail in this section, but were developed to be incrementally greater than the Primary Scenario while still achievable with robust state commitments. Execution of the modeling was the same for both the Primary and Accelerated Scenarios.

Generation

In the Accelerated Scenario, renewable generation projections were increased in both New England and New York above the Primary Scenario to help achieve the 50% reduction below 1990 levels by 2030.

Solar

In the Accelerated Scenario, utility-scale solar generation was projected to be 6.2% of the total generation mix by 2030 for the Northeast. While this target is greater than the Primary Scenario target, the solar results are still within the bounds of utility-scale solar potential identified in the NREL Economic Potential study. This solar capacity was incorporated in the model using the same method as the Primary Scenario. A solar capacity forecast was developed to meet the generation target, which was then translated into hourly generation profiles for the Northeast using the NREL PVWatts tool. Solar profiles were constructed in PVWatts using the averages of major population centers in New England and New York. This resulted in annual capacity factors for New England and New York of 14.9% and 14.3%, respectively. The projected hourly profile was then used to calculate annual generation and evaluate the yearly load shape.

Distributed solar generation was projected to be 16% of the total generation mix by 2030 for the Northeast. Again, capacity projections were developed and then translated into hourly generation profiles using the NREL PVWatts tool. As with utility-scale solar, distributed PV hourly generation was used to calculate annual generation and evaluate the yearly load shape.

Wind

The Accelerated Scenario inputs for onshore and offshore wind generation were projected to be 23% of the total generation mix for the Northeast in 2030. This level of generation is within the bounds of NREL's Economic Potential study for wind energy. The same methods were used to incorporate wind capacity into the model as the Primary Scenario. Wind capacity forecasts for both onshore and offshore wind were developed to meet the generation target. The capacity numbers were then used to calculate hourly generation profiles using the EWITS tool, assuming an annual average capacity factor of 33.5% for land-based wind and 40.1% for offshore wind, as an average of site data in the region. Like solar generation, the hourly wind generation profiles were used to calculate annual generation and evaluate yearly load shape.

Additional Imported Hydropower, Nuclear, and Fossil Fuel Generation

For these technologies, the model inputs for the Accelerated Scenario were the same as for the Primary Scenario. Additional imported hydropower and nuclear were the same as the Baseline Scenario, and for fossil generation, the yearly shapes were adjusted for winter and summer average electric efficiency savings, demand response, advance load management, and energy storage, in addition to the hourly profiles of solar and wind generation as in the Baseline Scenario.

Other Generation

Other Generation sources include landfill gas and waste/wood generation. In the Primary Scenario, generation from waste/wood in New England was decreased to the levels in New York due to the uncertainty around the carbon footprint of this resource. Landfill gas generation remained the same as the Baseline Scenario.

Figure 22: Accelerated Scenario Electricity Generation in the Northeast, 2015–2030

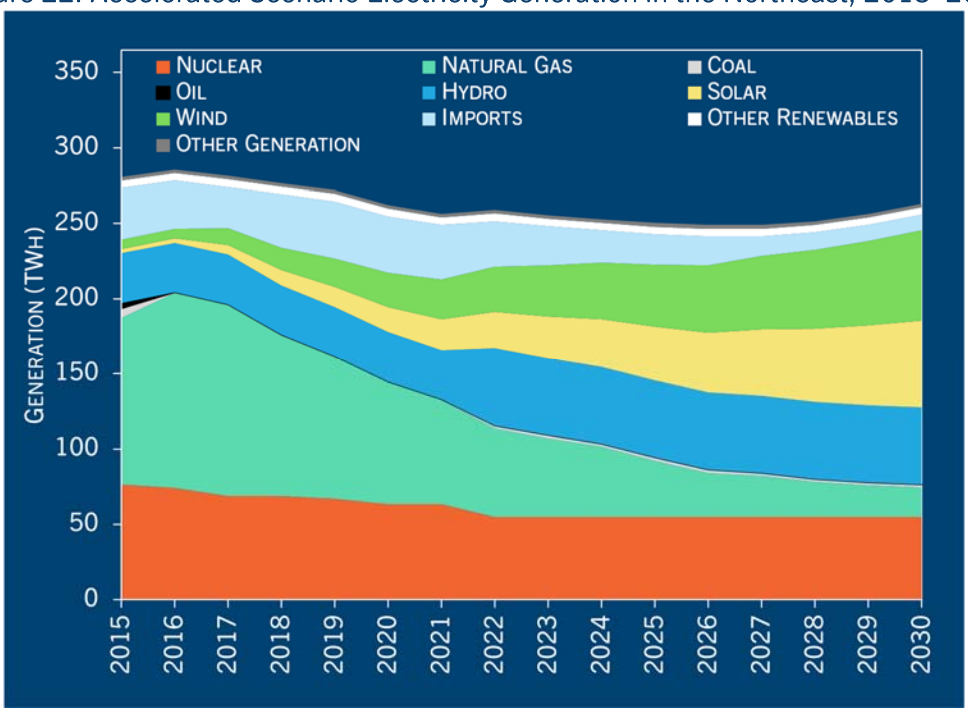
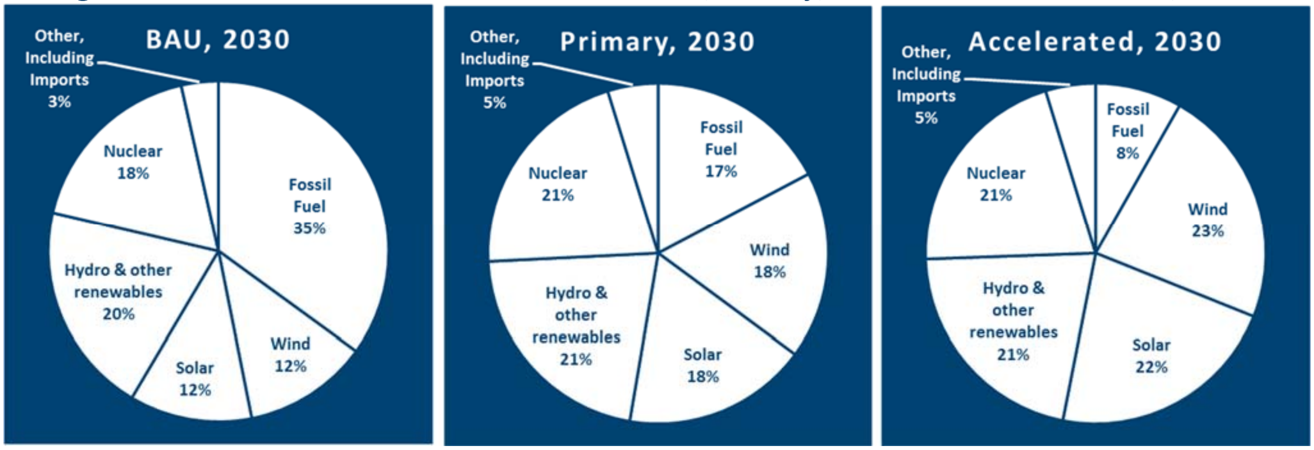


