Incorporating Solar Resources into the PJM Long Term Load Forecast

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Distributed Solar Generation

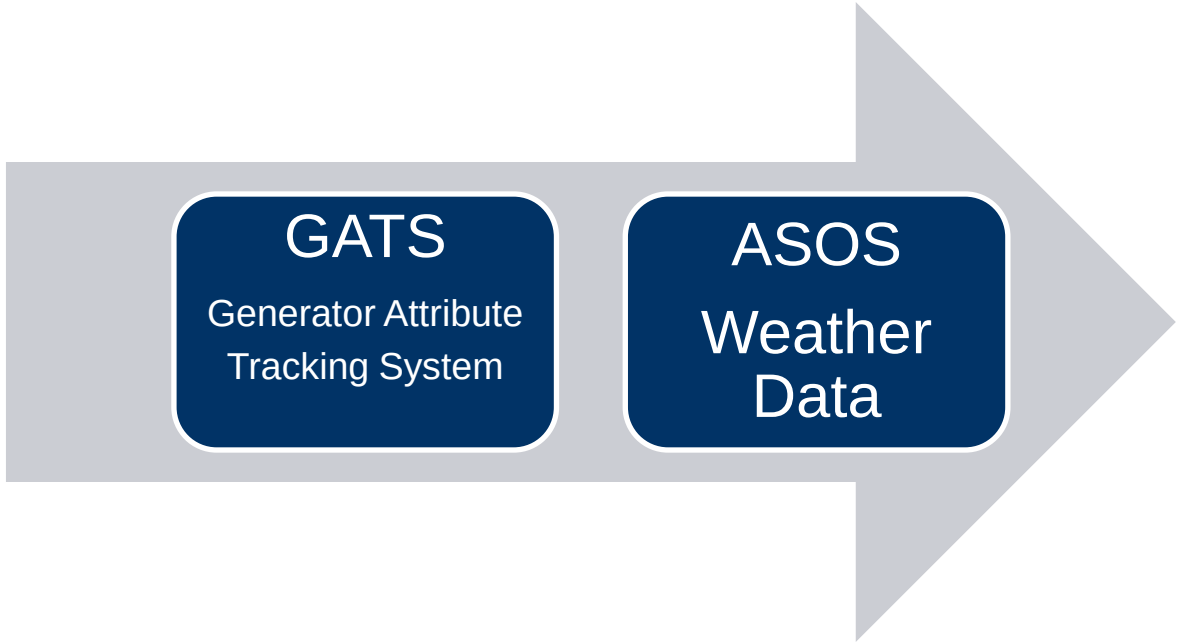
- Distributed solar generation:
  - Are not PJM grid- interconnected (i.e. non-wholesale)
  - Does not go through the full interconnection queue process
  - Does not offer as capacity nor energy resources
  - Nets directly with the load in terms of data submissions
    - Either at a customer site or via the distribution system
  - Does not provide metered production data

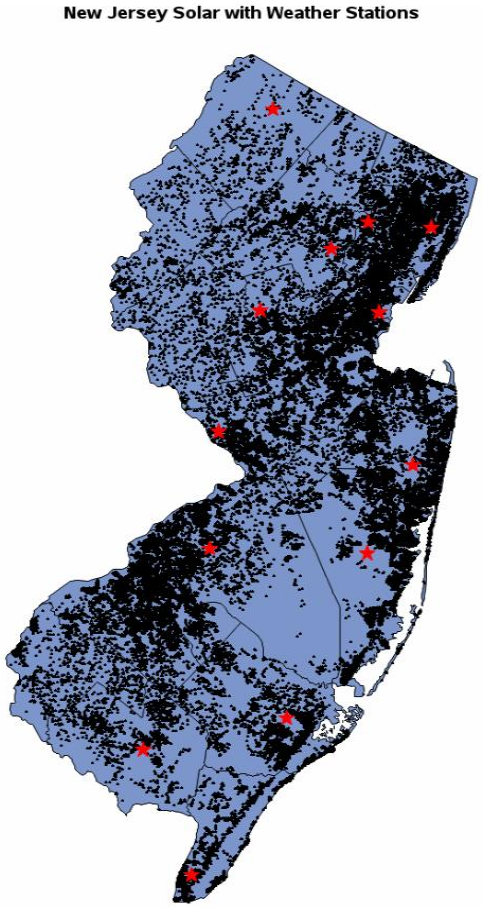
Long Term Forecast: Process Review

PJM uses a two-step approach to address distributed solar generation in the long term load forecast.

