May 5, 2021

Solar Power Growth in New England

BTM PV Increasingly Impacting Load Forecasting

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Operations - Load Forecasting

Topics

- BTM PV Growth in New England
- Challenges Due to Increasing Behind-the-Meter Photovoltaic (BTM PV)
- How BTM PV Has Changed the Shape of the Load Curve
- ISO New England's Recent Load Forecast Method
- Continued BTM PV Growth Will Alter the Load Curve Even More
- Dealing With Daily BTM PV Forecast Errors (Irradiance/Clouds)
- Better Cloud Cover and Irradiance Forecasts Needed

BTM PV Growth in New England

Load Forecast Challenges

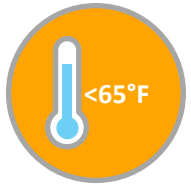
Challenges Due to Increasing Behind-the-Meter Photovoltaic (BTM PV)

Solar power in New England

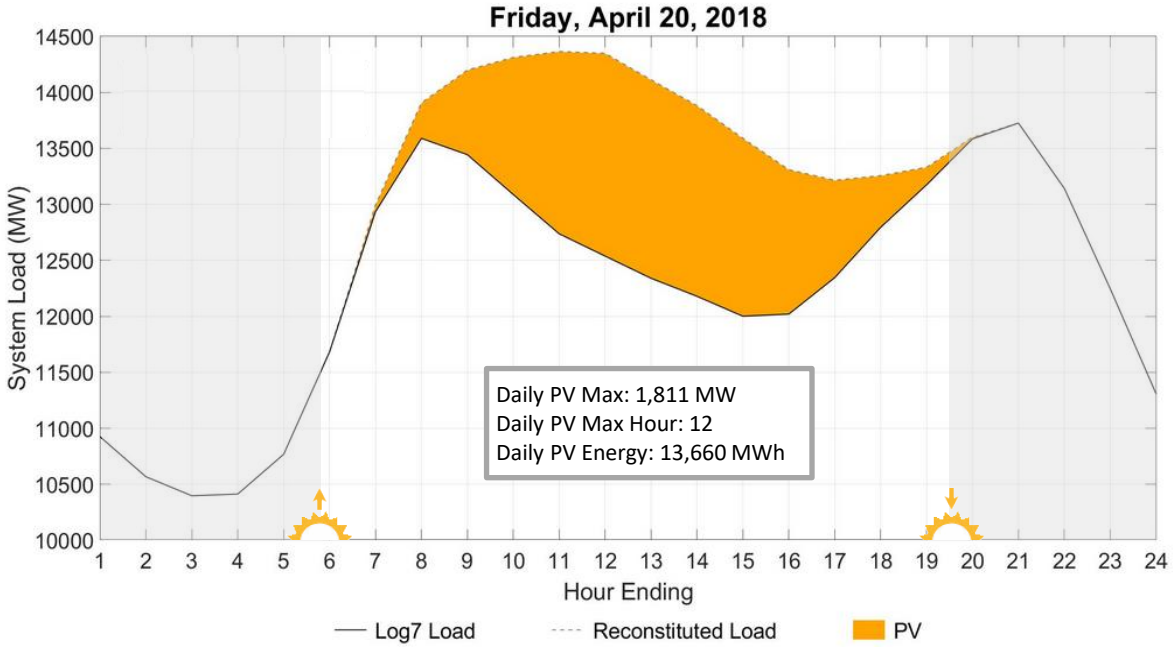
- More than 4,000 MW of PV installed in New England behind the meter
- BTM PV notably reduces load when sun shines

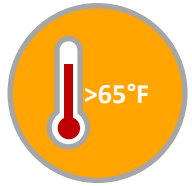
  Brighter sun = markedly more load reduction
- Contributes significant volatility in system load during daytime
- Must be accounted for in load forecasting process
- Apart from BTMPV, surface weather forecasts are generally good