Figure 23: Generation Mix Overview for the Baseline, Primary, and Accelerated Scenarios, 2030



Buildings

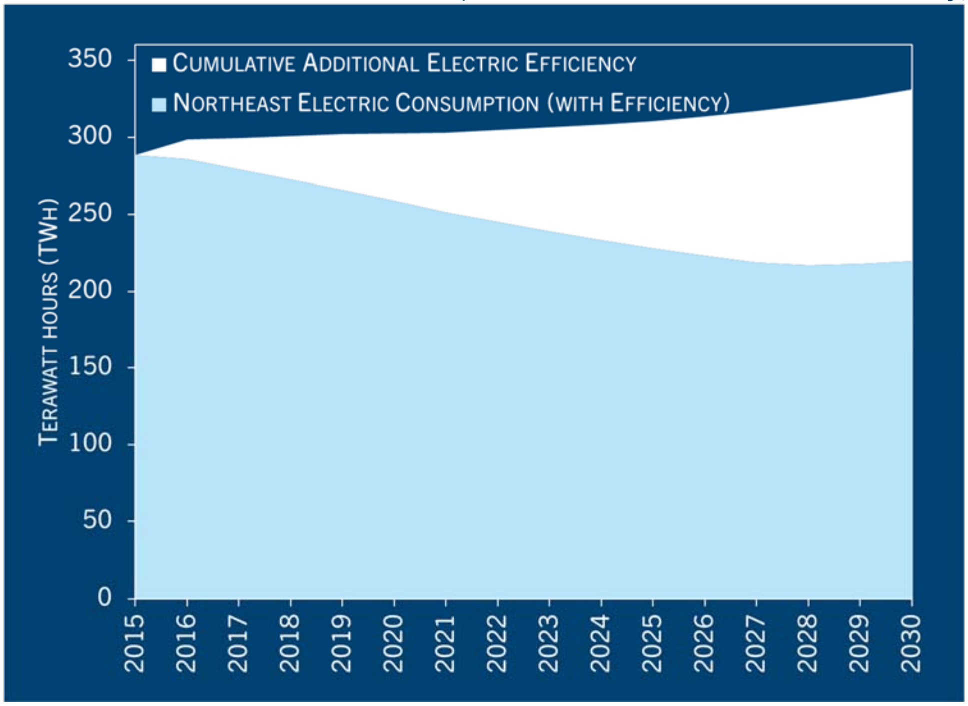
Energy Efficiency

Electric

For the projection of electric efficiency in the Accelerated Scenario, all states in New England and New York were targeted to achieve equivalent annual incremental electric efficiency to Rhode Island, or 2.7% annually. As in the Primary Scenario, installed measure lifespans were set to 11 years for electric efficiency programs, based on the average measure life observed by states. Half of the implemented efficiency was assumed to remain after the duration of an installed measure's life due to anticipated improvements in the future baseline efficiency of products.

Electric efficiency was implemented in the model following methods identical to those in the Primary Scenario. The 2016 electric consumption was used as the reference year to calculate savings, which was multiplied by the cumulative annual energy efficiency percentage to calculate efficiency savings in each year. Efficiency savings were then subtracted from the consumption forecast in each year to get net annual consumption with efficiency.

Figure 24: Accelerated Scenario Electric Consumption and Cumulative Electric Efficiency, 2015–2030

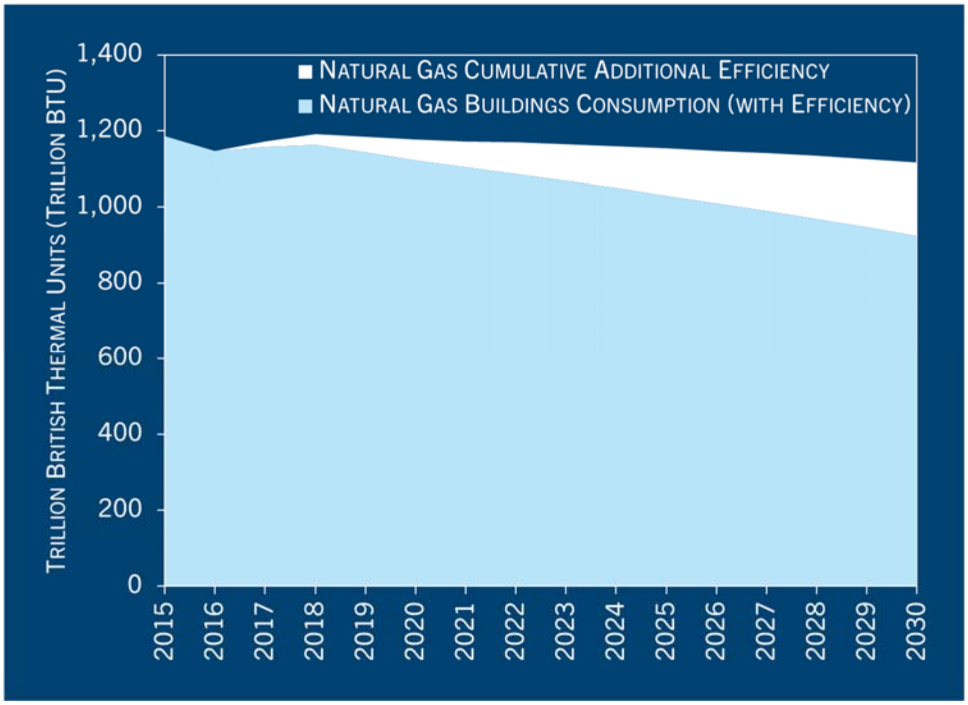


Natural Gas

For natural gas efficiency, the Accelerated Scenario considered that 0.7% additional annual efficiency would be achieved in New England and 1.2% additional efficiency would be achieved in New York (1.0% for the combined region) – slightly greater than the Primary Scenario but still based on what is expected to be achievable. Installed measure lifespans were set to 14 years for gas efficiency programs, based on the average of the measure life observed in the Northeast states. As with electric efficiency, half of the implemented efficiency was assumed to remain after the duration of an installed measure's life due to anticipated improvements in the baseline efficiency of products.

