MARCH 19, 2018 | HOLYOKE, MASSACHUSETTS

Final 2018 PV Forecast

Distributed Generation Forecast Working Group

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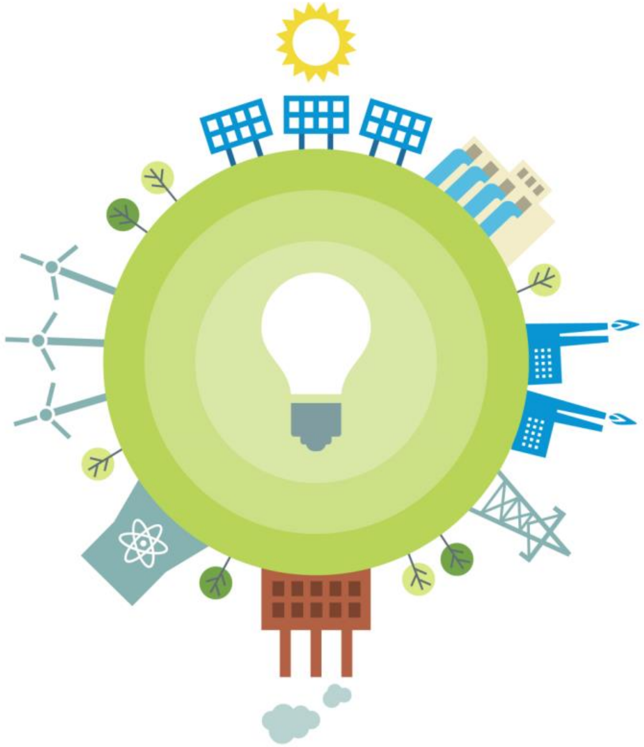
Presentation Outline

- Background and Forecast Process
- Changes to February 2018 Draft PV Forecast and Final 2018 PV Forecast
- 2018 PV Energy Forecast
- Behind-the-meter PV: Estimated Energy and Summer Peak Load Reductions
- Geographic Distribution of PV Forecast
- Summary and Next steps



BACKGROUND AND FORECAST PROCESS

Background and Forecast Review Process

- The ISO discussed the draft 2018 PV forecast with the DGFWG at the February 12, 2018 meeting
- Stakeholders provided comments on the draft forecast
  - See: https://www.iso-ne.com/committees/planning/distributed-generation/?eventId=134447
- The final PV forecast will be published in the 2018 CELT

CHANGES TO
FEBRUARY 2018 DRAFT PV FORECAST

Changes Reflected in the Final 2018 PV Forecast

State	Changes/Comments
Massachusetts	Based on updated SREC data, the total anticipated policy achievement used in the final forecast for SREC I and SREC II was increased to 2,198.8 MW_{DC}, up from 2,100 MW_{DC} in the draft forecast. This resulted in an additional 73.8 MW_{AC} (after DC-to-AC derate and policy discount) in year 2018 of the forecast for the state. All subsequent years remain unchanged.
Vermont	Due to evolving policies and their interrelated impacts, the VT forecast inputs for the year 2018 were increased by 10 MW (9 MW after policy discount) in excess of the anticipated 25 MW/year to reflect expectations that PV development will be greater than that needed for compliance with the RES DG carve out for another year. The forecast assumptions remain unchanged in subsequent years.

Discount Factors Used in Final 2018 PV Forecast

Policy-Based

Forecast	Draft 2018	Final 2018
2018	10%	10%
2019	10%	10%
2020	10%	10%
2021	15%	15%
2022	15%	15%
2023	15%	15%
2024	15%	15%
2025	15%	15%
2026	15%	15%
2027	15%	15%

Post-Policy

Forecast	Draft 2018	Final 2018
2018	35.0%	35.0%
2019	36.7%	36.7%
2020	38.3%	38.3%
2021	40.0%	40.0%
2022	41.7%	41.7%
2023	43.3%	43.3%
2024	45.0%	45.0%
2025	46.7%	46.7%
2026	48.3%	48.3%
2027	50.0%	50.0%

FINAL 2018 PV NAMEPLATE FORECAST

Draft 2018 PV Forecast

Nameplate Capacity, MW_{ac}

States	Annual Total MW (AC nameplate rating)											Totals
	Thru 2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	
CT	365.6	88.6	86.8	89.8	80.6	72.9	53.7	52.2	50.6	49.0	47.4	**1,037.3**
MA	1602.3	222.9	228.0	228.0	215.3	215.3	215.3	215.3	135.1	130.9	126.7	**3,535.1**
ME	33.5	10.2	10.2	10.2	9.6	9.6	9.6	9.6	9.6	9.6	9.6	**131.4**
NH	69.7	13.8	13.8	13.8	13.1	13.1	13.1	13.1	13.1	13.1	13.1	**202.7**
RI	62.2	34.5	34.5	31.4	29.6	29.6	29.6	29.6	29.6	29.6	29.6	**370.2**
VT	257.2	22.5	22.5	22.5	21.3	21.3	21.3	21.3	21.3	21.3	21.3	**473.5**
Regional - Annual (MW)	**2390.5**	**392.5**	**395.8**	**395.8**	**369.5**	**361.9**	**342.7**	**341.1**	**259.3**	**253.5**	**247.7**	**5,750.2**
Regional - Cumulative (MW)	**2390.5**	**2783.0**	**3178.8**	**3574.6**	**3944.1**	**4306.0**	**4648.7**	**4989.7**	**5249.0**	**5502.5**	**5750.2**	**5,750.2**