Typical Spring Day Load Curves Just a Few Years Ago

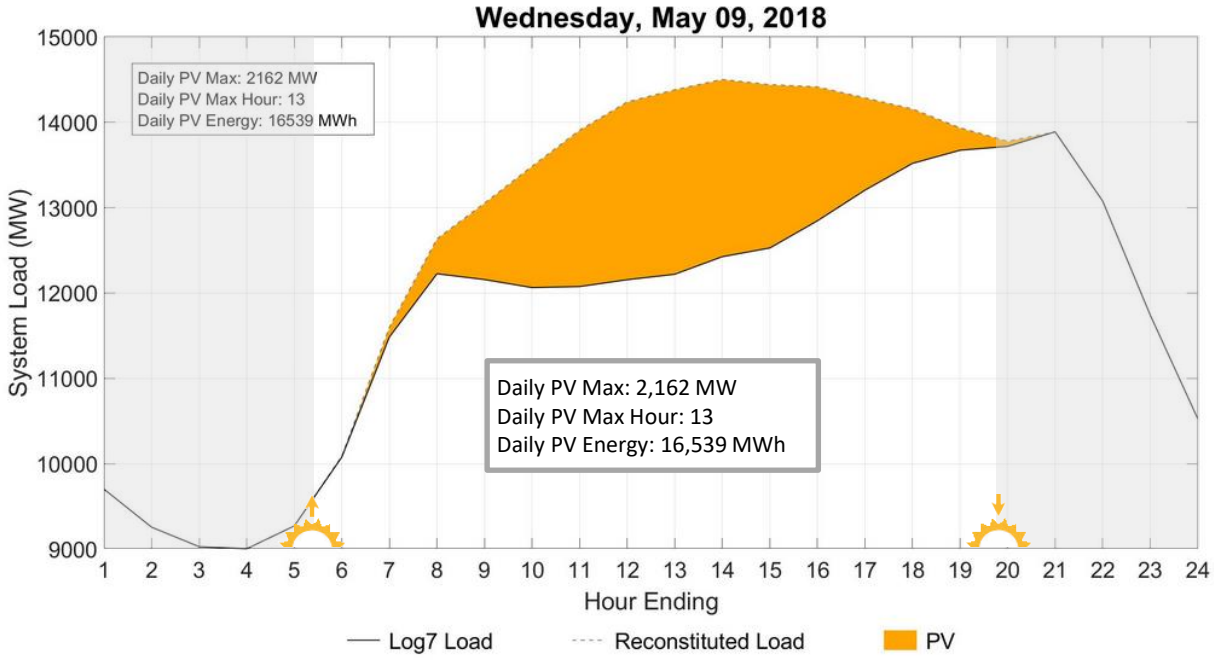


Common Load Curve on a Cool Spring Day

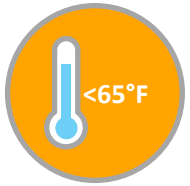




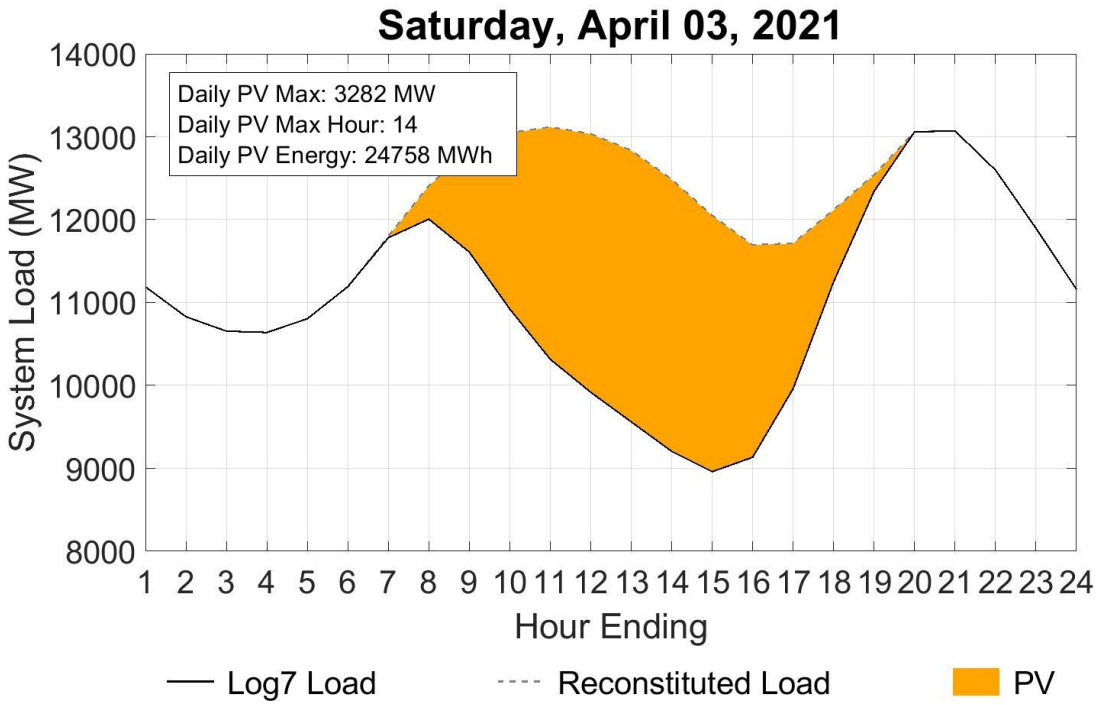
Common Load Curve on Warm Spring Day

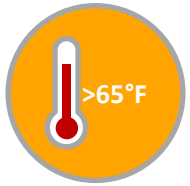


More Recently However, Spring Day Load Curves Have Changed



Recent Load Curve on a Cool Spring Day





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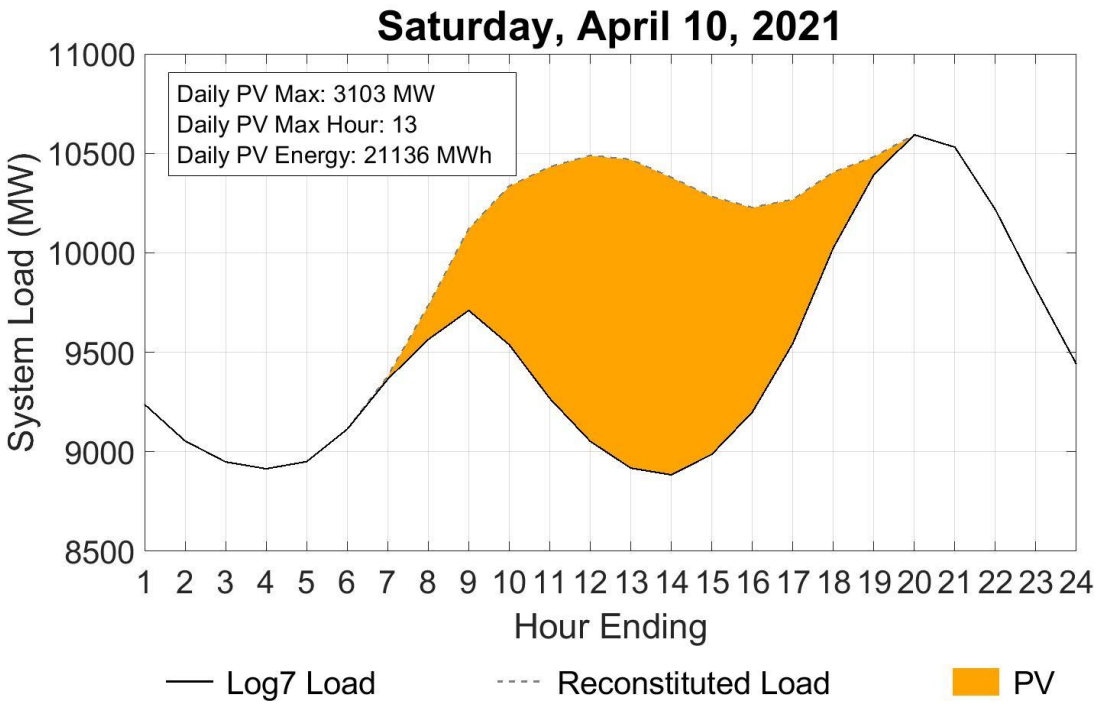
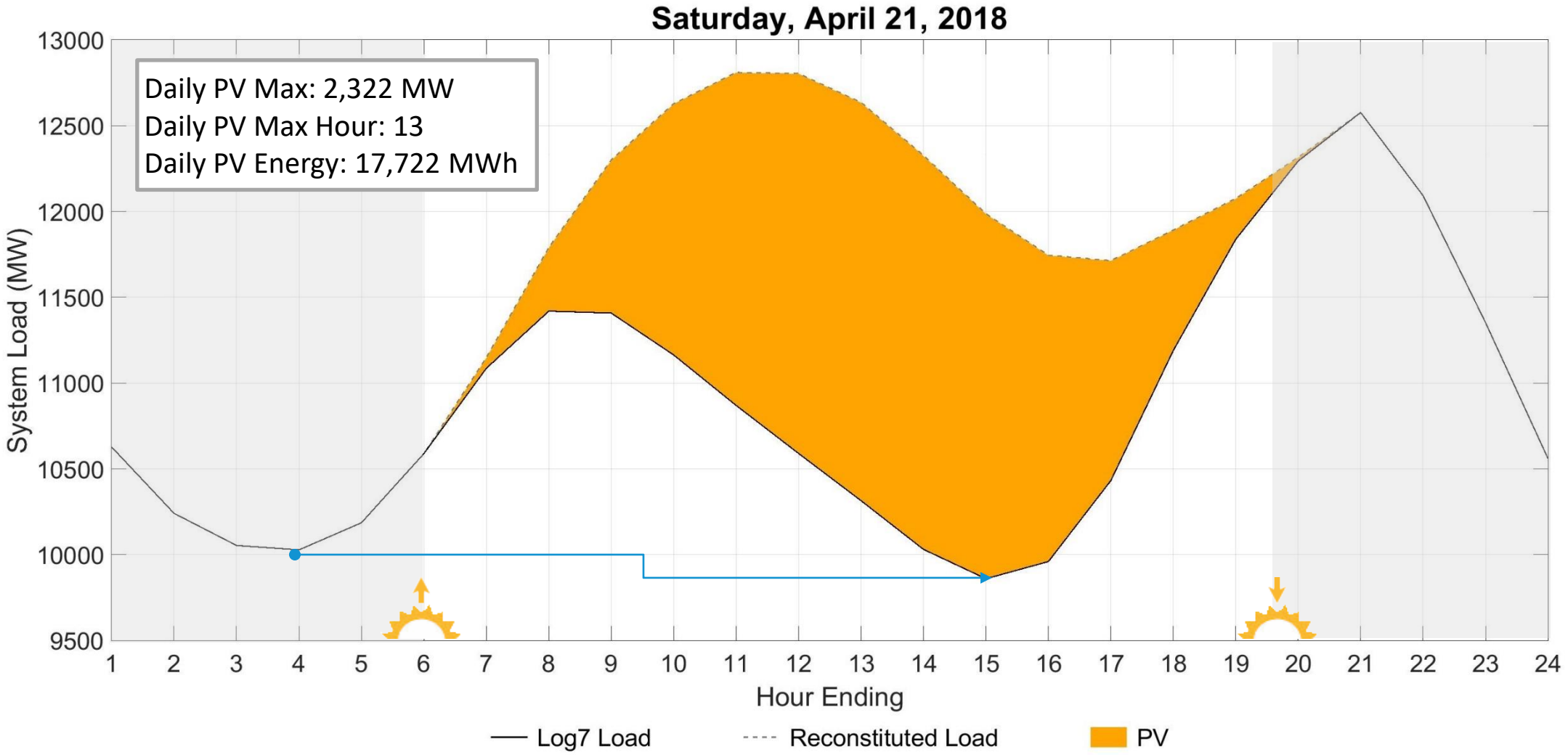
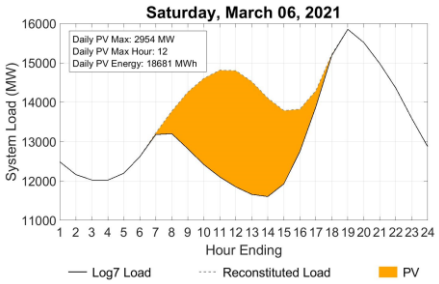
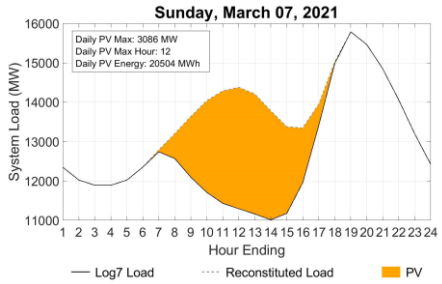