- Step 1 (current process):

  To account for the historical impacts of distributed solar generation, PJM back-casts hourly values by zone. These estimates are then **added** to the unrestricted load used in PJM load models.





Long Term Forecast: Process Review

PJM uses a two-step approach to address distributed solar generation in the long term load forecast.

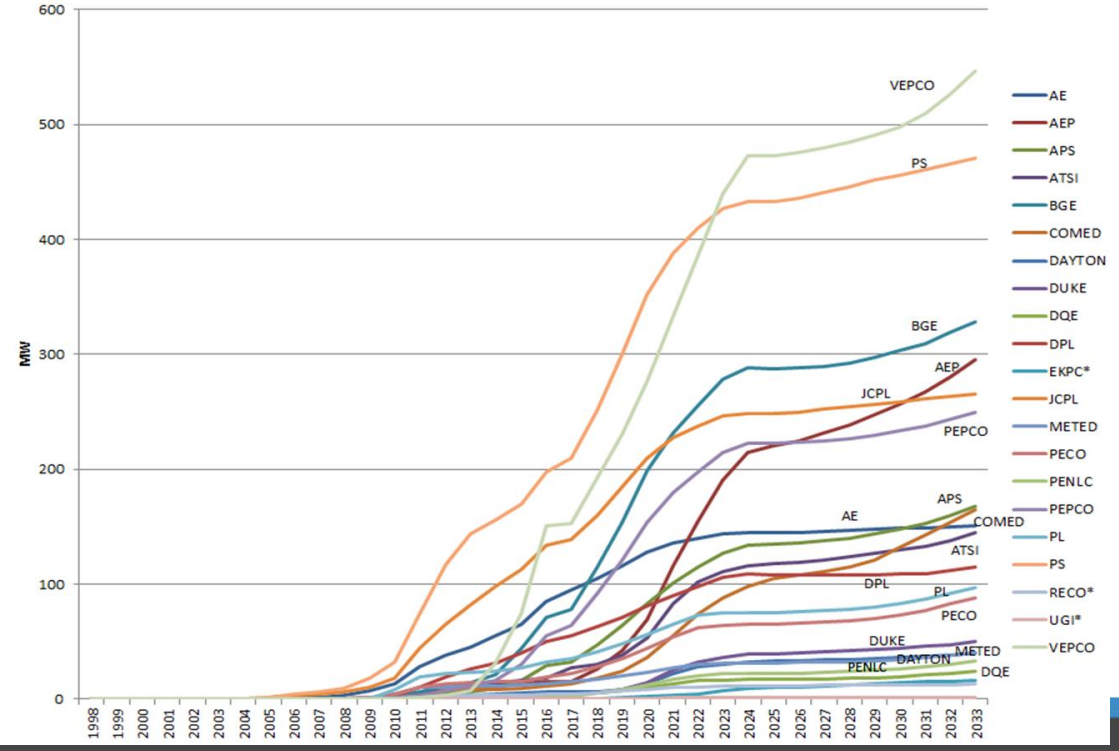
- Step 2:

  For forecasted values of distributed solar capacity, PJM contracts with IHS Energy to develop a distributed solar generation forecast specific to the PJM region. PJM then uses the state-level forecast to derive a zonal solar impact at peak.

  Those values are then **<u>subtracted</u>** from the forecast created with solar addbacks.

