Final 2024 Photovoltaic (PV) Forecast

Distributed Generation Forecast Working Group

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Objective

- Share the final 2024 PV forecast and related work products with the DGFWG

Forecast Review Process

- The following materials were presented as part of the 2024 forecast cycle:
  - Overview of NREL's Distributed Generation Market Demand Model (dGen™) - October 27, 2023
  - ISO's Preliminary Modeling Assumptions – December 4, 2023
  - December 2023 Distributed Generation Survey Results – February 16, 2024
- The ISO discussed the draft 2024 PV forecast with the DGFWG at the February 16, 2024 meeting
  - Stakeholders did not provide any comments on the draft forecast
- The ISO did not make additional changes since discussing the draft 2024 PV nameplate forecast

INTRODUCTION

Introduction

- The majority of state-sponsored distributed PV does not participate in wholesale markets, but reduces the system load observed by ISO
- The long-term PV forecast helps the ISO determine future system load characteristics that are important for the reliable planning and operation of the system
- To properly account for PV in long-term planning, the finalized PV forecast is categorized as follows:
  1. PV as a capacity resource in the Forward Capacity Market (FCM)
  2. Non-FCM Energy Only Resources (EOR) and Generators
  3. Behind-the-meter PV (BTM PV)

Similar to energy efficiency (EE), behind-the-meter PV is reconstituted into historical loads*

The 2024 gross load forecast reflects loads without PV load reductions

**Existing BTM PV decreases the historical metered loads, which are an input to the gross load forecast*

PV Forecast Focuses on Distributed Generation

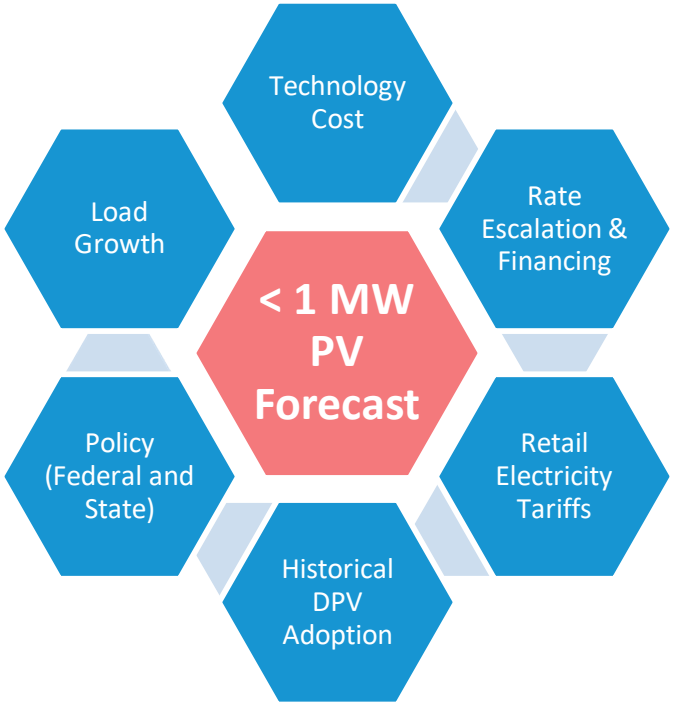
- The focus of the DGFWG is distributed generation (DG) projects:
  - "…defined as those that are typically 5 MW or less in nameplate capacity and are interconnected to the distribution system (typically 69 kV or below) according to state-jurisdictional interconnection standards."
  - Note that the industry has evolved since the formation of the DGFWG, and today DG is often referred to as a distributed energy resource (DER)
    - DER is defined in this context as *a source of electric power that is interconnected to the distribution system*
      - DER includes both generators and energy storage technologies
      - DER does not include demand response, controllable loads, or other load modifiers
- Therefore, the forecast does not consider policy drivers supporting larger-scale projects (i.e., those >5 MW)
- Large projects are generally accounted for as part of ISO's interconnection process and participate in wholesale markets

PV Forecast Methodology

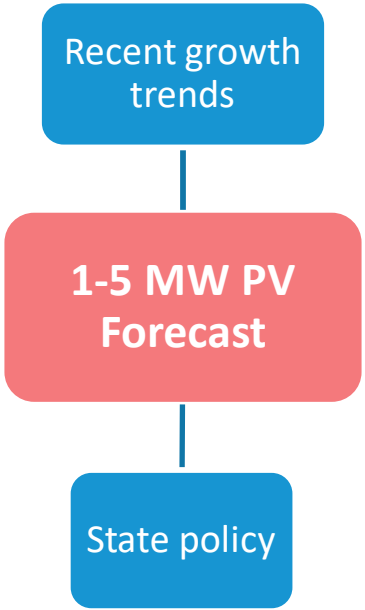
- The PV forecast is a projection of distributed PV resources to be used in ISO-NE System Planning studies, consistent with its role to ensure prudent planning assumptions for the bulk power system.
- For 2024 PV forecast, the ISO has updated its methodology to include the Distributed Generation Market Demand Model (dGen™), an agent-based simulation that was developed and open-sourced by the National Renewable Energy Laboratory (NREL)
- The ISO now develops the distributed PV nameplate forecast as part of two additive processes:
  1. For < 1 MW systems: Use residential and commercial dGen™ modeling
  2. For 1-5 MW systems: Use a policy-based approach
- The ISO used a policy-based forecasting approach to generate forecast for all PV systems in the New England states that are equal or greater than one megawatt, but less than five megawatts.

PV Forecast Inputs

PV Systems < 1 MW



PV Systems 1-5 MW



FINAL 2024 PV NAMEPLATE CAPACITY FORECAST

Final 2024 PV Forecast

Nameplate Capacity, MW_{ac}

States	Annual Total MW (AC nameplate rating)											Totals
	Thru 2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	
CT	1,090.5	150.8	160.6	164.9	164.7	158.5	160.4	162.4	170.9	174.4	170.0	**2,728.1**
MA	3,712.0	326.5	320.9	313.6	309.7	300.1	288.0	279.2	283.7	290.5	284.9	**6,709.1**
ME	588.0	223.6	123.0	119.6	118.9	113.0	111.0	107.6	109.3	107.0	105.8	**1,826.9**
NH	244.0	27.3	26.5	25.6	24.0	22.7	22.0	22.8	24.4	25.4	25.6	**490.3**
RI	400.0	46.4	49.0	49.0	49.3	48.2	48.7	49.2	52.0	53.1	51.3	**896.1**
VT	507.0	29.3	29.2	29.0	29.8	25.4	27.3	28.9	34.0	37.1	38.3	**815.3**
Regional - Annual (MW)	**6,541.5**	**803.9**	**709.1**	**701.7**	**696.5**	**667.9**	**657.5**	**650.2**	**674.3**	**687.5**	**675.8**	**13,465.8**
Regional - Cumulative (MW)	**6,541.5**	**7,345.4**	**8,054.5**	**8,756.2**	**9,452.6**	**10,120.5**	**10,778.0**	**11,428.2**	**12,102.5**	**12,790.0**	**13,465.8**	**13,465.8**