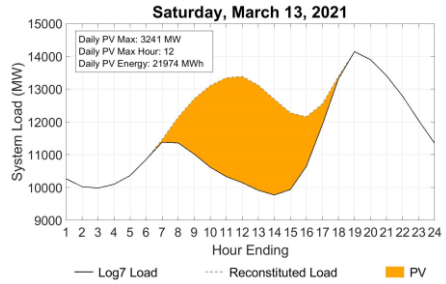
A Few Years Ago, Mid-Afternoon Loads Rarely Dropped Below Overnight Loads

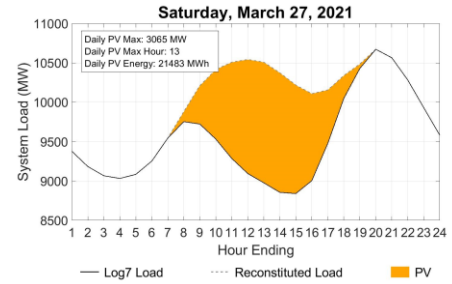


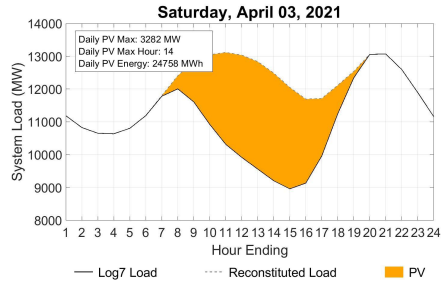
Now, Mid-Afternoon Loads Often Drop Below Overnight Lows on Weekends



