MARCH 24, 2025 | HOLYOKE, MA

Final 2025 Photovoltaic (PV) Forecast

Distributed Generation Forecast Working Group

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LEAD DATA SCIENTIST

ADVANCED FORECASTING & ANALYTICS

Acronyms

BTM	Behind-the-meter	**IOU**	Investor-owned utility
CBI	Capacity-based incentive	**ITC**	Investment tax credit
CELT	Capacity, Energy, Load, and Transmission report	**NEB**	Net energy billing (ME)
C&I	Commercial and industrial	**NM, NEM**	Net metering, net energy metering
DER	Distributed energy resource	**NREL**	National Renewable Energy Laboratory
DG	Distributed generation	**NRES**	Non-residential Renewable Energy Solutions (CT)
DGFWG	Distributed Generation Forecast Working Group	**PP12**	ISO-NE Planning Procedure 12
dGEN™	Distributed Generation Market Demand Model	**PV**	Photovoltaic
EOR	Energy only resources	**REF**	Renewable Energy Fund (RI)
FCM	Forward Capacity Market	**REG**	Renewable Energy Growth program (RI)
FITs	Feed-in-tariffs	**RRES**	Residential Renewable Energy Solutions (CT)
IBI	Investment-based incentive	**SCEF**	Shared Clean Energy Facility program (CT)
ICR	Installed Capacity Requirement	**SMART**	Solar Massachusetts Renewable Target

Objective

- Share the final 2025 PV forecast and related work products with the DGFWG

Forecast Review Process

- The following materials were presented as part of the 2025 forecast cycle:
  - DER forecast improvements – December 9, 2024
  - December 2024 DER Photovoltaic Interconnection Data Update – February 10, 2025
- The ISO discussed the draft 2025 PV forecast at the February 10, 2025 meeting
  - No formal written comments were submitted
- The ISO's updates to the draft 2025 PV forecast were based on feedback received during the February DGFWG meeting, and other planned updates to input variables

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 will be 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)

Behind-the-meter PV is reconstituted into historical loads*

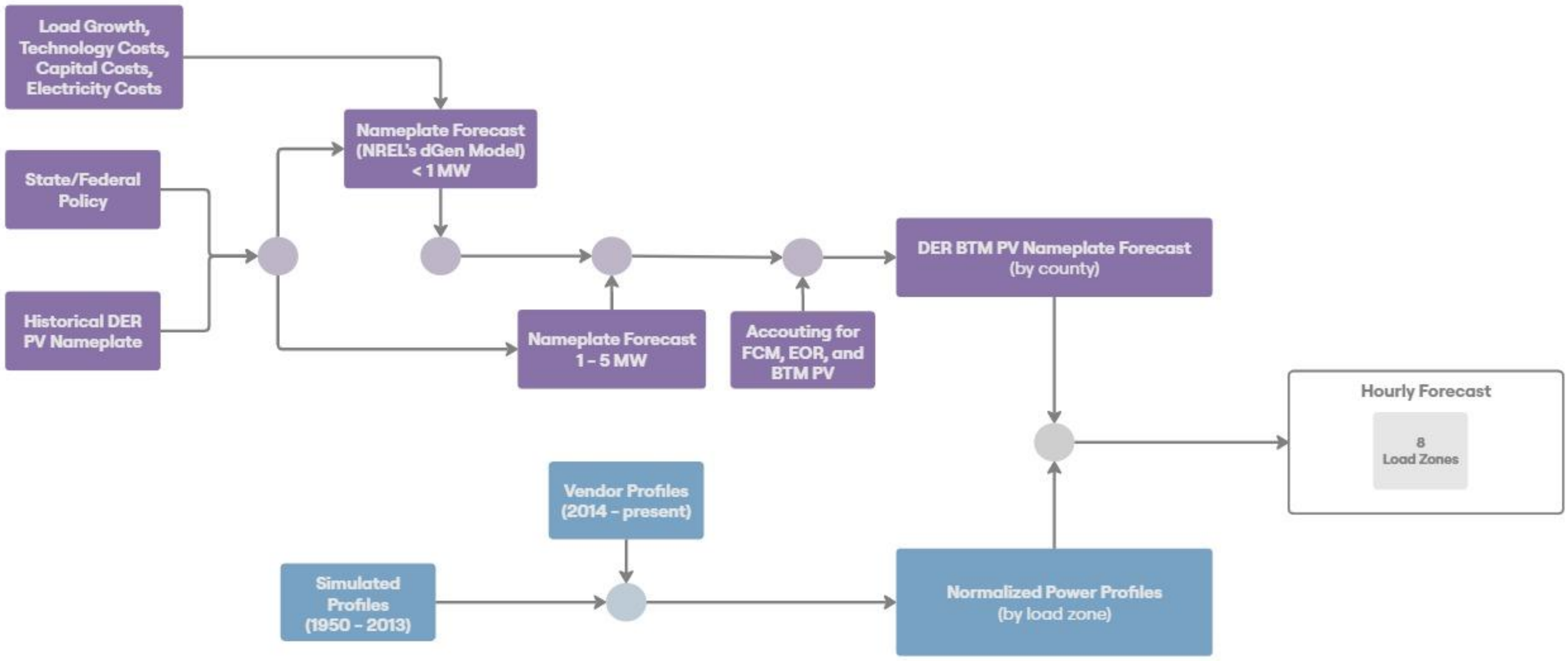
The 2025 gross load forecast reflects loads without BTM PV load reductions

******Historical BTM PV reduces historical metered loads; historical loads reconstituted for BTM PV are used to model base load in developing the base 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)
    - Per ISO's Planning Procedure 12, DER is defined *as any generator or energy storage facility located on the distribution system, any subsystem thereof, or behind a customer meter that is capable of providing energy injection, energy withdrawal, regulation or demand reduction*
      - DER does not include demand response, controllable loads, or other load modifiers
- While DER may include larger-scale DER projects greater than 5 MW in size, the forecast does not consider policy drivers and growth of larger-scale DER projects, since these projects are generally accounted for as part of ISO's interconnection process and participate in wholesale markets

CELT 2025 DER PV Forecast Process Flow



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

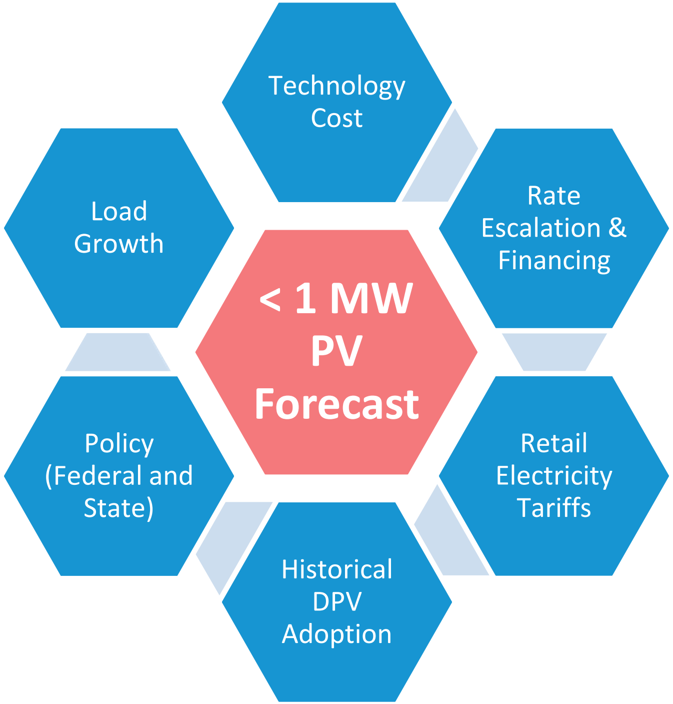
- Beginning with the 2024 PV forecast, the ISO's methodology includes use of the Distributed Generation Market Demand Model (dGen™), an agent-based simulation that was developed and open-sourced by the National Renewable Energy Laboratory (NREL)
  - An overview of the dGen™ model was presented by the NREL team at the October 2023 DGFWG meeting

- The nameplate PV forecast is developed using the two following additive processes:
  1. For < 1 MW systems: Use residential and commercial dGen™ modeling
  2. For 1-5 MW systems: Use a policy-based approach

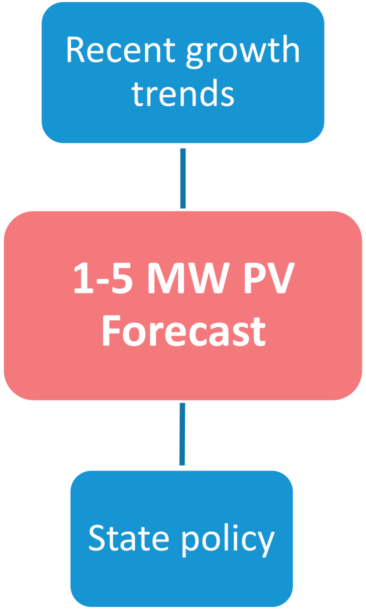
- For this year's forecast, the ISO is developing the forecast out through 2050

PV Forecast Inputs

PV Systems < 1 MW



PV Systems 1-5 MW



FINAL 2025 PV NAMEPLATE CAPACITY FORECAST

Updates to 2025 PV Draft Forecast

- Updated inputs to reflect 2024 Annual Technology Baseline (ATB) pricing and re-ran dGen™ forecasts
- Updated VT MW-scale forecast to reflect anticipated load growth based on the 2025 draft load forecast
- Update ME MW-scale forecast based on stakeholder feedback and research on NEB policy changes

Maine MW-Scale Forecast Updates

- Based on Maine's DGFWG December, 2024 presentation, all NEB "kWh" projects between 1-5 MW must reach commercial operation by December 31, 2024. Moving forward, projects that can participate in NEB programs must be less than 1MW
- All future projects in the C&I tariff NEB program must be collocated with 100% of the subscribed load in order to participate in the program
  - ISO has assumed that these projects are possible, but will be uncommon
- However, at the end of 2024, there were approximately 44 MW of MW-scale projects in queue based on the data submitted to ME PUC data
  - ISO assumed these will become operational
- All of the available information points toward a significant reduction of MW-scale projects in Maine in 2025 and onward

Final 2025 PV Forecast – 10 Year Horizon

Nameplate Capacity, MW_{ac}

States	Annual Total MW (AC nameplate rating)											Totals
	Thru 2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	
CT	1,289	180	178	179	173	169	162	164	164	145	124	**2,927**
MA	4,019	294	293	308	305	307	300	307	308	274	237	**6,952**
ME	1,053	72	58	59	57	66	69	76	78	72	64	**1,723**
NH	280	36	38	46	49	54	55	58	60	57	52	**785**
RI	465	67	66	73	77	72	60	52	52	46	39	**1,070**
VT	529	33	33	34	34	35	35	38	41	39	35	**886**
Regional - Cumulative (MW)	**7,634**	**8,315**	**8,982**	**9,681**	**10,376**	**11,080**	**11,762**	**12,457**	**13,159**	**13,793**	**14,343**	**14,343**

