APRIL 29, 2020 | HOLYOKE, MA

Estimating Summer Peak Demand Reductions from Behind-the-Meter Photovoltaics

Summary

- In response to stakeholder requests, the ISO has updated its 2016 analysis that informed the methodology used by the ISO to estimate summer peak load reductions from BTM PV as part of the long-term forecast
  - The original presentation is available in the Appendix of this presentation
- The updated analysis incorporates all BTM PV and load data covering the years 2012-2019, including several more recent summer peak load days
  - Original analysis was based on years 2012-2015
- The results of the updated analysis informed the use of a new model to estimate summer peak load reductions based on future PV penetrations indicated by the annual long-term PV forecast

Background

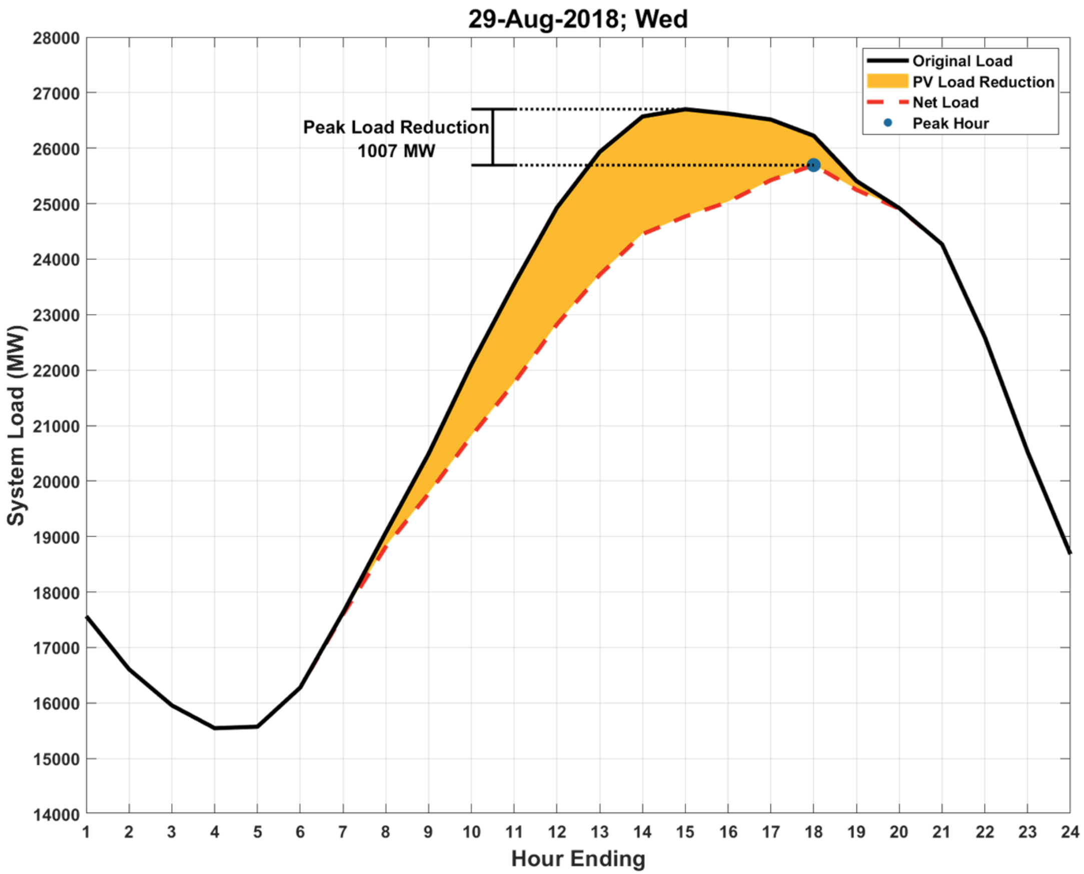
Estimating BTM PV Performance

- ISO-NE uses an *upscaling* process to estimate the aggregate performance of all BTM PV systems from:
  1. Town-level performance data obtained from a sample of BTM PV sites located throughout the region (supplied by a 3rd party vendor)
  2. Town-level installed PV capacity data (provided by regional Distribution Owners)
- Hourly BTM PV fleet performance is estimated by combining the town-level performance and installed capacity data
- PV performance profiles used to augment the load curve in this analysis have been modified to reflect the geographic distribution of installed PV capacity as of 12/31/2019
- More information and an example of how the upscaling process is used to estimate BTM PV production can be found within slides 18-28 of [this presentation]

Summer Peak Period Considerations

- PV performance is expected to differ across peak hours and across the variety of weather conditions that elicit summer peak load
- As PV penetration grows, the hour of the peak load (net of PV) is shifting later in the afternoon as PV performance diminishes due to the setting of the sun
  - Summer peak load reductions are calculated as the difference between the peak load reconstituted for BTM PV and the peak load net of BTM PV, regardless of hour
- The following slides summarize ISO's analysis of historical load and PV data to update the estimated relationship between PV penetration and estimated summer peak load reductions due to PV (i.e., the new peak load reduction model)
  - Slide 5 defines terms used in the analysis
  - Slides 6-11 provide an example of the steps of the analysis for the August 29, 2018 summer peak day

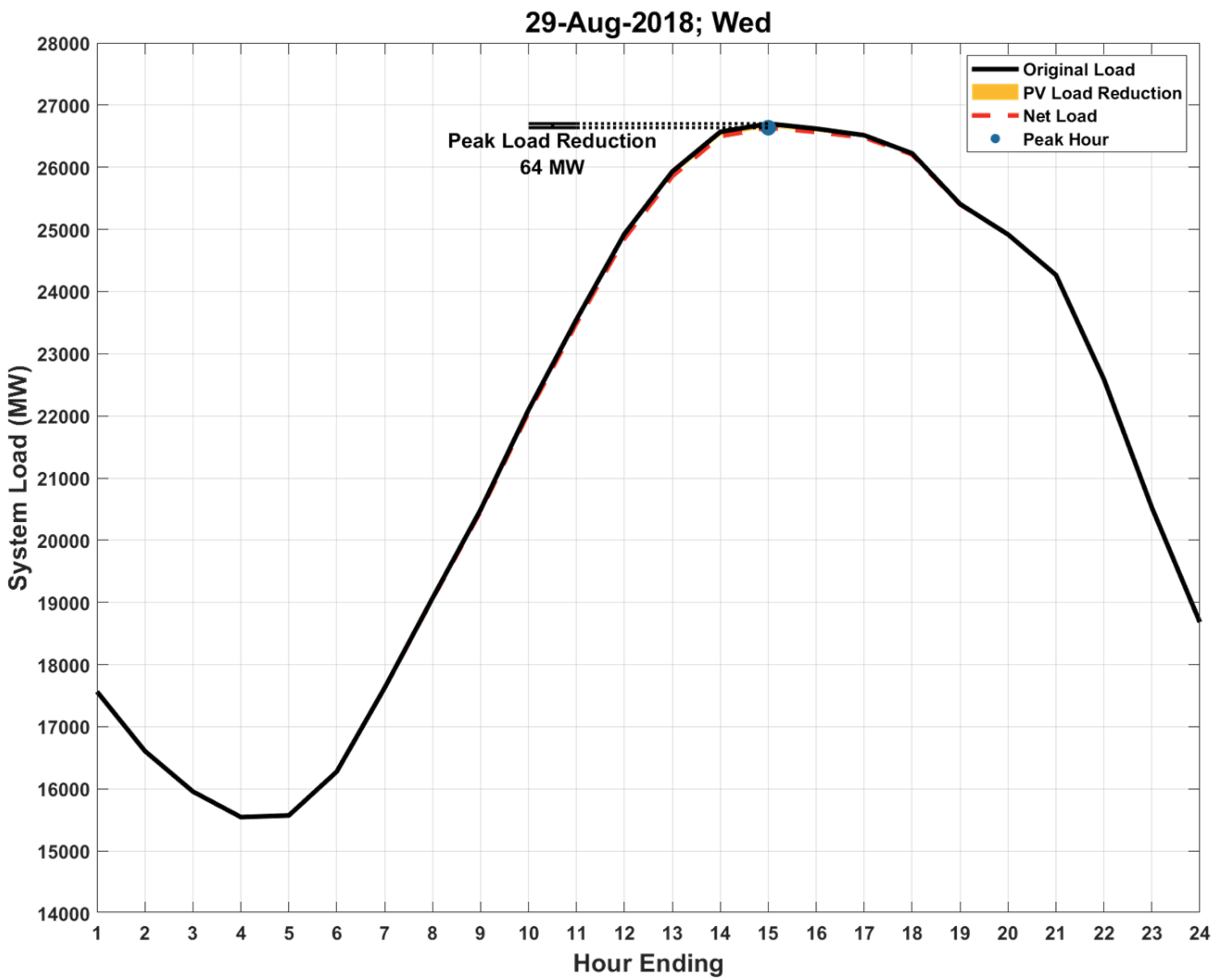
Terms Defined



- The top **black** curve is the PV reconstituted load
- The shaded yellow region represents the estimated PV load reduction
- The **dashed red** line is the net load profile associated with the installed PV capacity (3000 MW in figure shown)
- The **blue dot** indicates the hour of the net load peak

