SEPTEMBER 15, 2014 | HOLYOKE, MA

PV Energy Forecast Update

Distributed Generation Forecast Working Group

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SYSTEM PLANNING

Introduction

- ISO has been working to develop a PV energy forecast to accompany its forecast of installed nameplate capacity
- Uncertainty concerning anticipated energy contributions of future PV has been a topic of discussion at previous DGFWG meetings
  - In RSP14, statements regarding future energy contributions of PV were limited to an approximate 2023 value
- ISO is participating in several DOE projects and conducting independent work that will help support the development of an energy forecast
- Other than uncertainty in the PV capacity forecast (both timing and amounts of PV commercialization), key issues that should be considered in a PV energy forecast include:
  - Inter-annual fluctuations of the anticipated energy output due to weather
  - Future performance of these resources due to factors such as trends in future siting characteristics and future component reliability (e.g., inverters, modules)
- ISO plans on continuing to review and analyze actual PV performance and other types of data in support of generating a PV energy forecast for RSP15
- As work is completed it will be discussed with the DGFWG

Background

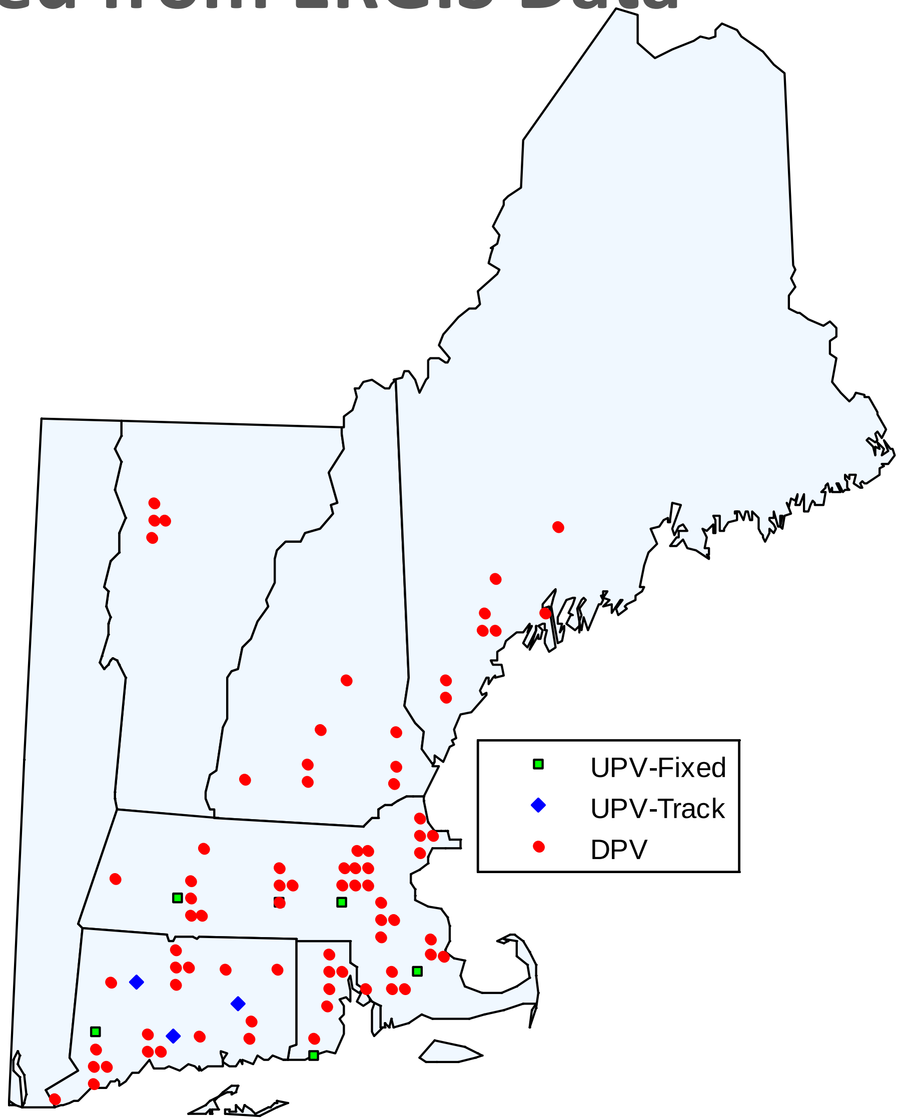
- PV's production characteristics will vary from year-to-year due to weather variations that are likely unique to New England
  - As data covering a longer time period become available, additional analysis will provide a greater understanding of PV's long-term characteristics that account for a degree of inter-annual weather variability
- Time-matched PV profiles are needed to represent future PV
  - Need to represent PV located throughout the six New England states
  - To date, it has been a challenge to obtain a sufficient amount of such PV production data with adequate geographical coverage
  - Simulated solar data offer a means of determining key characteristics of the future PV anticipated in New England
    - NREL's ERGIS simulated dataset represents weather from 2006
- Analysis of simulated and actual production data associated with additional years could provide a longer-term understanding of PV's characteristics that accounts for a degree of inter-annual weather variability
  - Collection/analysis of Solectria data and ISO's PV energy market data in ongoing
  - NREL is working towards developing similar datasets covering other years, which may be made available in the next couple of years