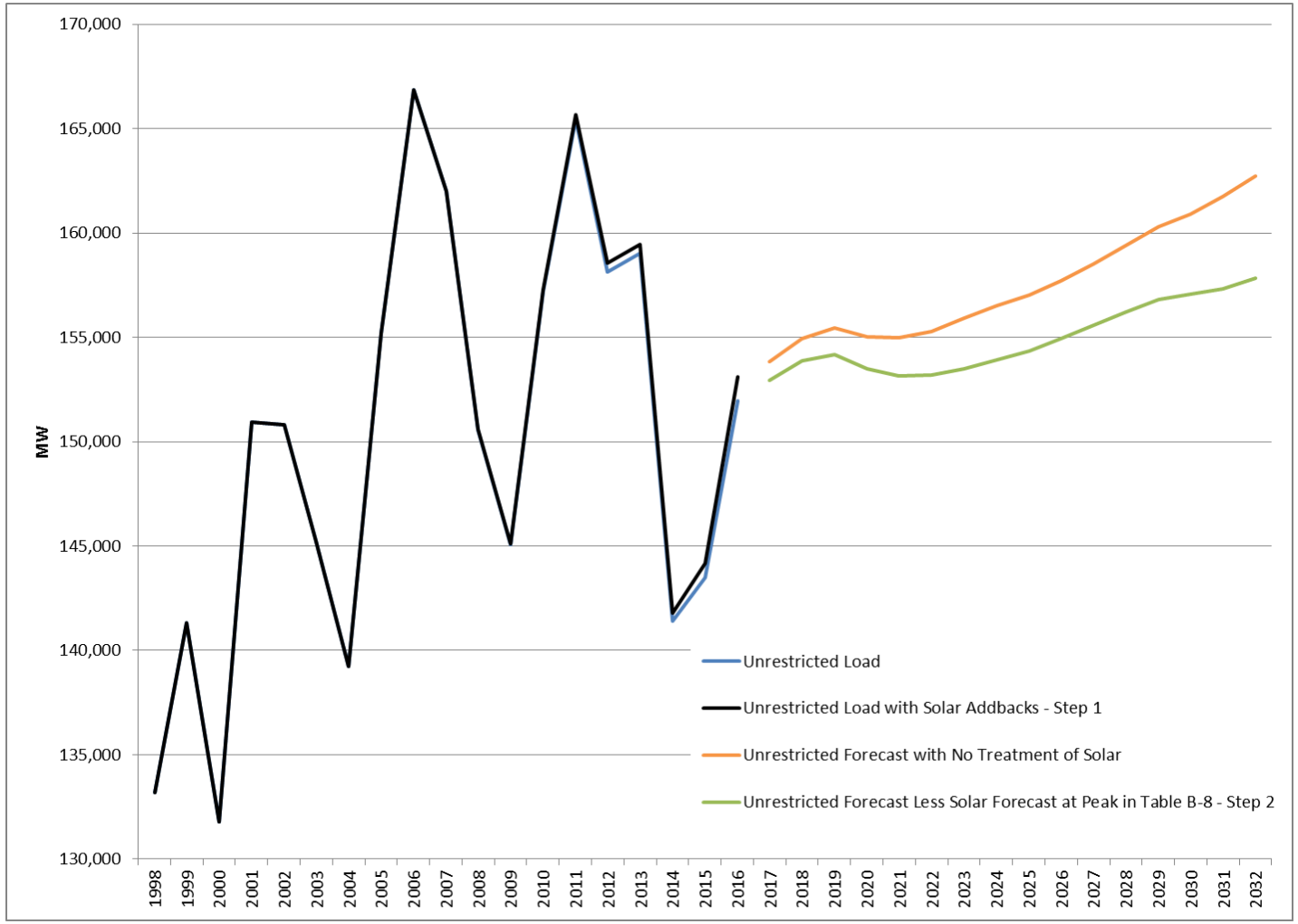
IHS Energy
state level solar forecast additions

PJM
converts to zonal solar peak impact



Long Term Forecast: Process Review

RTO Forecast Illustrating the Two-Step Approach
PJM RTO Summer Peak



Historical and IHS Nameplate Capacity

Distributed Solar Generation Forecast by Zone
Cumulative Nameplate Capacity
Includes Historical Degraded Values and IHS Forecast