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 2018 PV Forecast

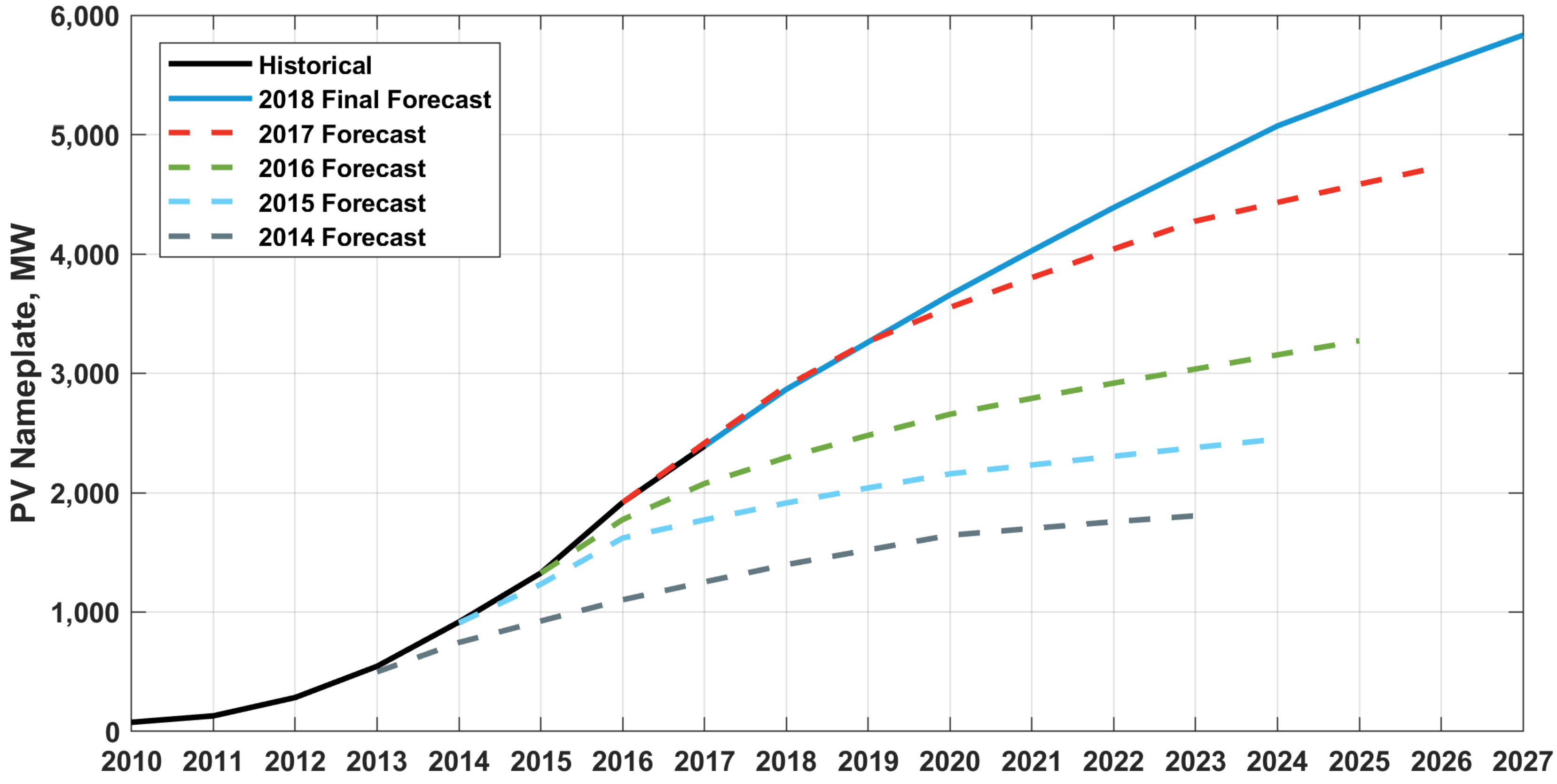
Nameplate Capacity, MW_{ac}

States	Annual Total MW (AC nameplate rating)											Totals
	Thru 2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	
CT	365.6	88.6	86.8	89.8	80.6	72.9	53.7	52.2	50.6	49.0	47.4	**1,037.3**
MA	1602.3	**296.7**	228.0	228.0	215.3	215.3	215.3	215.3	135.1	130.9	126.7	**3,608.9**
ME	33.5	10.2	10.2	10.2	9.6	9.6	9.6	9.6	9.6	9.6	9.6	**131.4**
NH	69.7	13.8	13.8	13.8	13.1	13.1	13.1	13.1	13.1	13.1	13.1	**202.7**
RI	62.2	34.5	34.5	31.4	29.6	29.6	29.6	29.6	29.6	29.6	29.6	**370.2**
VT	257.2	**31.5**	22.5	22.5	21.3	21.3	21.3	21.3	21.3	21.3	21.3	**482.5**
Regional - Annual (MW)	**2390.5**	**475.3**	**395.8**	**395.8**	**369.5**	**361.9**	**342.7**	**341.1**	**259.3**	**253.5**	**247.7**	**5,832.9**
Regional - Cumulative (MW)	**2390.5**	**2865.8**	**3261.6**	**3657.4**	**4026.9**	**4388.8**	**4731.4**	**5072.5**	**5331.8**	**5585.3**	**5832.9**	**5,832.9**

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

PV Growth: Reported Historical vs. Forecast



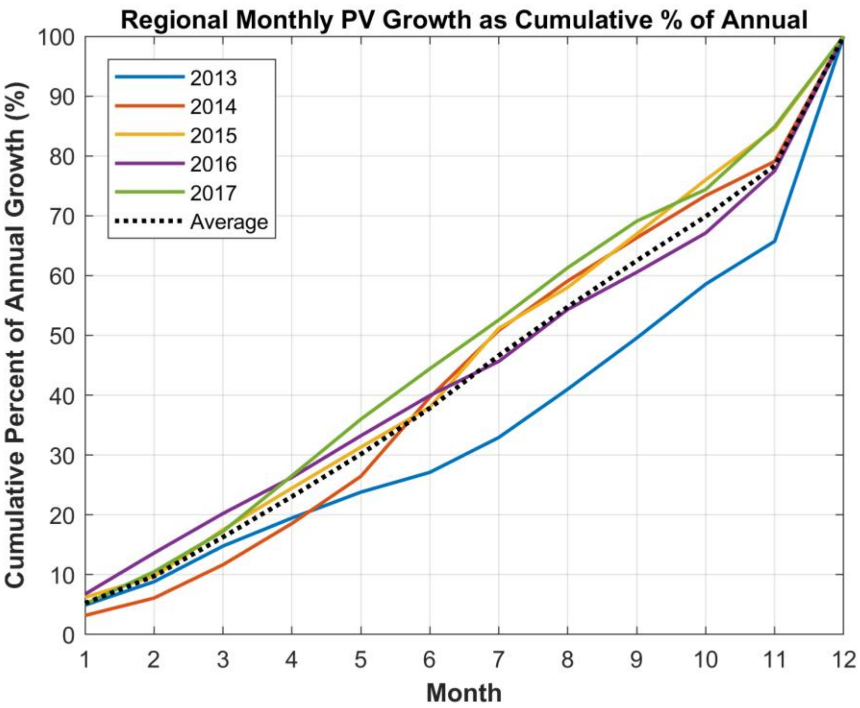
2018 PV ENERGY FORECAST

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 2013 and 2017 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 along with state average monthly capacity factors (CF) developed from 4 years of PV performance data (2014-2017)
  - Resulting state CFs are tabulated to the right, and plots of individual monthly capacity factors in each state are shown on slide 15

State	Average CF, %
CT	14.9
ME	14.5
NH	14.2
RI	14.9
VT	14.0
MA	14.7

Historical Monthly PV Growth Trends, 2012-2017



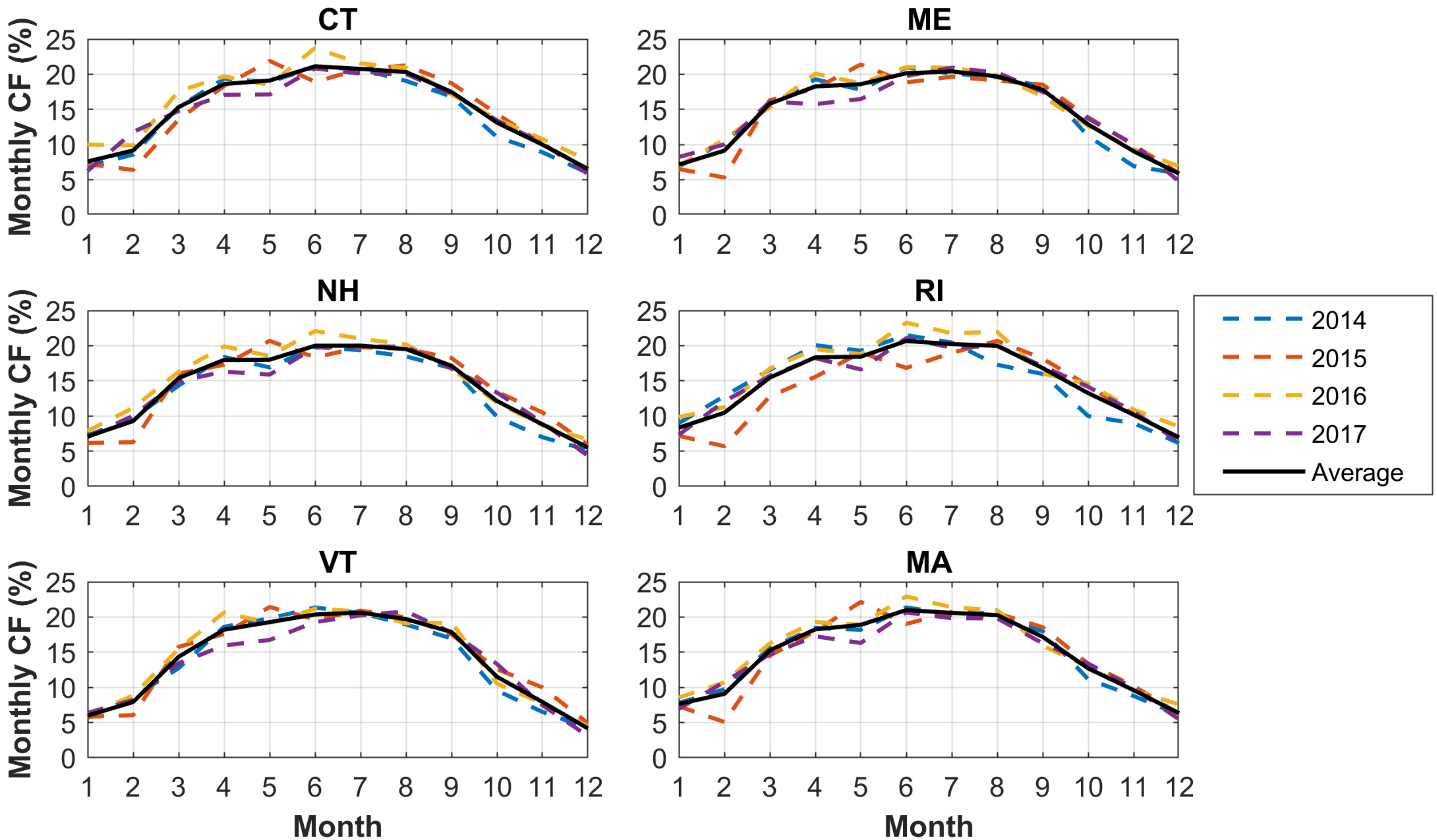
Average Monthly Growth Rates, % of Annual

Month	Monthly PV Growth (% of Annual)	Monthly PV Growth (Cumulative % of Annual)
1	6%	6%
2	4%	10%
3	6%	16%
4	7%	23%
5	6%	29%
6	8%	37%
7	9%	46%
8	9%	55%
9	7%	62%
10	8%	70%
11	7%	77%
12	23%	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, 2014-2017