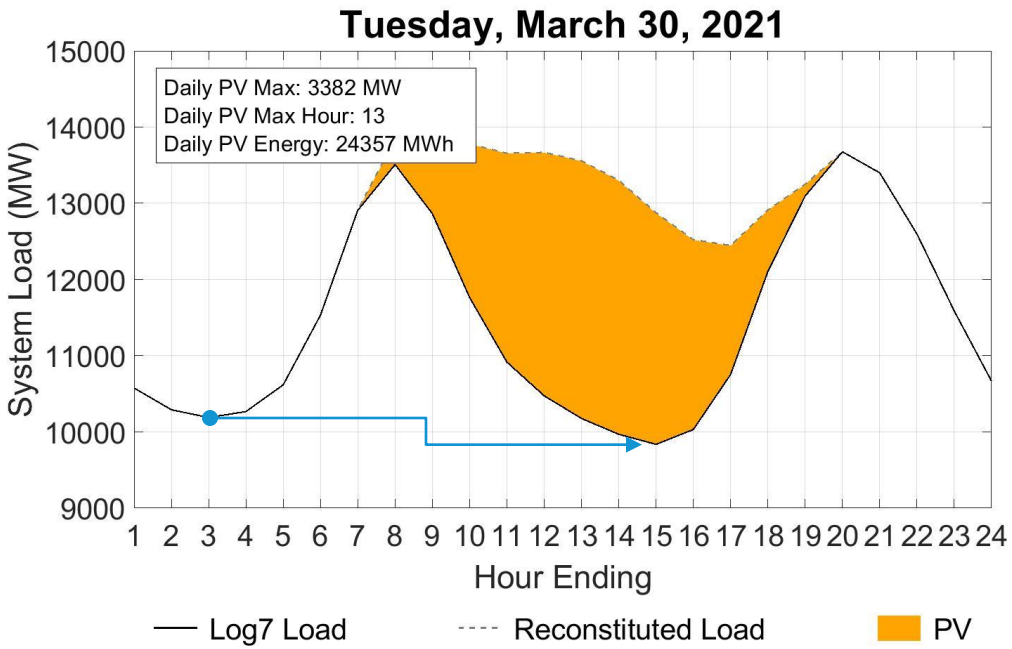


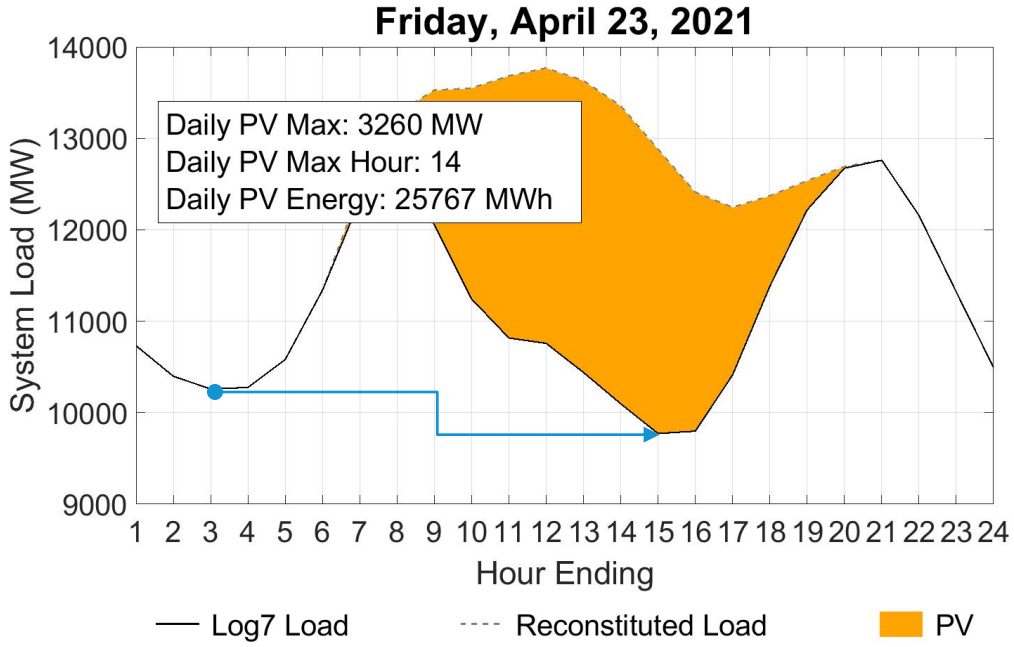






And for the First Time in ISO New England's History, During Some Weekdays





ISO New England's Recent Load Forecast Method

To Help Account For Behind The Meter PV in the LF Process

Forecaster Experience Combines With Neural Net Models to Make a Good Load Forecast

Similar Day (Hands-On Approach)	**Neural Networks**	**Zonal Models** (8 zones)
Forecaster makes adjustments to historic loads using differences between historic weather and forecasted weather as guide	Historic weather and loads are inputs to load models with an output of forecasted load	Neural network approach on smaller areas, which are aggregated into regional forecast

Multi-Part Forecasting Methods Help Adjust for PV Load Reduction

ISO's manual method

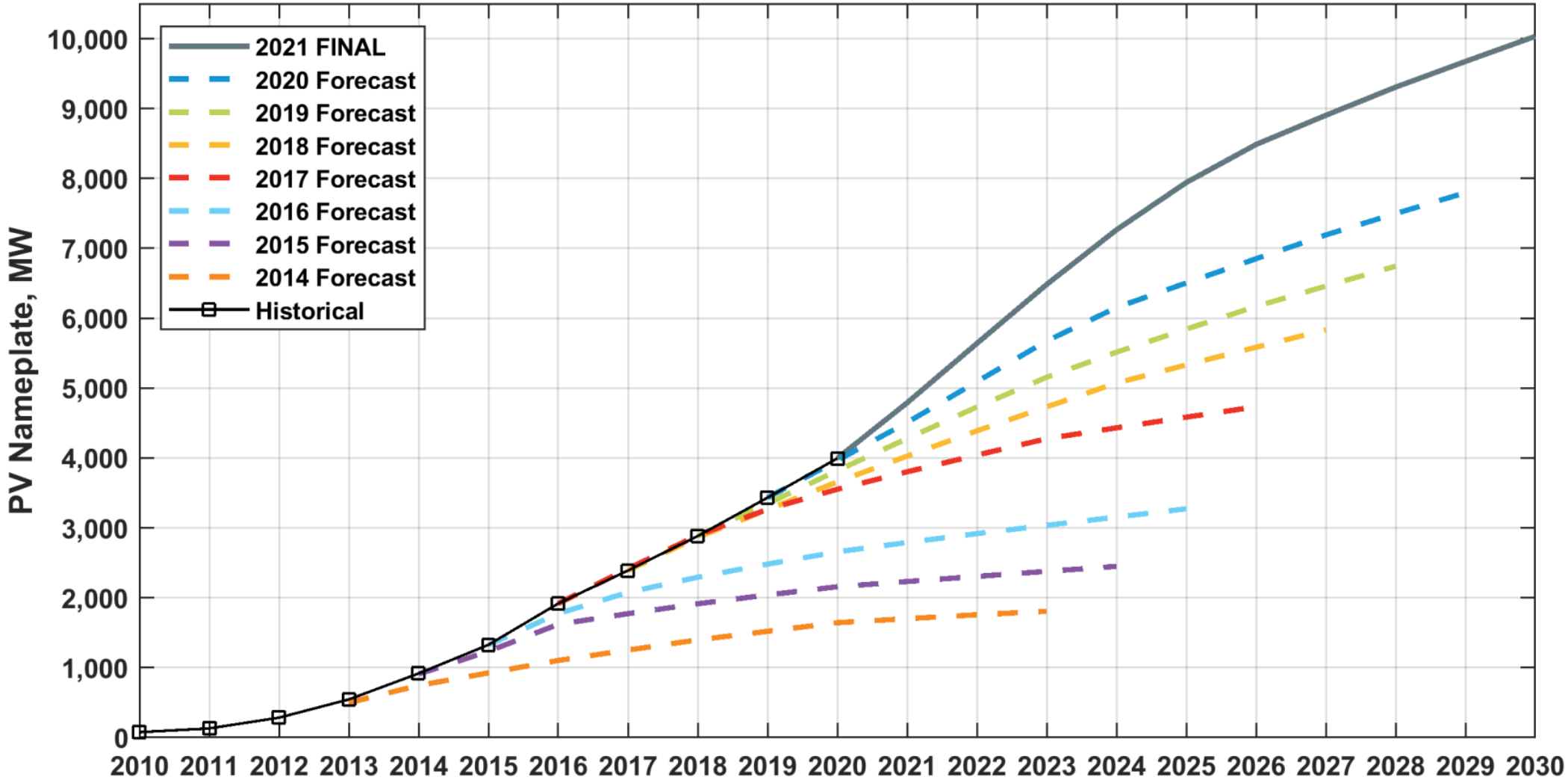
ISO's PV aware method

Error Correction	Direct Input	Reconstitution
• In a blending process, forecaster assess cloud-cover forecasts to estimate potential PV effect on load • Forecaster can add or subtracted load if they believe weather will be cloudier or sunnier • Since certain load models learn average effect, a partly cloudy day may not need adjustment	• Direct Input forecast models are trained using actual PV as an input, just like other weather variables • Model output is adjusted based on forecasted PV compared to actual PV from the past	• Load is "reconstituted"—actual past PV output data is added back into hourly loads • Models are retrained based on reconstituted load • PV forecast is subtracted from load in forecast models • Model output is NOT adjusted based on forecasted PV