Notes:

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

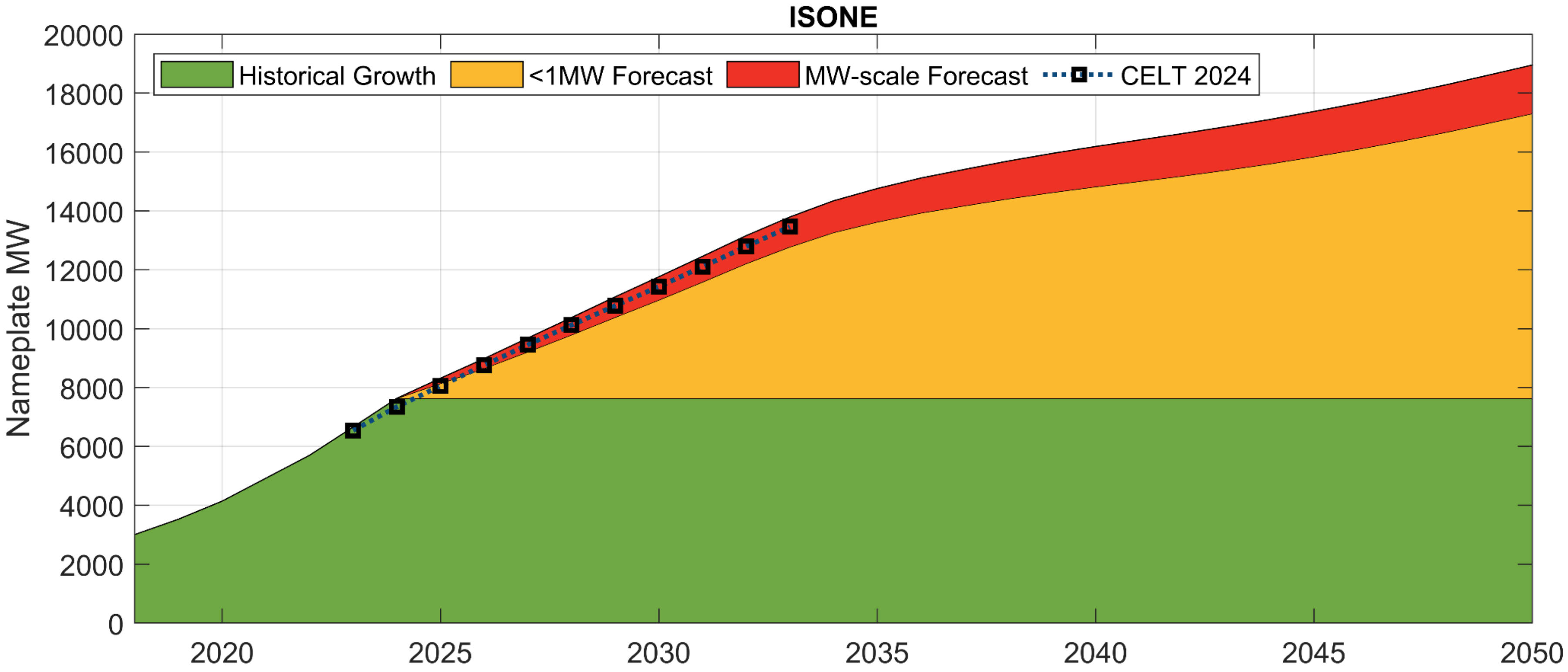
(2) The forecast values are net of the effects of discount factors applied to reflect a degree of uncertainty in the policy-based forecast