Notes:

(1) Forecast values include FCM Resources, non-FCM Energy Only Generators, and behind-the-meter PV resources

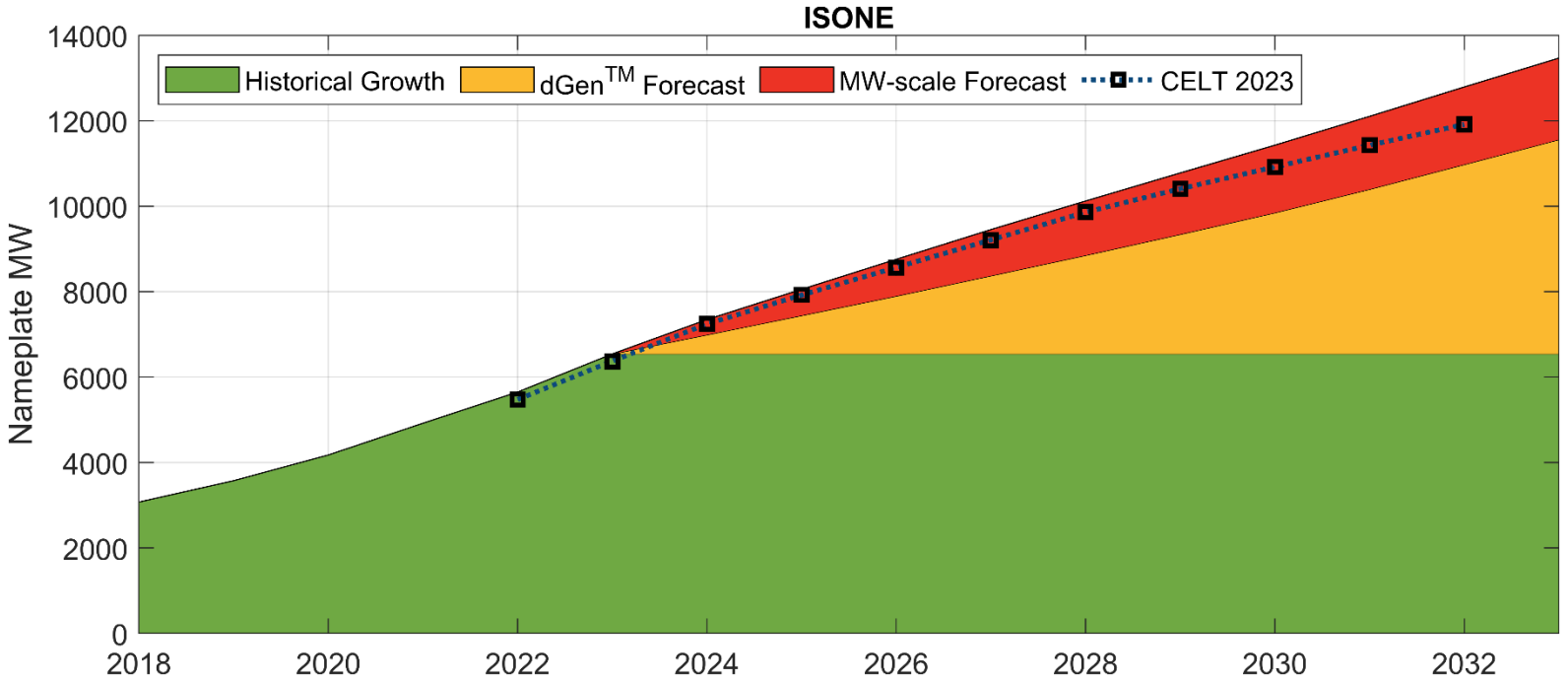
(2) The forecast values are net of the effects of discount factors applied to reflect a degree of uncertainty in the policy-based forecast

(3) All values represent end-of-year installed capacities

(4) Forecast does not include forward-looking PV projects > 5MW in nameplate capacity