The 2016 natural gas consumption from the Baseline Scenario was used as the reference year to implement natural gas efficiency in LEAP. This consumption was multiplied by the annual cumulative efficiency percentage to calculate gas efficiency savings in each year. Then annual efficiency savings were subtracted from annual consumption to get net consumption.

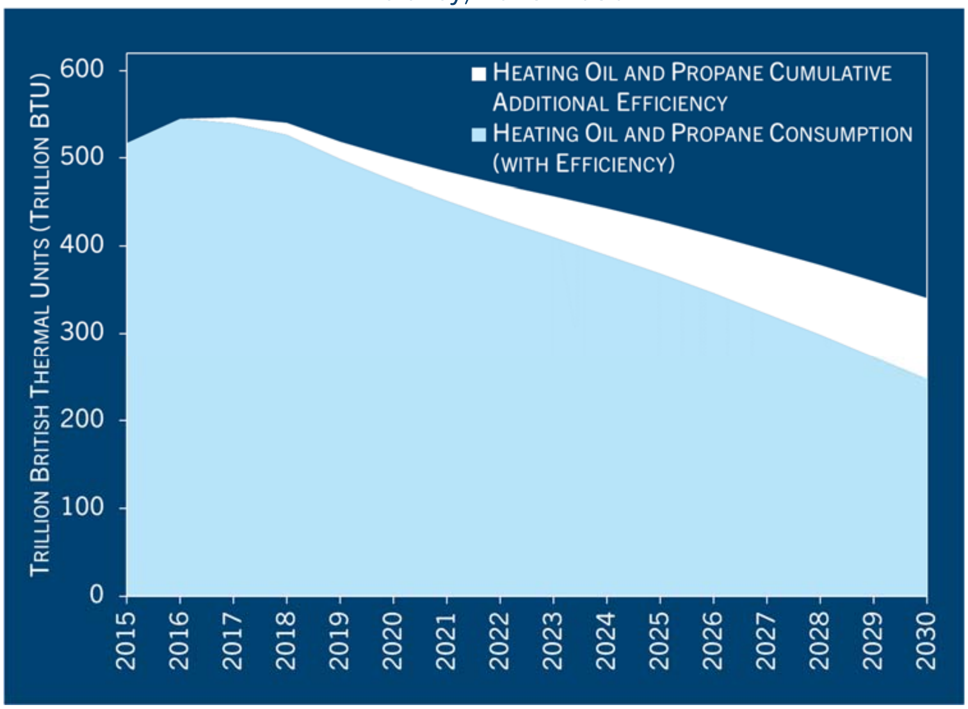
Figure 25: Accelerated Scenario Natural Gas Consumption and Cumulative Additional Efficiency, 2015–2030



Delivered Fuels

Propane and heating oil efficiency was calculated in a manner similar to natural gas efficiency, except a 1.3% annual additional efficiency was assumed in the Northeast (additional 1.2% in New England, additional 1.4% in New York). The baseline AEO delivered 2016 fuel consumption data was used as the reference year, which was multiplied by the annual cumulative savings to get savings each year. Annual savings were then subtracted from yearly consumption to get net consumption.

Figure 26: Accelerated Scenario Propane and Heating Oil Consumption and Cumulative Additional Efficiency, 2015–2030



Heat Pumps and Water Heaters

The Accelerated Scenario inputs for residential heat pumps were based on a bottom-up potential analysis conducted by Acadia Center. The analysis assumed that space heat pump efficiency is 250% in 2015 and increases linearly to 310% in 2030. For winter peak day gas consumption analysis, space heat pump efficiency is considered to be 150% for all years, while the total systems efficiency (including heating distribution systems losses) of natural gas, propane, and heating oil systems was set to 78%. The heat pump forecast considered that on average the fraction of heat that a heat pump provided in a home with a fossil fuel system is 55% in 2016 and increases to 90% in 2030. The remainder of heat is provided by the existing fossil fuel system. Cumulatively, 16% (18% in New England and 15% in New York) of residential space heating fossil fuel load was converted to heat pumps based on this potential forecast, inclusive of the 1.35% of the fossil fuel load conversion that was assumed to be in the AEO forecast, as described in the Baseline Scenario. Conversions of electric resistance heaters to heat pumps were not included in these figures, as they were accounted for under electric efficiency.

The decrease in residential natural gas, propane, and fuel oil consumption was evaluated by multiplying consumption from the EIA Residential Energy Consumption Survey (RECS) data by the heating load percentage converted for each fuel. Across the Northeast states, household space heating consumption from RECS was 67 MMBTU for natural gas, 53 MMBTU for propane, 82 MMBTU for fuel oil. The corresponding electricity increase was evaluated by multiplying the fuel consumption decrease with the ratio of fossil fuel system efficiency and heat pump efficiency described above.

Heat pump water heaters were assumed to be installed in a subset of residential homes that installed heat pump heating systems. Importantly, this assumption did not include conversions of fossil fuel hot water systems that occurred without converting home heating to heat pumps. These conversions were not included in this analysis, but would likely lead to a higher number of installations than forecasted. In the Northeast, 14% of water heating load was forecasted to convert to heat pump water heaters, with 16% of water heating load converting in New England and 13% of water heating load converting in New York.

For residential water heaters, a similar methodology was followed as for space heating heat pumps. Water heat pump efficiency was assumed to increase linearly from 290% in 2015 to 350% in 2030, while the efficiency of natural gas, propane, and heating oil systems was set at 61%, 65%, and 55%, respectively, from the EIA AEO 2016 forecast. Annual household fuel consumption for water heating was taken from the EIA RECS: natural gas consumption was 21 MMBTU, propane consumption was 13 MMBTU, and fuel oil consumption was 18 MMBTU.