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
AE	373.6	413.3	454.7	483.4	500.2	513.4	516.8	515.6	517.2	520.2	523.1	526.0	528.9	531.7	534.5	537.2
AEP	82.3	132.7	216.3	365.2	486.8	598.4	675.7	692.2	706.4	726.6	751.0	778.5	807.1	839.6	879.8	928.6
APS	169.6	227.7	296.0	360.2	410.9	451.8	477.2	479.8	485.0	491.8	499.9	511.8	527.2	546.0	571.0	598.2
ATSI	106.0	131.7	185.2	291.4	355.2	387.2	405.1	410.6	413.5	421.5	431.9	442.5	453.7	465.3	481.9	504.4
BGE	443.2	592.2	763.7	892.1	982.1	1,069.7	1,107.2	1,106.6	1,108.8	1,113.6	1,124.8	1,143.1	1,166.6	1,191.3	1,226.2	1,260.8
COMED	56.3	77.2	113.9	174.4	233.4	275.9	309.2	330.2	340.0	349.7	361.4	381.4	415.7	449.9	483.6	518.3
DAYTON	21.0	27.4	41.6	70.7	87.9	96.7	101.8	103.4	104.2	106.3	109.1	111.9	114.6	117.4	121.3	126.9
DPL	208.8	235.8	270.5	301.7	327.6	353.3	362.3	360.6	359.4	358.6	358.7	359.8	361.7	363.7	373.2	382.8
DQE	22.5	31.3	42.0	54.4	64.3	67.6	68.1	68.3	69.6	71.2	72.8	75.4	79.3	84.5	90.9	98.3
DUKE	20.8	30.5	51.8	95.1	121.1	135.3	144.1	146.7	148.1	151.8	156.5	161.2	165.9	170.4	176.8	185.6
EKPC	1.7	3.7	7.0	10.5	14.8	22.1	30.3	31.3	33.6	36.4	39.2	41.9	45.2	47.1	48.7	50.4
JCPL	613.3	706.2	802.8	870.1	910.4	942.6	952.3	951.5	957.0	965.6	974.2	982.8	991.3	999.7	1,008.0	1,016.2
METED	60.0	69.4	80.7	93.9	104.4	107.7	107.9	108.0	109.0	110.6	112.1	114.6	118.6	124.1	130.9	138.8
PECO	100.2	125.1	155.0	189.8	217.6	226.5	227.5	228.0	231.2	235.6	239.9	246.9	257.6	272.1	289.8	310.4
PENLC	17.6	28.4	41.3	56.4	68.4	72.4	73.0	73.4	75.0	77.0	79.0	82.1	86.8	93.0	100.6	109.4
PEPCO	365.9	481.0	614.2	715.1	787.7	855.1	887.1	889.0	890.8	894.3	902.1	914.6	930.8	947.8	971.8	995.6
PL	147.1	171.2	200.4	234.3	261.4	269.8	270.4	270.5	273.3	277.3	281.2	287.7	297.9	311.8	328.9	348.8
PS	936.1	1,117.7	1,307.6	1,441.0	1,521.8	1,586.7	1,607.6	1,608.0	1,620.7	1,639.6	1,658.4	1,677.0	1,695.5	1,713.8	1,731.7	1,749.5
RECO	20.8	27.0	33.5	38.1	40.9	43.1	43.9	44.0	44.5	45.2	45.9	46.6	47.3	48.0	48.7	49.4
UGI	1.1	1.7	2.5	3.3	4.0	4.2	4.3	4.3	4.4	4.5	4.6	4.8	5.0	5.4	5.8	6.3
VEPCO	718.6	859.0	1,027.6	1,239.9	1,438.3	1,637.0	1,758.8	1,761.1	1,770.9	1,787.2	1,806.3	1,828.4	1,854.8	1,898.8	1,960.9	2,035.4
PJM RTO	**4,486.3**	**5,490.3**	**6,708.3**	**7,980.8**	**8,939.1**	**9,716.5**	**10,130.5**	**10,183.2**	**10,262.6**	**10,384.7**	**10,532.4**	**10,719.1**	**10,951.4**	**11,221.4**	**11,565.2**	**11,951.5**

Capacity Factors

- Capacity Factors are calculated using the hourly back-casted values divided by the value of the GATS installations

- The average capacity factor over Hour Ending 17 for the months of June, July, and August will be applied to the Zonal level Nameplate Capacity for a value at peak

Capacity Factors

	Hour Ending 17; June, July, and August 2017 Back-casting Process
AE	28%
AEP	32%
APS	28%
ATSI	29%
BGE	26%
COMED	32%
DAYTON	32%
DPL	30%
DQE	25%
DUKE	27%
EKPC	32%
JCPL	26%
METED	29%
PECO	28%
PENLC	30%
PEPCO	25%
PL	28%
PS	27%
RECO	26%
UGI	26%
VEPCO	27%