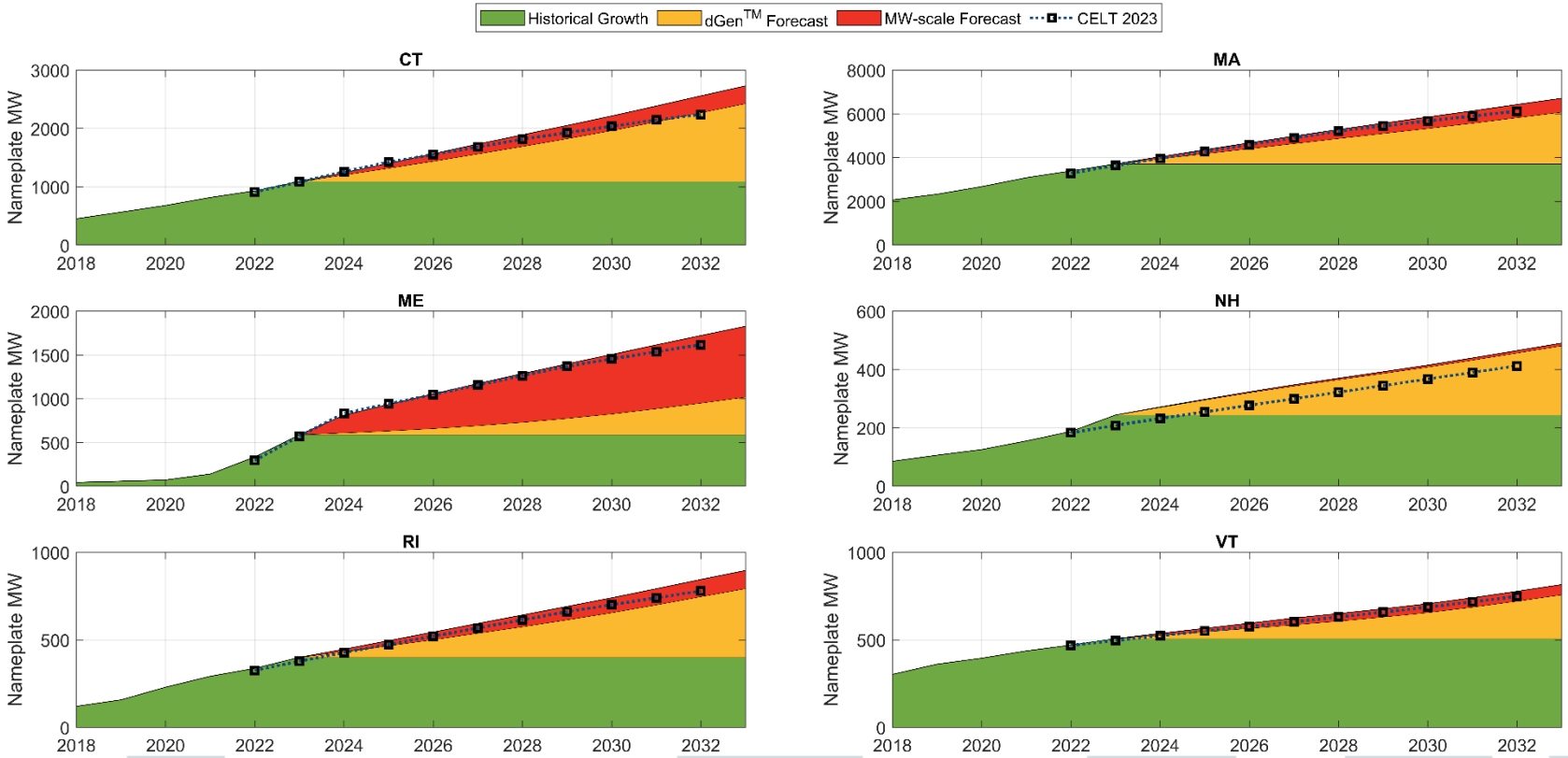
Regional PV Nameplate Capacity Growth

Historical vs. Forecast



State PV Nameplate Capacity Growth

Historical and Forecast



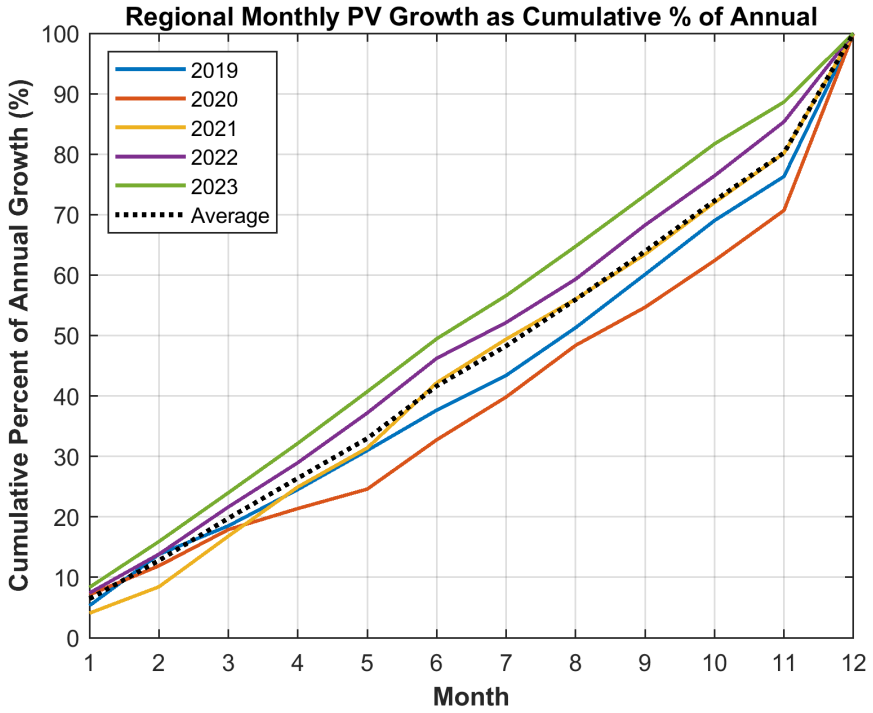
2024 PV ENERGY FORECAST

Development of PV Energy Forecast

- The PV nameplate forecast reflects end-of-year values
- Energy estimates in the PV forecast are inclusive of incremental growth during a given year
- ISO assumed that historical PV growth trends across the region are indicative of future intra-annual growth rates
  - Growth trends between 2019 and 2023 were used to estimate intra-annual incremental growth over the forecast horizon (see next slide)
- The PV energy forecast was developed at the state level, using state monthly nameplate forecasts and state average monthly capacity factors (CF) developed from 10 years of PV performance data (2014-2023)
  - Resulting state and regional CFs are tabulated to the right, and plots of individual monthly capacity factors in each state are shown on slide 45

State	Average CF, %
CT	14.7
ME	14.7
NH	14.2
RI	14.9
VT	13.8
MA	14.5
ISO-NE	**14.5**

Historical Monthly PV Growth Trends, 2019-2023



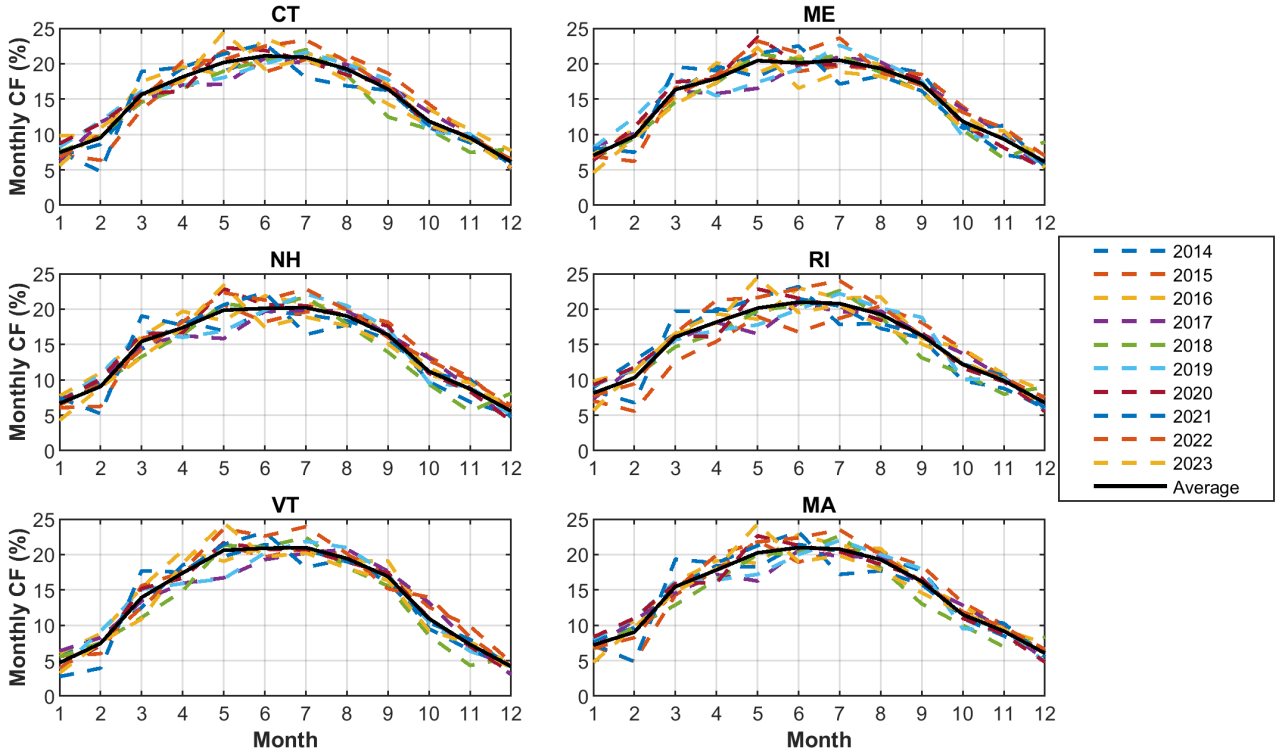
Average Monthly Growth Rates, % of Annual