Approach For Estimating Forecasted PV Energy

- The 2014 PV forecast is an end-of-year forecast of installed AC nameplate capacity
  - To estimate annual energy, ISO assumed that on average 50% of forecasted annual incremental PV growth was in operation for entire year
    - This value is a preliminary estimate only, and consideration of actual trends in annual installation rates may yield a more suitable value
- To avoid double counting, PV resources estimated to be in service before July 2013 were subtracted from the annual forecast values, as these are already accounted for in the 2014 CELT
  - To be consistent with the values that are proposed to be used for Transmission Planning, ISO subtracted a total of 328 MW from the forecast of PV nameplate capacity (see 'Thru Q2 2013' column on slide 7)
  - Refer to the discussion from earlier today about the reductions in the 2014 load forecast resulting from embedded solar
- State/regional PV profiles were developed from the ERGIS dataset to represent the forecasted PV fleet between 2014-2023, which includes all forms of future PV:
  - FCM PV resources
  - Settlement Only PV resources
  - Load reducing PV resources
- Comparison of capacity factors (CF) from year-to-year and between simulated/actual data aids in the characterization of PV resources
  - CF is the ratio of actual energy production to the hypothetical energy produced if a unit (or fleet) generated at its full nameplate capacity over a period of time:
    - Is normally expressed as a percentage (%)
    - Is typically used to illustrate performance over some time period of interest
      - E.g., annual, monthly, daily
    - Can be based on PV's DC or AC nameplate capacity

State PV Profiles Developed from ERGIS Data

- A more detailed description of the ERGIS dataset and ISO's use of it was presented at the May 5, 2014 DGFWG meeting:
  - http://www.iso-ne.com/static-assets/documents/committees/comm_wkgrps/othr/distributed_generation_frcst/2014mtrls/may52014/pv_profile_analysis_2006_final.pdf
- PV sites were selected based on expected patterns of PV development across New England
- NREL's **simulated** profiles from the 86 sites identified in the figure to the right were incorporated into ISO's annual energy estimate, including all DPV sites
- State profiles were developed using an aggregation of all site profiles within each state
- The six state profiles were then aggregated to represent the future 8,760 hour regional PV profiles
- Analysis of resulting state load profiles is included in subsequent slides



Final Interim PV Forecast

2014 CELT Report

States	Annual Total MW (AC nameplate rating)											Totals
	Through 2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	
CT	73.8	46.2	39.3	53.0	34.7	34.7	13.1	13.1	13.1	13.1	11.6	**345.4**
MA	361.6	168.5	117.4	110.5	103.6	98.7	98.7	98.7	32.9	32.9	32.9	**1,256.4**
ME	8.1	2.0	1.9	1.8	1.6	1.6	1.6	1.6	1.6	1.6	1.6	**25.2**
NH	8.2	2.5	2.3	2.2	2.0	2.0	2.0	2.0	2.0	0.7	0.7	**26.7**
RI	10.9	7.3	5.4	3.7	1.2	1.2	1.2	1.2	1.2	1.2	1.2	**35.5**
VT	36.1	20.1	13.4	7.0	6.5	6.5	6.5	6.5	6.5	6.5	1.7	**117.3**
Regional - Annual (MW)	**498.7**	**246.5**	**179.6**	**178.1**	**149.6**	**144.8**	**123.1**	**123.1**	**57.3**	**56.0**	**49.7**	**1,806.5**
Regional - Cumulative (MW)	**498.7**	**745.2**	**924.8**	**1102.9**	**1252.5**	**1397.3**	**1520.4**	**1643.6**	**1700.9**	**1756.9**	**1806.5**	**1,806.5**

Notes:

(1) Forecast values include cumulative PV installed at beginning of forecast period

(2) All PV resources, including FCM Resources, non-FCM Settlement Only Generators, and load reducing PV, are included in values above