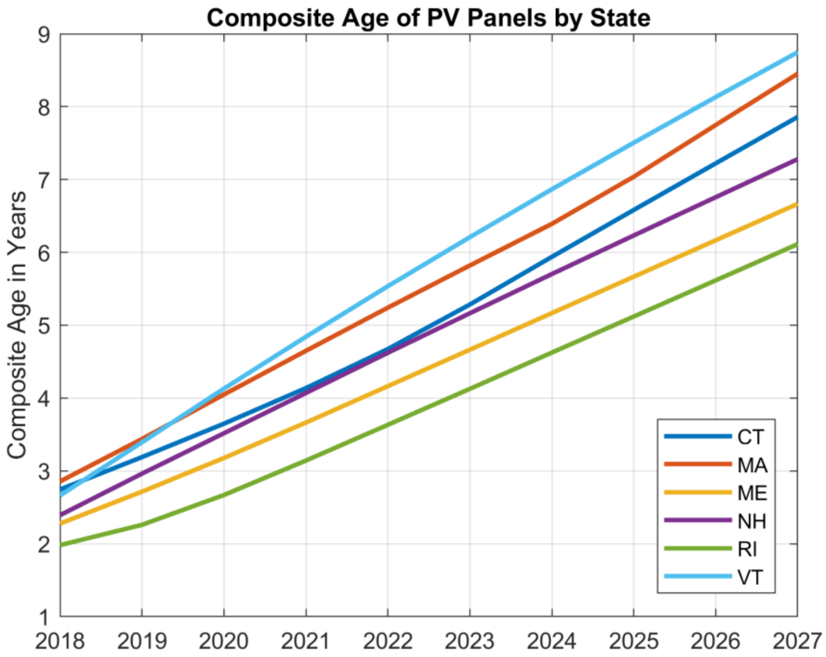
PV Panel Degradation Factors

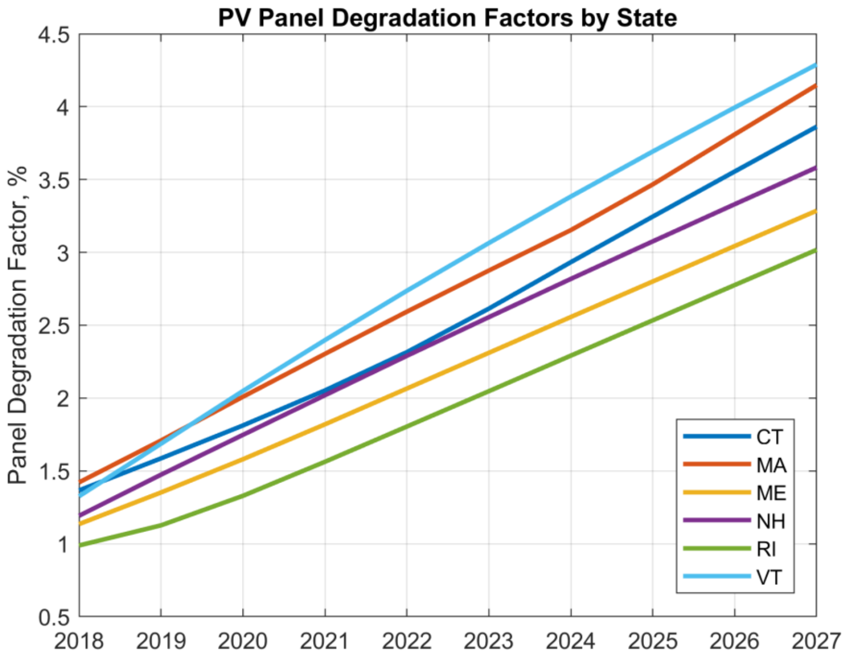
- Associated forecasts of energy and the estimated summer peak load reductions from BTM PV include a 0.5%/year degradation rate to account for expectations regarding a solar panel's declining conversion efficiency over the longer term
  - The ISO first raised this modeling issue at the January 24, 2014 DGFWG meeting (refer to slide 10)
- 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
- Accounting for this degradation becomes more important as the region's PV panels age
- 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 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 2018 PV Energy Forecast

Total PV Forecast Energy, GWh

States	Total Estimated Annual Energy (GWh)									
	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
CT	543	662	781	895	998	1,085	1,155	1,218	1,281	1,342
MA	2299	2,659	2,961	3,246	3,523	3,799	4,080	4,307	4,467	4,621
ME	50	63	77	90	102	115	127	139	152	164
NH	97	115	133	150	166	183	199	215	231	247
RI	102	149	195	236	276	316	356	395	434	472
VT	345	380	408	434	459	484	510	535	559	584
Regional - Annual Energy (GWh)	**3436**	**4,028**	**4,554**	**5,051**	**5,525**	**5,981**	**6,427**	**6,809**	**7,125**	**7,431**

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 6.5% to reflect avoided transmission and distribution losses

BREAKDOWN OF PV NAMEPLATE FORECAST INTO RESOURCE TYPES

Forecast Includes Classification by Resource Type

- In order to properly account for existing and future PV in planning studies and avoid double counting, ISO classified PV into three distinct types related to the resources assumed market participation/non-participation
- These market distinctions are important for the ISO's use of the PV forecast in a wide range of planning studies
- The classification process requires the estimation of hourly PV production that is behind-the-meter (BTM), i.e., PV that does not participate in ISO markets
  - This requires historical hourly BTM PV production data to reconstitute PV into the historical load data used to develop the long-term load forecast

Three Mutually Exclusive PV Resource Types

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

Determining PV Resource Type By State

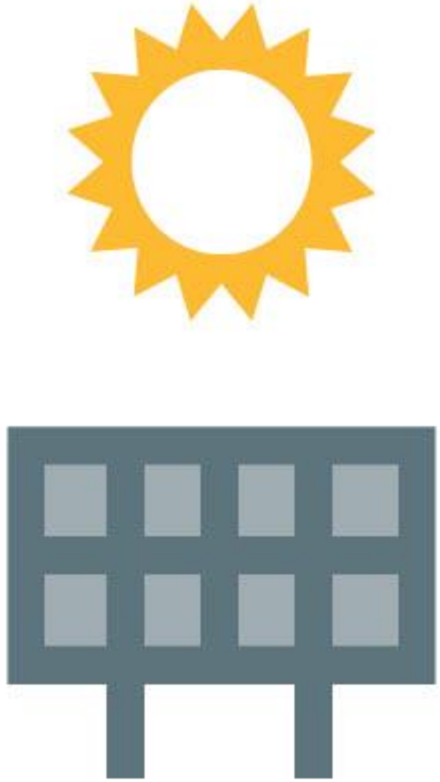
- Resource types vary by state
  - Disposition of PV projects can be influenced by state policies (*e.g.*, net metering requirements)
- The following steps were used to determine PV resource types for each state over the forecast horizon:
  1. **FCM**
     - Identify all Generation and Demand Response FCM PV resources for each Capacity Commitment Period (CCP) through FCA 12
  2. **Non-FCM EOR/Gen**
     - Determine the % share of non-FCM PV participating in energy market at the end of 2017 and assume this share remains constant throughout the forecast period
  3. **BTM**
     - Subtract the values from steps 1 and 2 from the annual state PV forecast, the remainder is the BTM PV

PV in ISO New England Markets

- **FCM**
  - ISO identified all PV generators or demand resources (DR) that have Capacity Supply Obligations (CSO) in FCM up through FCA 12
  - Assume aggregate total PV in FCM as of FCA 12 remains constant from 2021-2027
- **Non-FCM Gen/EOR**
  - ISO identified total nameplate capacity of PV in each state registered in the energy market as of 12/31/17
  - Assume % share of nameplate PV in energy market as of 12/31/17 remains constant throughout the forecast horizon
- Other assumptions:
  - Supply-side FCM PV resources operate as EOR/Gen prior to their first FCM commitment period (this has been observed in Massachusetts and Rhode Island)
  - 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

- In order to estimate hourly BTM PV production, ISO developed hourly state PV profiles for the period 1/1/2012 –1/31/2017 using historical production data
  - Data are aggregated into normalized PV profiles for each state, which represent a per-MW-of-nameplate production profile for PV
  - Data sources and method are described on the following slides