Month	Monthly PV Growth (% of Annual)	Monthly PV Growth (Cumulative % of Annual)
1	6%	6%
2	6%	12%
3	7%	19%
4	7%	26%
5	7%	33%
6	9%	42%
7	6%	48%
8	8%	56%
9	8%	64%
10	8%	72%
11	8%	80%
12	20%	100%

Note:
Monthly percentages represent end-of-month values, and may not sum to total due to rounding

Monthly PV Capacity Factors by State

PV Production Data, 2014-2023



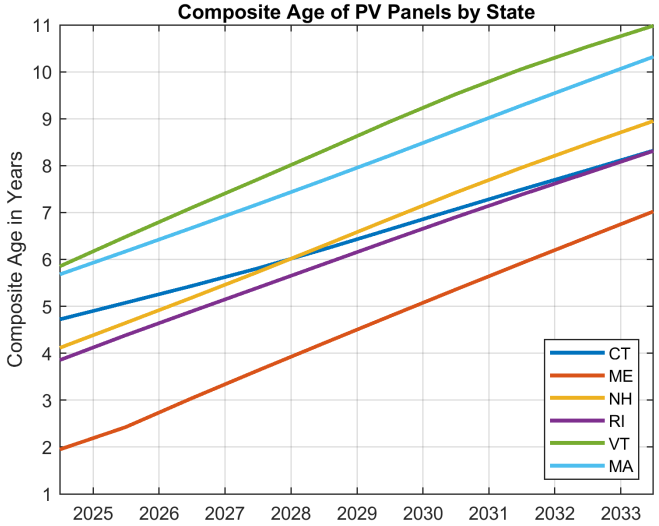
PV Panel Degradation Factors

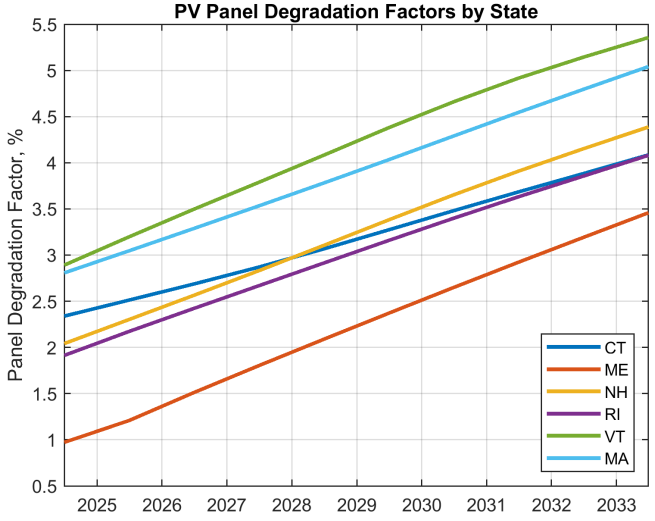
- No changes to the methodology to account for panel degradation were made since last year's forecast
- Forecasts of BTM PV energy and estimated summer peak load reductions include the effects of a 0.5%/year panel degradation rate to account for the expected declining conversion efficiency of solar panels over time
  - Accounting for this degradation becomes more important as the region's PV panels age
- Long-term panel degradation is often caused by:
  - Degradation of silicon or solder joints
  - Problems with the encapsulant that cause delamination, increased opacity, or water ingress
- Based on research by the National Renewable Energy Laboratory (NREL), the median rate of degradation is 0.5%/year, and is assumed to be linear over time
  - More information available here: https://www.nrel.gov/pv/lifetime.html
- The ISO estimated the capacity-weighted composite age of the forecasted PV fleet to develop appropriate degradation factors to use for the forecast

PV Panel Degradation Factors

Composite Age (left) & Degradation Factors (right) by State

- The resulting capacity-weighted, composite age of all PV in each state (left plot) and corresponding degradation factors (right plot) over the forecast horizon are plotted below
- The degradation factors are the assumed percent reduction of PV performance over time that reflect the anticipated degradation of PV panels





Final 2024 PV Energy Forecast

All Forecast PV (FCM+EOR+BTM), GWh

States	Total Estimated Annual Energy (GWh)										
	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
CT	1,355	1,547	1,748	1,961	2,176	2,390	2,591	2,798	3,011	3,237	3,450
MA	4,667	5,059	5,461	5,861	6,251	6,642	6,994	7,342	7,684	8,045	8,379
ME	628	931	1,167	1,327	1,482	1,636	1,778	1,918	2,056	2,197	2,327
NH	279	331	364	396	427	456	483	510	538	569	599
RI	513	573	635	700	764	830	891	955	1,020	1,089	1,154
VT	598	646	679	713	747	780	808	840	876	918	960
Regional - Annual Energy (GWh)	**8,040**	**9,086**	**10,054**	**10,958**	**11,848**	**12,734**	**13,545**	**14,362**	**15,184**	**16,054**	**16,869**

Notes:

(1) Forecast values include energy from FCM Resources, non-FCM Energy Only Generators, and behind-the-meter PV resources

(2) Monthly in service dates of PV assumed based on historical development

(3) Values include the effects of an assumed 0.5%/year PV panel degradation rate

(4) All values are grossed up by 6% to reflect avoided transmission and distribution losses

CLASSIFICATION OF PV FORECAST

Background & Methods

Classification Needed to Determine BTM PV

- Ultimately, the ISO needs to determine the amount of PV that is not expected to participate in wholesale markets, and instead reduces load
  - This is the amount of BTM PV that is reflected in the long-term load forecast
- In order to properly account for existing and future PV in planning studies and avoid double counting, ISO classifies PV into three distinct categories related to its assumed market participation/non-participation
- Accounting for these market distinctions is performed for both installed nameplate capacity (historical and forecast) and estimates of hourly energy production (historical), and is important for the ISO's use of the PV forecast for load forecasting and a wide range of planning studies