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

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

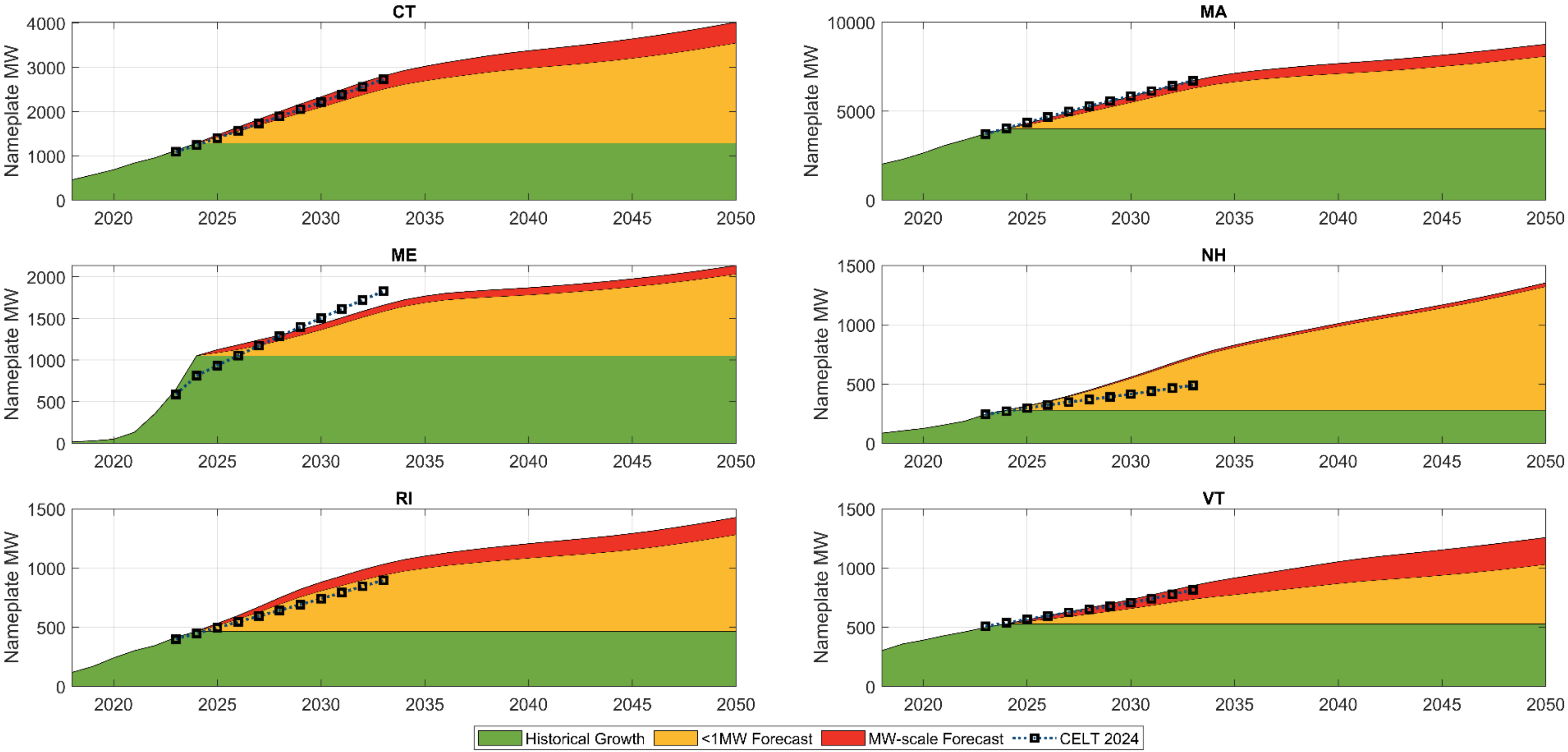
Regional PV Nameplate Capacity Growth

Historical vs. Forecast



State PV Nameplate Capacity Growth

Historical and Forecast

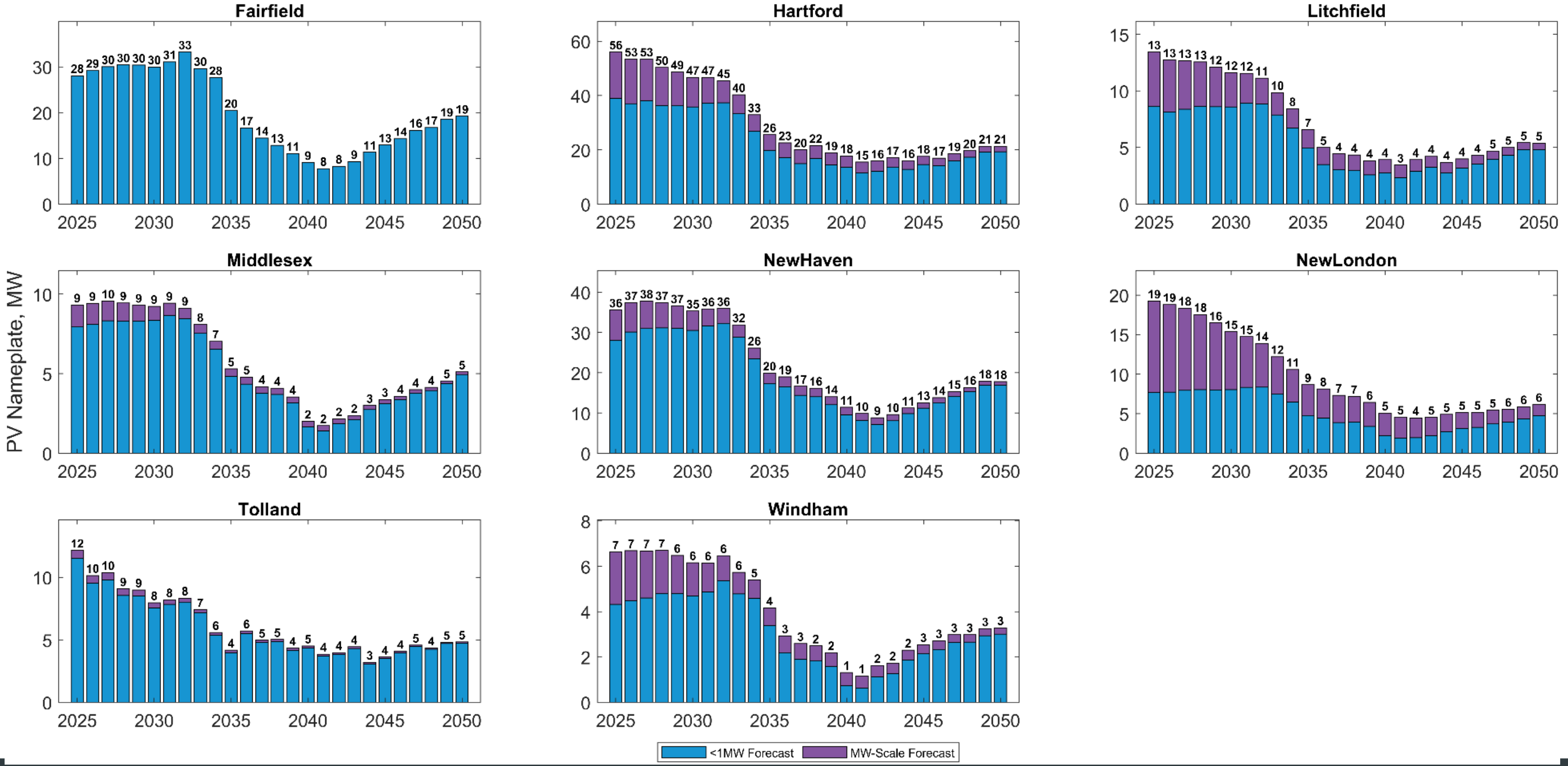


COUNTY-LEVEL 2025 PV NAMEPLATE CAPACITY FORECAST

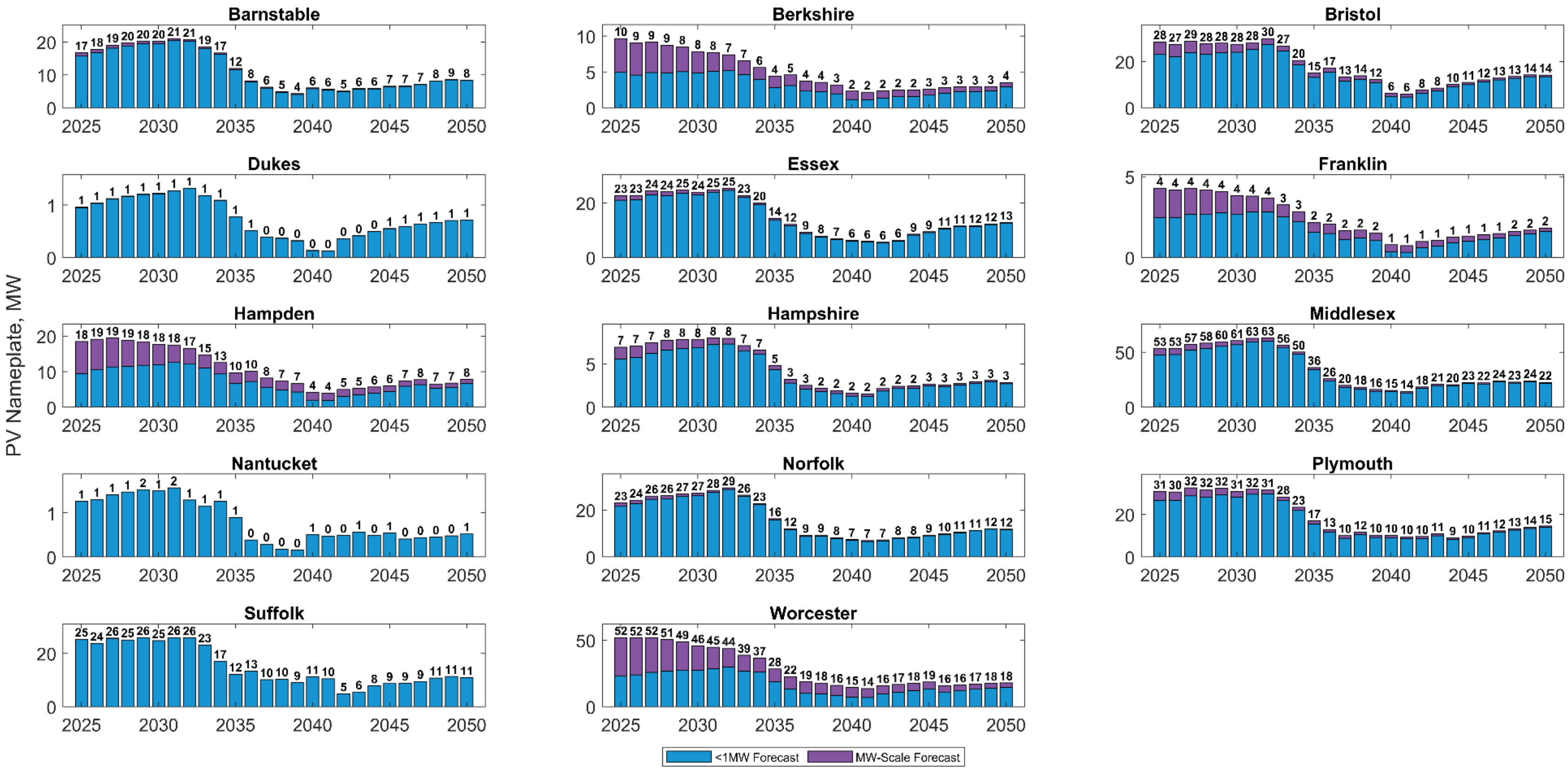
Development of County-Level Forecasts

- County-level PV forecast for systems with nameplate capacity less than 1 MW is generated by dGen™
- County-level allocations of forecast for MW-scale systems are developed based on:
  - Historical share of MW-scale system in each county of each state
  - Land availability (using county population density as proxy)
  - Land value (using county median income as proxy)
  - Remaining area hosting capacity (estimated using substation electricity demand data)
- County-level forecast results are shown on the next slides for each New England state

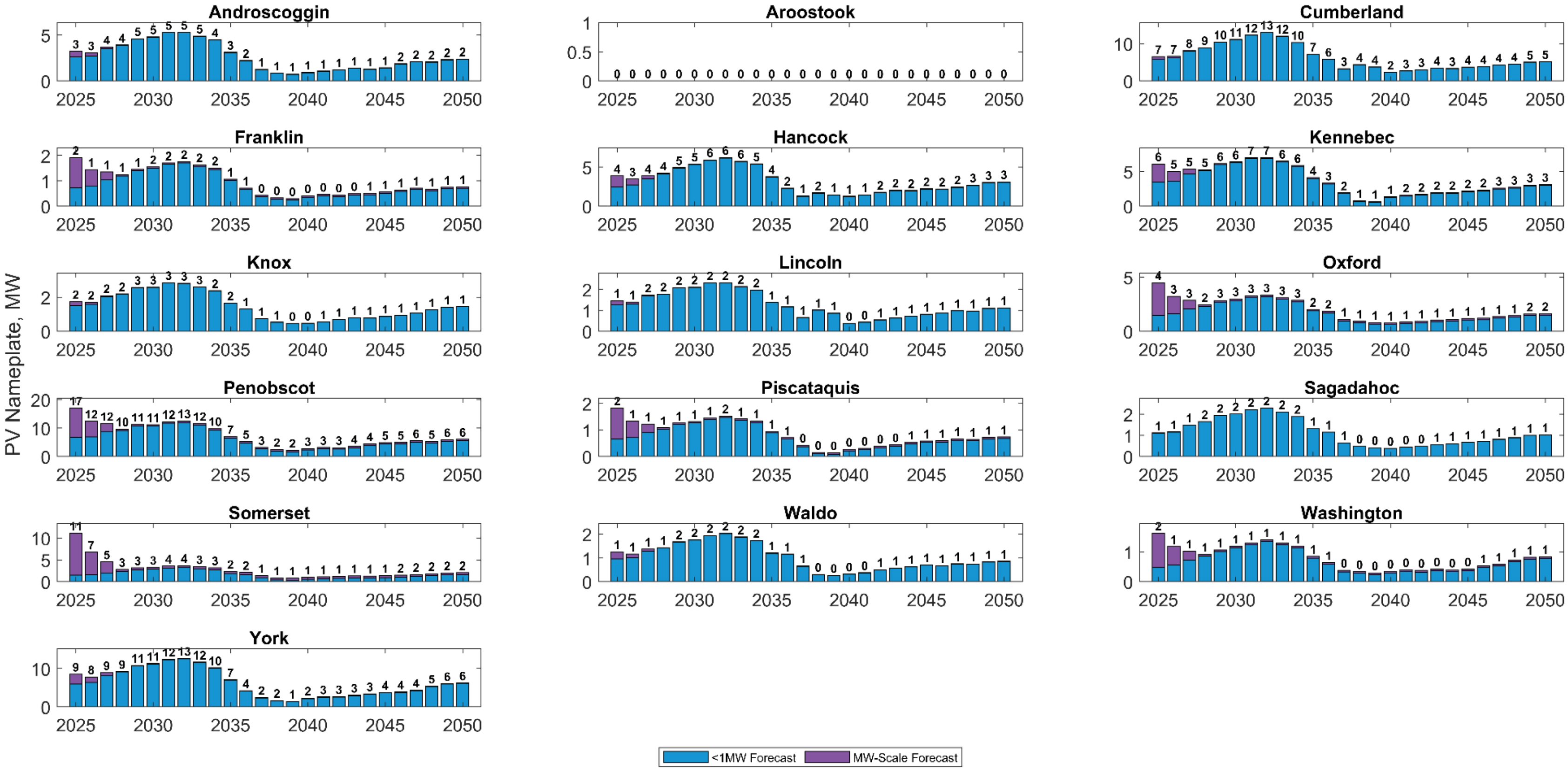
Final 2025 County PV Forecast – Connecticut