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

Estimated Nameplate Capacity Contributing to Annual Energy

States	Annual Total MW (AC nameplate rating)											
	Thru Q2 2013**	Q3/Q4 2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
CT	55.0	18.8	41.9	84.6	130.7	174.6	209.3	233.1	246.2	259.2	272.3	284.6
MA	232.0	129.6	213.9	356.8	470.8	577.8	678.9	777.6	876.4	942.2	975.1	1008.0
ME	5.0	3.1	4.1	6.0	7.8	9.5	11.1	12.8	14.4	16.1	17.7	19.4
NH	5.0	3.2	4.4	6.8	9.1	11.2	13.2	15.2	17.3	19.3	20.7	21.4
RI	6.0	4.9	8.6	14.9	19.5	21.9	23.1	24.3	25.4	26.6	27.8	28.9
VT	25.0	11.1	21.1	37.9	48.0	54.8	61.3	67.8	74.3	80.8	87.4	91.5
Regional Total	**328.0**	**170.7**	**294.0**	**507.0**	**685.9**	**849.7**	**996.9**	**1130.9**	**1254.0**	**1344.2**	**1400.9**	**1453.7**

Notes:

- ** Estimated PV in operation before July 2013 that was removed from Interim 2014 PV forecast
- **Incremental growth in state installed PV assumes that 50% of annual PV forecasted for each year is in operation**

Preliminary Estimate of PV Energy, 2014-2023

- Capacity factor of aggregate regional PV profile:
  - 15.4% based on AC nameplate
  - ~12.8% based on estimated DC nameplate
- Estimated PV energy in 2023 equivalent to approximately 1.3% of the 2023 forecast of regional net load energy (151,525 GWh)

States	Annual PV Energy Forecast (GWh)									
	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
CT	59	118	183	244	293	326	345	363	381	399
MA	288	481	635	779	916	1,049	1,182	1,271	1,315	1,359
ME	6	8	11	13	15	17	19	22	24	26
NH	6	9	12	15	17	20	23	25	27	28
RI	12	20	26	30	31	33	35	36	38	39
VT	26	47	59	67	75	83	91	99	107	112
Total Regional PV GWh	**396**	**684**	**926**	**1,148**	**1,348**	**1,529**	**1,695**	**1,816**	**1,892**	**1,964**

PV Capacity Factors By State

Based on Simulated ERGIS Data – 2006 Weather

- Annual average capacity factors of ERGIS-based state profiles are listed below for both DC and AC nameplate capacities

States	Capacity Factor (based on DC)	Capacity Factor (based on AC)
CT	13.7%	16.0%
MA	13.1%	15.4%
ME	13.0%	15.4%
NH	12.8%	15.1%
RI	13.2%	15.5%
VT	12.0%	14.0%
Regional Profile	**12.8%**	**15.4%**

Note: AC-based CFs are estimated with an assumed AC-to-DC ratio of 83%

Comparison to MA DOER SREC Data

- As required by regulation, MA DOER calculates and publishes capacity factors of SREC sites over time
- Table to the right shows annual CFs for a number of PV systems over 3 years
- Annual CFs are similar to the CFs exhibited by the state profiles developed from ERGIS simulated data
- ISO conducted additional analysis to help understand the variation and seasonality of individual and aggregate PV production
  - See slides in Appendix

Commonwealth of Massachusetts
Executive Office of Energy and Environmental Affairs
DEPARTMENT OF ENERGY RESOURCES
RPS SOLAR CARVE-OUT

Determination of Average Solar PV Capacity Factor
(per 225 CMR 14.07(2)(e)1.)

Year	# of Systems in Sample	Average Capacity Factor
2010-2011	574	12.99%
2011-2012	983	13.50%
2012-2013	2302	13.15%

3-Year Average Capacity Factor	13.21%

Note: Systems with capacity factors less than 10% or greater than 20% were excluded from yearly samples. Systems without 12-months of production data were also removed.

Source: http://www.mass.gov/eea/docs/doer/renewables/solar/capacity-factor-analysis.xlsx