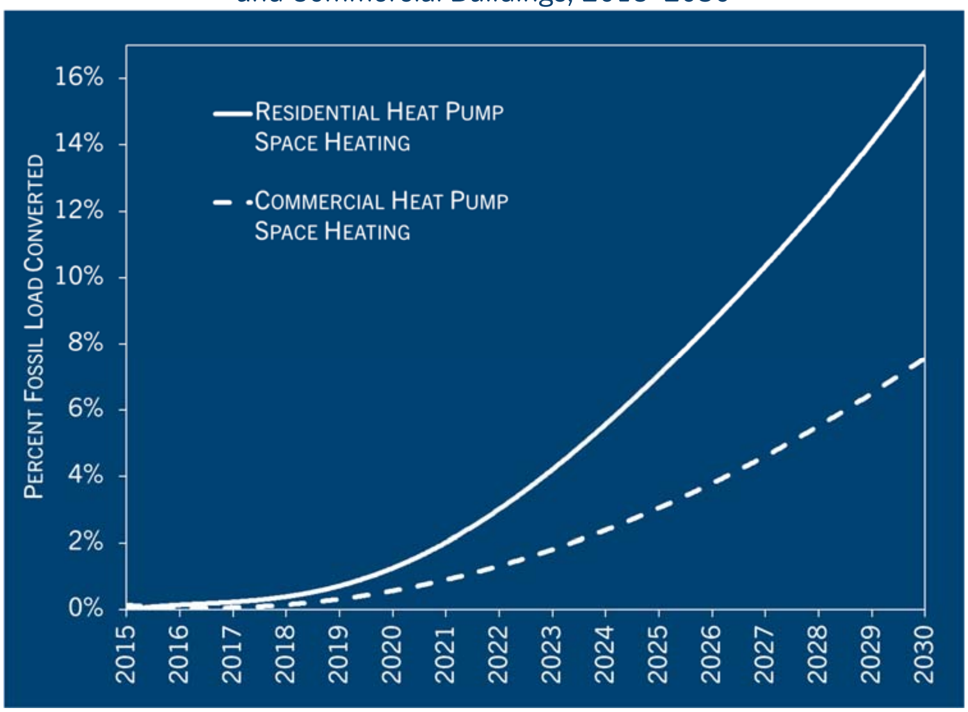
Solar water heater penetration was projected to increase linearly, replacing 2% of household water heating in 2030. To evaluate solar water heaters in the model, annual consumption for each natural gas, propane, and fuel oil from AEO was multiplied by the annual cumulative percent penetration of solar thermal water heaters to get consumption to be replaced.

Commercial heat pump assumptions for the Accelerated Scenario were based on a bottom-up potential analysis conducted by Acadia Center. Similar efficiency increases were assumed in commercial buildings as for residential buildings. Cumulatively, 8% (10% in New England and 6% in New York) of commercial fossil fuel load was considered to convert to heat pumps. Conversion of electric resistance heaters to heat pumps were not included in this estimate, as they were accounted for under electric efficiency.

For commercial sector space heat pumps, a forecast of total heated floor-space was developed. It was evaluated in a similar manner to the residential sector, except that the forecasted total floor-space available for electrification was used rather than available units. The forecasted available floor-space was multiplied by annual fuel consumption per floor-space from the EIA Commercial Buildings Energy Consumption Survey (CBECS) to calculate the fossil fuel consumption decrease. EIA CBECS reports annual natural gas consumption per floor-space at 36,485 BTU/SQFT, annual propane consumption per floor-space at 1,901 BTU/SQFT, and annual fuel oil consumption per floor-space at 33,400 BTU/SQFT. The corresponding electricity increase was evaluated by multiplying the fuel consumption decrease by the ratio of fuel equipment system efficiency and heat pump efficiency. Natural gas, propane, and fuel oil buildings were evaluated separately.

Fuel reductions due to efficiency changes, residential and commercial sector electrification and solar water heater penetration were added together and subtracted from annual AEO fuel consumption forecast to calculate the net fuel consumption forecast for the Accelerated Scenario. New electric consumption due to electrification was added to the electric consumption forecasts.

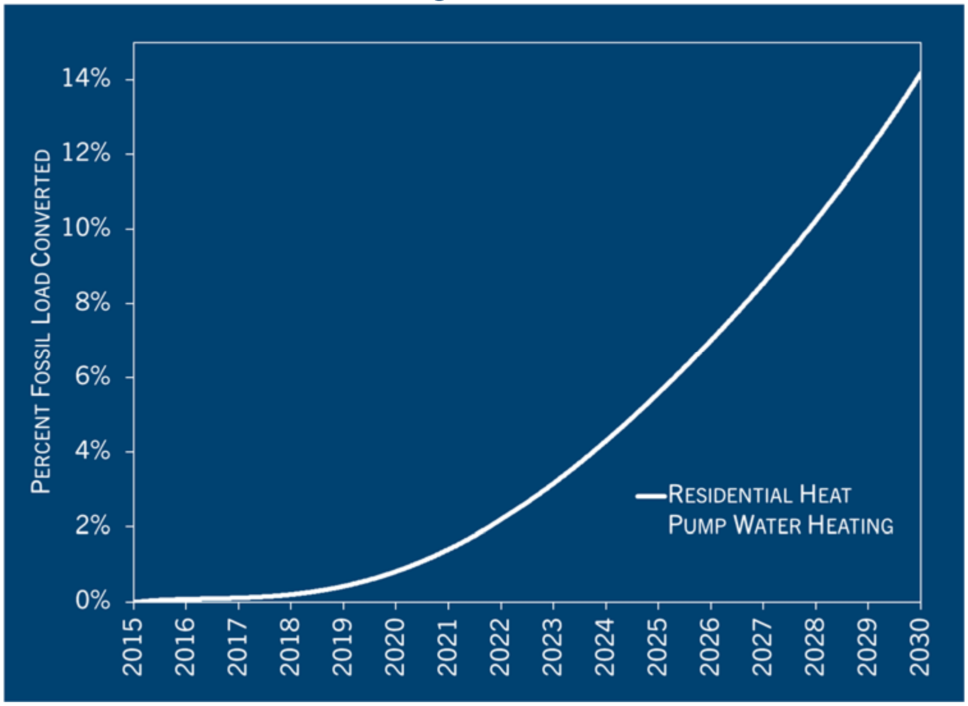
Figure 27: Accelerated Scenario Percent of Fossil Fuel Load Converted to Heat Pumps in Residential and Commercial Buildings, 2015–2030