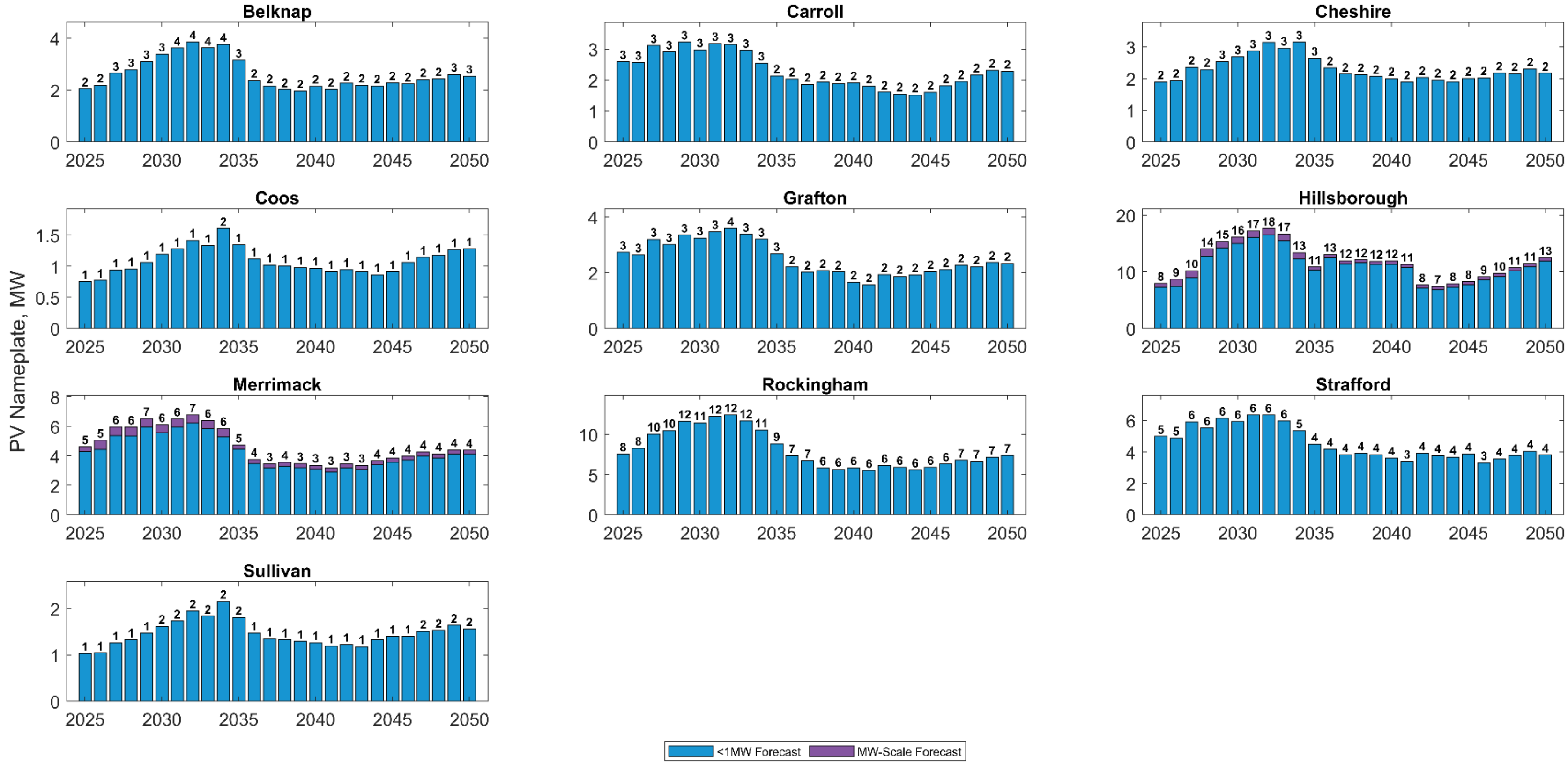
Final 2025 County PV Forecast – Massachusetts



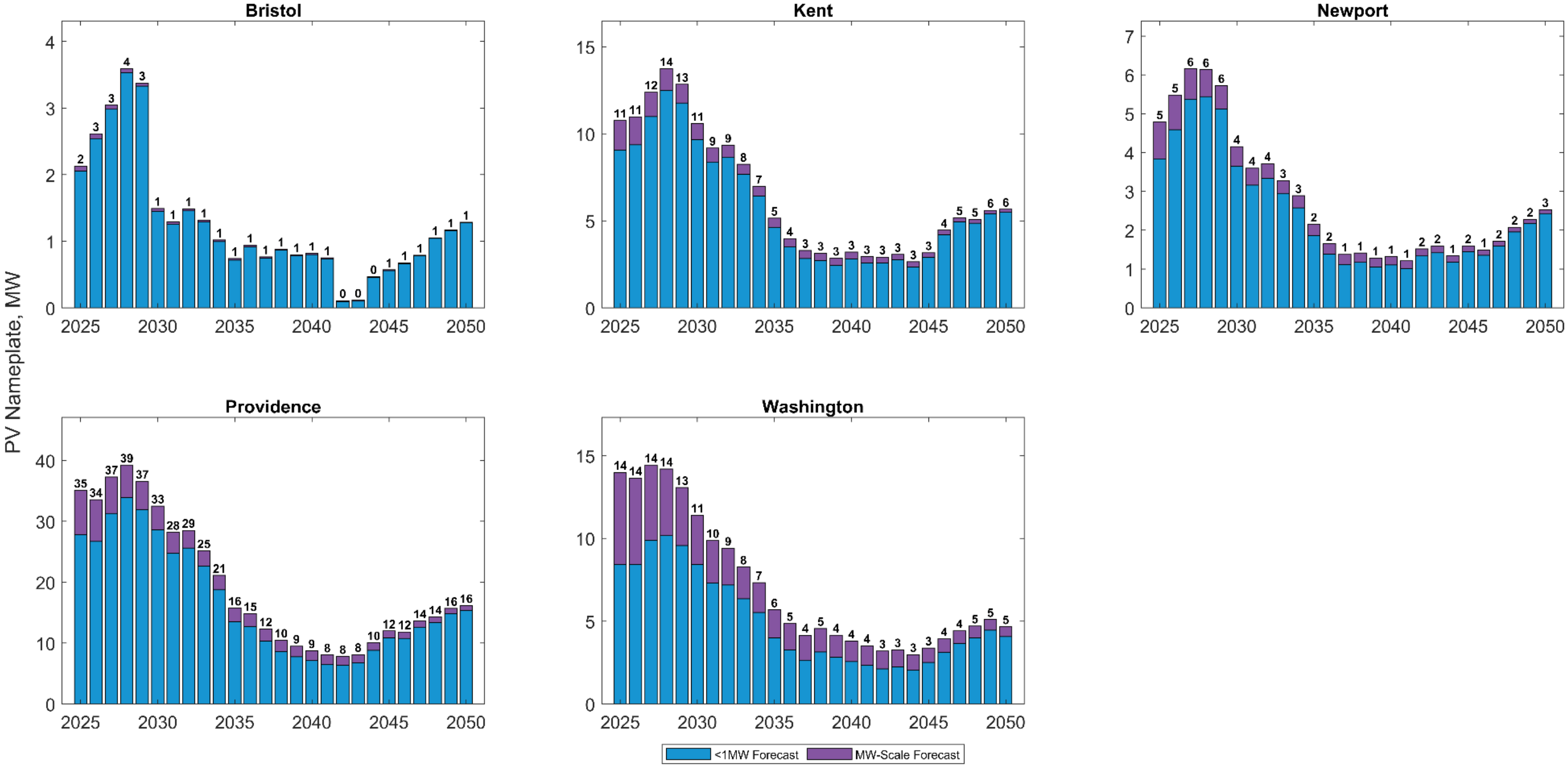
Final 2025 County PV Forecast – Maine



Final 2025 County PV Forecast – New Hampshire



Final 2025 County PV Forecast – Rhode Island



Final 2025 County PV Forecast – Vermont

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
- 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 and estimates of hourly energy production (historical and forecast), and is important for the ISO's use of the PV forecast in 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 2024
  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

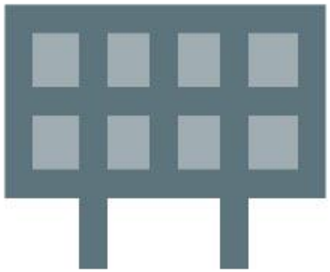
Data and Assumptions

- 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 2027-2050
- Non-FCM Gen/EOR
  - ISO identified total nameplate capacity of PV in each state registered in the energy market as of 12/31/24
  - Assume the ($EOR+FCM_{supply}$) share of total PV at the end of 2024 in each state *except Maine* remains constant throughout the forecast horizon
    - For Maine, assume ($EOR+FCM_{supply}$) share is 40% over the forecast horizon to reflect how updated assumptions about NEB programs no longer reflect as much future MW-scale, resulting in less participation in wholesale markets than assumed in the 2024 forecast
- 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 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 2025 PV FORECAST

Results

Final 2025 PV Forecast – 10 Year Horizon

Cumulative Nameplate Capacity, MW_{AC}

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Notes:

(1) Forecast values include FCM Resources, non-FCM Energy Only Generators, and behind-the-meter PV resources
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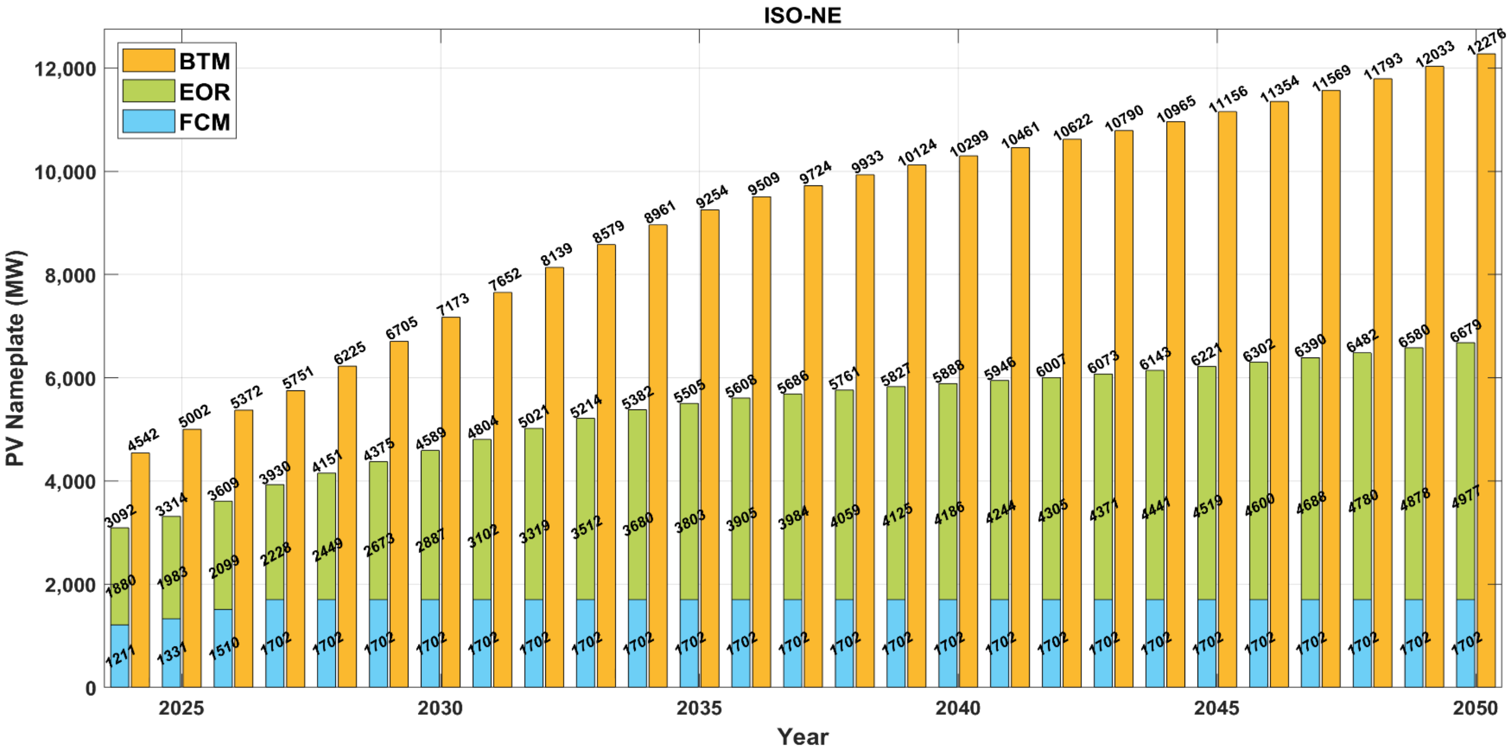
(3) All values represent end-of-year installed capacities
(4) Forecast does not include forward-looking PV projects > 5MW in nameplate capacity