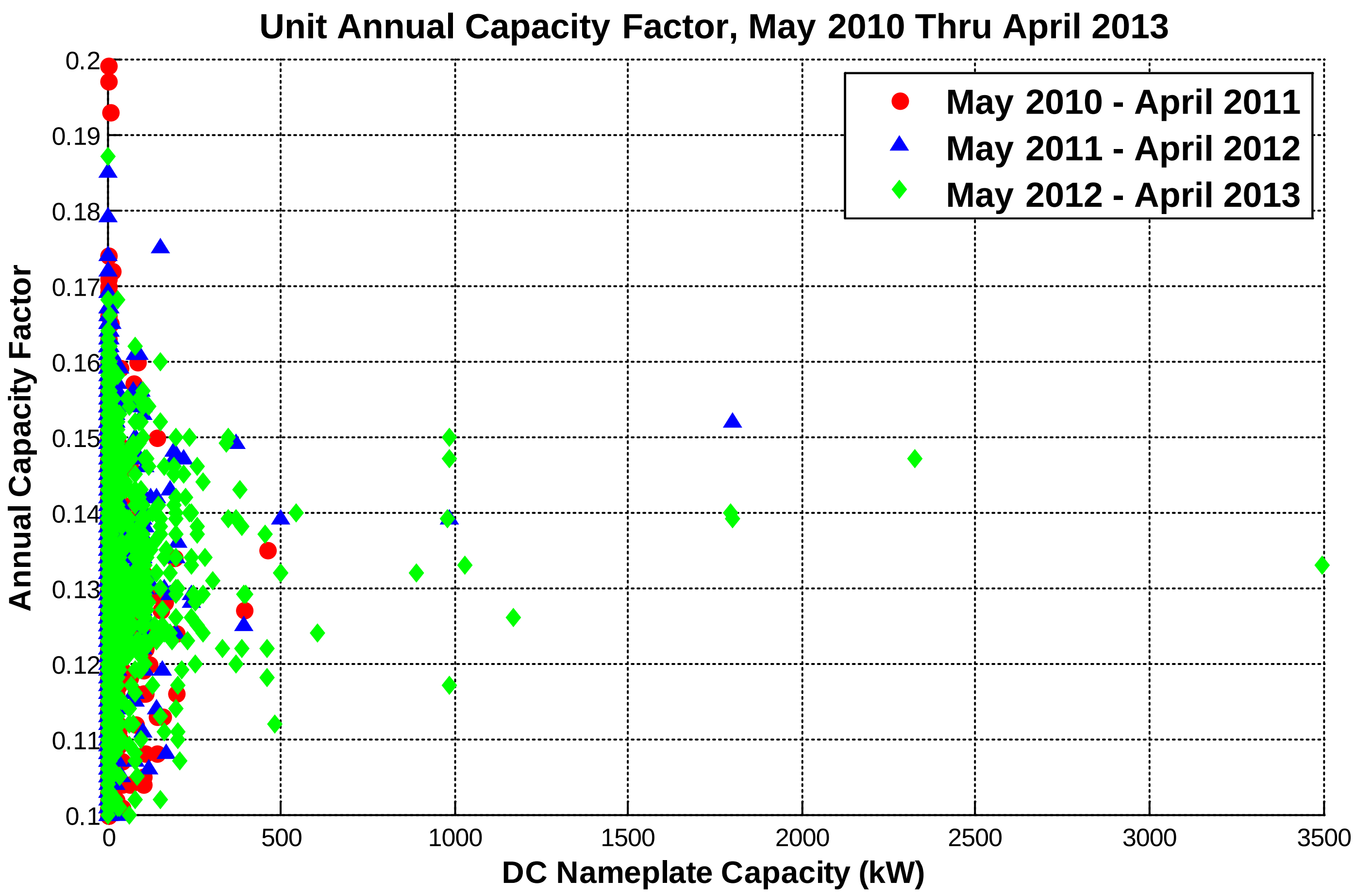
Conclusions

- ISO's work to generate a forecast of PV energy to accompany its annual forecast installed PV nameplate capacity is ongoing
- PV module degradation rates were not included in this forecast estimate of PV energy
  - A degradation rate of 0.5%/yr would result in an estimated 3% reduction of annual energy production in 2023
- ISO plans on developing a forecast of PV energy for inclusion in RSP15