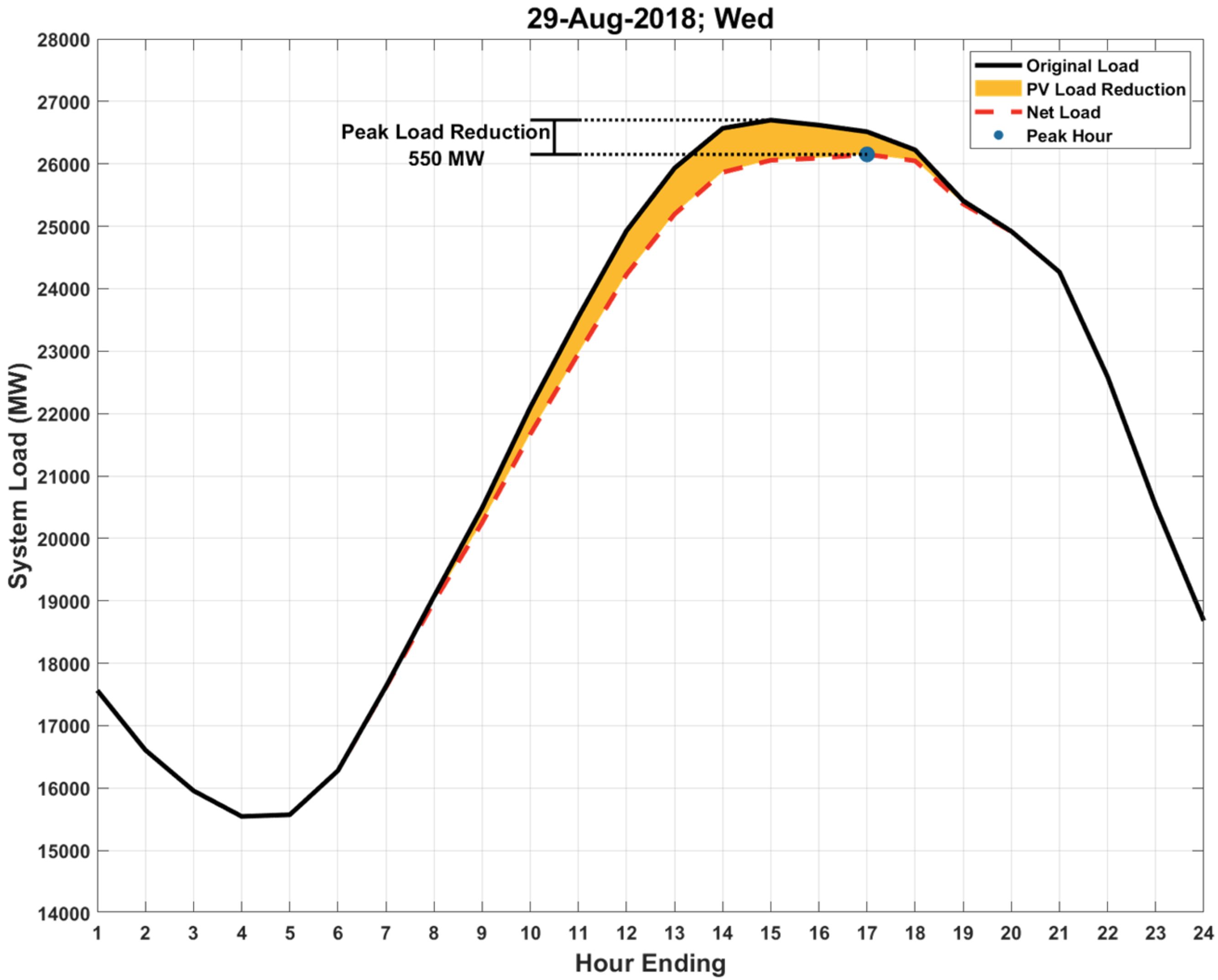
August 29, 2018 Net Load Profile

100 MW PV



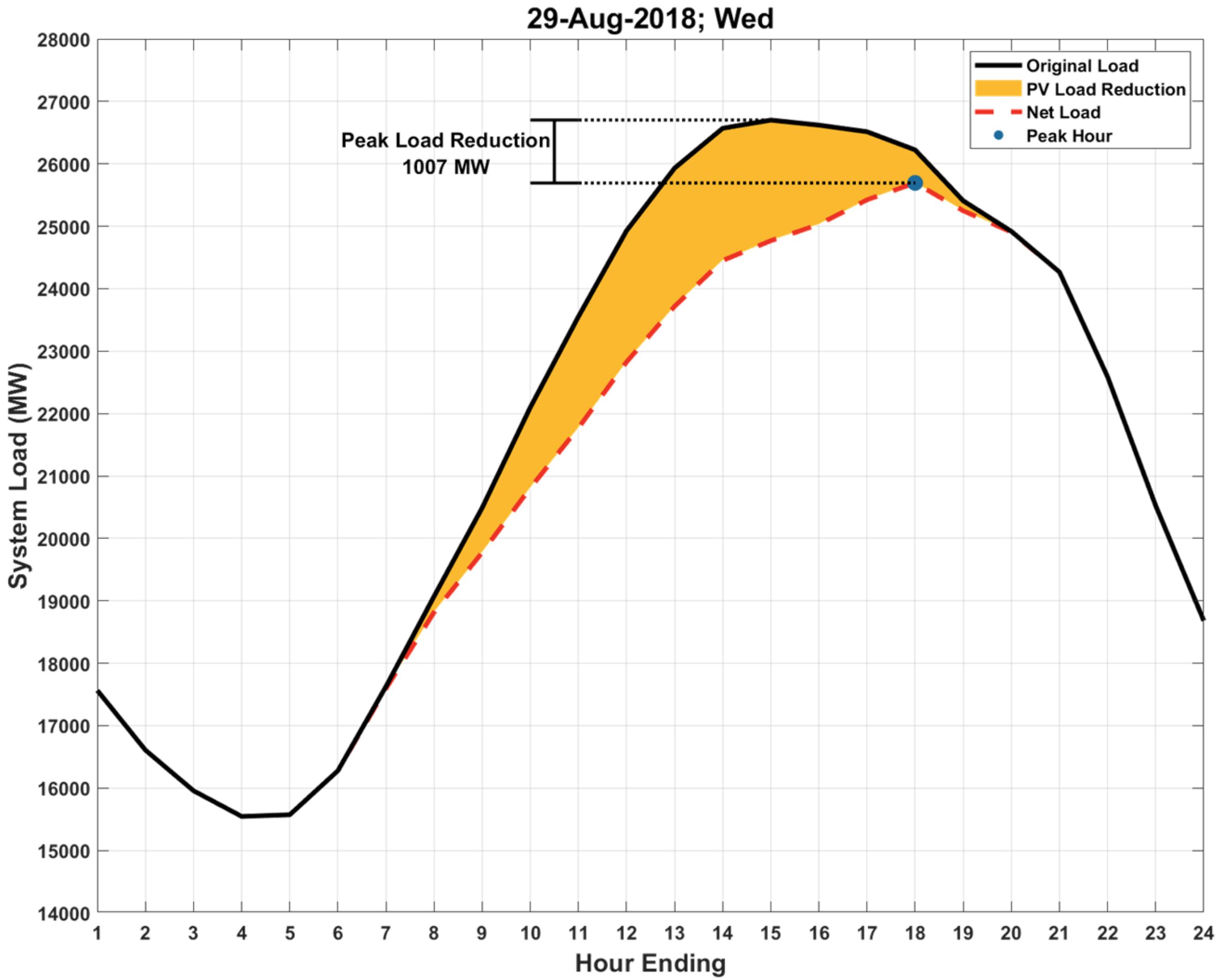
August 29, 2018 Net Load Profile

1,000 MW PV



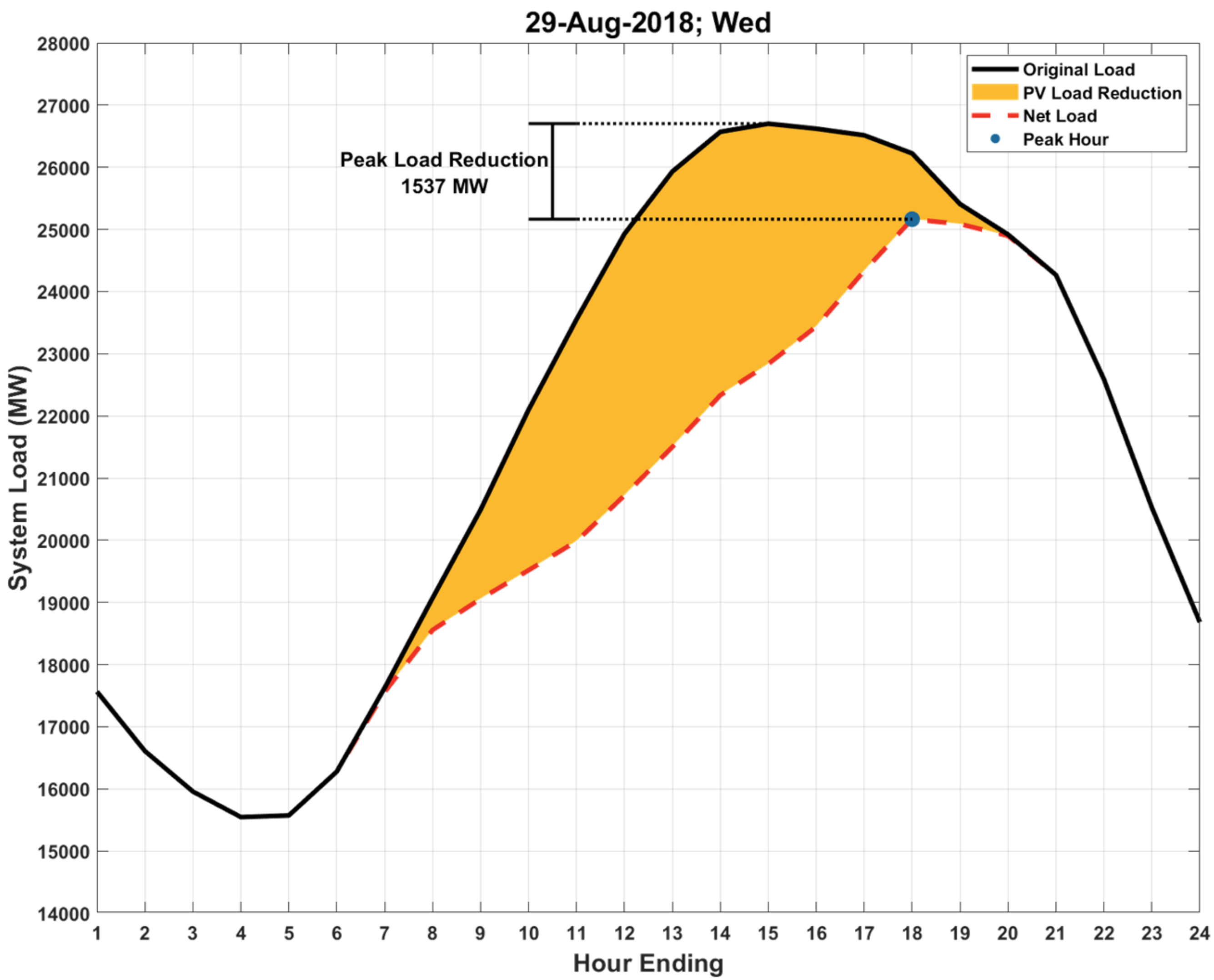
August 29, 2018 Net Load Profile

3,000 MW PV



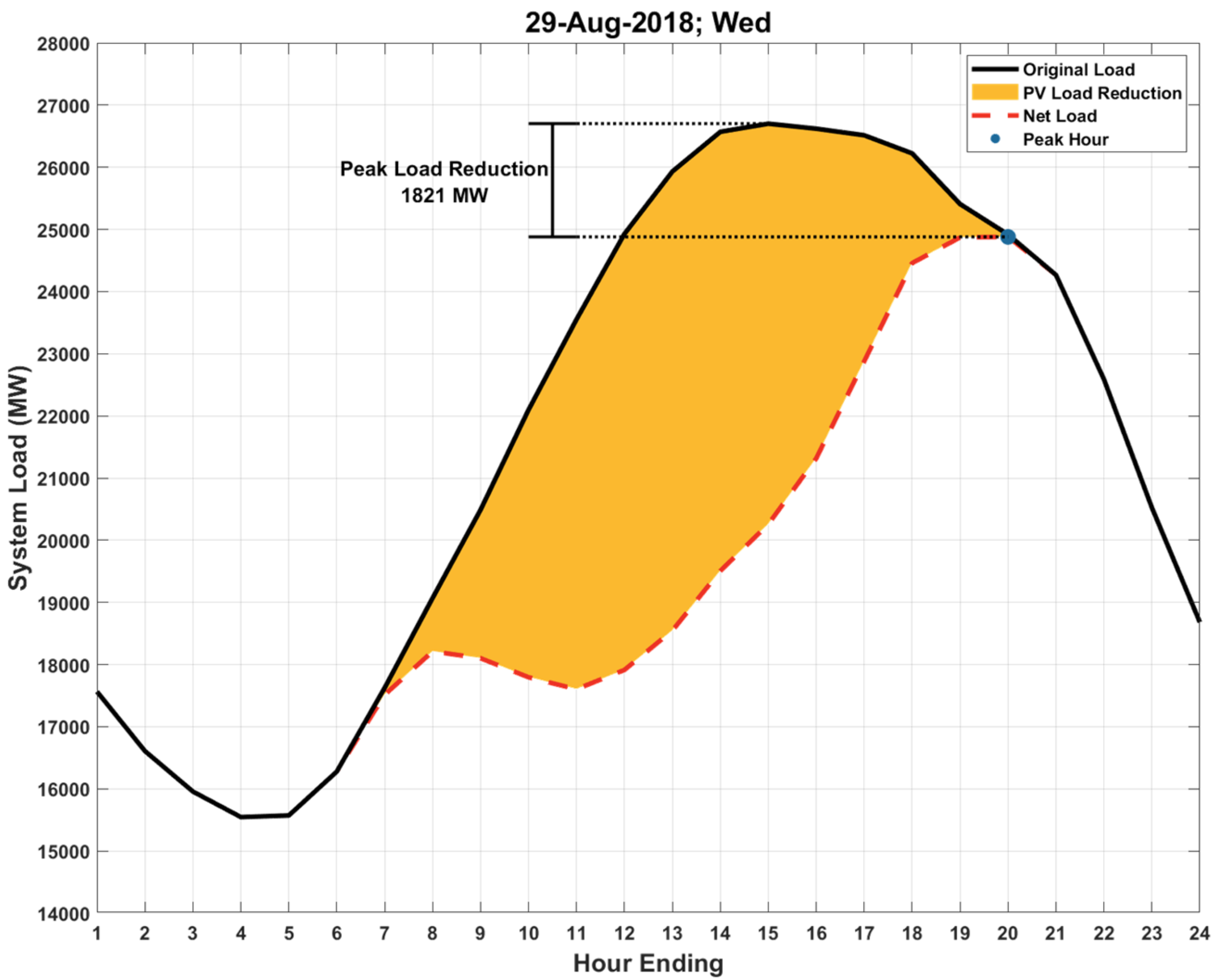
August 29, 2018 Net Load Profile

6,000 MW PV



August 29, 2018 Net Load Profile

10,000 MW PV



August 29, 2018 Peak Load Reductions

- Table lists the incremental peak load reductions as PV penetrations increase
- As the installed nameplate capacity increases, the percent (of PV nameplate capacity) peak reduction decreases
- Values are for August 29, 2018
  - 15 peak days were analyzed and are discussed on the following slides