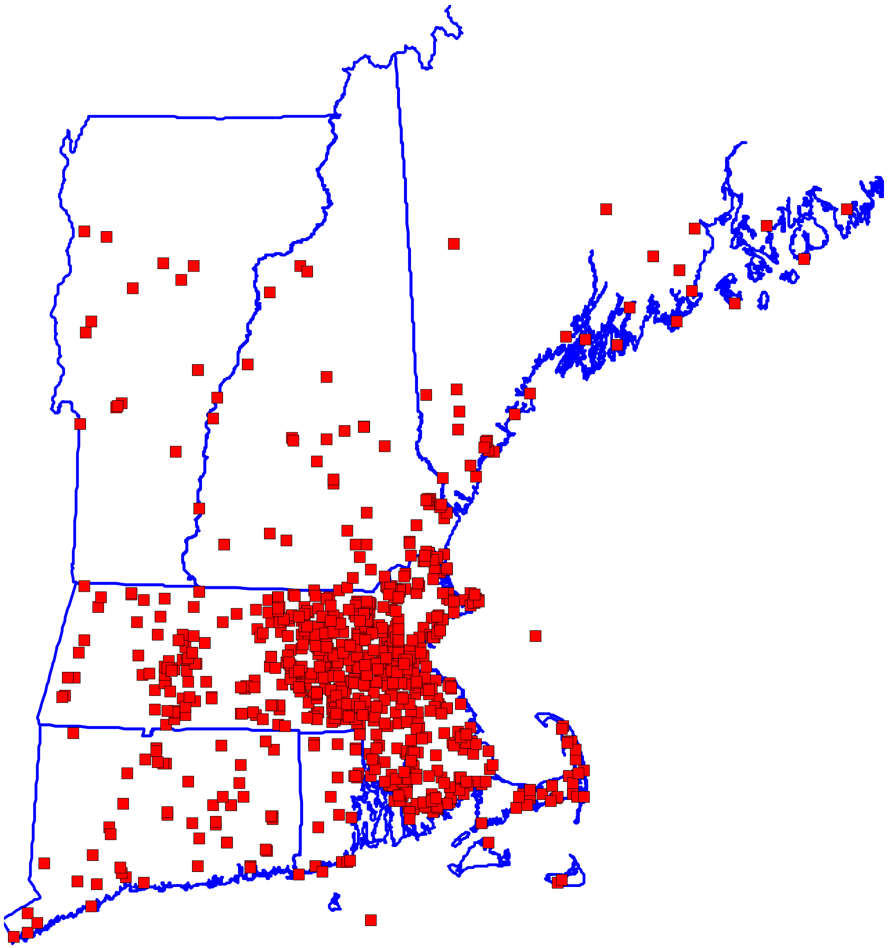
Estimation of Hourly BTM PV (*continued*)

- Using the normalized PV profiles, total state PV production was then estimated by scaling the profiles up to the total PV installed over the period according to recently-submitted distribution utility data
  - (Normalized Hourly Profile) x (Total installed PV Capacity) = Hourly PV production
- Subtracting the hourly PV settlements energy (where applicable) yields the total BTM PV energy for each state
  - BTM profiles were used for PV reconstitution in the development of the gross load forecast

Historical PV Profile Development and Analysis *1/1/12-12/31/13*

- Hourly state PV profiles developed for two years (2012-2013) using production data using Yaskawa-Solectria Solar's web-based monitoring system, SolrenView*
  - Represents PV generation at the inverter or at the revenue-grade meter
- A total of more than 1,200 individual sites representing more than 125 MW_{ac} in nameplate capacity were used
  - Site locations depicted on adjacent map

Yaskawa-Solectria Sites



**Source*: http://www.solrenview.com/

Historical PV Profile Development and Analysis

1/1/14-12/31/17

- ISO has contracted with a third-party vendor for PV production data services
  - Includes data from more than 9,000 PV installations
  - Data are 5-minutely and at the town level
  - Broad geographic coverage
  - Data provided begins in 2014
- An example snapshot of regional data is plotted to the right
  - Data are from August 12, 2016 at 03:00 pm
  - Yellow/red coloring shows level of PV production
  - No data available in towns colored gray
  - Data not requested in towns colored black
- Using these data, hourly state PV profiles for years 2014-2016 are developed using the method previously described

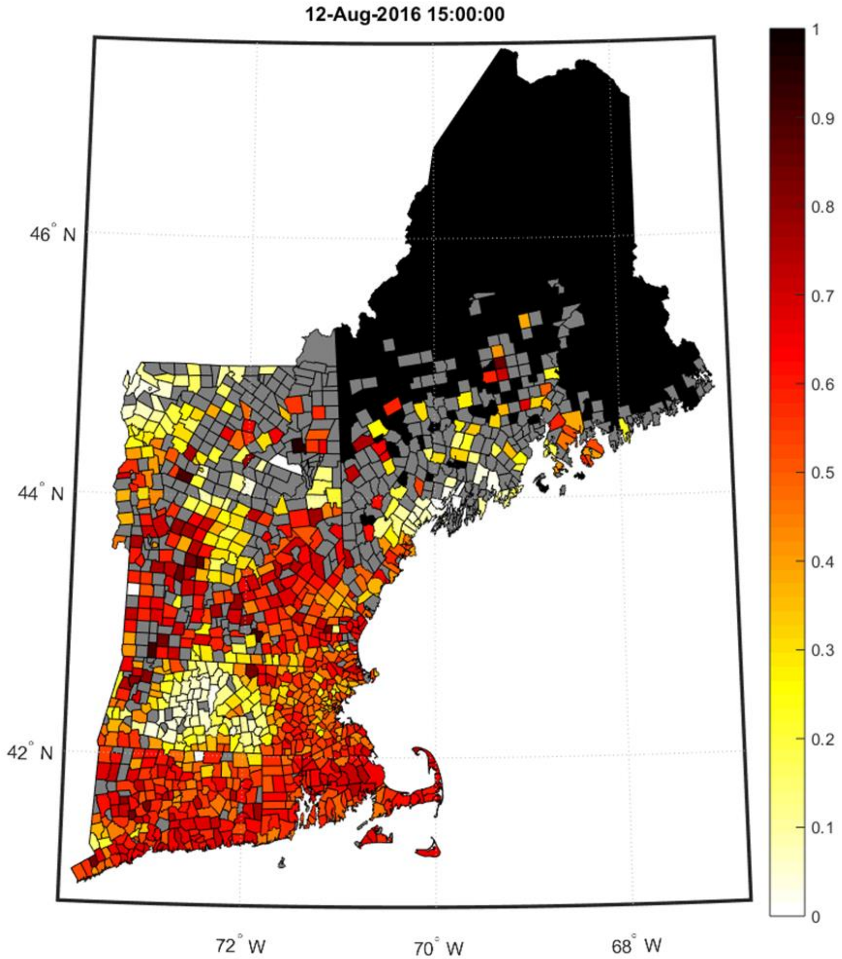


Figure notes:

1. Graphic developed by ISO New England
2. Data source: Quantitative Business Analytics, Inc.

FINAL 2018 PV NAMEPLATE FORECAST BY RESOURCE TYPE

Final 2018 PV Forecast

Cumulative Nameplate, MW_{ac}

States	Cumulative Total MW (AC nameplate rating)										
	Thru 2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
CT	365.6	454.3	541.0	630.9	711.5	784.4	838.2	890.3	940.9	989.9	1037.3
MA	1602.3	1898.9	2126.9	2354.9	2570.3	2785.6	3000.9	3216.3	3351.4	3482.3	3608.9
ME	33.5	43.6	53.8	64.0	73.6	83.3	92.9	102.5	112.1	121.8	131.4
NH	69.7	83.5	97.4	111.2	124.3	137.3	150.4	163.5	176.5	189.6	202.7
RI	62.2	96.7	131.2	162.6	192.3	221.9	251.6	281.2	310.9	340.5	370.2
VT	257.2	288.7	311.2	333.7	355.0	376.2	397.5	418.7	440.0	461.2	482.5
Regional - Cumulative (MW)	**2390.5**	**2865.8**	**3261.6**	**3657.4**	**4026.9**	**4388.8**	**4731.4**	**5072.5**	**5331.8**	**5585.3**	**5832.9**

Notes:

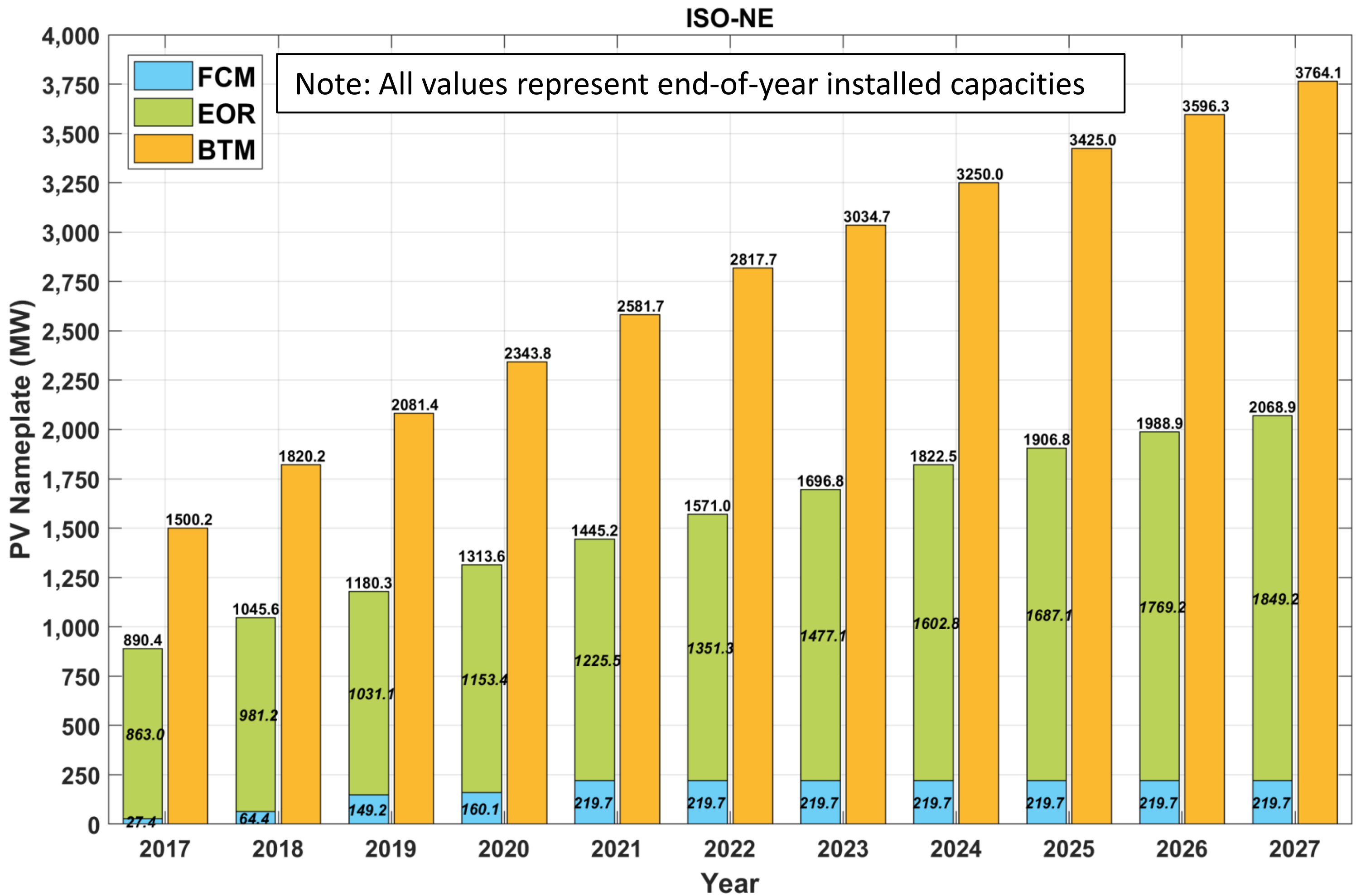
(1) Forecast values include FCM Resources, non-FCM Energy Only Generators, and behind-the-meter PV resources

(2) The forecast reflects discount factors to account for uncertainty in meeting state policy goals

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

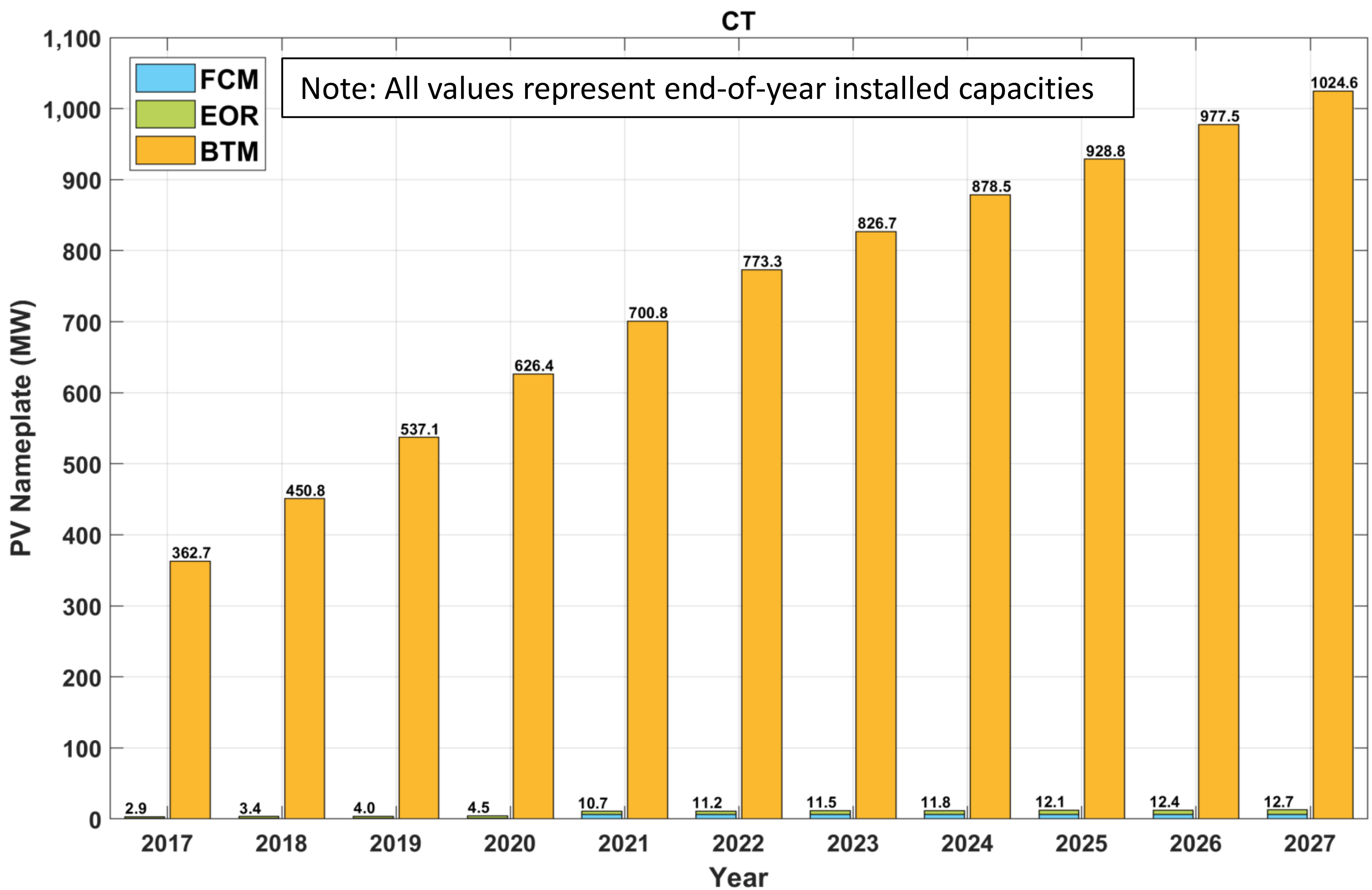
Final 2018 PV Forecast

Cumulative Nameplate, MW_{ac}



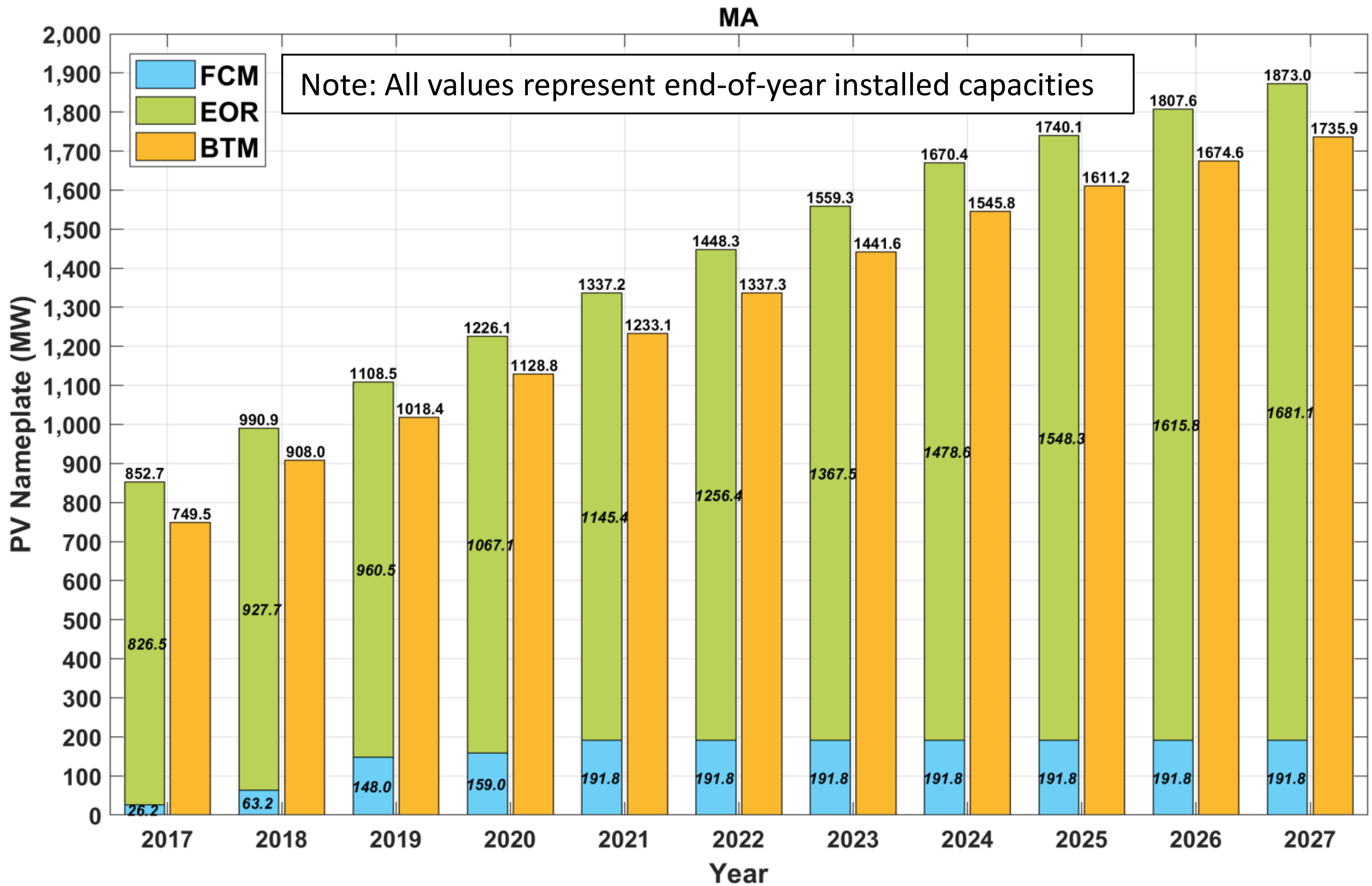
Cumulative Nameplate by Resource Type, MW_{ac}