Three Mutually Exclusive Categories

1. PV as a resource in the Forward Capacity Market (FCM)
   - Qualified for the FCM and have acquired capacity supply obligations
   - Size and location identified and visible to the ISO
   - May be supply or demand-side resources
2. Non-FCM Energy Only Resources (EOR) and Generators
   - ISO collects energy output
   - Participate only in the energy market
3. Behind-the-Meter (BTM) PV
   - Not in ISO Market
   - Reduces system load
   - ISO has an incomplete set of information on generator characteristics
   - ISO does not collect energy meter data, but can estimate it using other available data

Nameplate Classification By State

- Classification varies by state
  - Market disposition of PV projects can be influenced by state policies (*e.g.*, net metering requirements)
- The following steps were used to determine PV resource types for each state over the forecast horizon:
  1. FCM
     - Identify all Generation and Demand Response FCM PV resources for each Capacity Commitment Period (CCP) through FCA 18
  2. Non-FCM EOR/Gen
     - Determine the % share of non-FCM PV participating in energy market at the end of 2023
  3. BTM
     - Net the values from steps 1 and 2 from the annual state PV forecast according to assumptions detailed on the next slide; the remainder is the BTM PV

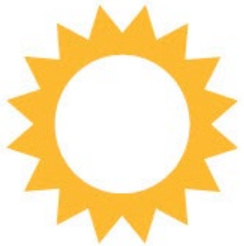
PV in ISO New England Markets

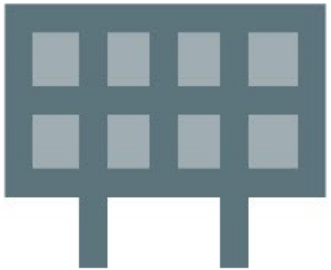
Data and Assumptions

- FCM
  - ISO identified all PV generators or demand resources (DR) that have Capacity Supply Obligations (CSO) in FCM up through FCA 18
    - Maintain separate accounting for FCM_{supply} and FCM_{DR}
  - Assume aggregate total PV in FCM as of FCA 18 remains constant from 2027-2033
- Non-FCM Gen/EOR
  - ISO identified total nameplate capacity of PV in each state registered in the energy market as of 12/31/23
  - Assume the (EOR+FCM_{supply}) share of total PV at the end of 2023 in each state *except Maine* remains constant throughout the forecast horizon
    - For Maine, assume (EOR+FCM_{supply}) share is 75% over the forecast horizon to reflect how new policies prompting the majority of future PV growth require participation in wholesale markets
- Other assumptions
  - FCM_{supply} PV resources operate as EOR/Gen prior to their first FCM commitment period (this has been observed in MA and RI)
  - Planned PV projects known to be > 5 MW_{ac} nameplate are assumed to trigger OP-14 requirement to register in ISO energy market as a Generator

Estimation of Hourly BTM PV For Reconstitution

- Historical BTM PV production estimates are developed at the hourly level for reconstitution in the development of the long-term gross load forecast
  - Estimates cover the historical period starting January 1, 2012
- The ISO estimates historical hourly BTM PV using:
  - Historical BTM PV performance data
  - Installed capacity data submitted by utilities
  - Historical energy production of market-facing PV
- BTM PV data and supporting documentation are available here on the ISO New England website





CLASSIFICATION OF 2024 PV FORECAST

Results

Final 2024 PV Forecast

Cumulative Nameplate Capacity, MW_{ac}

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Regional - Cumulative (MW)	**6,541.5**	**7,345.4**	**8,054.5**	**8,756.2**	**9,452.6**	**10,120.5**	**10,778.0**	**11,428.2**	**12,102.5**	**12,790.0**	**13,465.8**	**13,465.8**

Notes:

(1) Forecast values include FCM Resources, non-FCM Energy Only Generators, and behind-the-meter PV resources

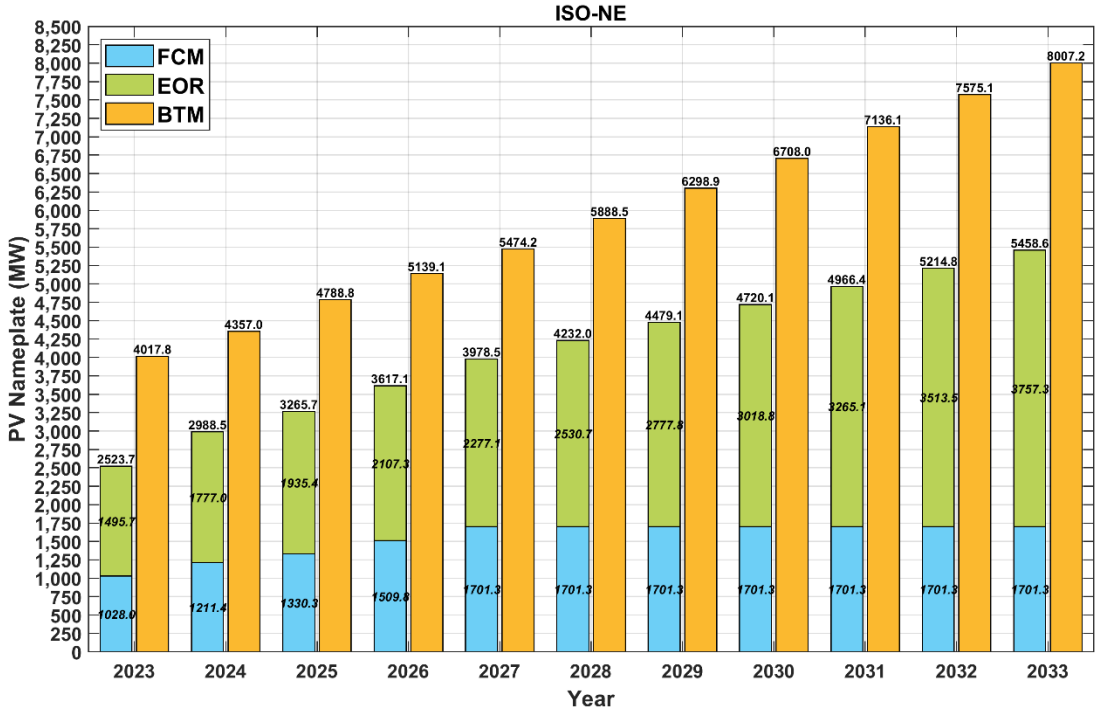
(2) The forecast values are net of the effects of discount factors applied to reflect a degree of uncertainty in the policy-based forecast