However, BTM PV Growth is Outpacing Expectations

So Load Forecast Challenges Continue

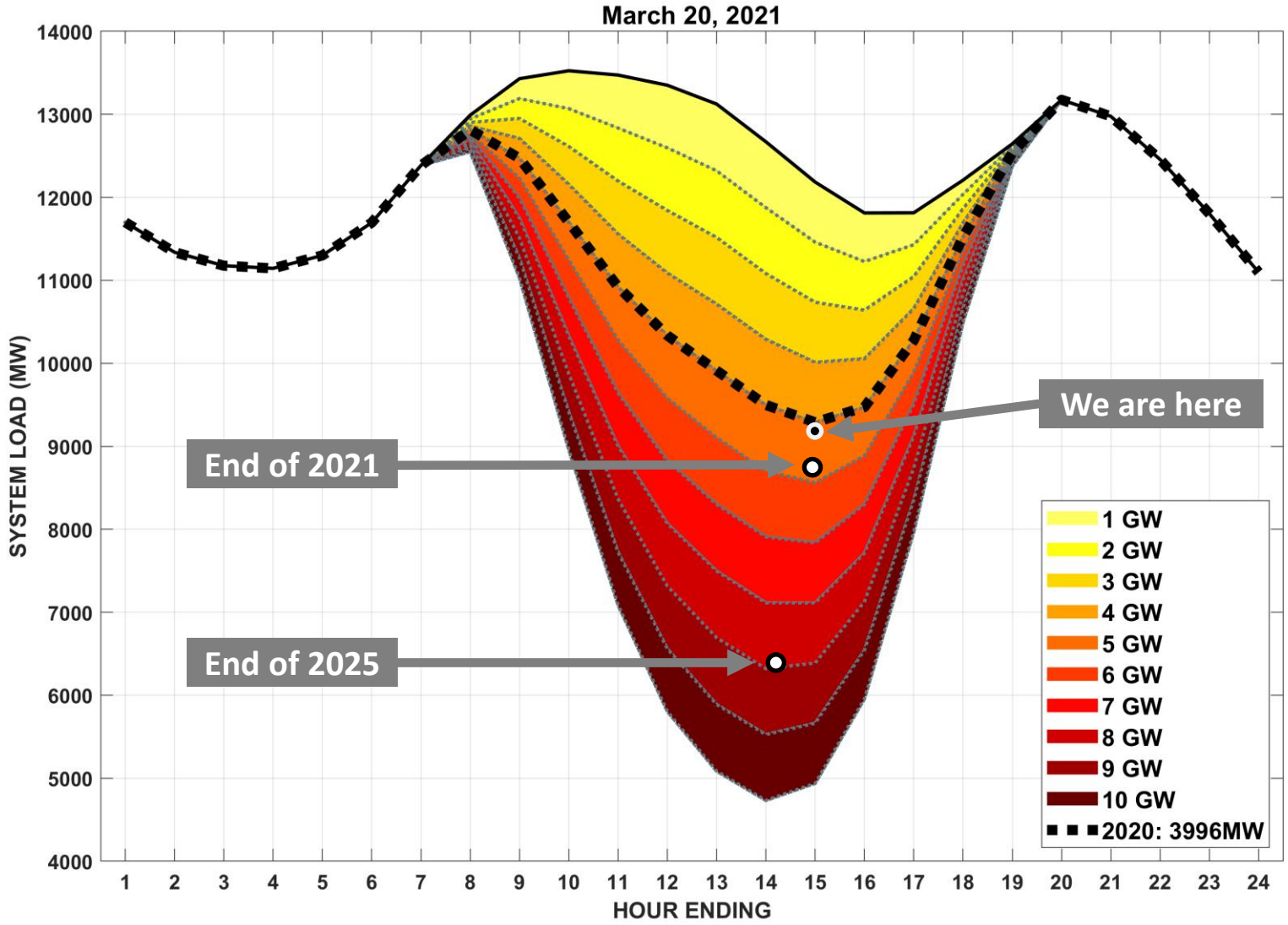
New England BTMPV Growth: Historical vs. Forecast



New England PV Forecast through 2030

End of Year Forecast for Each Year

Year	MW of BTM PV
2020	4,000
2021	4,790
2022	5,639
2023	6,484
2024	7,265
2025	7,942
2026	8,486
2027	8,904
2028	9,306
2029	9,674
2030	10,033



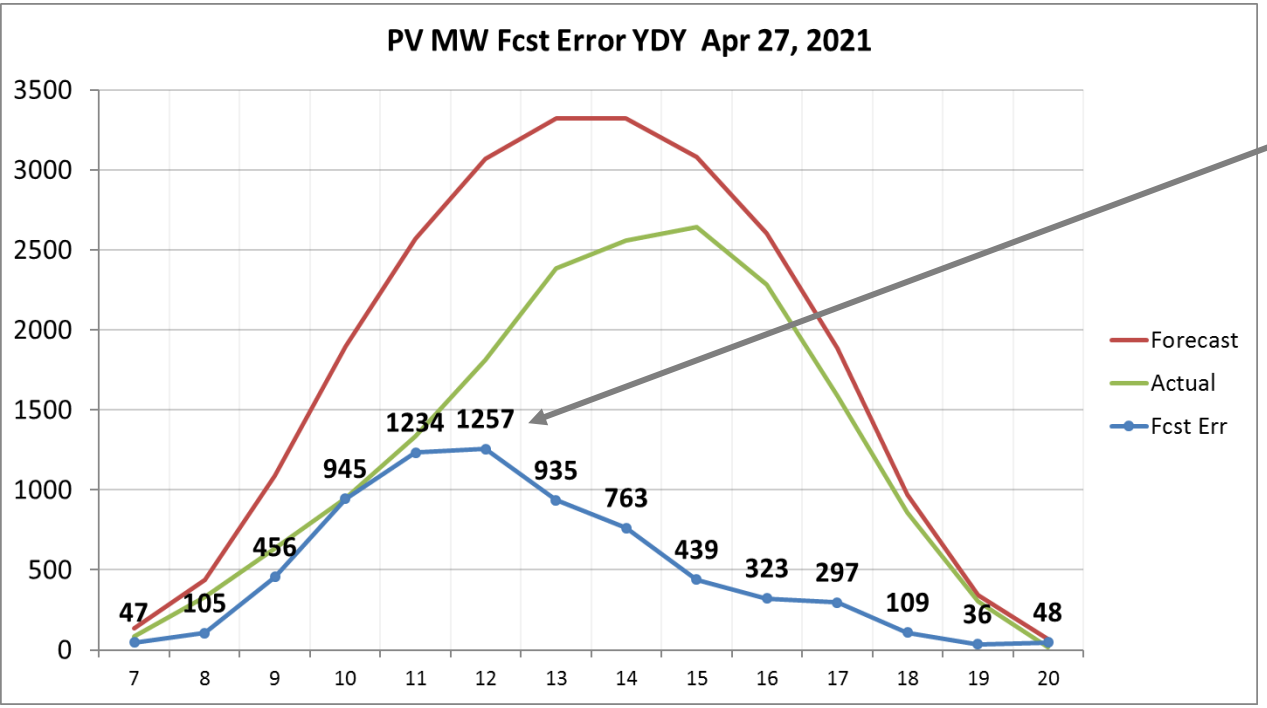
Source: *Final 2021 PV Forecast*

Dealing With Daily BTM PV Forecast Errors (Irradiance/Clouds)