APPENDIX

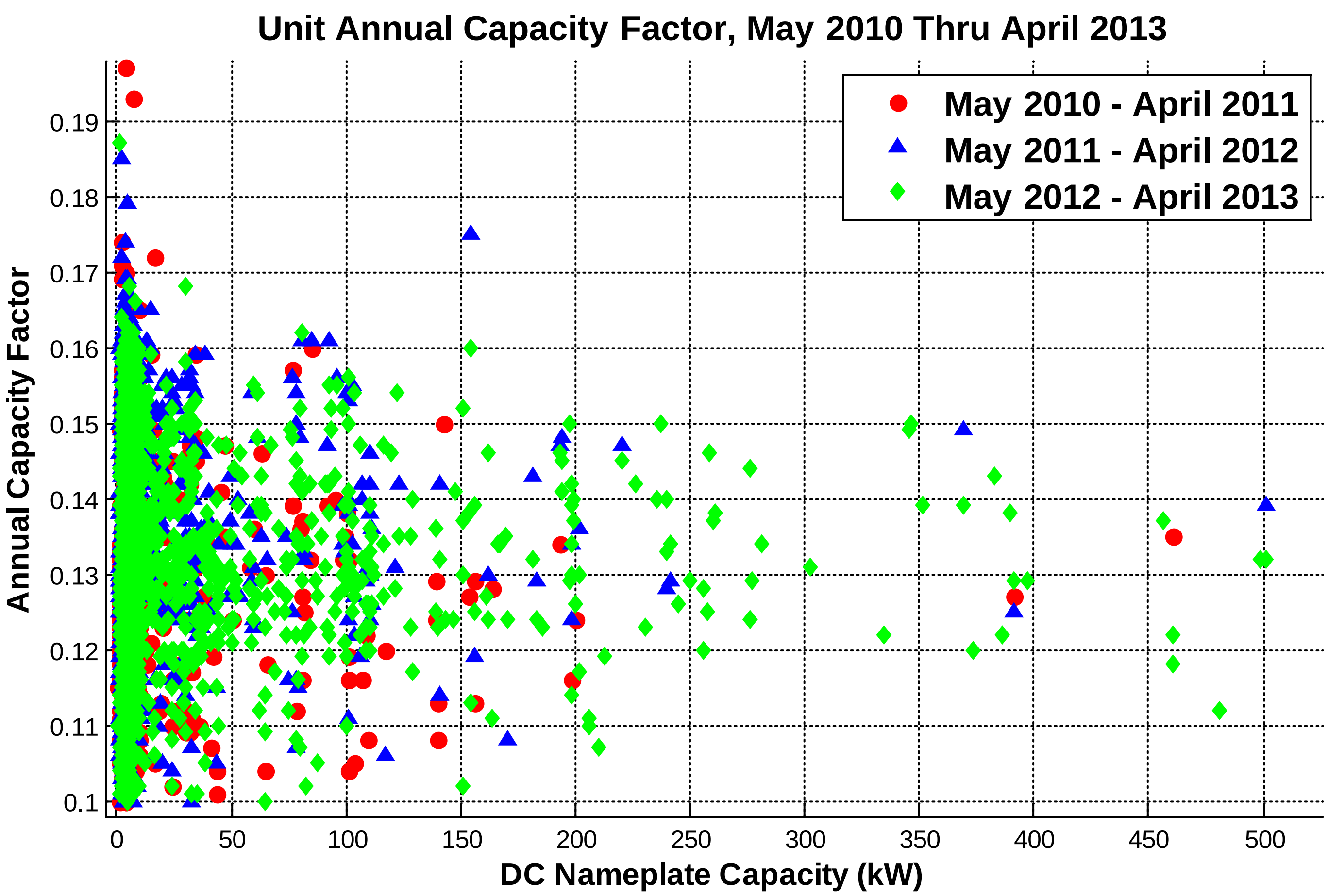
Unit-Level Capacity Factors of PV in MA SREC Program, 2010-2013