(3) All values represent end-of-year installed capacities

(4) Forecast does not include forward-looking PV projects > 5MW in nameplate capacity

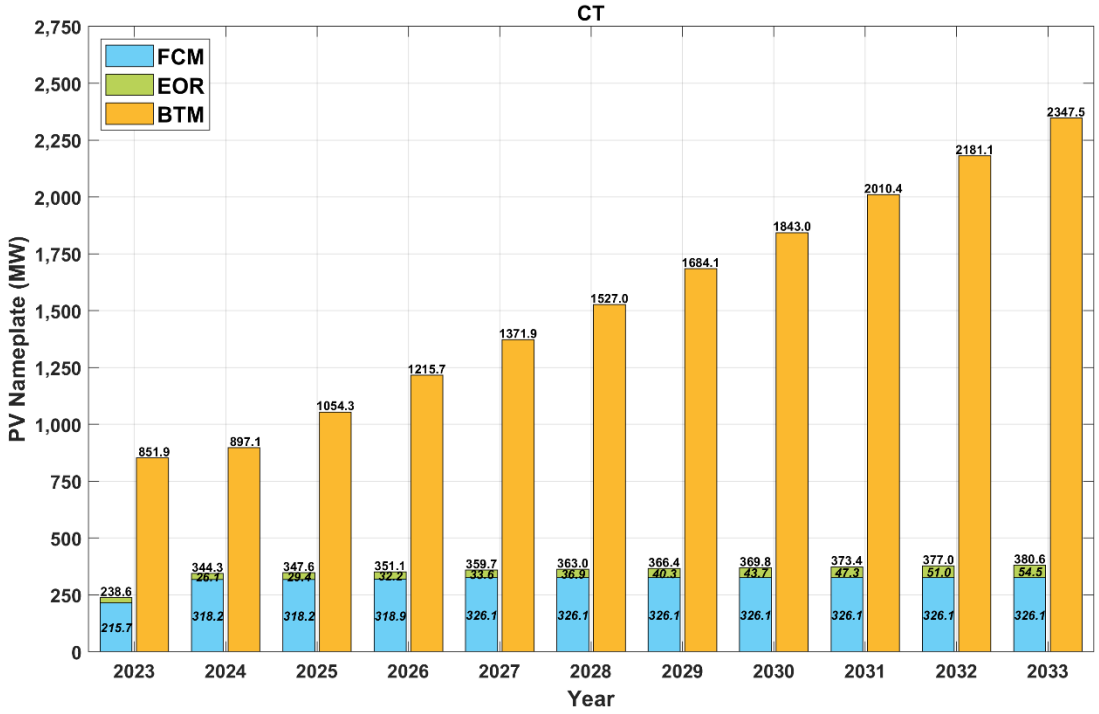
Final 2024 PV Forecast – New England

Cumulative Nameplate by Category, MW_{ac}



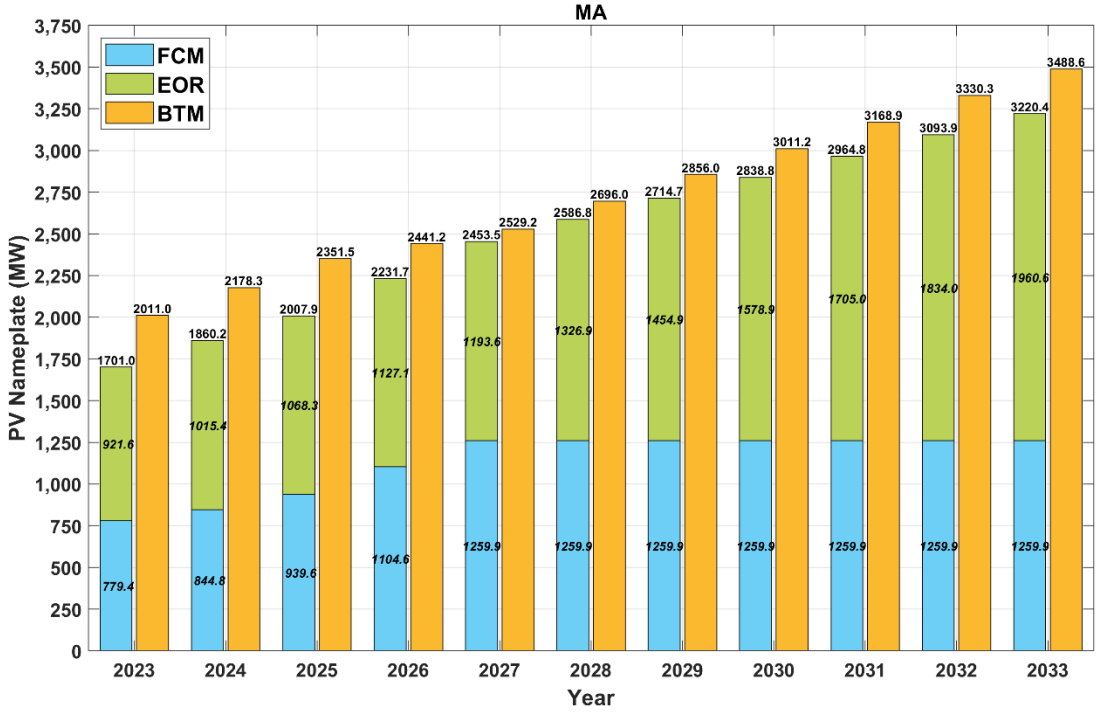
Final 2024 PV Forecast – Connecticut

Cumulative Nameplate by Category, MW_{ac}



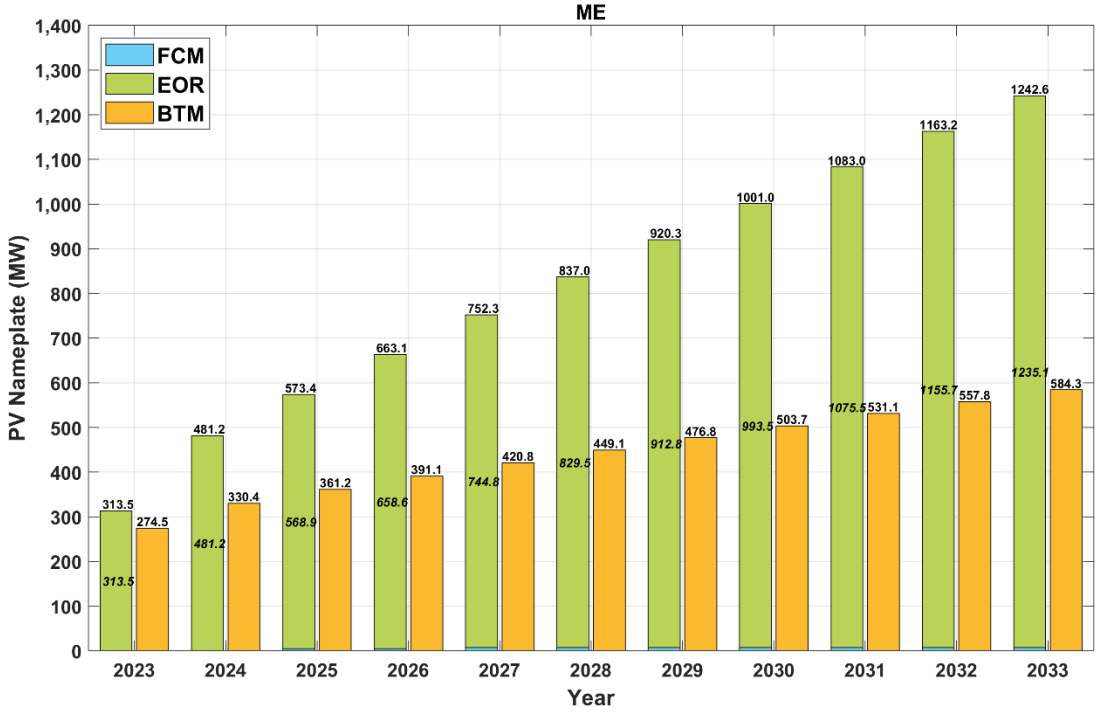
Final 2024 PV Forecast – Massachusetts

Cumulative Nameplate by Category, MW_{ac}



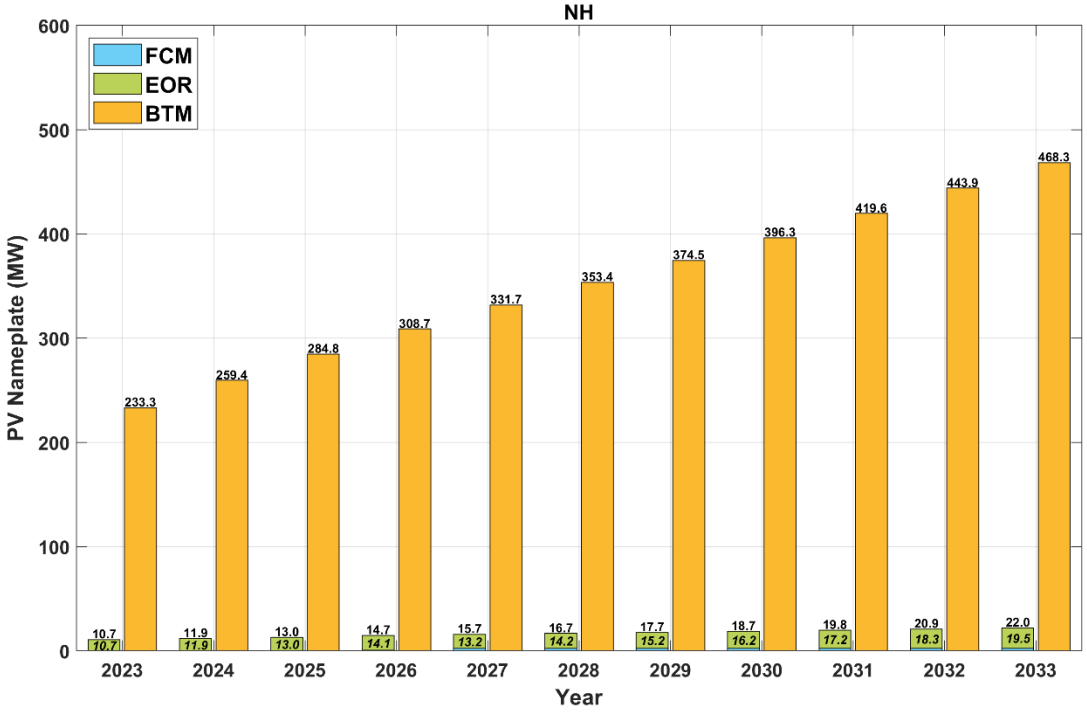
Final 2024 PV Forecast – Maine

Cumulative Nameplate by Category, MW_{ac}



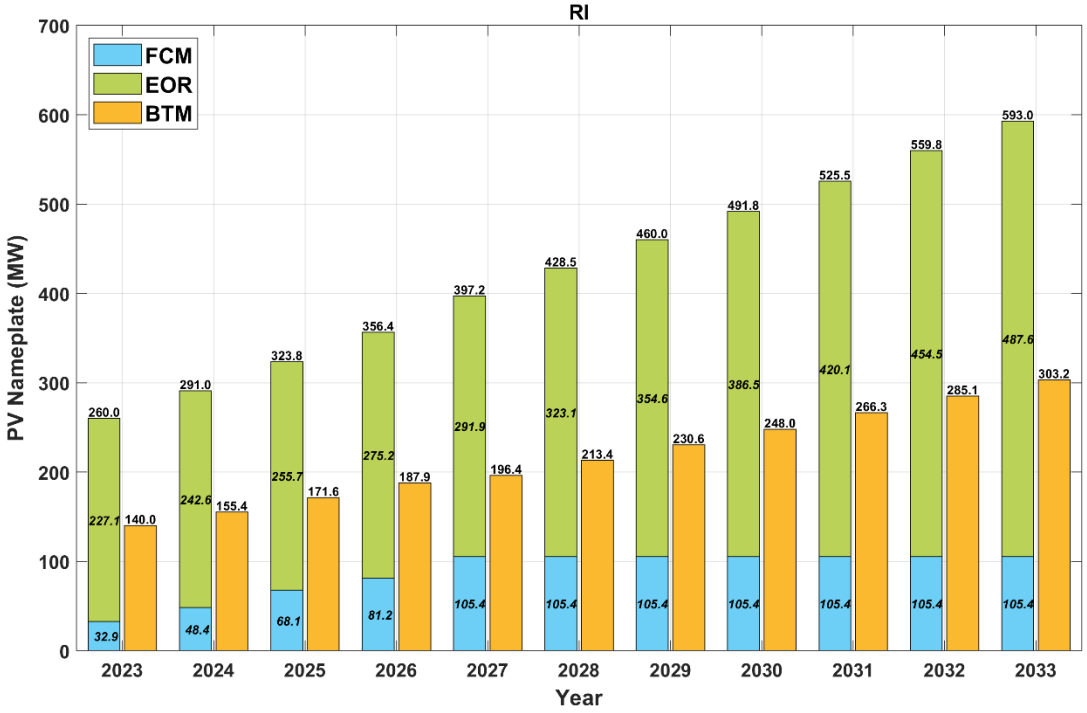
Final 2024 PV Forecast – New Hampshire

Cumulative Nameplate by Category, MW_{ac}



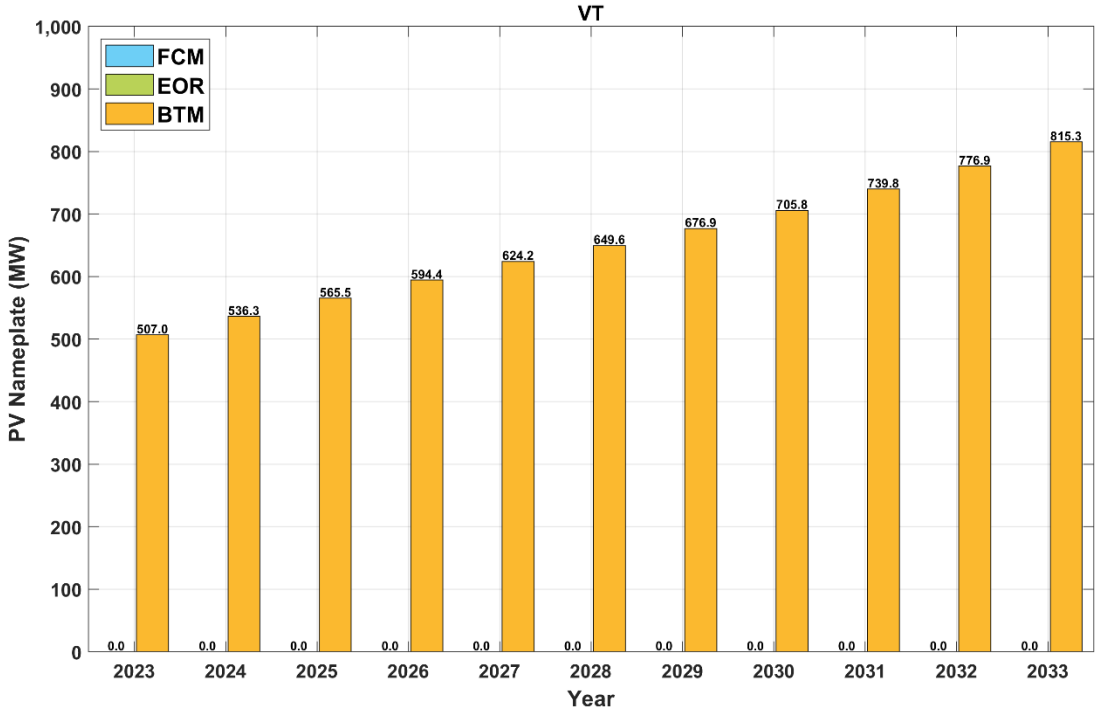
Final 2024 PV Forecast – Rhode Island

Cumulative Nameplate by Category, MW_{ac}



Final 2024 PV Forecast – Vermont

Cumulative Nameplate by Category, MW_{ac}



BTM PV Forecast Used in CELT Net Load Forecast

- The 2024 CELT net load forecast will reflect deductions associated with the BTM PV portion of the PV forecast
- The following slides show values for annual energy and summer peak load reductions anticipated from BTM PV that will be reflected in the 2024 CELT
  - PV does not reduce winter peak loads, which occur after sunset
- Documentation of the ISO's methodology for estimating summer peak load reduction associated with BTM PV over the forecast horizon is available here