Connecticut



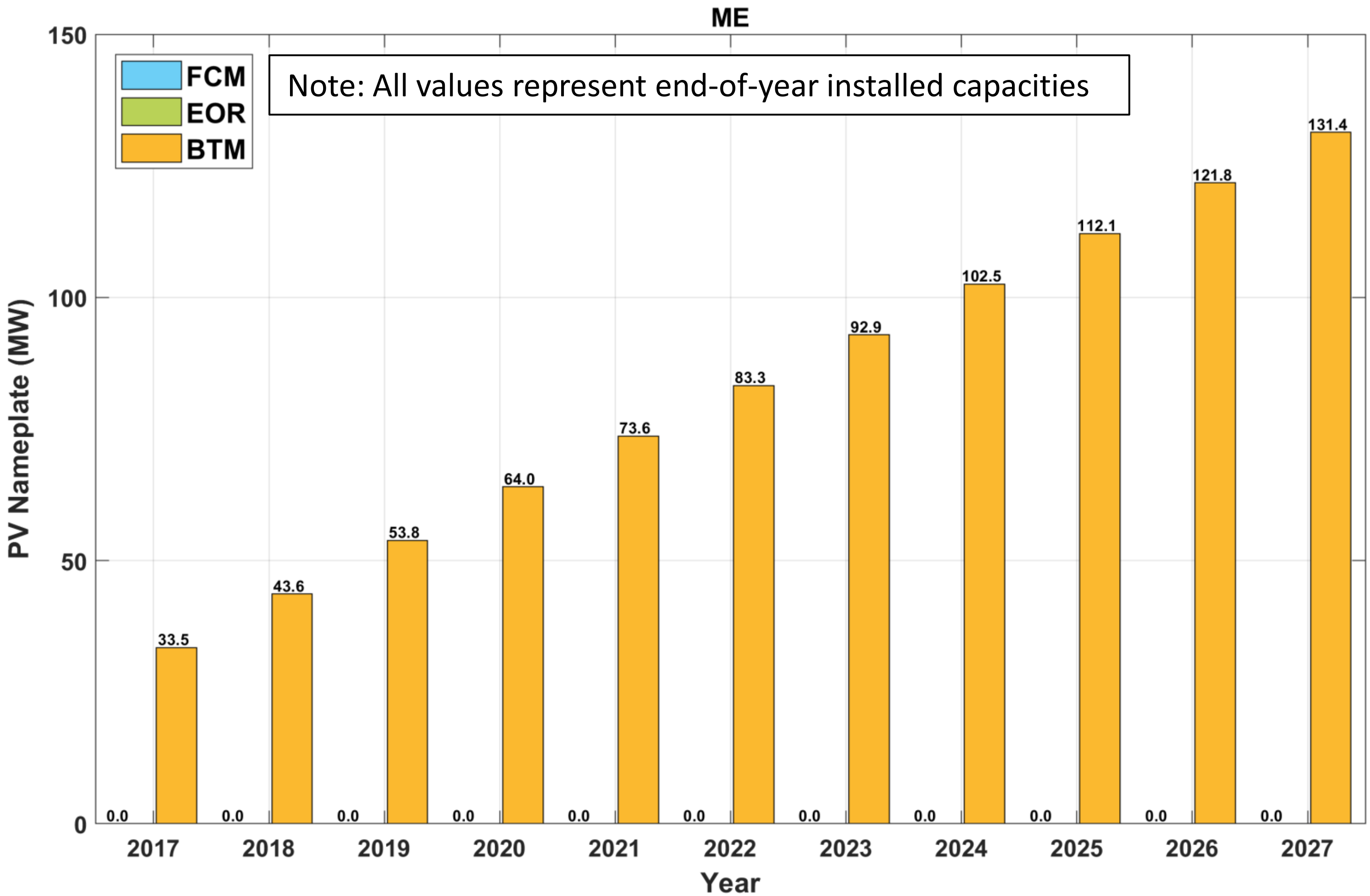
Cumulative Nameplate by Resource Type, MW_{ac}

Massachusetts



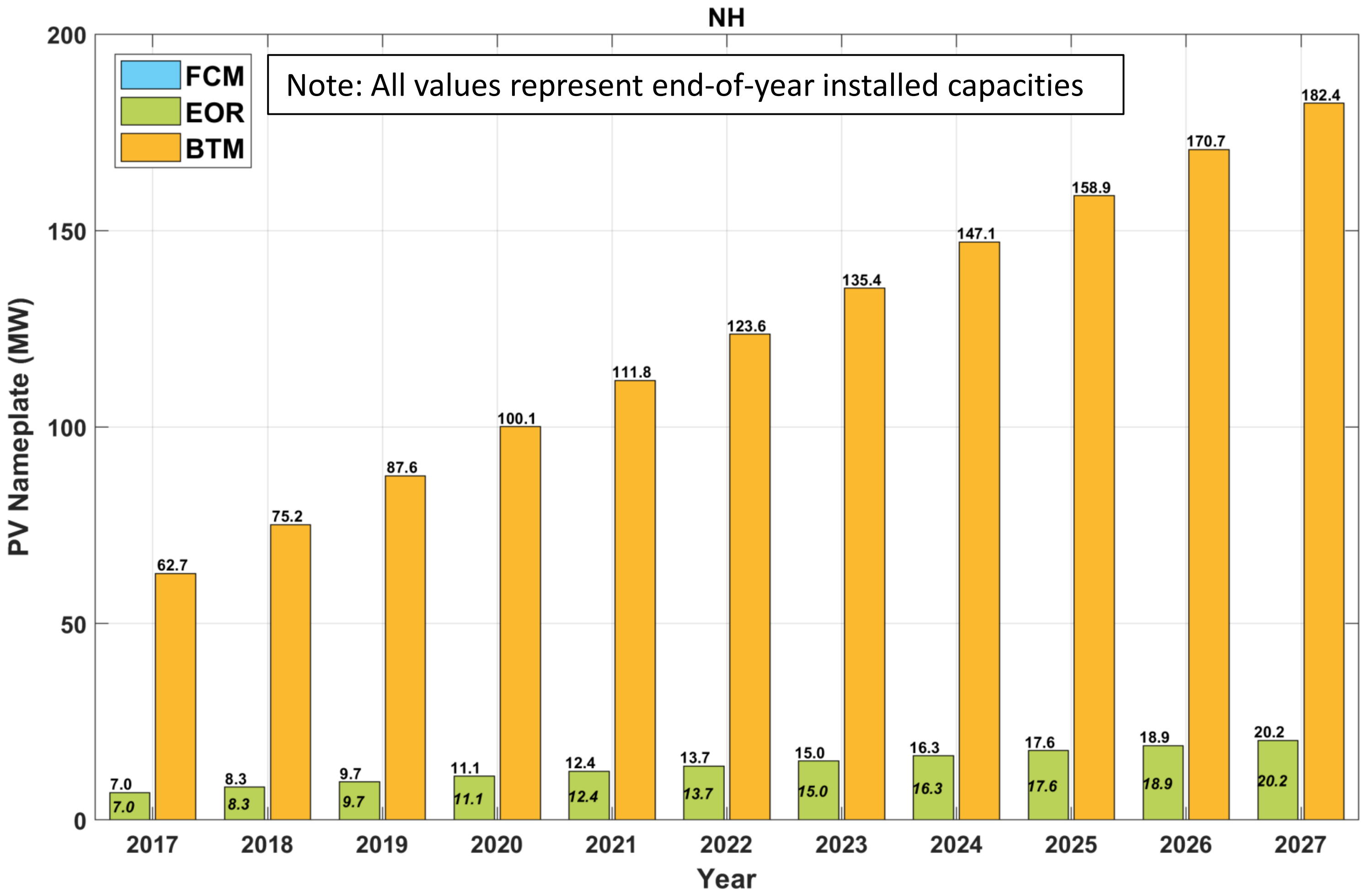
Cumulative Nameplate by Resource Type, MW_{ac}