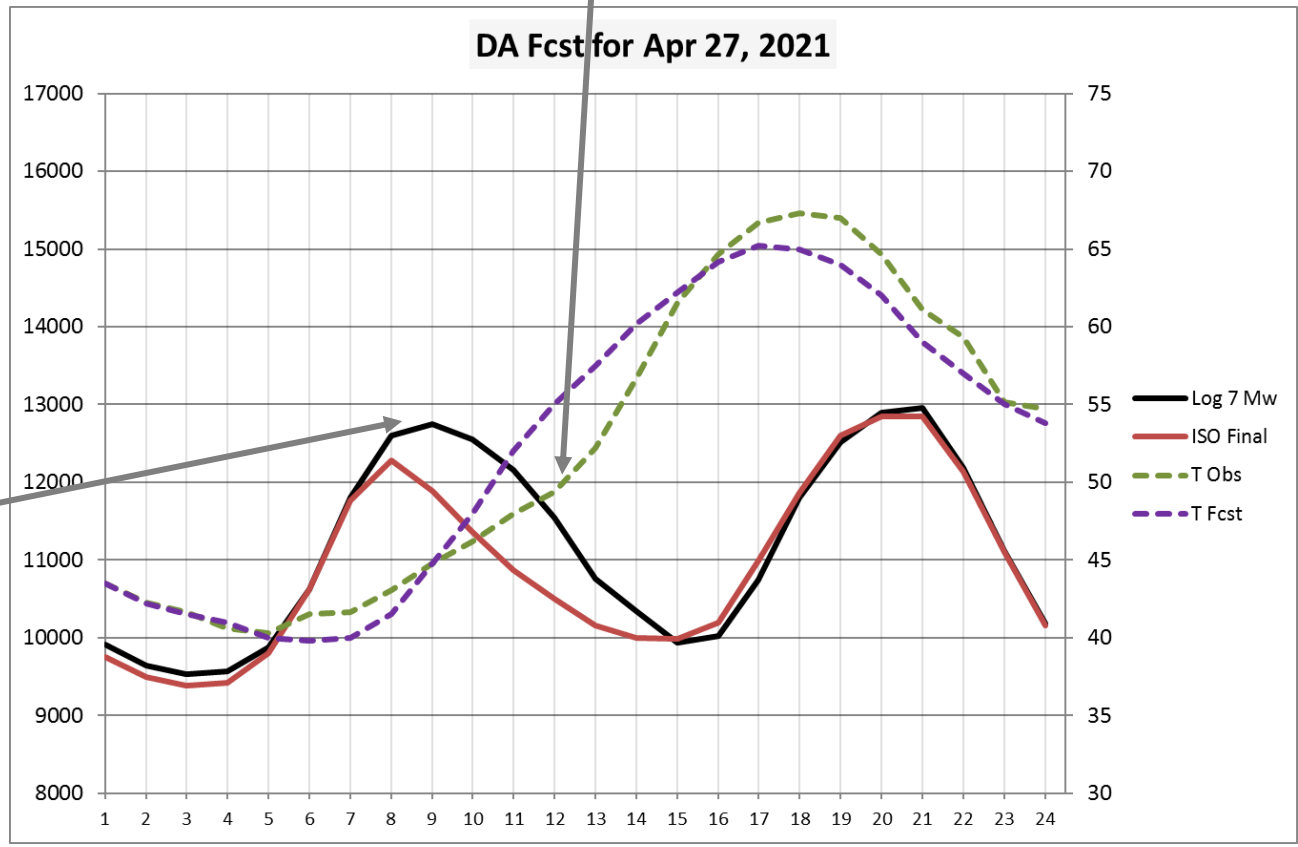
Even a Good Weather Forecast Can Be Undone By a Bad PV Forecast

With a Poor PV Forecast - Ex.1

Less **Sunshine Occurred Than Forecast**



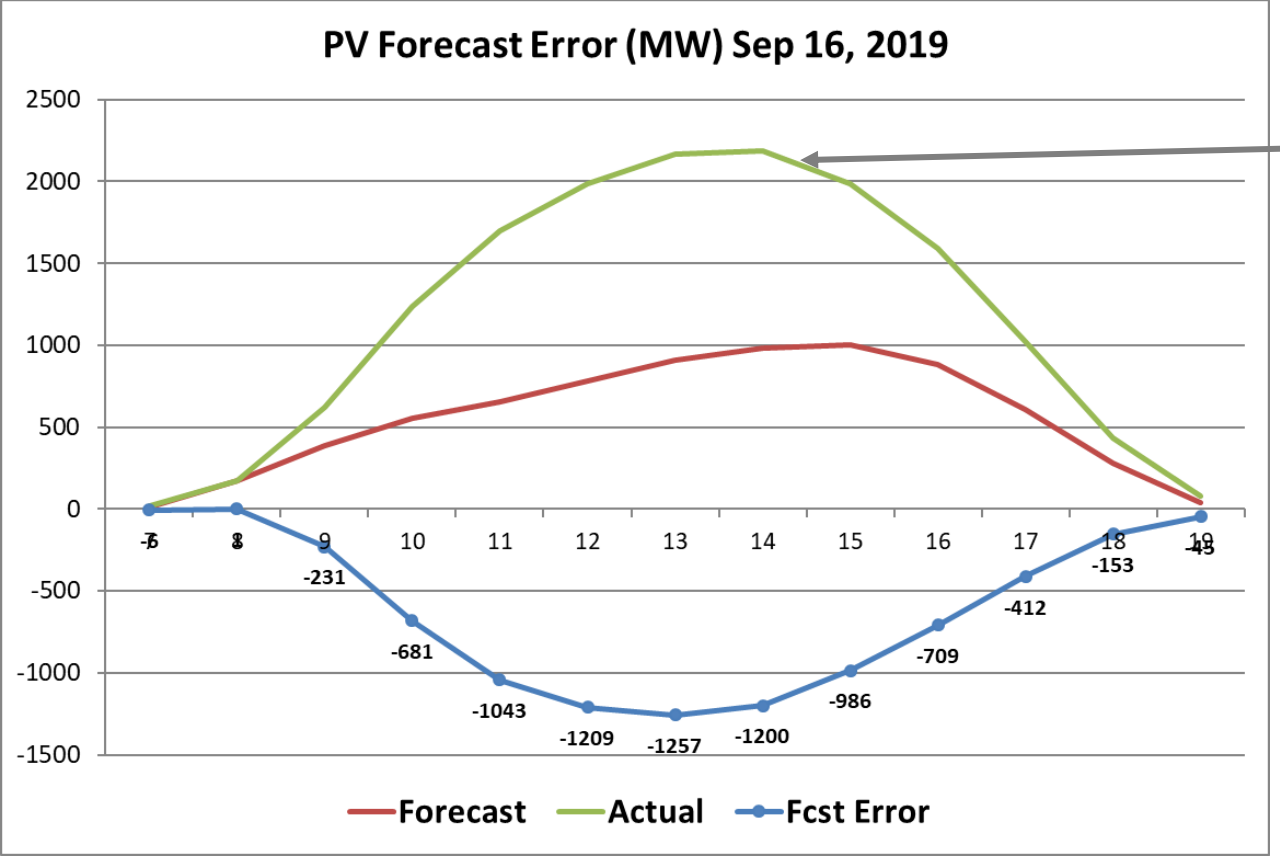
Actual Temperatures Were Much Cooler Than Expected as a Result of the Poor PV Forecast