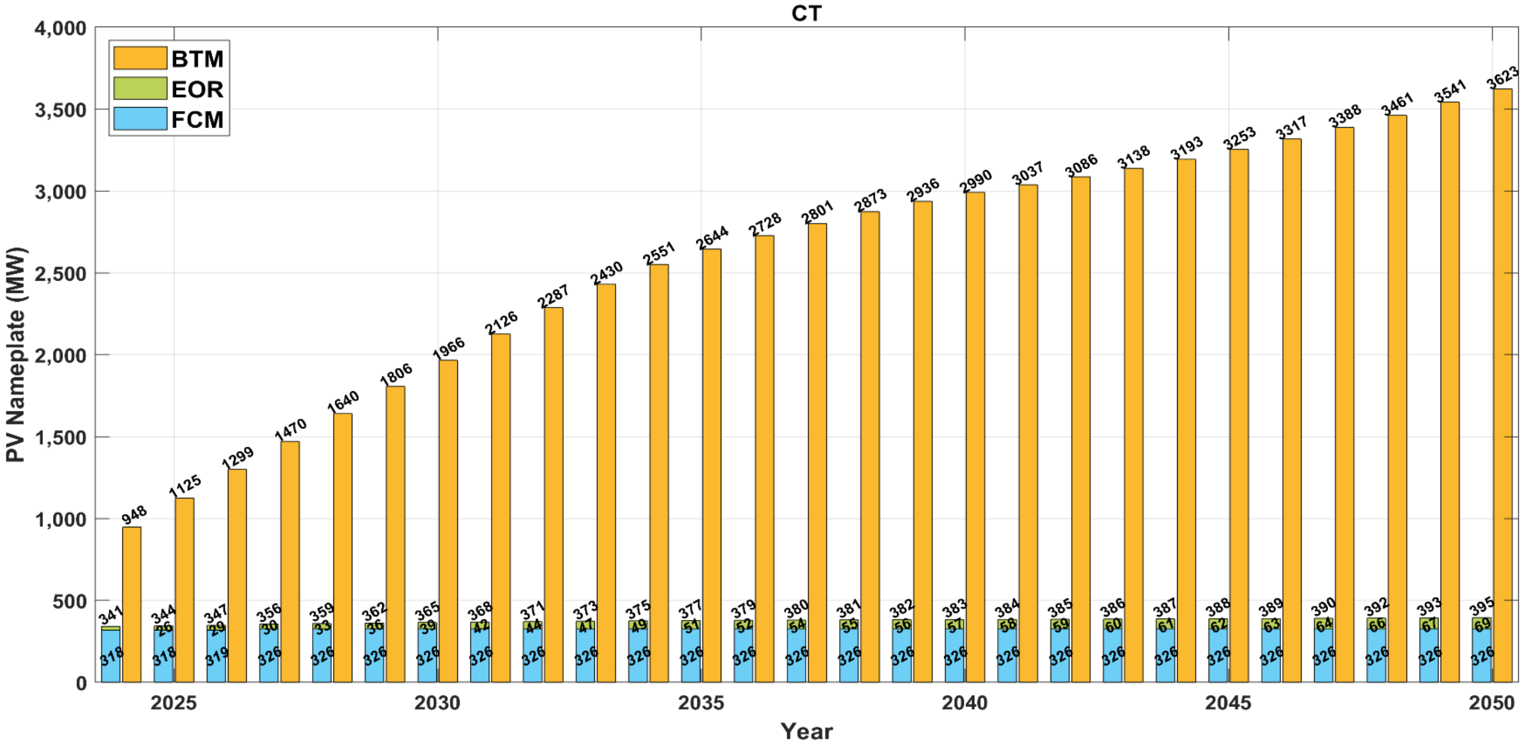
Final 2025 PV Forecast – New England

Cumulative Nameplate by Category, MW_{ac}



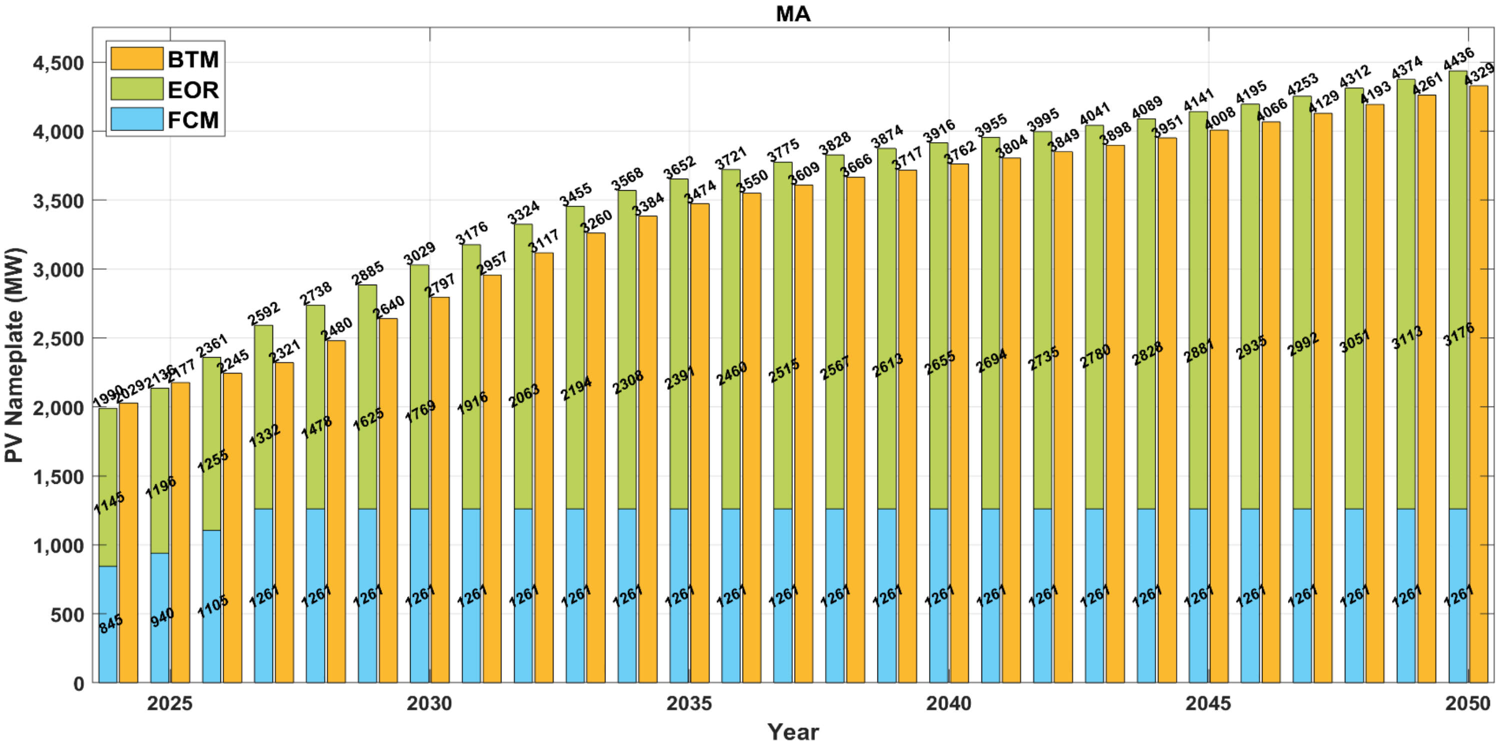
Final 2025 PV Forecast – Connecticut

Cumulative Nameplate by Category, MW_{ac}



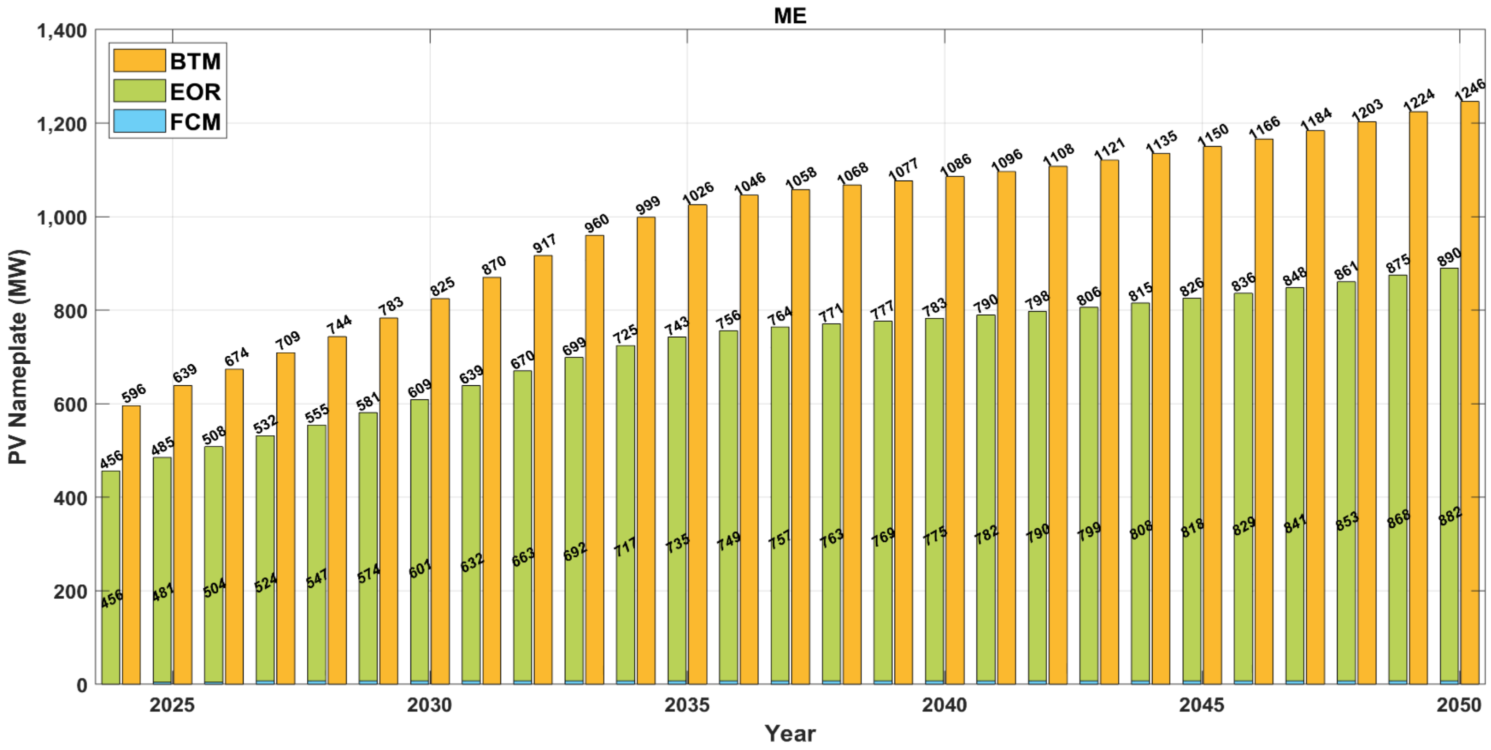
Final 2025 PV Forecast – Massachusetts

Cumulative Nameplate by Category, MW_{ac}



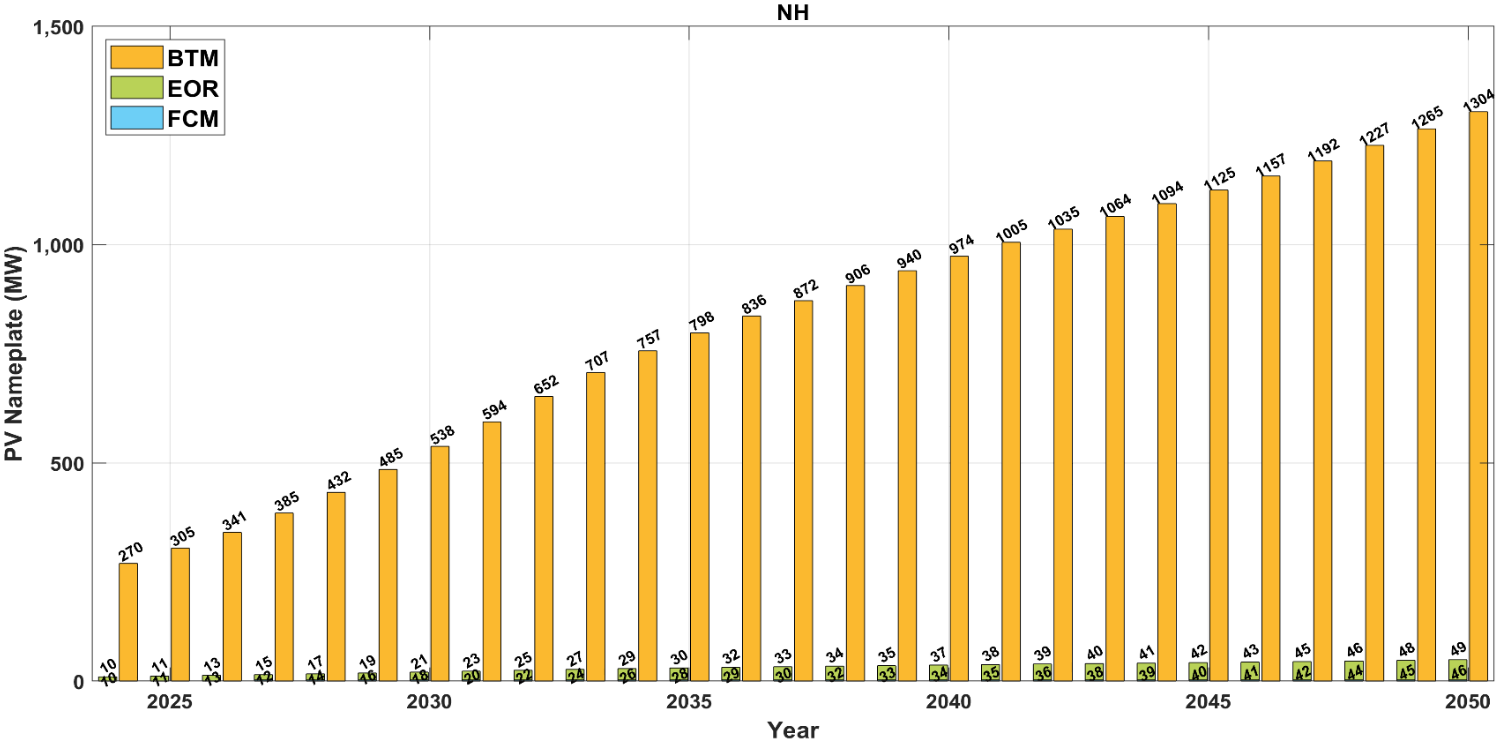
Final 2025 PV Forecast – Maine

Cumulative Nameplate by Category, MW_{ac}



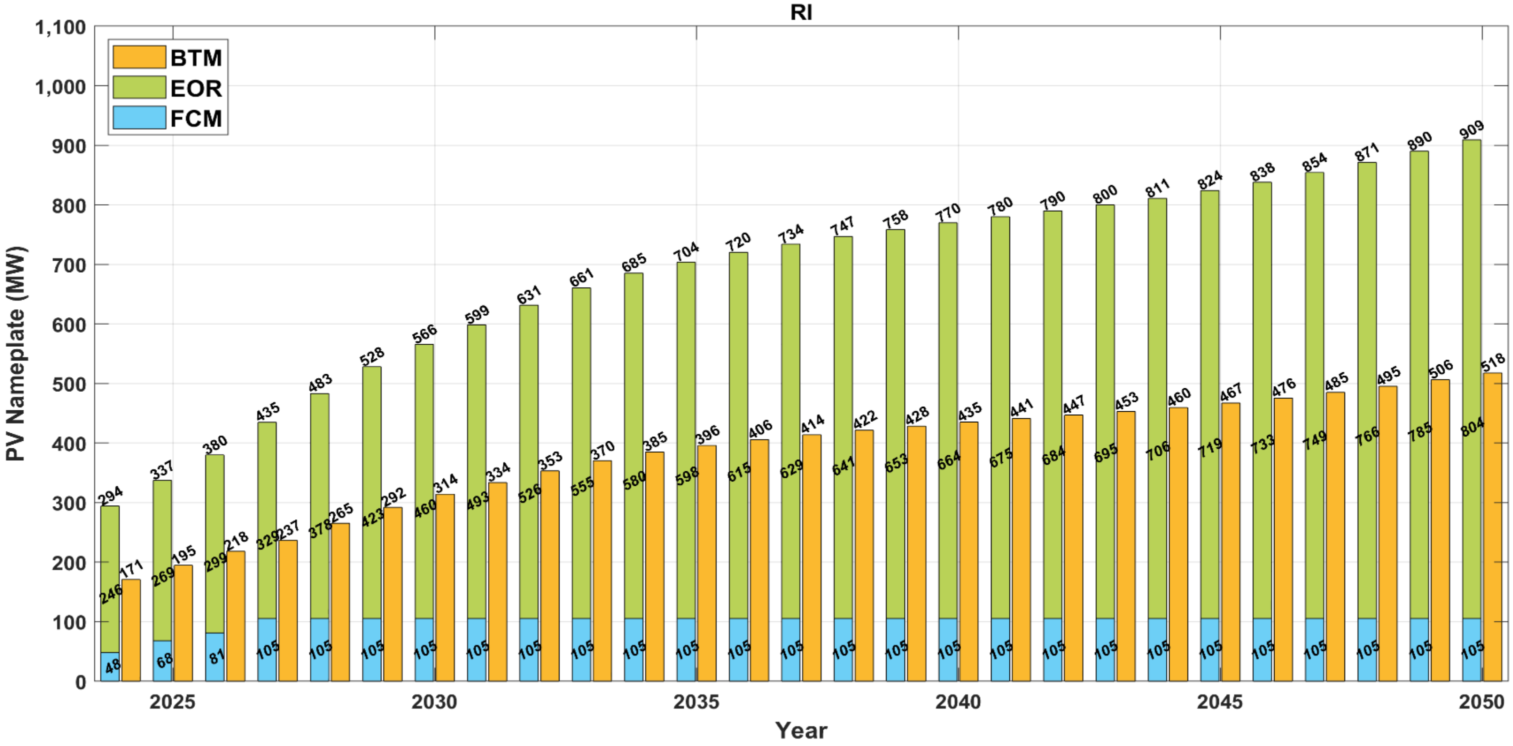
Final 2025 PV Forecast – New Hampshire

Cumulative Nameplate by Category, MW_{ac}



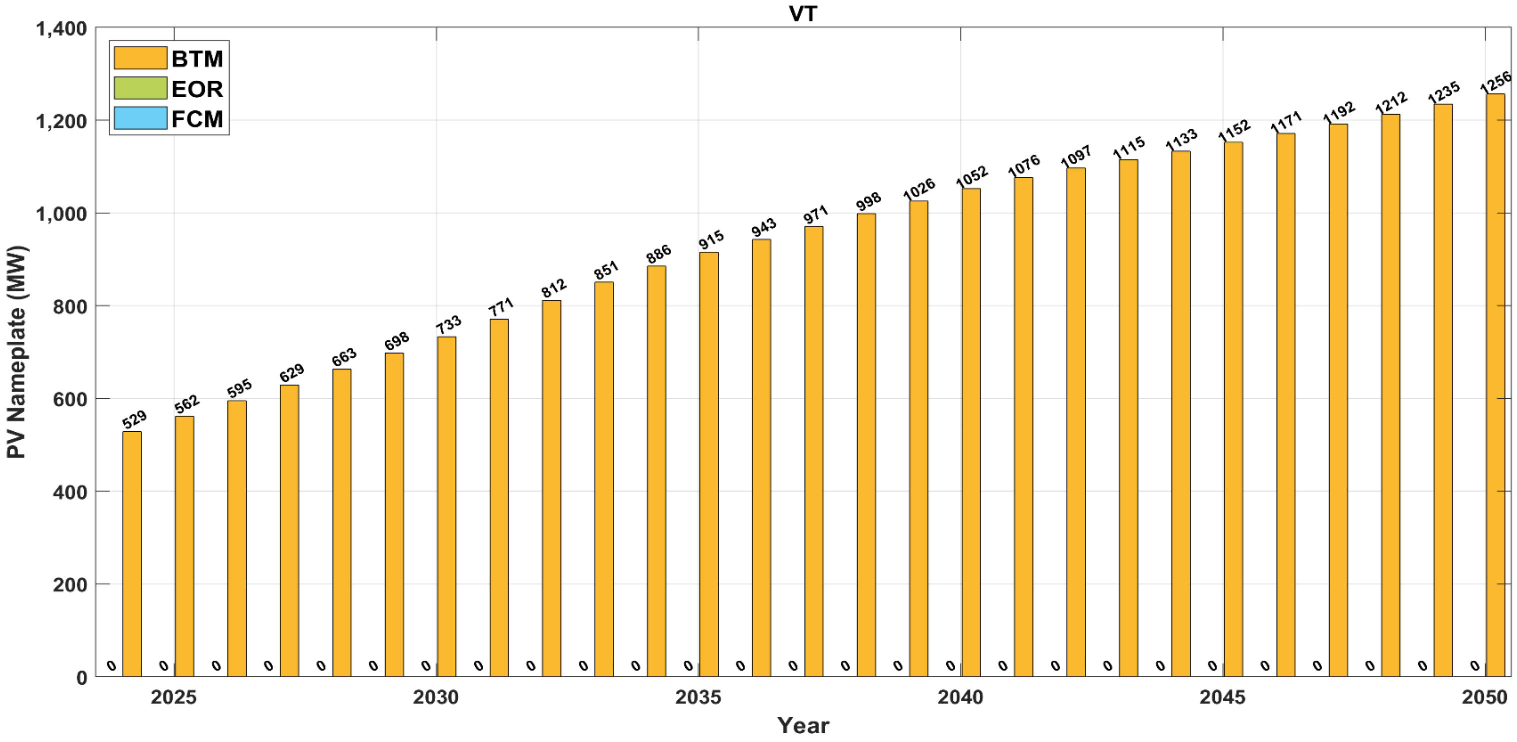
Final 2025 PV Forecast – Rhode Island

Cumulative Nameplate by Category, MW_{ac}



Final 2025 PV Forecast – Vermont

Cumulative Nameplate by Category, MW_{ac}

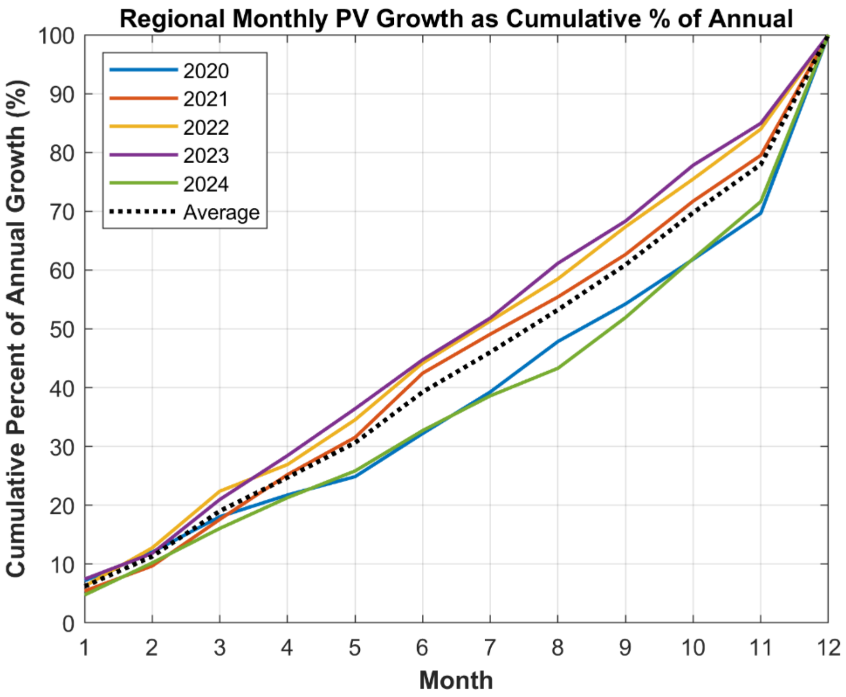


2025 BTM PV ENERGY FORECAST

Development of BTMPV Energy Forecast

- The BTM PV nameplate forecast reflects end-of-year values
- Energy estimates in the BTM PV forecast are inclusive of incremental growth during a given year