Maine



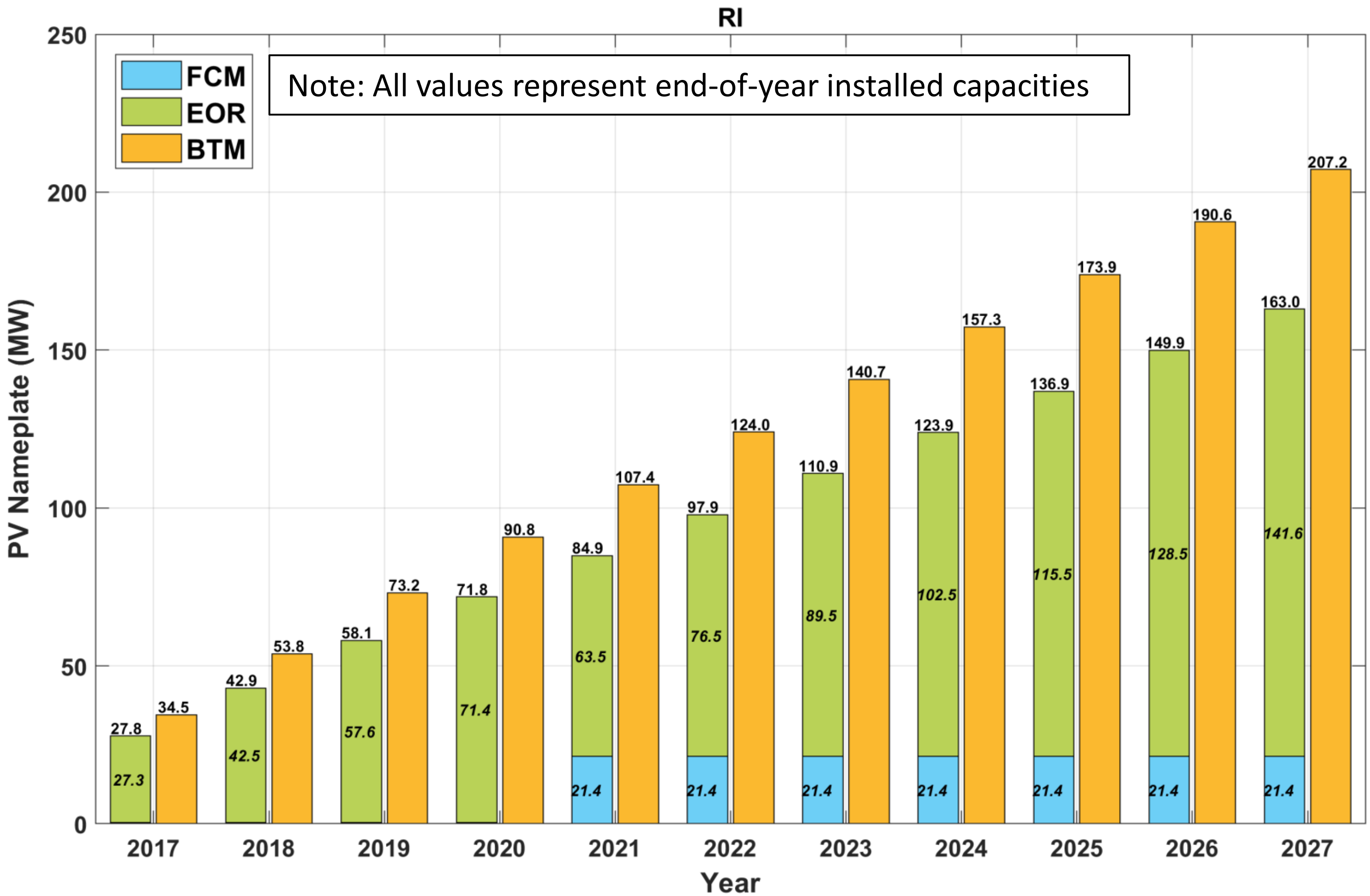
Cumulative Nameplate by Resource Type, MW_{ac}

New Hampshire



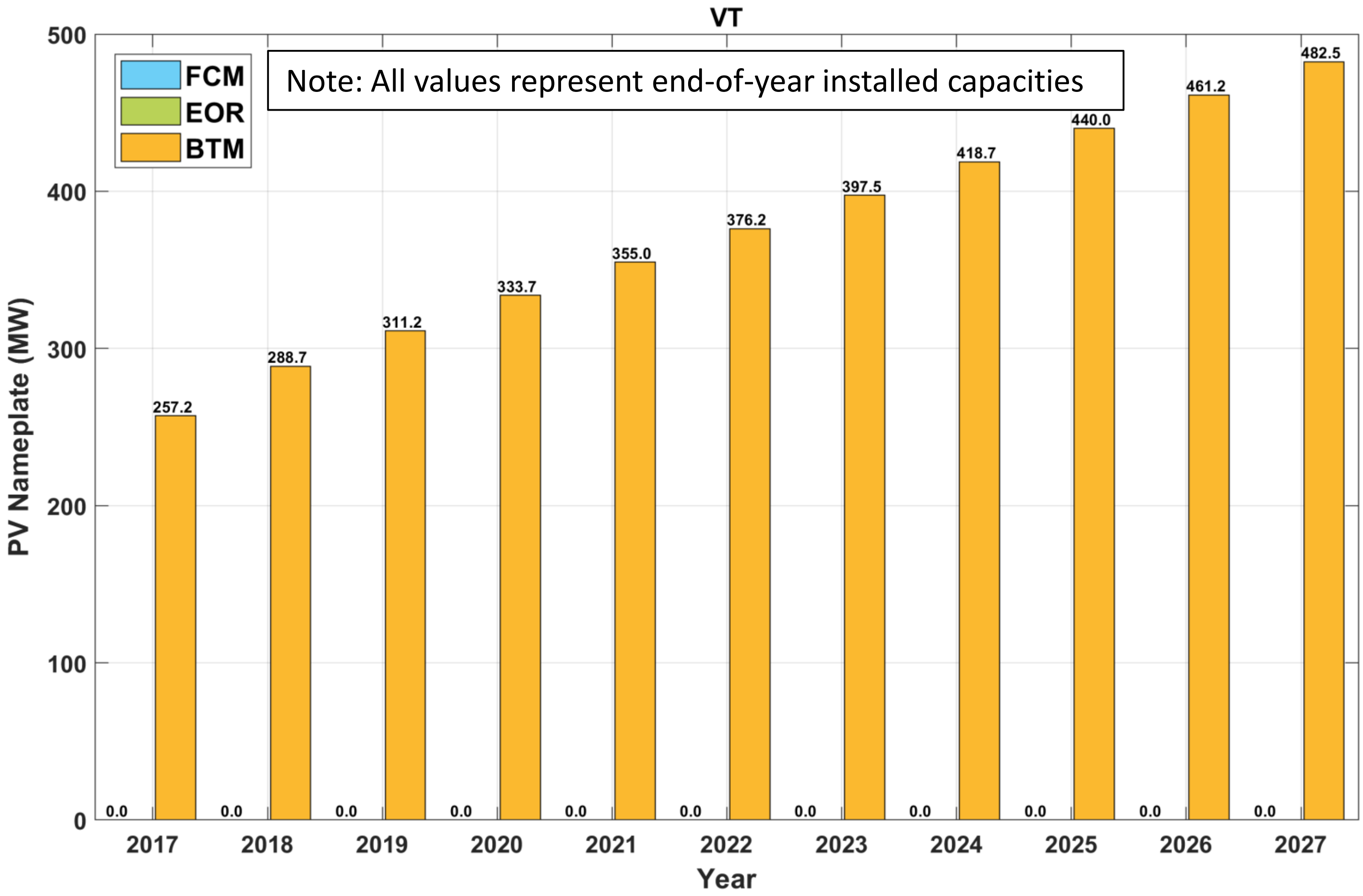
Cumulative Nameplate by Resource Type, MW_{ac}