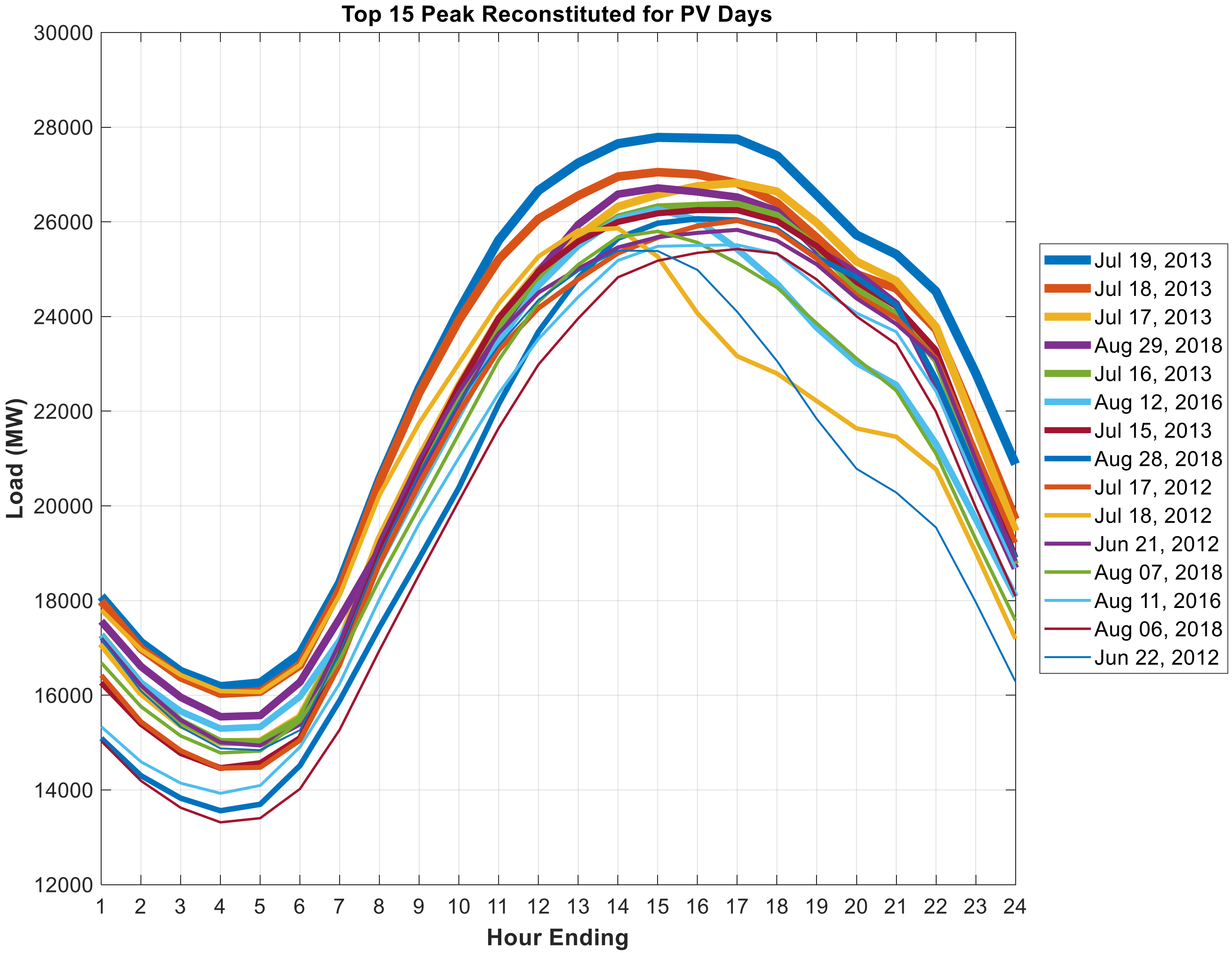
Installed PV Nameplate Capacity (MW)	Cumulative Peak Reduction (MW)	Cumulative Peak Reduction (% of nameplate)
0	0	0.0%
100	64	64.4%
500	322	64.4%
1000	550	55.0%
1500	732	48.8%
2000	831	41.5%
2500	919	36.8%
3000	1007	33.6%
3500	1095	31.3%
4000	1184	29.6%
4500	1272	28.3%
5000	1360	27.2%
5500	1449	26.3%
6000	1537	25.6%
6500	1625	25.0%
7000	1669	23.8%
7500	1696	22.6%
8000	1722	21.5%
8500	1749	20.6%
9000	1776	19.7%
9500	1803	19.0%
10000	1821	18.2%

Initial Selection of Top 15 Peak Days

- Initially, ISO selected the highest 15 peak load days from 2012-2019 to perform its analysis
  - Selection criteria was the highest 15 daily peaks, based on load reconstituted for BTM PV
  - The resulting days all had a reconstituted peak load of greater than 25,000 MW and occurred on non-holiday weekdays in June, July, and August
- For reference, the load profiles (reconstituted for BTM PV) shown on the next slide are the highest 15 peak load days, selected by highest reconstituted daily peak