	Residential Space Heat Pumps as % of Heating Load					
	New England			New York		
	Oil	Gas	Propane	Oil	Gas	Propane
2016	0.10%	0.06%	0.14%	0.10%	0.04%	0.12%
2017	0.45%	0.18%	0.55%	0.45%	0.12%	0.51%
2018	0.73%	0.33%	0.93%	0.72%	0.22%	0.86%
2019	1.01%	0.52%	1.35%	1.01%	0.34%	1.23%
2020	1.67%	1.02%	2.26%	1.66%	0.71%	2.06%
2021	2.63%	1.78%	3.58%	2.62%	1.32%	3.27%
2022	3.91%	2.80%	5.28%	3.89%	2.16%	4.86%
2023	5.40%	3.91%	7.23%	5.37%	3.07%	6.70%
2024	7.09%	5.11%	9.42%	7.06%	4.05%	8.79%
2025	9.00%	6.38%	11.84%	8.96%	5.10%	11.11%
2026	11.13%	7.74%	14.47%	11.08%	6.22%	13.67%
2027	13.48%	9.18%	17.33%	13.43%	7.42%	16.47%
2028	16.06%	10.68%	20.37%	16.00%	8.67%	19.48%
2029	18.88%	12.25%	23.61%	18.80%	9.99%	22.72%
2030	21.93%	13.89%	27.06%	21.85%	11.38%	26.19%

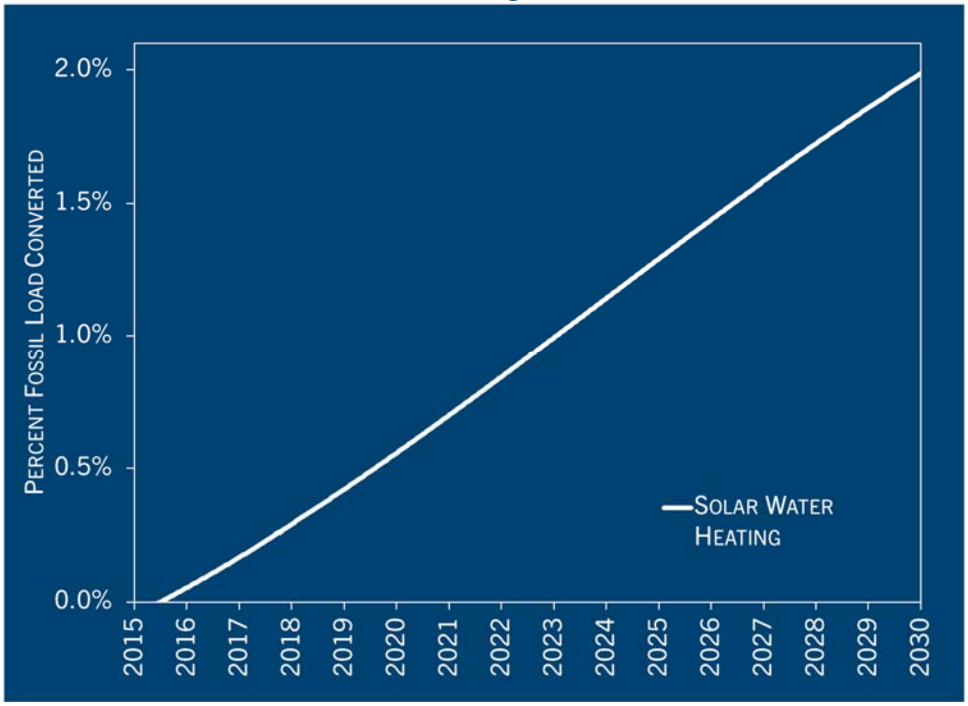
	Commercial Space Heat Pumps as % of Heating Load					
	New England			New York		
	Oil	Gas	Propane	Oil	Gas	Propane
2016	0.15%	0.02%	0.10%	0.16%	0.02%	0.09%
2017	0.38%	0.04%	0.26%	0.40%	0.04%	0.24%
2018	0.70%	0.06%	0.50%	0.71%	0.06%	0.44%
2019	1.12%	0.08%	0.80%	1.11%	0.08%	0.69%
2020	1.77%	0.18%	1.55%	1.70%	0.18%	1.44%
2021	2.52%	0.34%	2.45%	2.41%	0.34%	2.34%
2022	3.43%	0.56%	3.52%	3.25%	0.54%	3.39%
2023	4.49%	0.84%	4.74%	4.24%	0.80%	4.60%
2024	5.72%	1.17%	6.11%	5.38%	1.11%	5.97%
2025	7.11%	1.57%	7.65%	6.66%	1.48%	7.50%
2026	8.68%	2.03%	9.35%	8.11%	1.90%	9.19%
2027	10.41%	2.55%	11.22%	9.72%	2.37%	11.04%
2028	12.32%	3.13%	13.25%	11.49%	2.90%	13.06%
2029	14.42%	3.76%	15.45%	13.43%	3.48%	15.24%
2030	16.74%	4.64%	17.81%	15.57%	4.30%	17.59%

Figure 28: Accelerated Scenario Percent of Fossil Fuel Load Converted to Heat Pumps in Residential Buildings, 2015–2030



	Residential Water Heat Pumps as % of Heating Load					
	New England			New York		
	Oil	Gas	Propane	Oil	Gas	Propane
2016	0.05%	0.03%	0.07%	0.05%	0.02%	0.06%
2017	0.26%	0.09%	0.29%	0.25%	0.06%	0.27%
2018	0.45%	0.19%	0.53%	0.43%	0.12%	0.48%
2019	0.68%	0.32%	0.81%	0.65%	0.20%	0.72%
2020	1.18%	0.69%	1.41%	1.13%	0.49%	1.27%
2021	1.95%	1.27%	2.33%	1.87%	0.98%	2.11%
2022	3.04%	2.07%	3.56%	2.91%	1.66%	3.25%
2023	4.36%	2.96%	5.03%	4.18%	2.43%	4.62%
2024	5.93%	3.95%	6.74%	5.69%	3.27%	6.24%
2025	7.78%	5.04%	8.70%	7.47%	4.20%	8.11%
2026	9.92%	6.23%	10.91%	9.52%	5.21%	10.24%
2027	12.37%	7.53%	13.38%	11.88%	6.31%	12.64%
2028	15.15%	8.91%	16.09%	14.56%	7.50%	15.30%
2029	18.28%	10.39%	19.06%	17.57%	8.77%	18.24%
2030	21.78%	11.98%	22.30%	20.94%	10.13%	21.48%