Rhode Island



Cumulative Nameplate by Resource Type, MW_{ac}

Vermont



CELT BTM PV FORECAST: ESTIMATED ENERGY & SUMMER PEAK LOAD REDUCTIONS USED

BTM PV Forecast Used in CELT Net Load Forecast

- The 2018 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 2018 CELT net load forecast
  - PV does not reduce winter peak loads, which occur after sunset
- ISO developed estimated summer peak load reductions associated with BTM PV forecast using the methodology established for the 2016 CELT PV forecast
  - See Appendix of 2016 PV Forecast slides: https://www.iso-ne.com/static-assets/documents/2016/09/2016_solar_forecast_details_final.pdf

Final 2018 PV Energy Forecast

BTM PV, GWh

States	Total Estimated Annual Energy (GWh)									
	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
CT	539	657	775	886	984	1,069	1,139	1,202	1,265	1,325
MA	1085	1,272	1,418	1,556	1,691	1,824	1,960	2,070	2,148	2,222
ME	50	63	77	90	102	115	127	139	152	164
NH	88	104	120	135	150	165	180	194	208	223
RI	57	83	109	132	154	177	199	221	243	264
VT	345	380	408	434	459	484	510	535	559	584
Regional - Annual Energy (GWh)	**2162**	**2,558**	**2,906**	**3,233**	**3,540**	**3,834**	**4,115**	**4,361**	**4,575**	**4,783**

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 6.5% to reflect avoided transmission and distribution losses

Final 2018 Forecast

BTM PV: July 1st Estimated Summer Peak Load Reductions

States	Estimated Summer Peak Load Reduction - BTM PV (MW)									
	2018	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**
CT	154.5	181.6	207.1	229.2	246.2	258.9	266.5	273.4	280.3	286.1
MA	315.7	356.4	383.8	408.0	429.0	448.0	465.3	477.2	482.5	486.5
ME	14.6	17.9	21.0	23.7	26.2	28.4	30.5	32.5	34.4	36.3
NH	26.4	30.0	33.5	36.6	39.3	41.8	44.1	46.2	48.4	50.5
RI	16.4	23.1	29.1	34.2	38.6	42.8	46.6	50.2	53.8	57.1
VT	105.1	111.6	115.7	119.2	122.2	124.8	127.1	129.4	132.0	134.3
Regional - Cumulative Peak Load Reduction (MW)	**632.6**	**720.6**	**790.2**	**850.9**	**901.5**	**944.8**	**980.1**	**1008.9**	**1031.4**	**1050.7**

% of BTM AC nameplate	**36.6%**	**35.3%**	**34.2%**	**33.1%**	**32.0%**	**31.0%**	**30.0%**	**29.1%**	**28.4%**	**27.7%**

Notes:

(1) Forecast values are for 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

(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

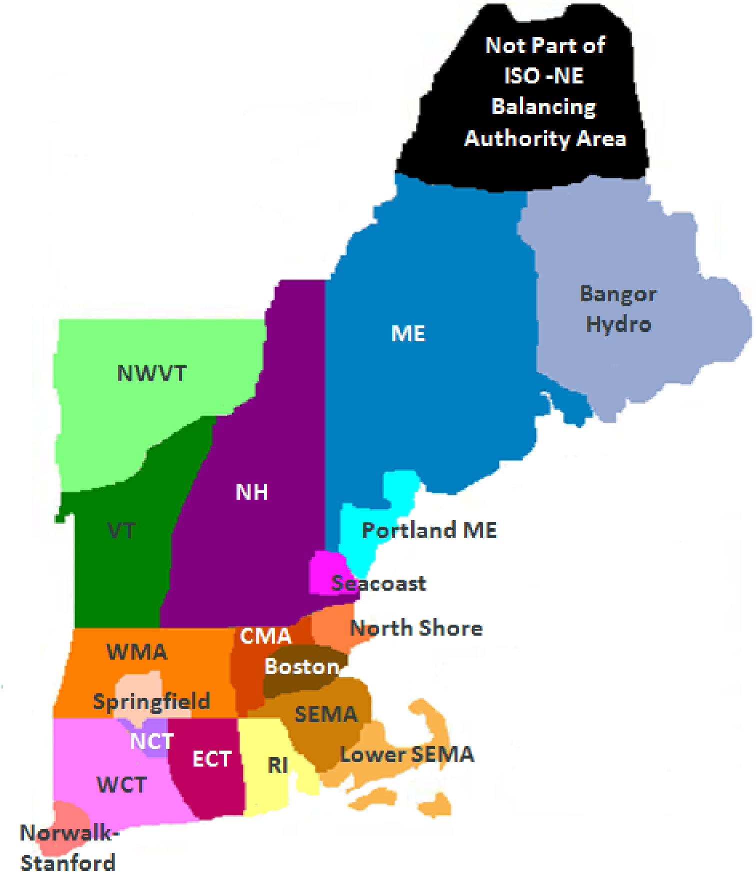
GEOGRAPHIC DISTRIBUTION OF PV FORECAST

Background

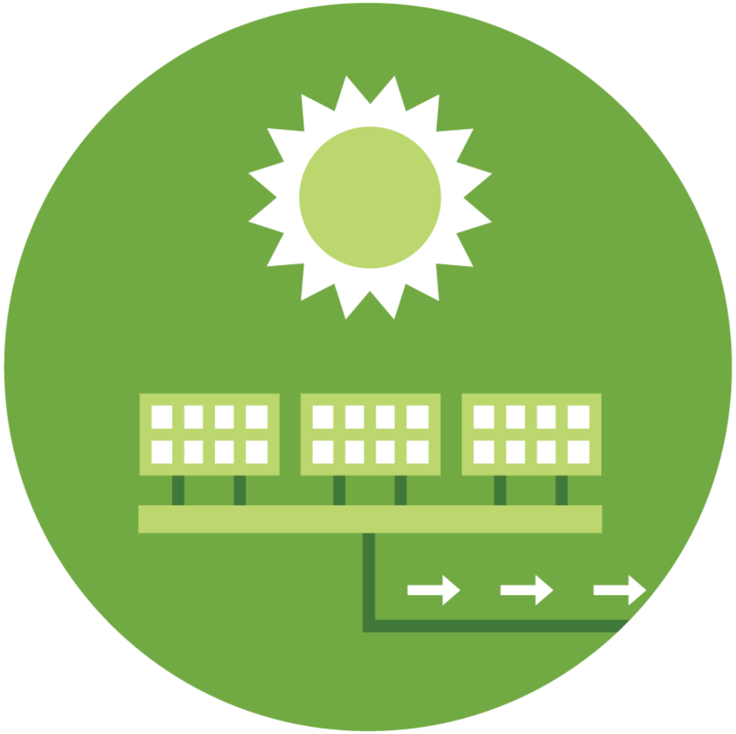
- A reasonable representation of the locations of existing and future PV resources is required for appropriate modeling
- The locations of most future PV resources are ultimately unknown
- Mitigation of some of this uncertainty (especially for near-term development) is possible via analysis of available data

Forecasting PV By DR Dispatch Zone

- Demand Response (DR) Dispatch Zones were created as part of the DR Integration project
- These zones were created in consideration of electrical interfaces
- Quantifying existing and forecasted PV resources by Dispatch Zone (with nodal placement of some) will aid in the modeling of PV resources for planning and operations purposes



Geographic Distribution of PV Forecast



- Existing MWs:
  - Apply I.3.9 project MWs nodally
  - For remaining existing MWs, determine Dispatch Zone locations of projects already interconnected based on utility distribution queue data (town/zip), and apply MWs equally to all nodes in Zone
- Future MWs:
  - Apply I.3.9 project MWs nodally
  - For longer-term forecast, assume the same distribution as existing MWs

Dispatch Zone Distribution of PV

Based on December 31, 2017 Utility Data

State	Load Zone	Dispatch Zone	% of State
CT	CT	EasternCT	18.9%
	CT	NorthernCT	19.4%
	CT	Norwalk_Stamford	7.7%
	CT	WesternCT	54.0%
ME	ME	BangorHydro	12.1%
	ME	Maine	52.4%
	ME	PortlandMaine	35.5%
MA	NEMA	Boston	11.5%
	NEMA	NorthShore	5.6%
	SEMA	LowerSEMA	14.4%
	SEMA	SEMA	22.2%
	WCMA	CentralMA	15.0%
	WCMA	SpringfieldMA	6.9%
	WCMA	WesternMA	24.4%
NH	NH	NewHampshire	87.3%
	NH	Seacoast	12.7%
RI	RI	RhodeIsland	100.0%
VT	VT	NorthwestVermont	63.2%
	VT	Vermont	36.8%

SUMMARY AND NEXT STEPS

Summary and Next Steps

- The 2018 PV nameplate and energy forecasts have been finalized
- The ISO has categorized the 2018 state and regional PV forecasts according to the three PV resource categories
- The ISO has updated its geographic distribution assumptions based on recent data
- The final PV forecast will appear in the 2018 CELT, which will be published by May 1st

Questions