Top 15 Peak Load Days

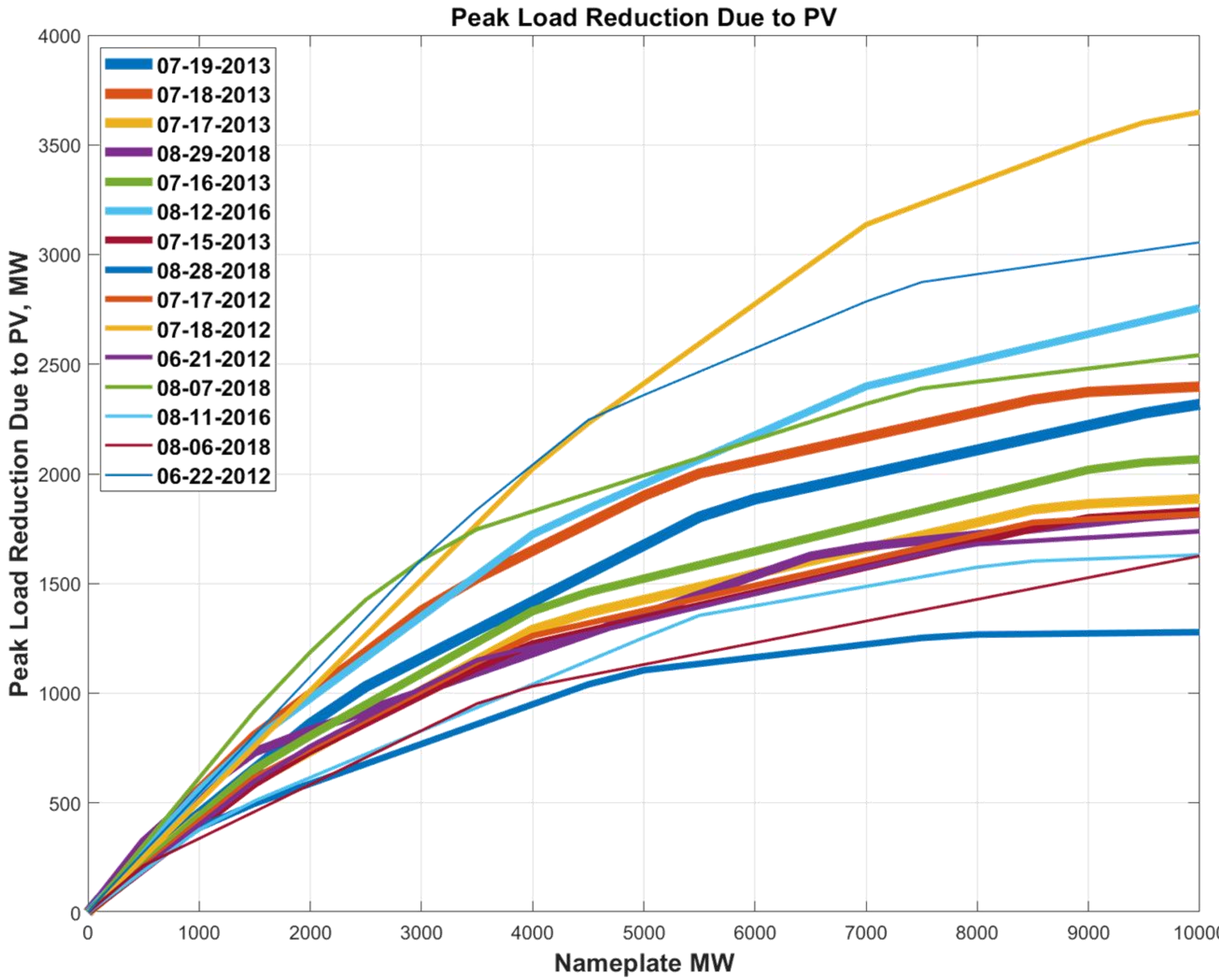
Selected by PV Reconstituted Peak Load



Note: Line weights represent magnitudes of reconstituted daily peaks

Top 15 days: Peak Load Reduction

Peak Load Reduction (MW) with Increasing PV Penetration



Note: Line weights represent magnitudes of reconstituted daily peaks

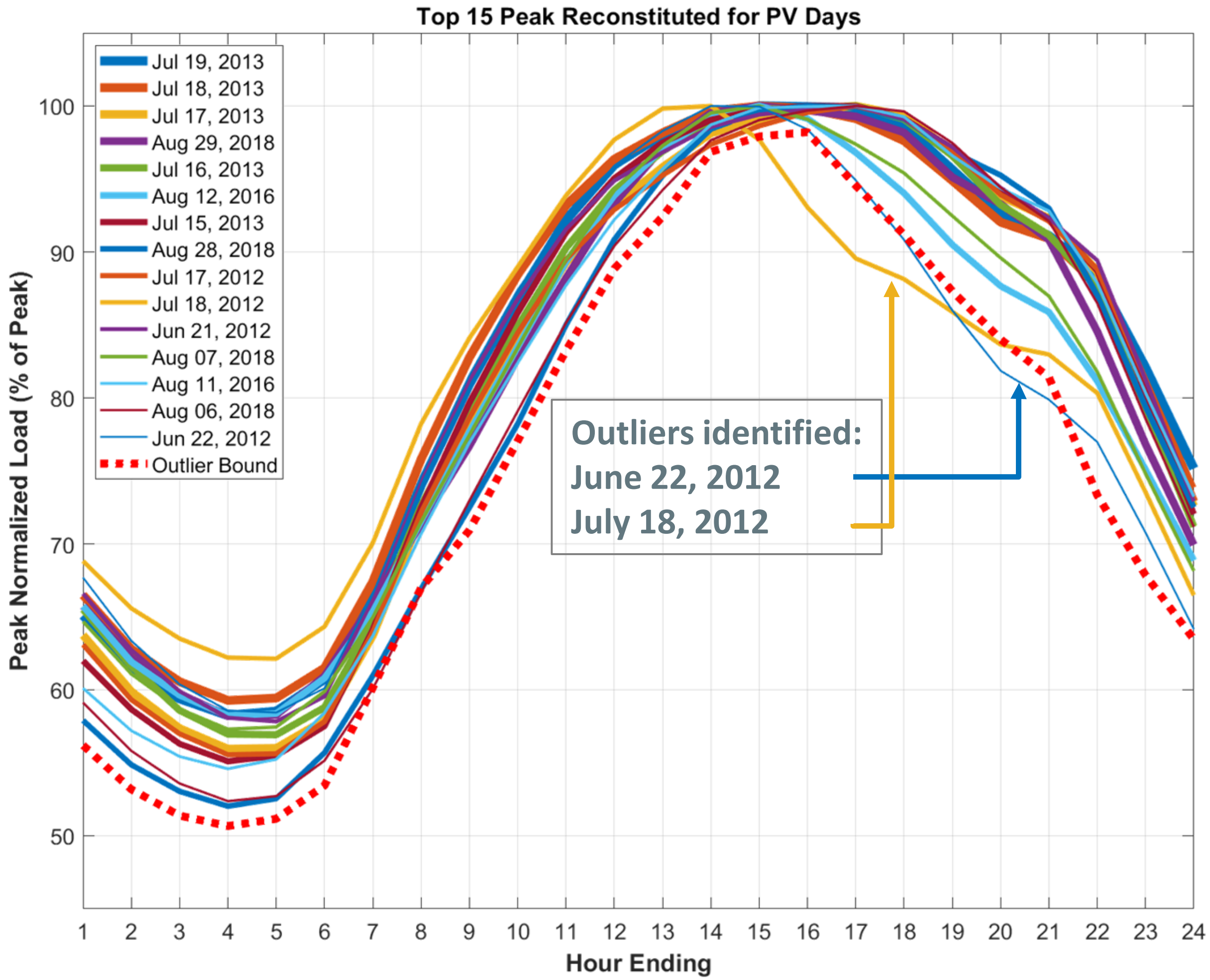
Additional Analysis of Peak Load Shapes

Identifying and Removing The Effects of Thunderstorms

- Summer peak load days with widespread thunderstorm activity across load centers have a different load shape than other peak load days
  - Thunderstorms can cause a significant reduction in load for the remainder of the afternoon
- BTM PV causes noticeably greater peak load reductions as PV penetrations increase on days severely impacted by storms than it does on days that do not have widespread thunderstorm activity
  - During most summer peak load days there is little to no thunderstorm activity, and load remains much higher later in the afternoon
- To ensure that days with significant thunderstorms during peak load hours do not skew the desired results, ISO identified and removed these “outlier” days with thunderstorm impacts by using the following steps:
  1. Normalized all peak day load shapes to the peak load hour
  2. Used Tukey’s Method of outlier detection (i.e., a threshold of 1.5 times the interquartile range, or IQR), on normalized peak load shapes to identify outliers
  3. Verified that widespread thunderstorm activity occurred on outlier days during peak load hours via radar imagery
- Two outlier days of the original 15 top peak days are illustrated on the following slide
  - Radar imagery verifying the thunderstorm activity is included on the subsequent slide