MA SREC Unit-Level Capacity Factors



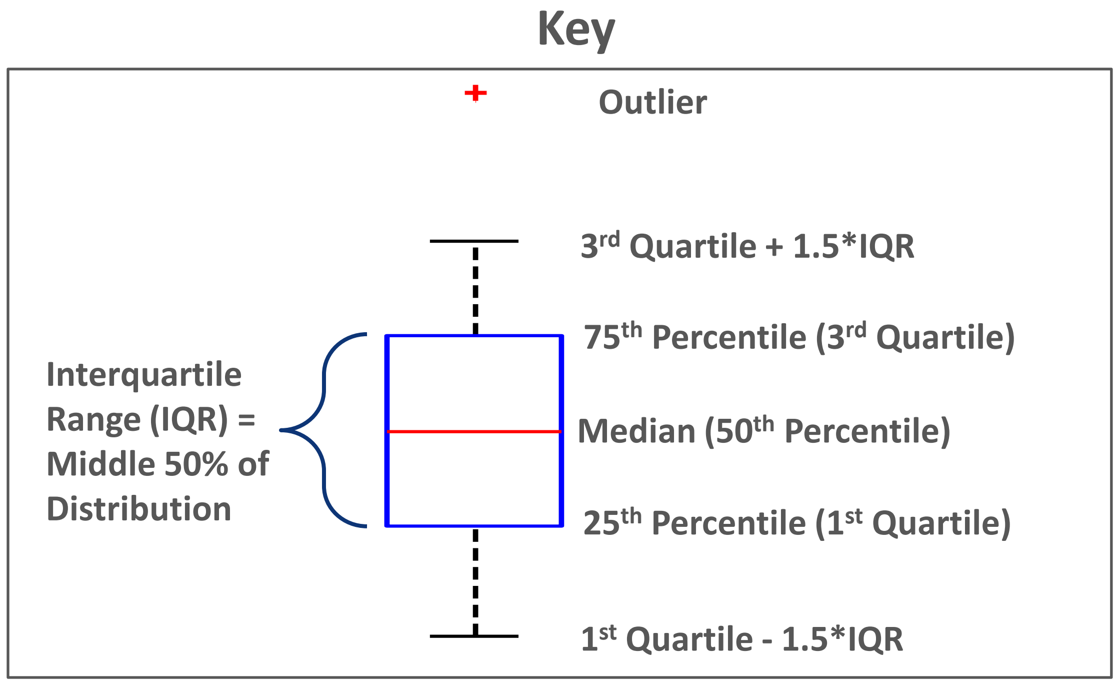
MA SREC Unit-Level Capacity Factors

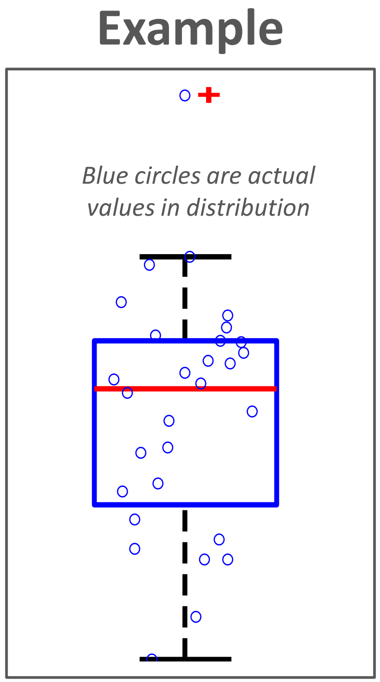
Zoom-in View of Smaller Sites



Boxplots

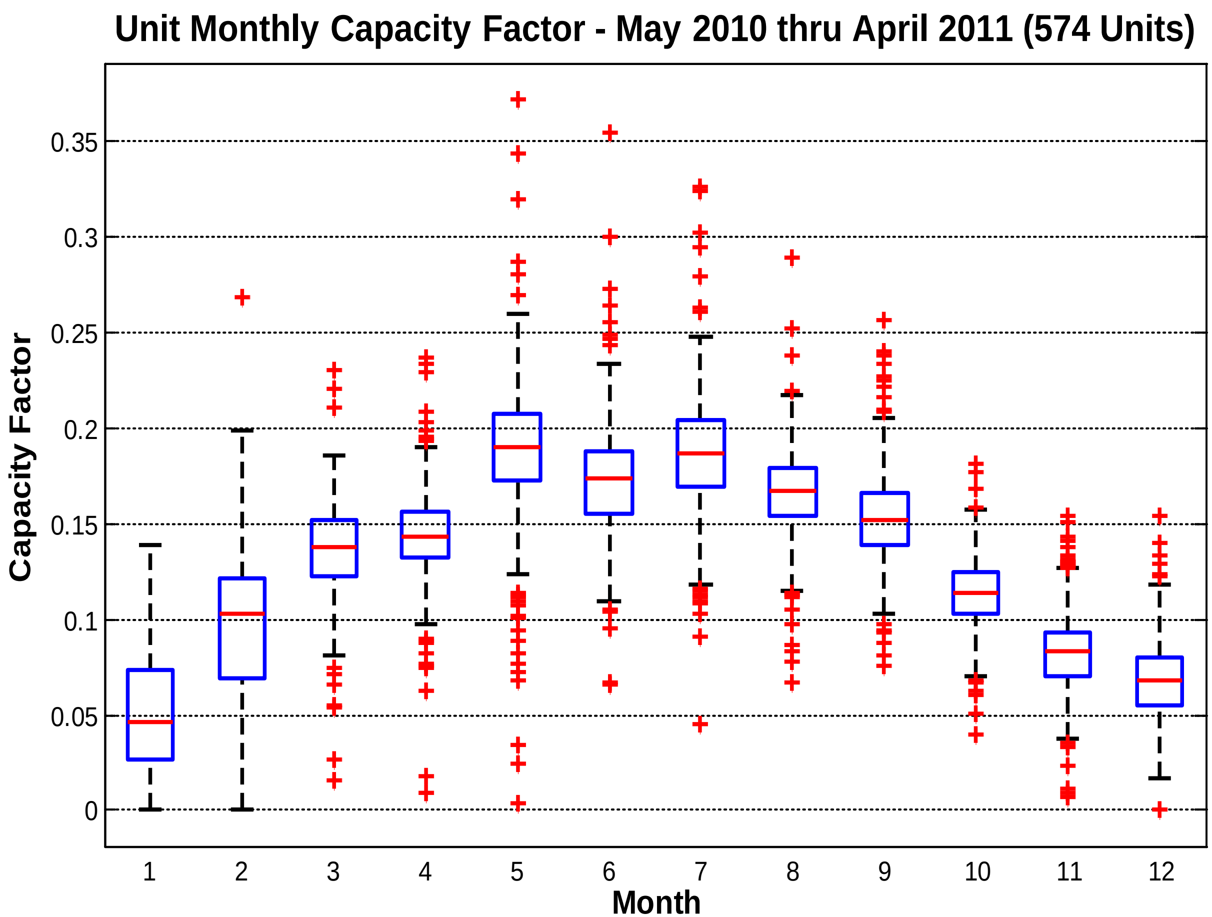
- Boxplots are a.k.a. "box-and-whisker" plots
- Boxplots are useful for presenting a good overview of the distribution of data
- Boxplot components are illustrated below