- ISO assumes historical BTM PV growth trends across the region are indicative of future intra-annual growth rates
  - Growth trends between 2020 and 2024 were used to estimate intra-annual incremental growth over the forecast horizon (see next slide)
- For CELT 2025, monthly derated nameplate forecasts are used with historical hourly capacity factor profiles to generate the 70 years (1/1/1953 – 10/31/2023) of hourly forecasts, for each load zone and forecast year
- Monthly energy forecasts are the averages of the 70 monthly energy values of simulations performed for each forecast year
  - For example, January energy forecast is the average of all 70 January energy values withing the 70-year simulation period for a given forecast year
- Annual energy forecast is calculated as the sum of monthly energy forecasts for each forecast year

Historical Monthly PV Growth Trends, 2020-2024



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%

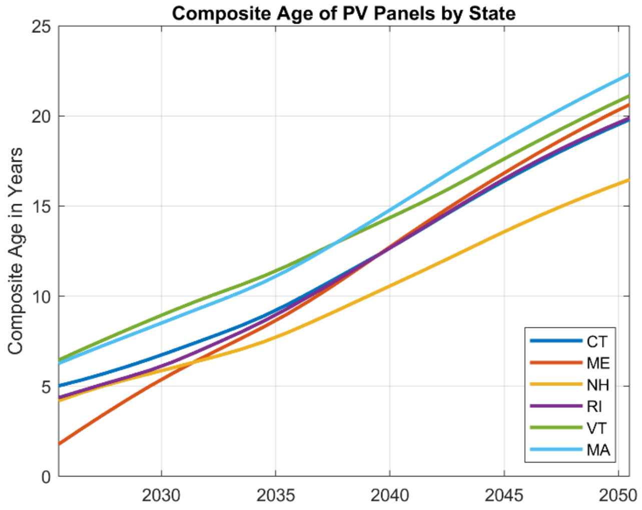
PV Panel Degradation Factors

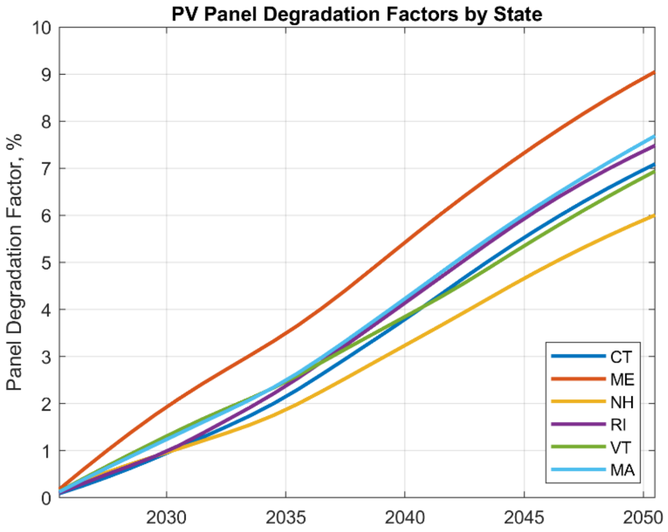