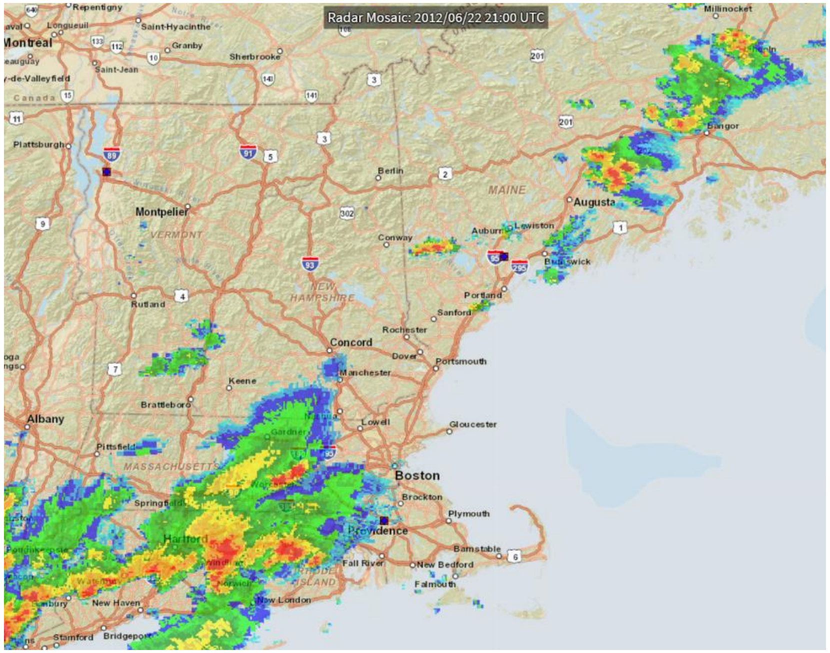
Peak Normalized Peak Load Curves

Co-plotted Lower Outlier Bound

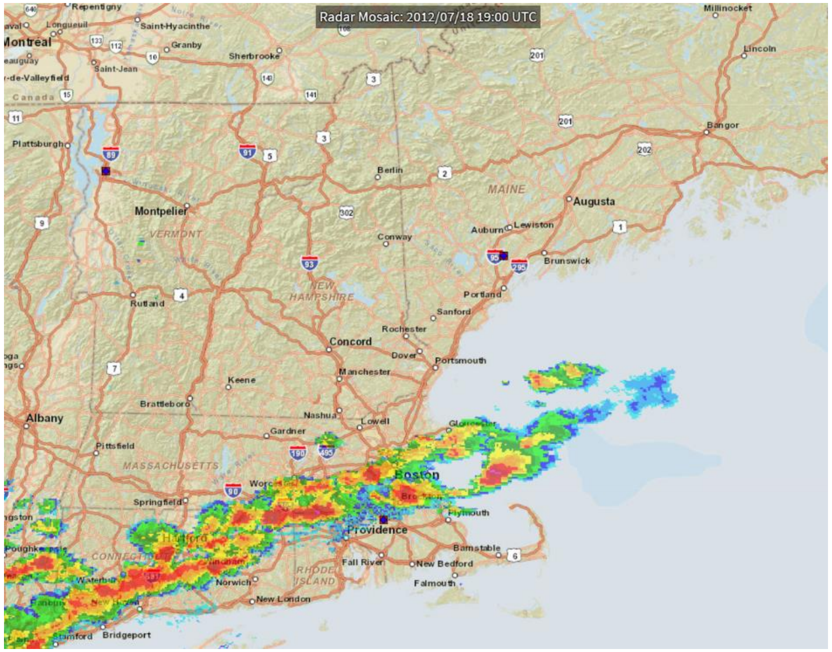


Radar Imagery

June 22, 2012
5:00 pm



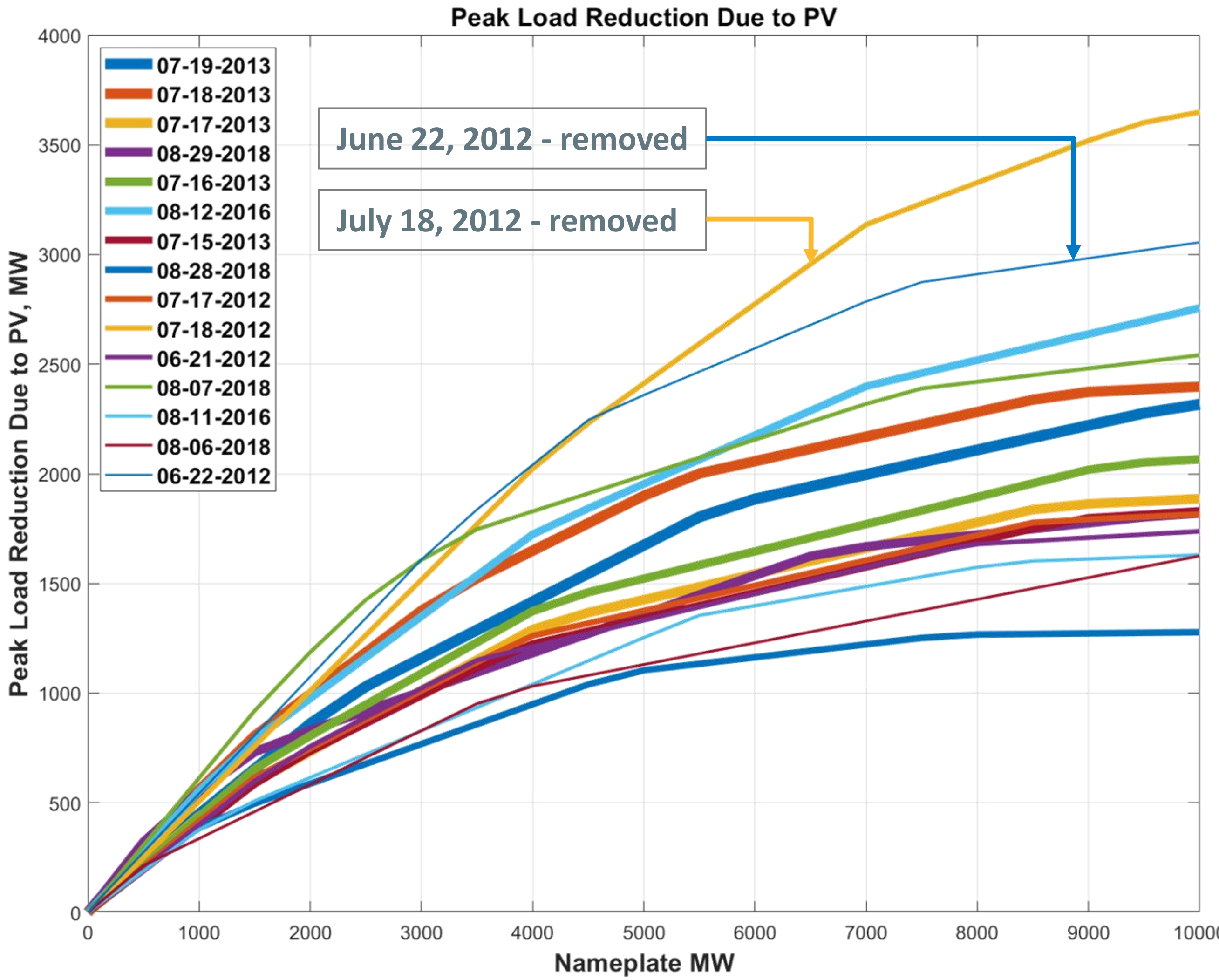
July 18, 2012
3:00 pm



Source: https://gis.ncdc.noaa.gov/maps/ncei/radar

Comparison of Highest 15 Peak Days With Prior Outliers

Peak Load Reduction (MW) with Increasing PV Penetration



Note: Line weights represent magnitudes of reconstituted daily peaks

Selection of Peak Load Days

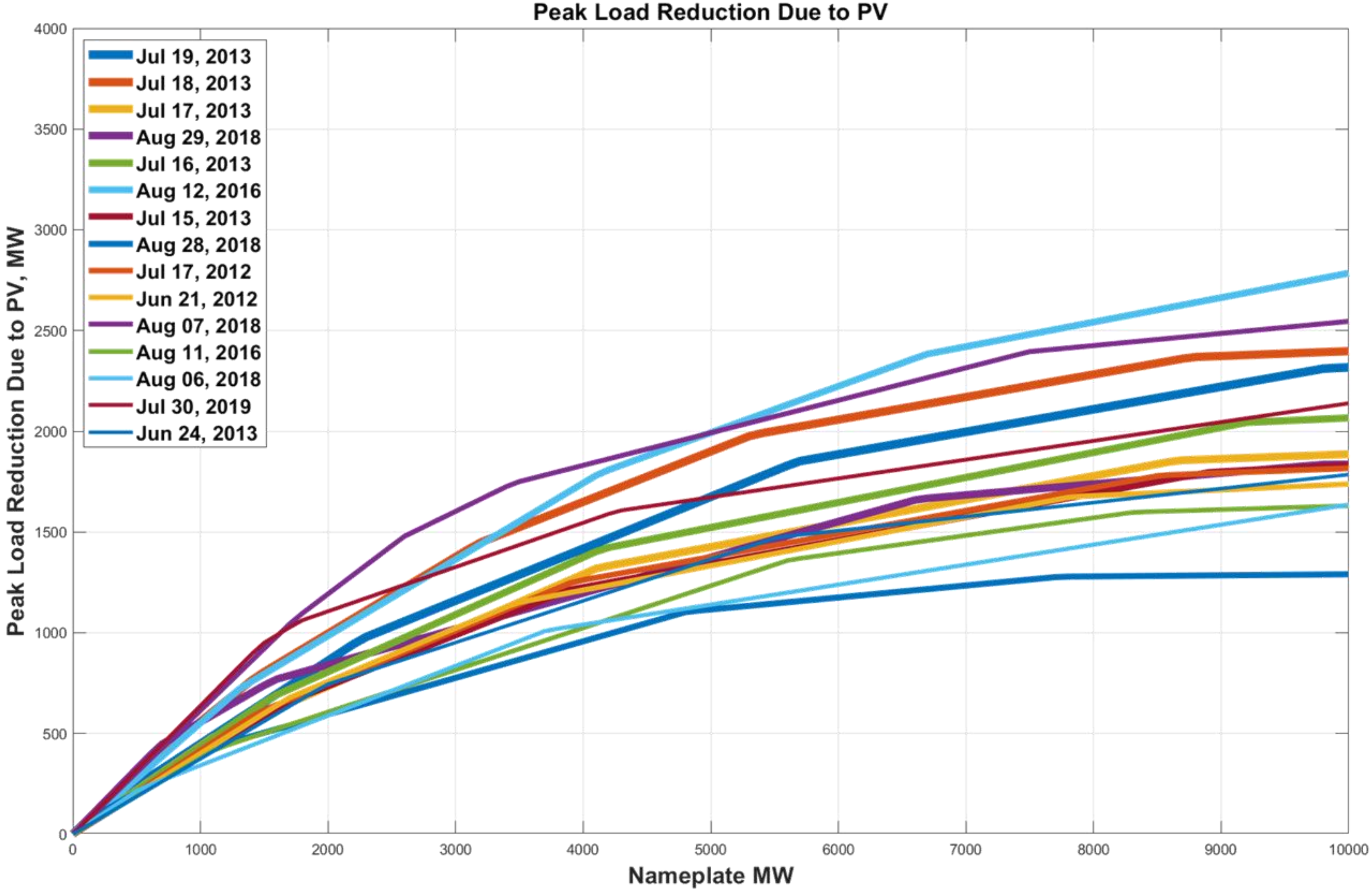
Top 15 Peak Load Days

- After removing the two outlier days, ISO included peak load days to maintain a sample of 15 days
- The resulting days (tabulated to the right) are all non-holiday weekdays in June, July, and August
  - Days in table are sorted in descending peak load value
  - All days still have a peak reconstituted load greater than 25,000 MW
  - Two peak load days added to replace the outlier days are in **boldface**