Figure 29: Accelerated Scenario Percent of Fossil Fuel Load Converted to Solar Water Heaters in Residential Buildings, 2015–2030



Transportation

Passenger EVs

In the Accelerated Scenario, electric vehicles were forecast to grow exponentially from 2015 to 2030 by the factor 1.28^x. First, annual gasoline VMT were determined using fuel consumption forecast multiplied by the fuel efficiency forecast, both from the AEO. Then the total number of fossil fuel light-duty vehicles was calculated each year by dividing vehicle miles traveled (VMT) from AEO by annual VMT per vehicle, which was assumed to be 12,000. Then electric vehicles as a percentage of total light duty vehicles was calculated. The model considered that 80% of electric vehicles will be fully electric and 20% will be plug-in hybrids that run on 90% electricity and 10% gasoline.

To model the fossil fuel savings from electrification of the light-duty fleet, the projected number of electric vehicles was first multiplied by the annual VMT per vehicle (12,000) to determine electric vehicle VMT. The electric vehicle VMT, which set to replace fossil fuel VMT, were then divided by average light duty vehicle fuel efficiency data from AEO to calculate the reduction in fossil fuel consumption due to vehicle electrification. Gasoline savings due to the increased fuel efficiency of PHEVs compared to the average light duty vehicle stock was also used to calculate overall fossil fuel decrease due to electric vehicles.

To calculate the associated increase in electric load due to electric vehicle charging, the electric vehicle VMT was multiplied by an assumed electric vehicle efficiency factor of 0.3 kWh/mile, and the product was added to total electric consumption.

Medium-Duty EVs

The Accelerated Scenario considered that 5.0% electrification of the medium duty fleet will occur by 2030. The same methodology as described for passenger EVs was applied to medium duty vehicles, using annual diesel consumption and vehicle fuel efficiency from AEO to calculate fuel reduction and electricity increase. Average annual VMT per vehicle of 20,000 miles from EIA and electric vehicle efficiency of 1.1 kWh/mile was used for the analysis.

VMT

Vehicle miles traveled in the Accelerated Scenario was calculated by reducing the baseline VMT for light duty vehicles in 2030 by 7%. VMT reductions compared to the Baseline Scenario were multiplied by fuel efficiency data from AEO to calculate the annual fossil fuel consumption and decrease.

Fuel reductions due to VMT reductions and electrification were added together and subtracted from the annual AEO fuel consumption forecast to calculate the net fuel consumption forecast for the Accelerated Scenario. New electric consumption due to electrification was added to the ISOs' electric consumption forecasts.

Figure 30: Accelerated Scenario Electric Vehicles as a Percentage of the Passenger Vehicle Fleet

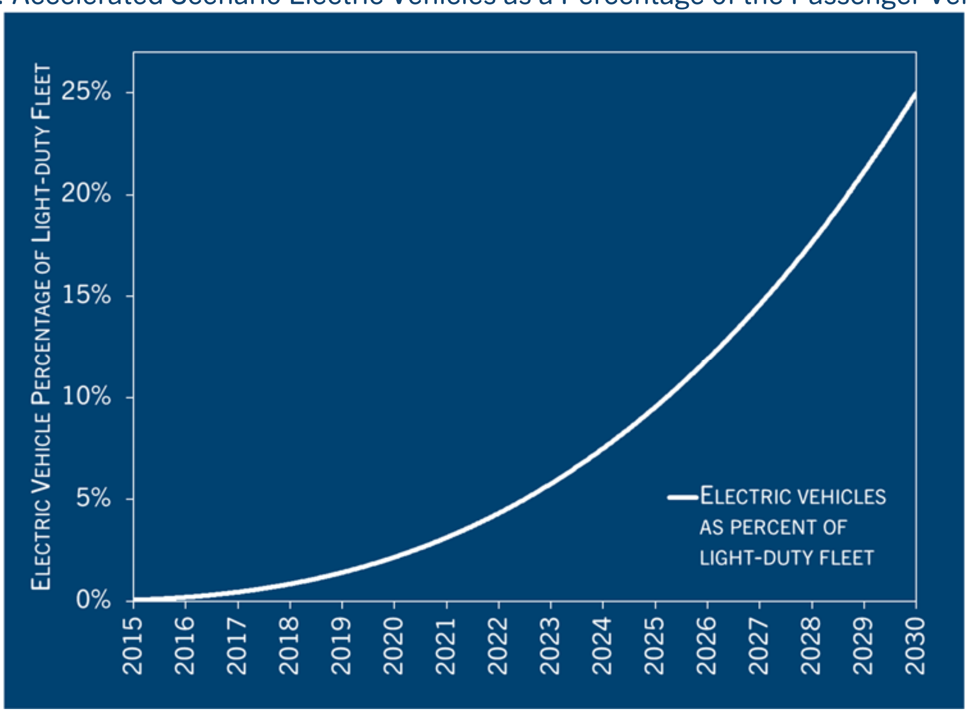


Figure 31: Accelerated Scenario Medium Duty Electric Vehicles as a Percentage of the Fleet