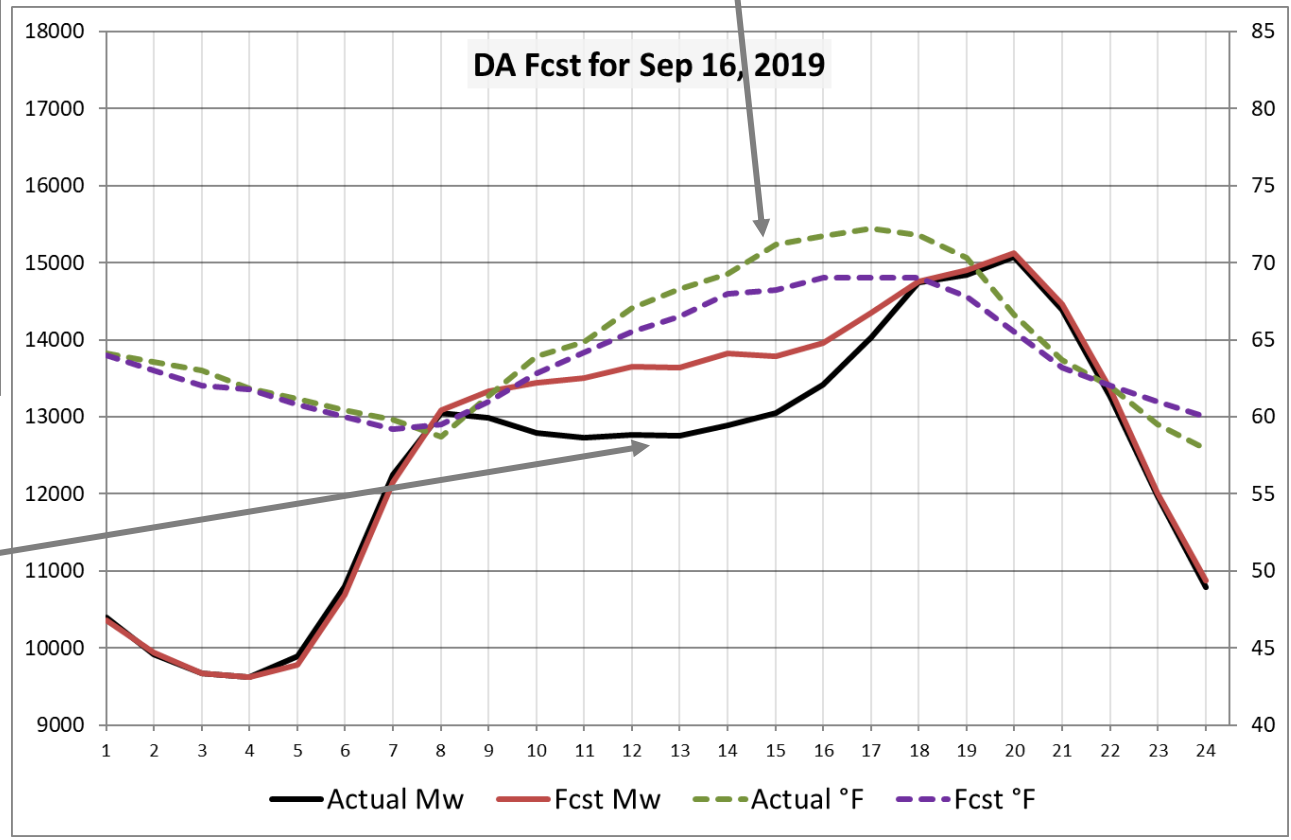
In This Case, Less PV Than Forecast Allowed the Cooler Temperatures to add to Already Increased Load