Final 2024 BTM PV Energy Forecast

GWh

Category	States	Estimated Annual Energy (GWh)										
		2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Behind-the-Meter PV	CT	955	1,144	1,288	1,497	1,704	1,911	2,110	2,313	2,522	2,743	2,954
	MA	2,147	2,732	2,945	3,098	3,206	3,380	3,577	3,771	3,962	4,163	4,350
	ME	208	405	464	503	541	580	614	649	683	718	750
	NH	250	316	348	378	408	436	461	487	514	543	572
	RI	130	200	220	242	257	275	297	319	342	367	390
	VT	595	646	679	713	747	780	808	840	876	918	960
Behind-the Meter Total	**Regional Total**	**4,284**	**5,444**	**5,943**	**6,431**	**6,863**	**7,361**	**7,867**	**8,379**	**8,899**	**9,452**	**9,975**

Notes:

(1) Forecast values include energy from behind-the-meter PV resources only

(2) Monthly in service dates of PV assumed based on historical development

(3) Values include the effects of an assumed 0.5%/year PV panel degradation rate

(4) All values are grossed up by 6% to reflect avoided transmission and distribution losses

Final 2024 BTM PV Forecast

July 1st Estimated Coincident Summer Peak Load Reductions

Category	States	Cumulative Total MW - Estimated Summer Seasonal Peak Load Reduction										
		2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Behind-the-Meter PV	CT	222.3	217.3	242.5	267.5	288.3	306.6	322.1	336.6	350.4	363.7	375.5
	MA	538.9	554.3	564.1	554.2	543.0	549.1	552.9	555.3	556.9	558.3	559.2
	ME	65.7	80.9	87.5	89.9	91.6	92.8	93.5	94.0	94.4	94.7	94.8
	NH	58.9	65.9	68.4	70.4	71.9	72.7	73.1	73.6	74.1	74.7	75.4