MA SREC Unit-Level Capacity Factors

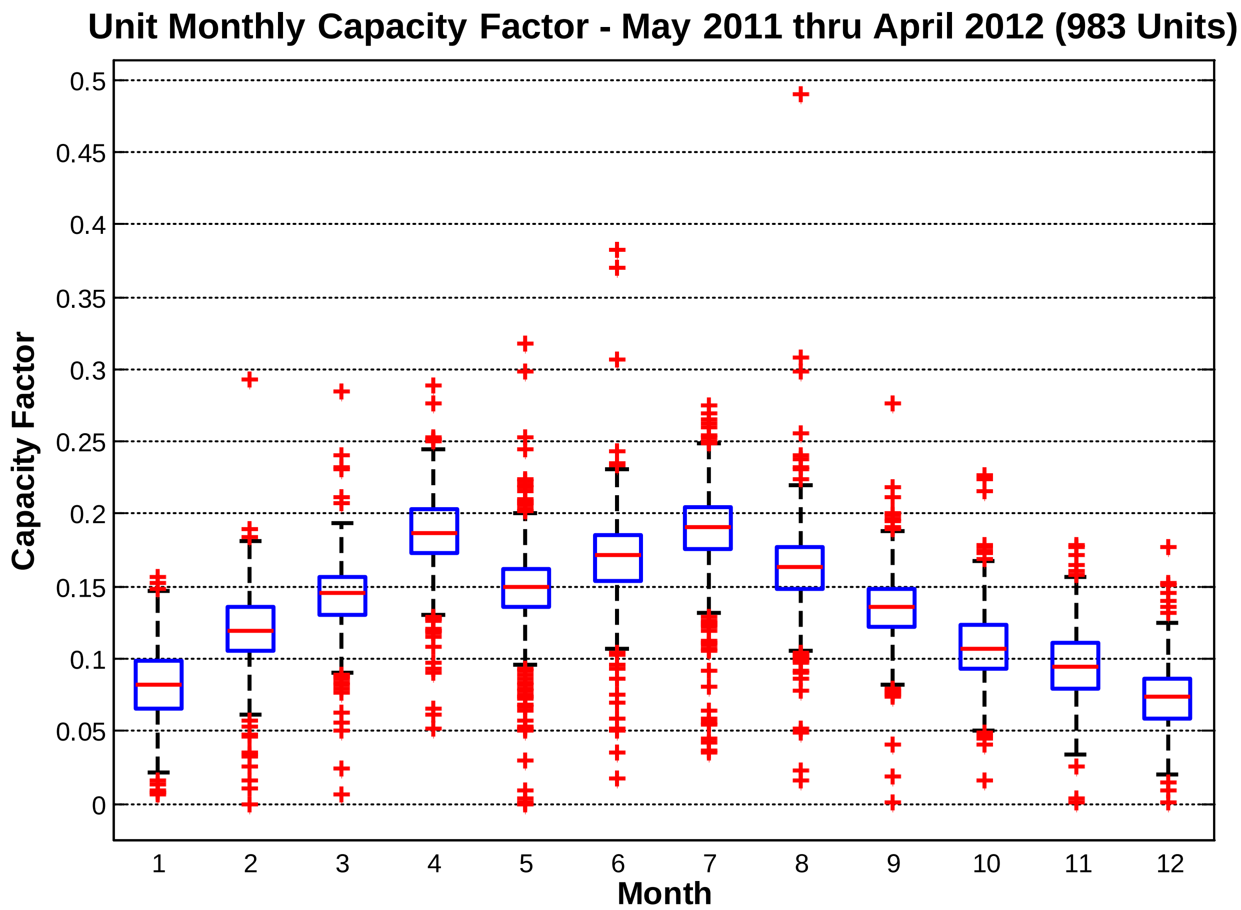
May 2010 through April 2011 – 574 Units



Note: CFs are based on DC nameplate; these can be converted to an estimated AC nameplate basis by multiplying by 0.83