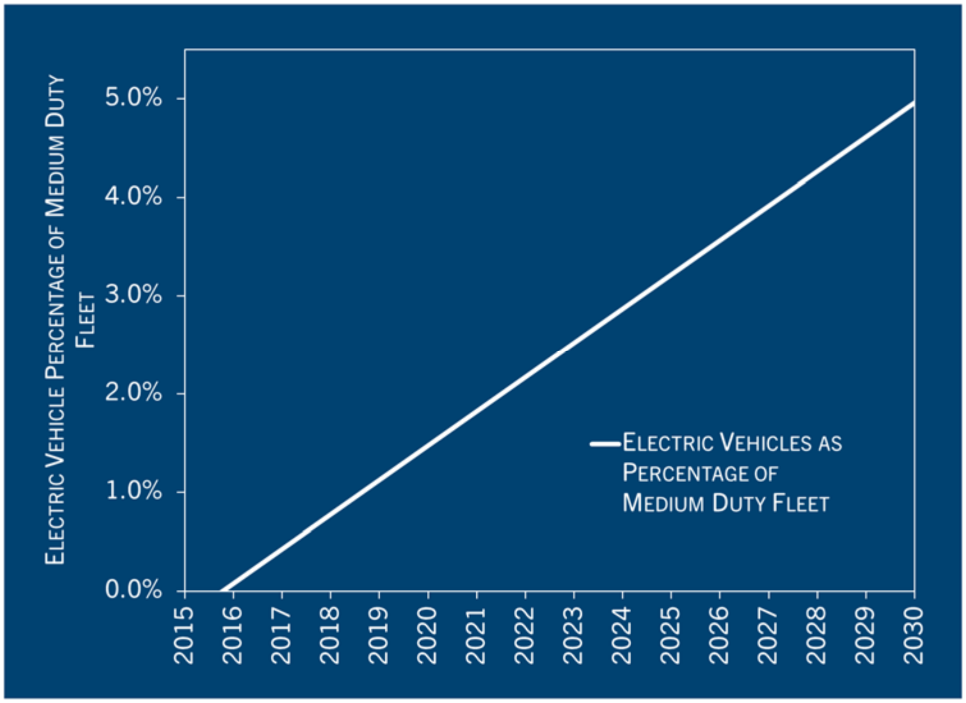
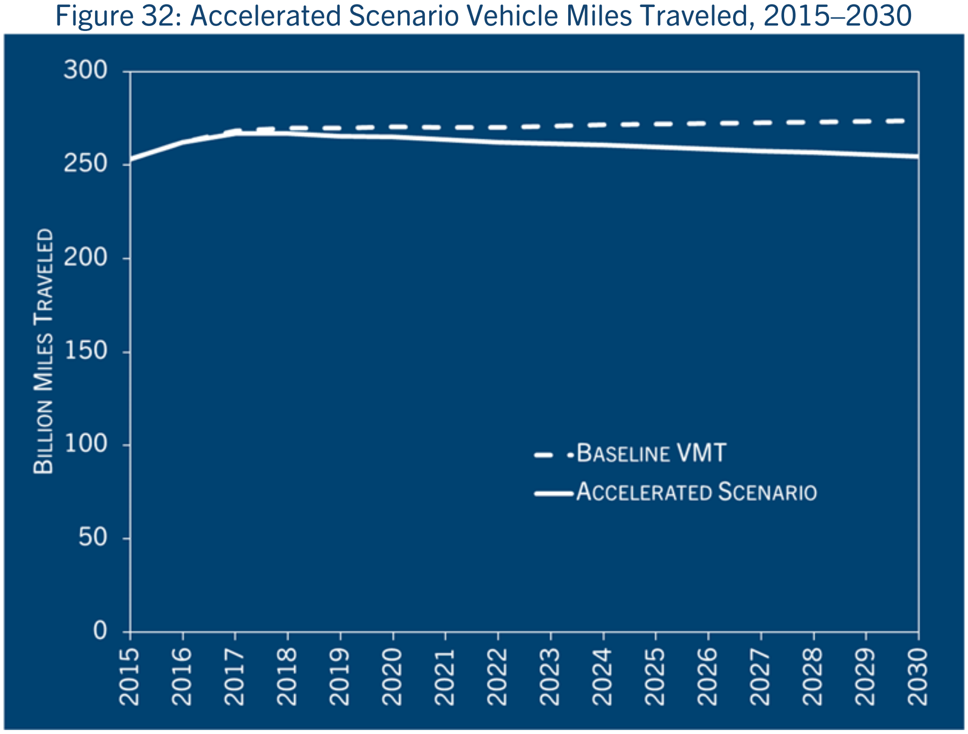


Figure 32: Accelerated Scenario Vehicle Miles Traveled, 2015–2030



Grid Modernization

The Accelerated Scenario considers that additional load management resources will be available by 2030, including demand response, advanced load management, and energy storage, compared to the Primary Scenario. To model these resources, hourly load from ISO-NE and NYISO was adjusted with electricity consumption changes due to electrification (in buildings and transportation), efficiency, and renewable energy integration. Daily average load was subtracted from adjusted hourly load each day to calculate load variation in MWs each day. The peaks in the daily load variations were adjusted with demand response capacity, advanced load management, and energy storage capacity. The Accelerated Scenario considers that an additional 3020 MW of demand response resources will be available to reduce peak load by 2030. The Accelerated Scenario also sets 3000 MW of advanced load management capacity and 6,000 MW of energy storage capacity to be installed by 2030 to shift and smooth daily load.

Results

The emissions outputs from the Accelerated Scenario are shown in Figure 33, including historical data from 1990, as well as the projection for the Primary and Baseline Scenarios. The data show that the Accelerated Scenario will meet the stronger target of a 50% reduction from 1990 levels. Figure 34 shows the contribution of each sector to the reductions in the Accelerated Scenario compared to the Baseline Scenario. Table 3 shows Accelerated Scenario projections for emissions from 2015 to 2030 by sector and region.

Figure 33: Emissions: Historical, Baseline, Primary Scenario, and Accelerated Scenario, 1990–2030