Rank	Day
1	Jul 19, 2013
2	Jul 18, 2013
3	Jul 17, 2013
4	Aug 29, 2018
5	Jul 16, 2013
6	Aug 12, 2016
7	Jul 15, 2013
8	Aug 28, 2018
9	Jul 17, 2012
10	Jun 21, 2012
11	Aug 07, 2018
12	Aug 11, 2016
13	Aug 06, 2018
14	**Jul 30, 2019**
15	**Jun 24, 2013**

Highest 15 Peak Days After Removing Outliers

Peak Load Reduction (MW) with Increasing PV Penetration



Note: Line weights represent magnitudes of reconstituted daily peaks

PV Peak Load Reduction Model

- Based on the results, a peak load reduction model can be developed to reflect the relationship between PV penetration and estimated summer peak load reductions
  - For any PV penetration, the model outputs a MW value used in "net of BTM PV" load forecast values reported in CELT
- The results indicate there is a distribution of summer peak load reductions from PV
  - Variation is likely attributable to a variety of factors that affect either load shape or PV performance, including specific weather conditions, length of daylight, day of week, etc.
- For long-term peak demand forecasting, it is reasonable to use the middle of the distribution for estimating peak reductions due to PV
  - Should reflect an approximately equal chance for the actual values to be slightly higher or lower on any particular day

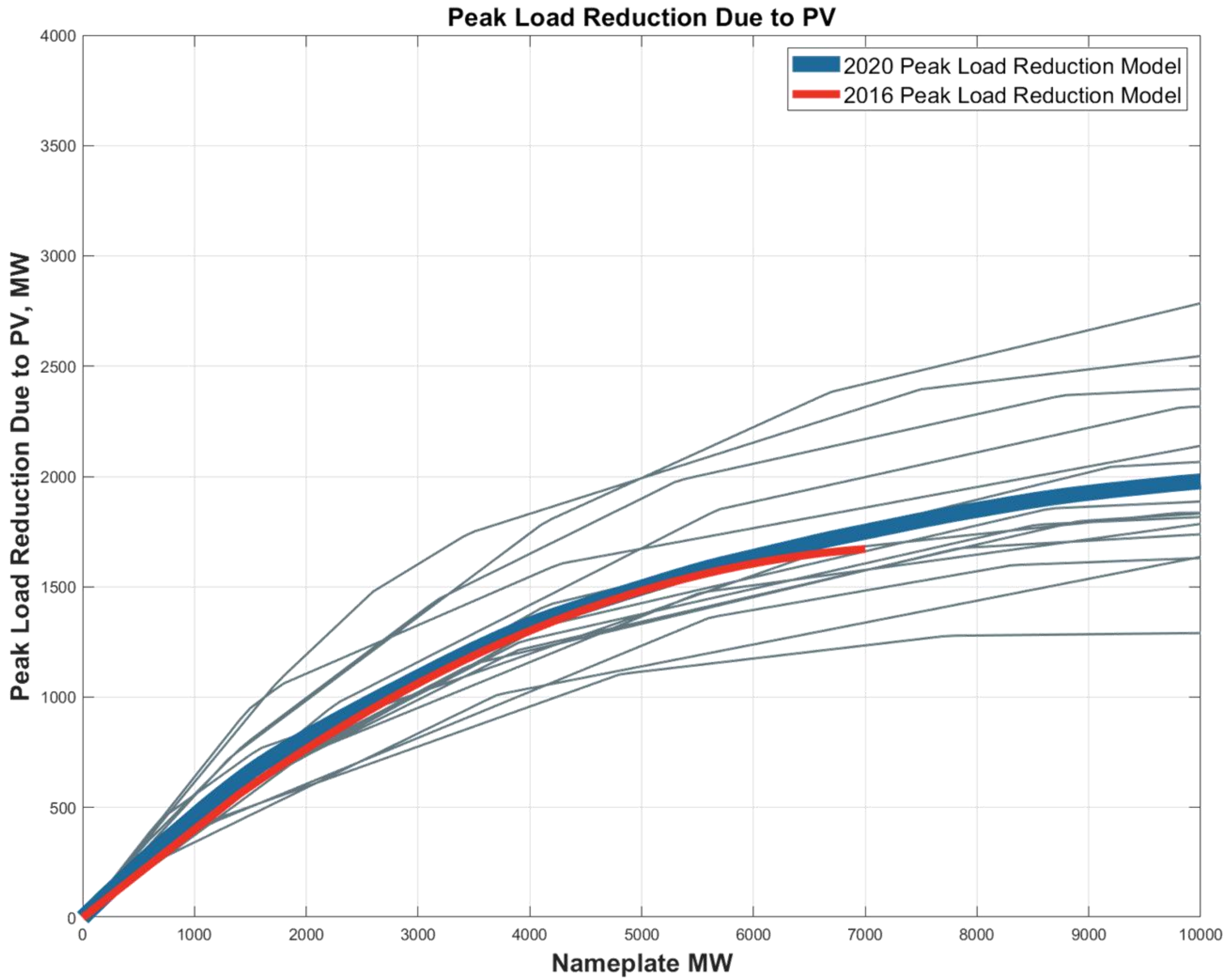
Peak Load Reduction

Existing and Proposed

- Using the results shown for the top 15 peak days, a model curve based on the load-weighted average peak reduction is shown in **blue** on the next slide
  - This curve is calculated by using the magnitude of net peak for each day to weight the peak reduction for each increment of PV nameplate
- The solid gray lines on the next slide indicate the distribution of results for the top 15 load days analyzed
- To compare these results with those of the 2016 analysis, the solid **red** line on the next slide represents the model developed from the results of the 2016 analysis