- No changes to the methodology to account for panel degradation were made since last year's forecast
- Forecast of BTM PV energy and summer peak load reductions include the effects of a 0.5%/year panel degradation rate to account for the expected declining conversion efficiency of solar panels over 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 assumed precent reduction of PV performance over time that reflect the anticipated degradation of PV panels





Final 2025 BTM PV Energy Forecast – 10 Year Horizon

BTM PV, GWh

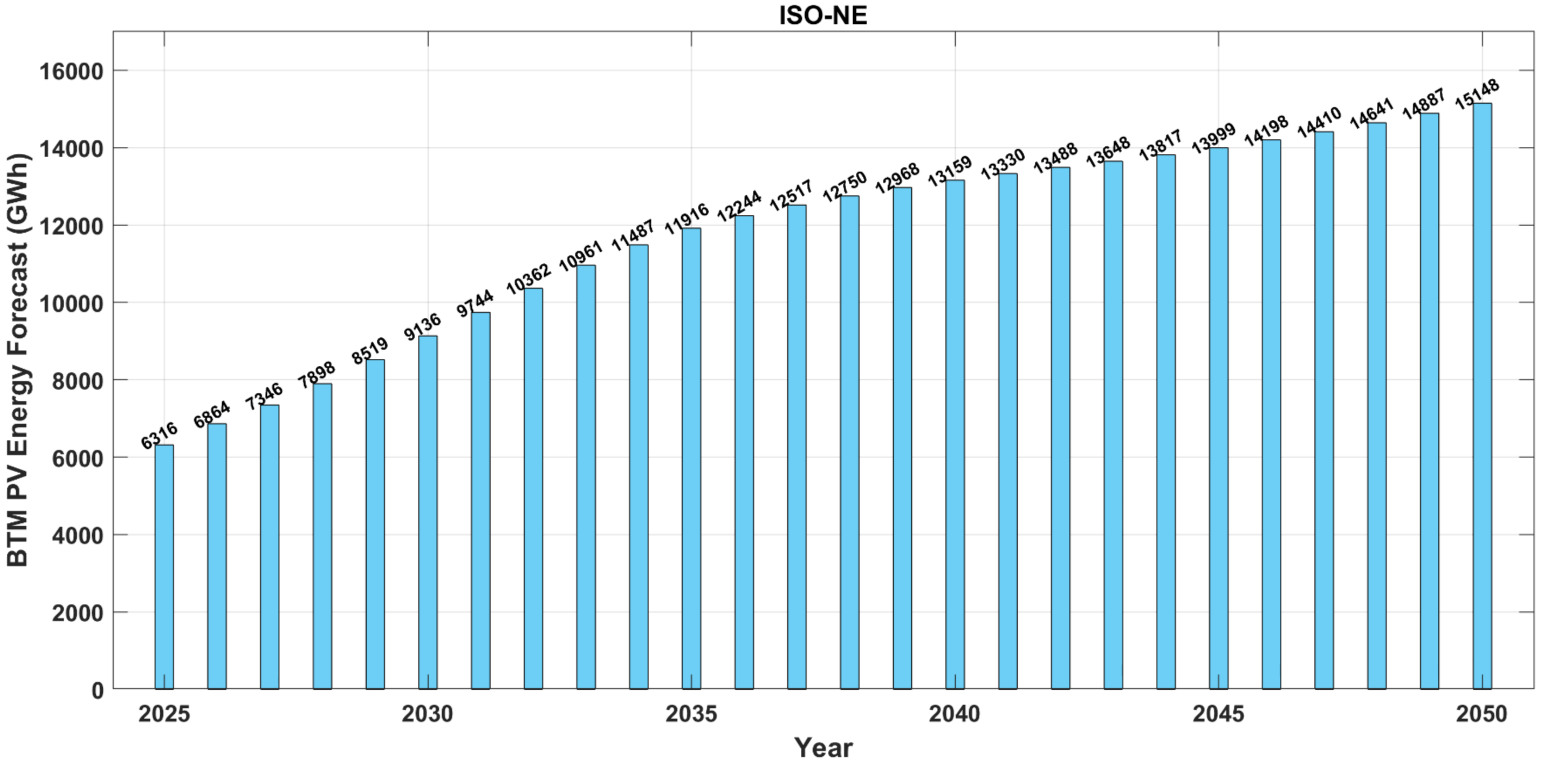
States	Total Estimated Annual Energy (GWh)									
	2025	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**
CT	1,391	1,633	1,868	2,101	2,329	2,549	2,762	2,976	3,180	3,355
MA	2,815	2,954	3,039	3,187	3,394	3,600	3,802	4,008	4,203	4,373
ME	819	869	912	955	999	1,049	1,101	1,158	1,214	1,264
NH	367	412	462	519	582	649	718	790	861	928
RI	253	286	315	347	385	420	449	474	499	520
VT	670	710	749	789	829	870	912	957	1,004	1,047
Regional - Annual Energy (GWh)	**6,316**	**6,864**	**7,346**	**7,898**	**8,519**	**9,136**	**9,744**	**10,362**	**10,961**	**11,487**