Capacity at Peak

Distributed Solar Generation Forecast by Zone
Annual Capacity at Peak 2018-2033

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
AE	104.8	116.0	127.6	135.6	140.3	144.0	145.0	144.6	145.1	145.9	146.7	147.6	148.4	149.2	149.9	150.7
AEP	26.2	42.2	68.8	116.2	154.9	190.4	215.0	220.3	224.8	231.2	239.0	247.7	256.8	267.2	280.0	295.5
APS	47.5	63.8	83.0	101.0	115.2	126.6	133.8	134.5	136.0	137.9	140.1	143.5	147.8	153.1	160.1	167.7
ATSI	30.4	37.7	53.1	83.5	101.8	110.9	116.1	117.6	118.5	120.8	123.7	126.8	130.0	133.3	138.1	144.5
BGE	115.2	154.0	198.6	232.0	255.4	278.2	287.9	287.7	288.3	289.6	292.5	297.2	303.3	309.8	318.8	327.8
COMED	17.9	24.5	36.2	55.4	74.1	87.6	98.2	104.9	108.0	111.0	114.8	121.1	132.0	142.9	153.6	164.6
DAYTON	6.7	8.7	13.2	22.4	27.9	30.7	32.3	32.8	33.1	33.7	34.6	35.5	36.4	37.2	38.5	40.3
DPL	62.6	70.7	81.2	90.5	98.3	106.0	108.7	108.2	107.8	107.6	107.6	108.0	108.5	109.1	112.0	114.9
DQE	5.5	7.7	10.4	13.4	15.9	16.7	16.8	16.9	17.2	17.6	18.0	18.6	19.6	20.9	22.4	24.3
DUKE	5.6	8.2	13.9	25.6	32.6	36.4	38.7	39.4	39.8	40.8	42.1	43.3	44.6	45.8	47.5	49.9
EKPC	0.5	1.2	2.2	3.3	4.7	7.0	9.6	9.9	10.6	11.5	12.4	13.3	14.3	14.9	15.4	16.0
JCPL	160.1	184.4	209.6	227.2	237.7	246.1	248.7	248.4	249.9	252.1	254.4	256.6	258.8	261.0	263.2	265.3
METED	17.5	20.2	23.6	27.4	30.5	31.4	31.5	31.5	31.8	32.3	32.7	33.4	34.6	36.2	38.2	40.5
PECO	28.5	35.6	44.2	54.1	62.0	64.5	64.8	65.0	65.9	67.1	68.3	70.3	73.4	77.5	82.6	88.4
PENLC	5.3	8.6	12.5	17.1	20.7	21.9	22.1	22.2	22.7	23.3	23.9	24.9	26.3	28.2	30.5	33.1
PEPCO	91.8	120.6	154.0	179.3	197.5	214.5	222.5	223.0	223.4	224.3	226.2	229.4	233.4	237.7	243.7	249.7
PL	41.1	47.8	55.9	65.4	72.9	75.3	75.5	75.5	76.3	77.4	78.5	80.3	83.1	87.0	91.8	97.4
PS	251.9	300.8	351.9	387.8	409.5	427.0	432.6	432.7	436.2	441.3	446.3	451.3	456.3	461.2	466.0	470.8
RECO	5.5	7.1	8.8	10.0	10.7	11.3	11.5	11.5	11.7	11.9	12.1	12.2	12.4	12.6	12.8	13.0
UGI	0.3	0.5	0.7	0.9	1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.3	1.3	1.4	1.5	1.7
VEPCO	193.0	230.6	275.9	332.9	386.2	439.6	472.3	472.9	475.5	479.9	485.0	490.9	498.0	509.8	526.5	546.5
PJM RTO	**1,217.9**	**1,491.1**	**1,825.1**	**2,180.9**	**2,449.9**	**2,667.3**	**2,784.6**	**2,800.8**	**2,823.6**	**2,858.4**	**2,900.3**	**2,953.3**	**3,019.5**	**3,096.0**	**3,193.2**	**3,302.5**

Long Term Forecast: Next Steps

- Step 1 (future enhancement):
  - PJM recognizes the advancements in the precision of estimating solar generation with more granular weather data.
  - PJM is currently working with AWS Truepower to enhance the historical back-casts for behind the meter solar facilities in the PJM footprint.

AWS-T granularity

- Acquire 24 years (1993-2016) of visible satellite imagery at 15-minute intervals on a 2-km grid cropped around the PJM Service area.
- Estimate Global Horizontal Irradiance (GHI) and Clear Sky Index (CSI)
- Correct the bias at each BTM site and time in the 24-year history to generate a 24 year GHI time series at each site. Bias correction is performed using a machine-learning technique to capture the relationship between estimated and observed GHI at reliable observation sites, including the effects of elevation, satellite viewing angle and season. This relationship is then applied to all PV generation sites.

AWS-T presentation to PJM's Load Analysis Subcommittee:
http://www.pjm.com/-/media/committees-groups/subcommittees/las/20180314/20180314-item-03-awst-pjm-satellite-based-solar-generation-backcast.ashx

Additional Information

- Load Analysis Subcommittee
  - November 15, 2017 Meeting
    - http://www.pjm.com/-/media/committees-groups/subcommittees/las/20171115/20171115-item-03-pjm-distributed-solar-generation-forecast-2018.ashx
  - March 14, 2018 Meeting
    - http://www.pjm.com/-/media/committees-groups/subcommittees/las/20180314/20180314-item-03-awst-pjm-satellite-based-solar-generation-backcast.ashx
    - http://www.pjm.com/-/media/committees-groups/subcommittees/las/20180314/20180314-item-03-distributed-solar-generation-backcast-pjm.ashx
  - May 22, 2018 Meeting
    - http://www.pjm.com/-/media/committees-groups/subcommittees/las/20180522/20180522-item-03-distributed-solar-generation-backcast.ashx