With a Poor PV Forecast - Ex.2

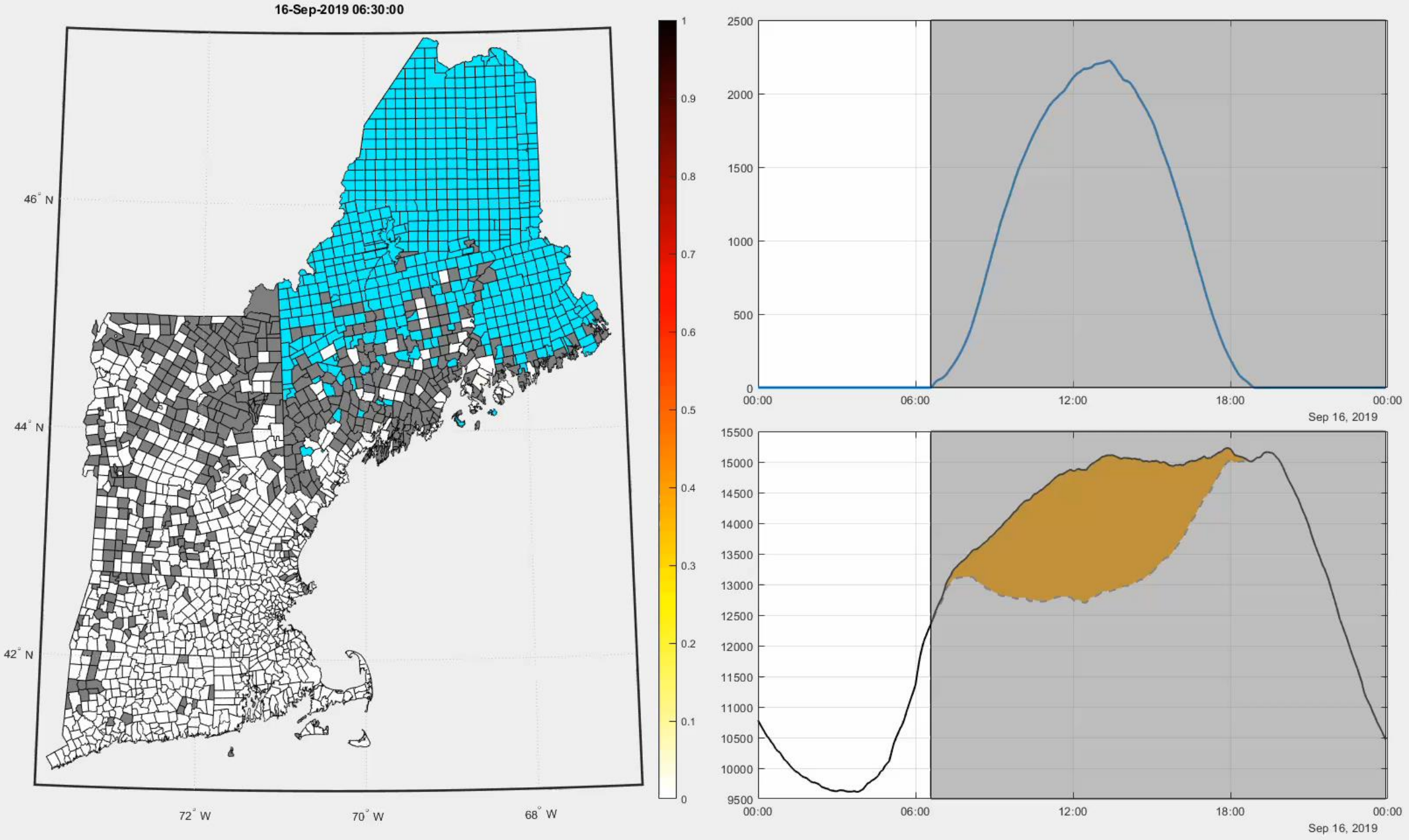
More Sunshine Occurred Than Forecast



Temperatures Averaged 3°F Above Forecast And Were Greater than 5°F Warmer Than Forecast in Some New England Cities



Resultant Loads Were Significantly Lower Than Forecast for Much of the Daylight Hours. Although Temperatures Were Warmer Than Expected, They Were Not Warm Enough to Add Significant Air Conditioning Load.


16-Sep-2019 06:30:00
46° N
44° N
42° N
72° W
70° W
68° W
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2500
2000
1500
1000
500
0
00:00
06:00
12:00
18:00
00:00
Sep 16, 2019
15500
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14000
13500
13000
12500
12000
11500
11000
10500
10000
9500
00:00
06:00
12:00
18:00
00:00
Sep 16, 2019

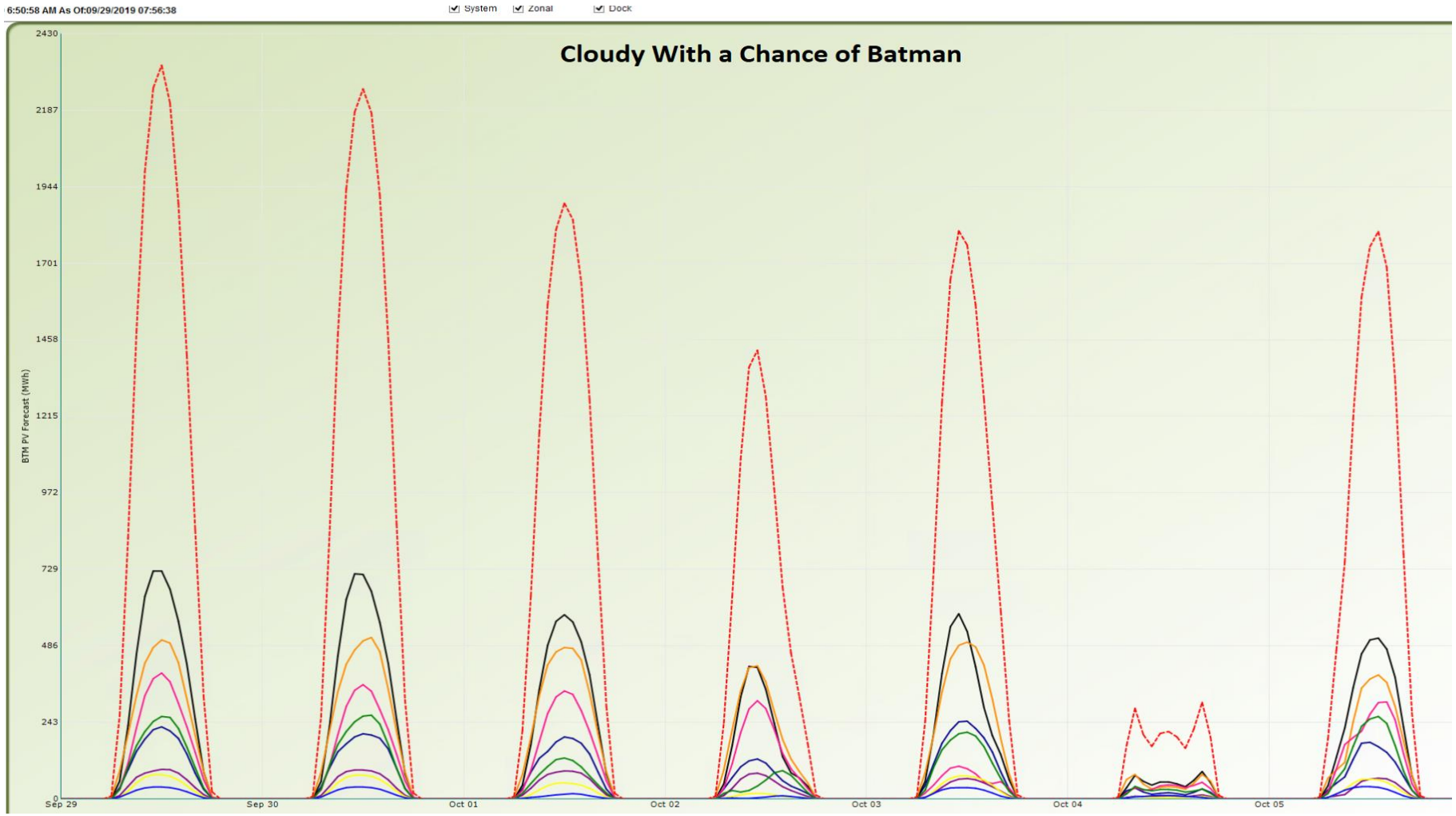
Better Cloud Cover Forecasting Needed to Address BTMPV Growth Problem

LF Models - Good (mostly)

Cloud Cover Forecasting - Not So Good

And Improving	Why so difficult?	Work Needed
• Better Load Forecast models are continuing to be developed • Forecasters can call upon better and better tools • ISOs and RTOs collaborate to made better methods available	• As with surface weather forecasting, computer models are relied upon to produce accurate simulations of multi-layer cloud cover in the atmosphere • Computer models cannot simulate all the small-scale detail present in the vast layers of the atmosphere	• NOAA, WMO and private entities need to improve upon satellite ABI instruments and other remote sensing technologies to better feed NWP models • Cloud chemistry and physics modeling can then be improved in the different atmospheric layers with resulting better 1-2 day cloud cover forecasts

Thank You!



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