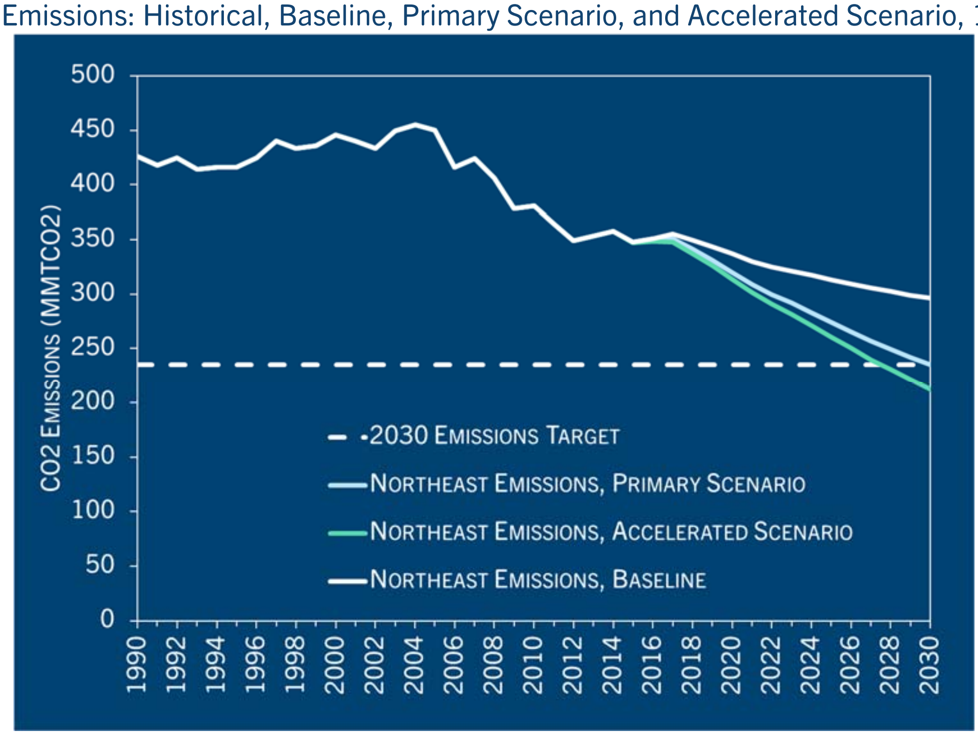
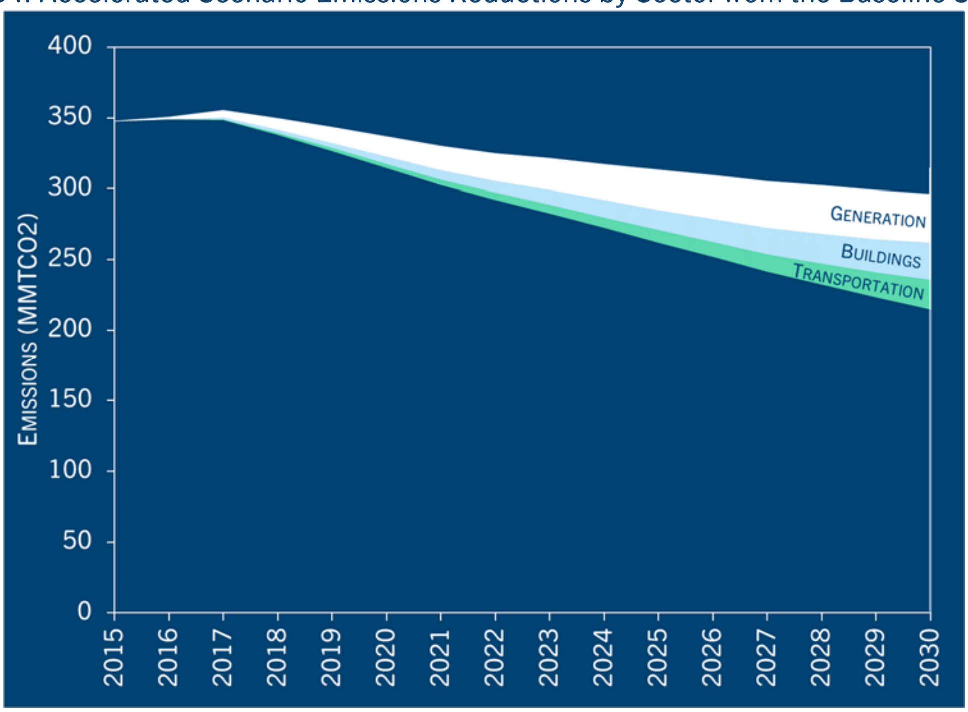


Figure 34: Accelerated Scenario Emissions Reductions by Sector from the Baseline Scenario



Scenario 2 Emissions by Sector, MMTCO2

New England	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Residential	31	28	27	27	26	25	24	23	22	21	20	19	18	17	16	14
Commercial	16	17	17	17	17	16	16	16	16	16	15	15	15	15	15	14
Transportation	66	68	68	67	67	65	64	62	61	60	58	56	54	52	50	48
Industry	8	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Electric Power	25	25	26	20	17	14	11	6	6	4	3	2	2	2	3	3
Total	146	148	149	142	137	131	125	118	115	111	107	103	99	97	93	90
Agriculture	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1
Waste	7	7	7	7	6	6	6	6	6	6	6	5	5	5	5	5
Imports	2	2	1	2	2	2	2	2	2	1	1	1	1	1	1	1
Final Total'	156	158	158	152	147	141	135	127	124	119	115	111	107	103	100	96

New York	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Residential	34	32	32	31	31	30	29	28	27	26	25	23	22	21	20	18
Commercial	21	24	24	25	24	23	23	22	22	22	22	21	21	21	20	20
Transportation	72	71	71	70	69	68	66	65	64	62	61	59	57	56	54	51
Industry	9	9	9	9	10	10	10	10	10	10	10	10	10	10	10	10
Electric Power	27	27	25	22	20	18	16	18	16	15	12	10	10	8	7	6
Total	162	164	162	158	153	148	143	143	138	135	129	124	120	115	111	106
Agriculture	5	5	4	4	4	4	4	3	3	3	3	2	2	2	2	2
Waste	15	15	14	14	13	13	13	12	12	11	11	11	10	10	10	9
Imports	9	8	10	10	9	8	7	6	5	3	3	2	0	0	0	0
Final Total'	191	191	190	186	179	173	167	164	158	152	146	140	133	127	122	117

Combined	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Residential	64	60	60	58	56	55	53	51	49	47	45	43	40	38	35	33
Commercial	36	41	42	42	41	40	39	38	38	37	37	36	36	35	35	34
Transportation	138	140	140	138	135	133	130	127	125	122	119	115	112	108	104	99
Industry	17	19	19	20	20	20	20	20	20	20	20	20	20	20	20	20
Electric Power	52	52	51	42	37	32	27	24	22	19	16	12	12	10	9	9
Total	308	311	311	300	289	279	269	261	253	246	236	227	220	212	204	195
Agriculture	7	7	6	6	6	5	5	5	4	4	4	3	3	3	3	2
Waste	22	21	21	20	20	19	19	18	18	17	17	16	16	15	14	14
Imports	10	9	10	11	11	10	9	7	6	4	4	4	1	1	1	1
Final Total'	347	349	348	337	326	314	302	291	282	271	261	250	240	230	221	212