Notes:

(1) Forecast values include energy 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

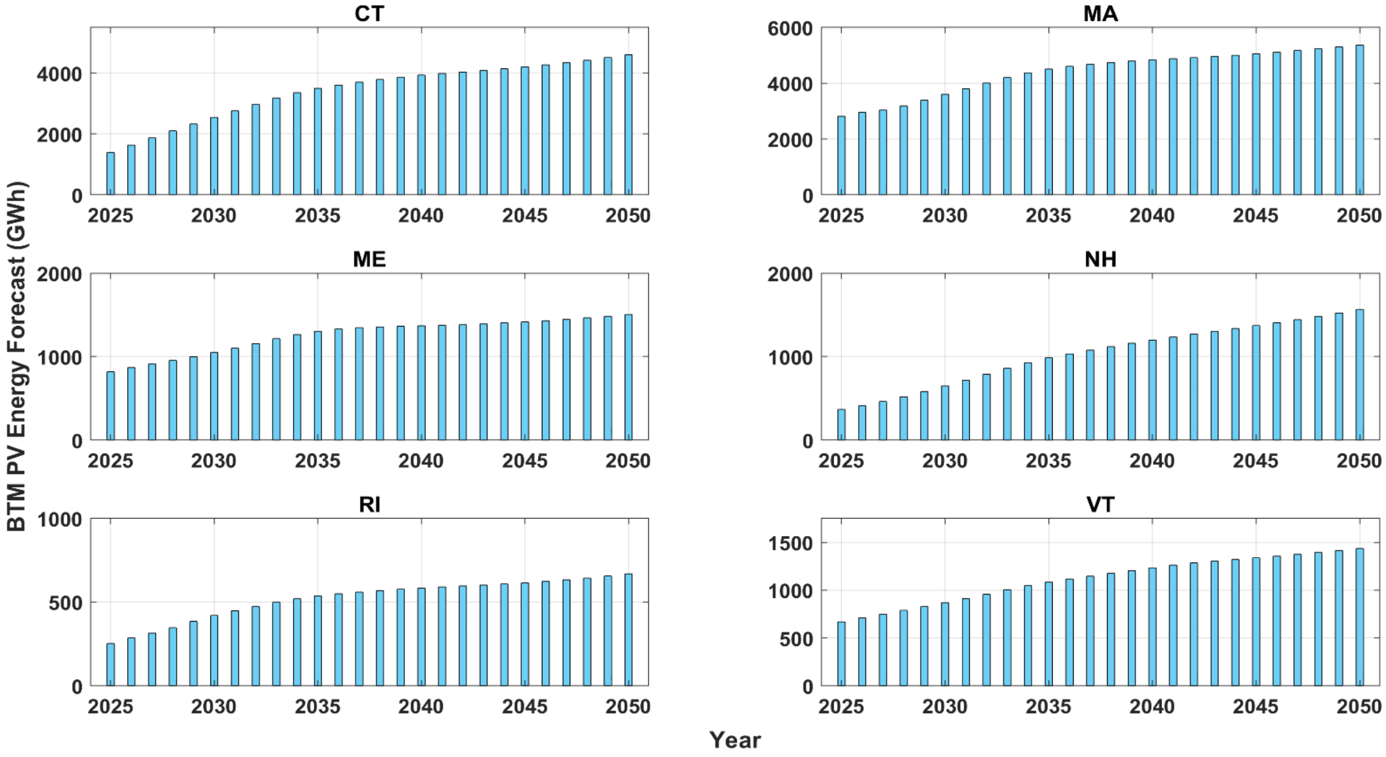
Final 2025 BTM PV Energy Forecast – New England

BTM PV, GWh



Final 2025 BTM PV Energy Forecast – State Level

BTM PV, GWh



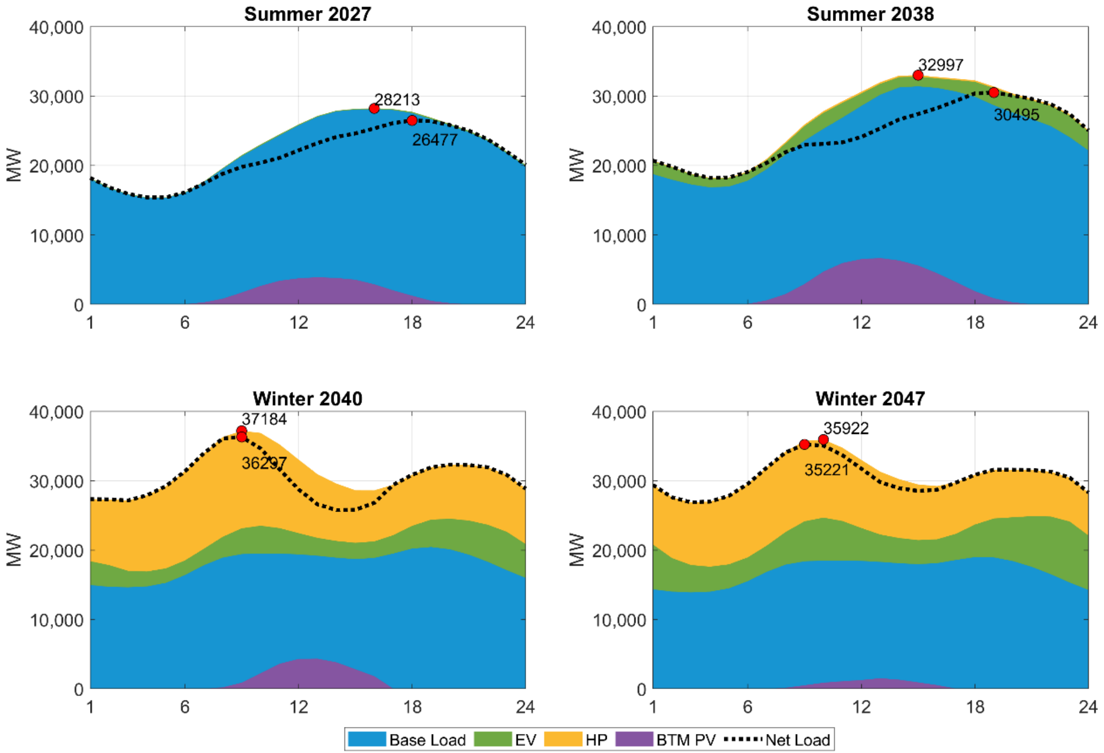
2025 BTM PV PEAK DEMAND REDUCTIONS

BTM PV Forecast Used in CELT Net Load Forecast

- The 2025 CELT net load forecast will reflect deductions associated with the BTM PV portion of the PV forecast
- Summer and winter peak load reductions associated with BTM PV over the forecast horizon are calculated using waterfall approach described in slide 14 of the February 21st LFC presentation

Seasonal Demand Impacts of BTM PV

- Example plots are shown for two summer and winter days to illustrate how BTM PV demand impacts are calculated for specific days
  - For each forecast year, probabilistic forecasts are based on the hourly results from 70 seasonal peak days
- Calculations are tabulated below



Calculations From Plots

Example Day	Gross Peak	Net Peak	Peak Load Reduction
Summer 2027	28,213	26,477	1,736
Summer 2038	32,997	30,495	2,502
Winter 2040	37,184	36,297	887
Winter 2047	35,922	35,221	701

Final 2025 BTM PV Forecast – Summer

Coincident "50-50" Summer Peak Load Reductions

Category	Zones	Cumulative Total MW - "50-50" Summer Seasonal Peak Load Reduction									
		2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Behind-the-Meter PV	CT	345	356	363	386	397	403	408	409	400	391
	NEMA	239	247	252	260	270	277	279	282	287	287
	SEMA	343	340	340	344	346	346	347	349	346	342
	WCMA	298	290	291	288	287	285	289	289	291	293
	ME	170	168	164	161	155	144	135	126	112	101
	NH	106	110	116	124	130	135	139	140	139	142
	RI	90	90	90	91	91	90	89	88	86	85
	VT	152	148	145	138	130	120	113	108	105	102
	ISONE	**1,742**	**1,749**	**1,760**	**1,793**	**1,807**	**1,800**	**1,799**	**1,792**	**1,767**	**1,742**

***Notes*:**

(1) Forecast values include energy 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 8% to reflect avoided transmission and distribution losses

Final 2025 BTM PV Forecast – Winter

Coincident "50-50" Winter Peak Load Reductions

Category	Zones	Cumulative Total MW - "50-50" Winter Seasonal Peak Load Reduction									
		2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Behind-the-Meter PV	CT	0	0	4	4	4	5	6	16	30	52
	NEMA	0	0	5	13	15	36	63	80	86	95
	SEMA	0	0	0	1	2	6	11	25	42	67
	WCMA	0	0	1	3	4	16	37	60	78	99
	ME	0	0	3	6	7	18	27	52	82	109
	NH	0	0	1	1	2	6	9	16	24	33
	RI	0	0	1	1	1	4	6	8	17	27
	VT	0	0	1	2	2	6	10	17	25	33
	ISONE	**0**	**0**	**14**	**31**	**37**	**95**	**169**	**274**	**384**	**516**

Notes:

(1) Forecast values include energy 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 8% to reflect avoided transmission and distribution losses

SUMMARY AND NEXT STEPS

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Next Steps

- The 2025 PV forecast has been finalized
  - The ISO has developed the associated energy and seasonal peak reduction forecasts, and categorized the forecast according to the three PV resource categories
  - The ISO continues efforts to develop the county-level accountings for all PV categories (FCM, EOR and BTM)
- The final PV forecast will appear in the 2025 CELT, which will be published by May 1, 2025

Questions