Estimated Peak Load Reductions

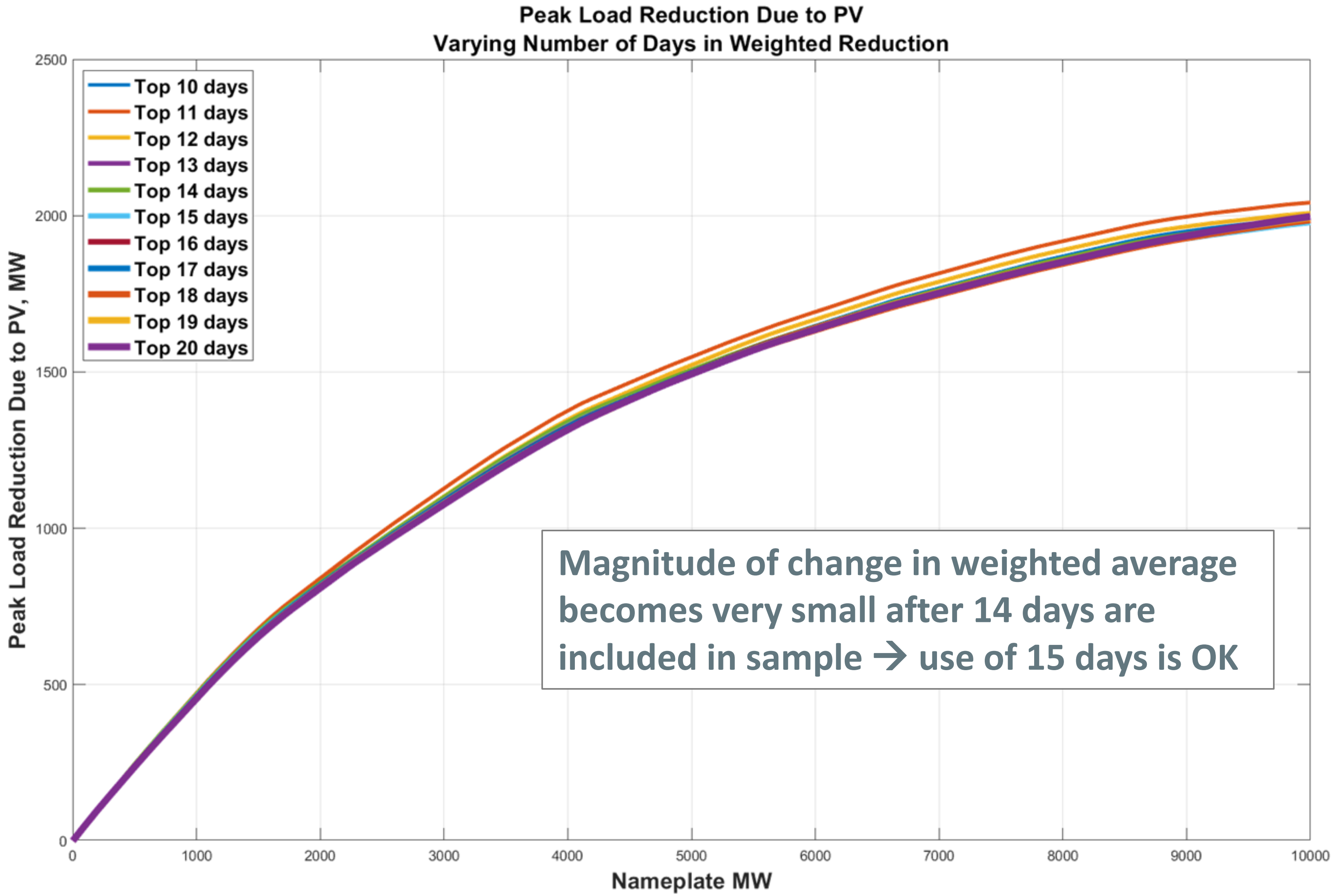
Comparison of Existing and Proposed Models



Effects of Sample Size on Weighted Average

- ISO reanalyzed the assumption that 15 days is sufficient by varying the number of days used to develop the peak load reduction model
- The next slide shows the peak-load weighted peak reduction models resulting from varying the sample size
  - The same analysis as described in this presentation was done for sample sizes of 10 through 20 days

Effect of Sample Size on Weighted Average

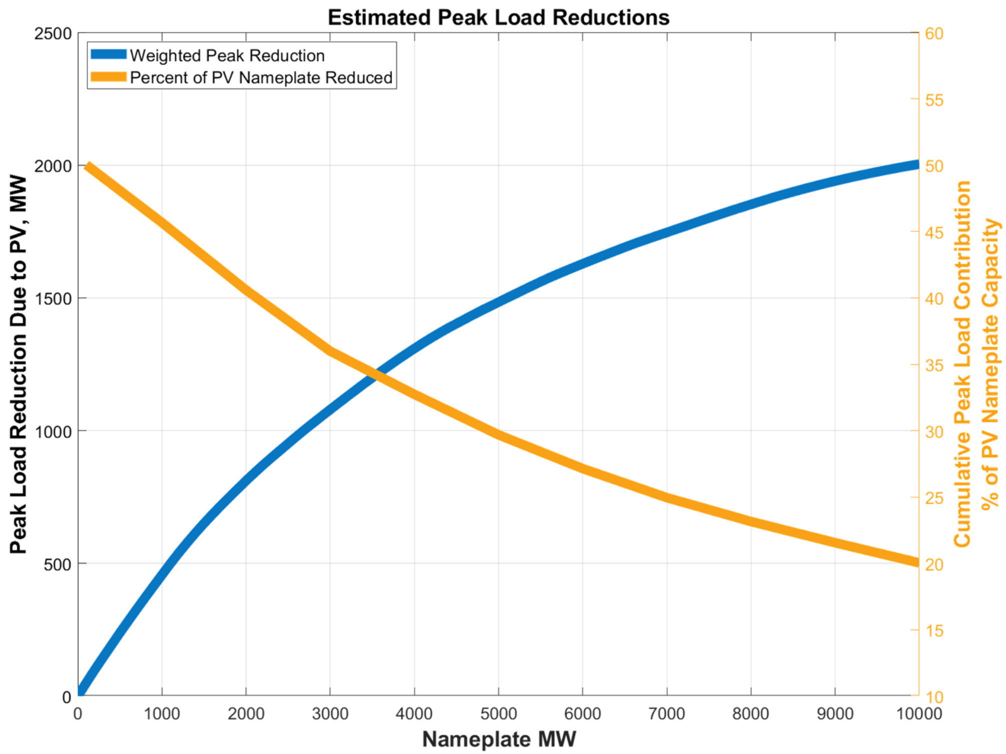


Magnitude of change in weighted average becomes very small after 14 days are included in sample → use of 15 days is OK

Final Model for Estimating Summer Peak Load Reductions

Expressed as both MW and Percent of Nameplate Capacity

- The orange line is the load-weighted peak load reduction as a percent of PV nameplate capacity
  - These percent values are used to calculate BTM PV peak load reductions according to the equation below
  - Percent values are reported in tab 3.2 of CELT
- Percent values are calculated by dividing the peak load reduction MWs (blue line) by the cumulative PV nameplate capacity (values on horizontal axis)



- Equation to estimate BTM PV summer peak load reductions (in MW) is as follows:

BTM PV Peak Load Reduction, MW = (BTM PV Installed Capacity) * (% PV Nameplate)

Estimated Normalized PV Production

Highest 15 Peak Days After Removing Outliers

Hour Ending	07/19/2013	07/18/2013	07/17/2013	08/29/2018	07/16/2013	08/12/2016	07/15/2013	08/28/2018	07/17/2012	06/21/2012	08/07/2018	08/11/2016	08/06/2018	07/30/2019	06/24/2013
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.04	0.04	0.04	0.01	0.04	0.02	0.04	0.01	0.04	0.05	0.03	0.02	0.03	0.04	0.05
8	0.13	0.15	0.16	0.09	0.16	0.10	0.16	0.09	0.14	0.17	0.11	0.10	0.12	0.12	0.16
9	0.29	0.32	0.32	0.24	0.32	0.23	0.33	0.22	0.28	0.34	0.26	0.23	0.27	0.27	0.34
10	0.45	0.48	0.48	0.43	0.49	0.43	0.48	0.39	0.42	0.48	0.46	0.40	0.45	0.46	0.49
11	0.57	0.59	0.60	0.59	0.61	0.59	0.60	0.57	0.55	0.59	0.61	0.53	0.60	0.61	0.60
12	0.65	0.65	0.66	0.70	0.67	0.68	0.62	0.68	0.61	0.65	0.69	0.63	0.70	0.71	0.66
13	0.68	0.65	0.69	0.74	0.69	0.70	0.64	0.71	0.60	0.66	0.71	0.69	0.76	0.72	0.68
14	0.66	0.65	0.68	0.71	0.66	0.66	0.61	0.68	0.58	0.64	0.69	0.68	0.77	0.70	0.66
15	0.60	0.60	0.64	0.65	0.61	0.55	0.59	0.63	0.59	0.59	0.61	0.62	0.71	0.64	0.58
16	0.52	0.51	0.56	0.53	0.55	0.38	0.50	0.53	0.54	0.50	0.48	0.52	0.59	0.55	0.50
17	0.41	0.38	0.44	0.36	0.44	0.23	0.39	0.36	0.42	0.40	0.31	0.38	0.43	0.38	0.37
18	0.26	0.25	0.28	0.18	0.28	0.12	0.25	0.18	0.26	0.26	0.16	0.21	0.25	0.22	0.21
19	0.11	0.11	0.12	0.05	0.12	0.05	0.12	0.06	0.11	0.12	0.06	0.09	0.10	0.09	0.07
20	0.03	0.02	0.02	0.00	0.03	0.01	0.03	0.01	0.02	0.03	0.01	0.02	0.02	0.02	0.01
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: These data represent the regional estimated hourly normalized PV production