	RI	35.7	39.4	40.9	42.6	42.1	43.4	44.6	45.7	46.8	47.8	48.7
	VT	137.4	138.8	137.5	136.7	135.7	134.0	132.1	130.7	130.0	130.0	130.3
Total	Cumulative	1,059.0	1,096.7	1,140.9	1,161.3	1,172.6	1,198.6	1,218.3	1,235.9	1,252.5	1,269.2	1,283.8
Corresponding % of BTM PV AC nameplate capacity		27.3%	25.5%	24.0%	22.7%	21.5%	20.4%	19.3%	18.4%	17.6%	16.8%	16.1%

Notes:

(1) Forecast values reflect New England coincident summer peak reductions associated with behind-the-meter PV resources only

(2) Values include the effect of diminishing PV production as increasing PV penetrations shift the timing of peaks later in the day; details of the methodology used to determine the estimated peak demand reductions are available at: http://www.iso-ne.com/static-assets/documents/2020/04/final_btm_pv_peak_reduction.pdf

(3) Values include the effects of an assumed 0.5%/year PV panel degradation rate

(4) All values represent anticipated July 1st installed PV, and are grossed up by 8% to reflect avoided transmission and distribution losses

(5) Different planning studies may use values different that these estimated peak load reductions based on the intent of the study

Summary and Next Steps

- The 2024 PV forecast has been finalized
  - The ISO has developed the associated energy and summer peak reduction forecasts, and categorized the forecast according to the three PV resource categories
- The final PV forecast will appear in the 2024 CELT, which will be published by May 1, 2024

Questions