MA SREC Unit-Level Capacity Factors

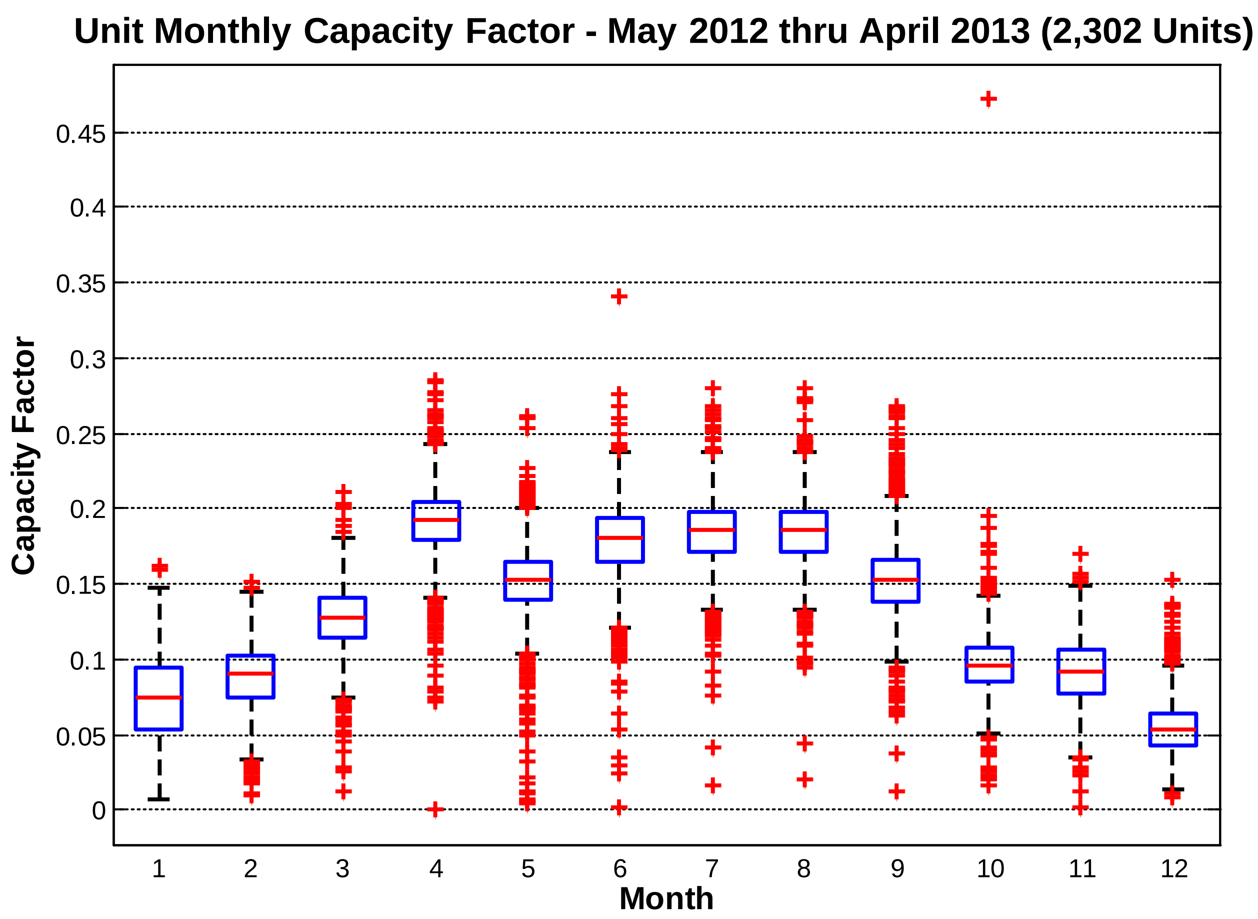
May 2011 through April 2012 – 983 Units



Note: CFs are based on DC nameplate; these can be converted to an estimated AC nameplate basis by multiplying by 0.83

MA SREC Unit-Level Capacity Factors

May 2012 through April 2013 – 2,302 Units



<u>**Note**</u>: CFs are based on DC nameplate; these can be converted to an estimated AC nameplate basis by multiplying by 0.83

Questions