Load Research and PV

Accounting for PV in Sample Design

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Objective: Adapt Sampling for PV

- Develop optimal sample design strategy for future class load studies for a population that includes substantial DER (PV) saturation with net energy metering (NEM)
  - Adequately represent NEM customers (e.g. Distinct NEM and non-NEM load shapes can be separated from an otherwise muddled load profile for the rate as a whole)
  - Manage costs of larger sample size while achieving target precisions
- Consider alternate stratification approaches, given issues with correlation between demands and billed energy (kWh)
  - Consider PV system size (kW) for NEM customers
- Generate estimated load curves for residential NEM customers with PV

Background: PV at Hawaiian Electric

- Net Energy Metering (NEM) Program
  - **Customer sited & customer controlled**
  - Customer credited for energy at the retail rate trued up annually
  - Program closed to new applications effective October 12, 2015
  - Existing and pending participants grandfathered into the program
- Grid Supply and Self Supply program replace NEM in the interim
- Most systems for NEM customers designed to match generation and household use annually (near zero annual kWh)

Cumulative PV Installed as of 3/31/16

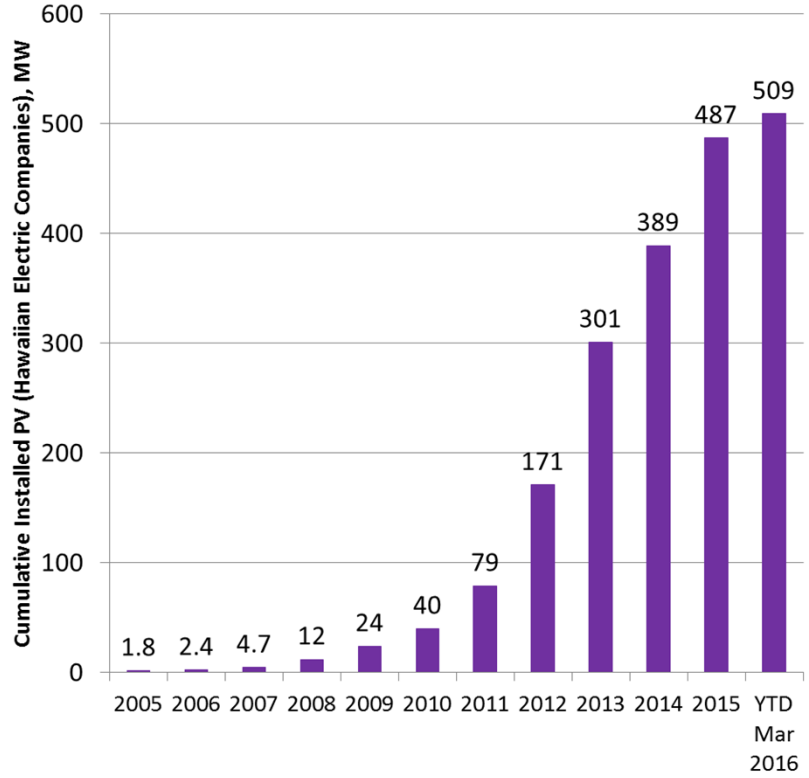
GRID

- 30% of 2015 System Peak
- 70% of 2015 System Minimum
- 21% of total Firm system generation capacity

CUSTOMER

- 14% of all customers
- 16% of residential
- 27% of Single Family dwellings

	Number of PV Systems			PV Capacity, MW		
	Number	% Residential	% Commercial	Capacity	% Residential	% Commercial
Hawaiian Electric	43,067	97%	3%	356	64%	36%
Hawai'i Electric Light	10,186	94%	6%	73.3	65%	35%
Maui Electric	10,060	93%	7%	80.3	64%	36%
Total	63,313			509		



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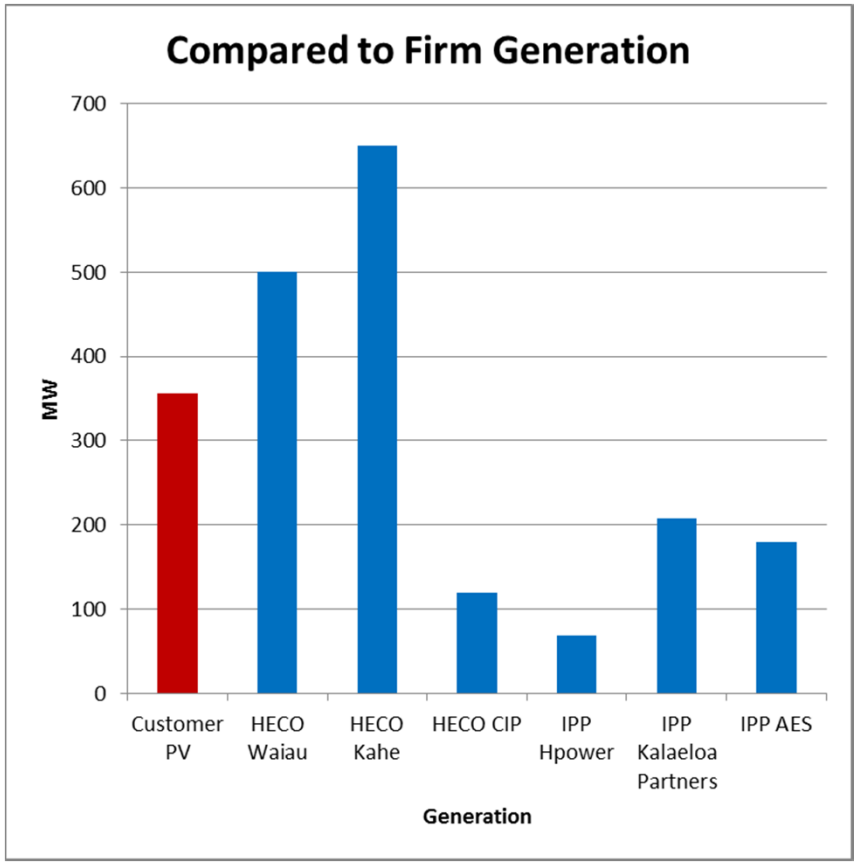
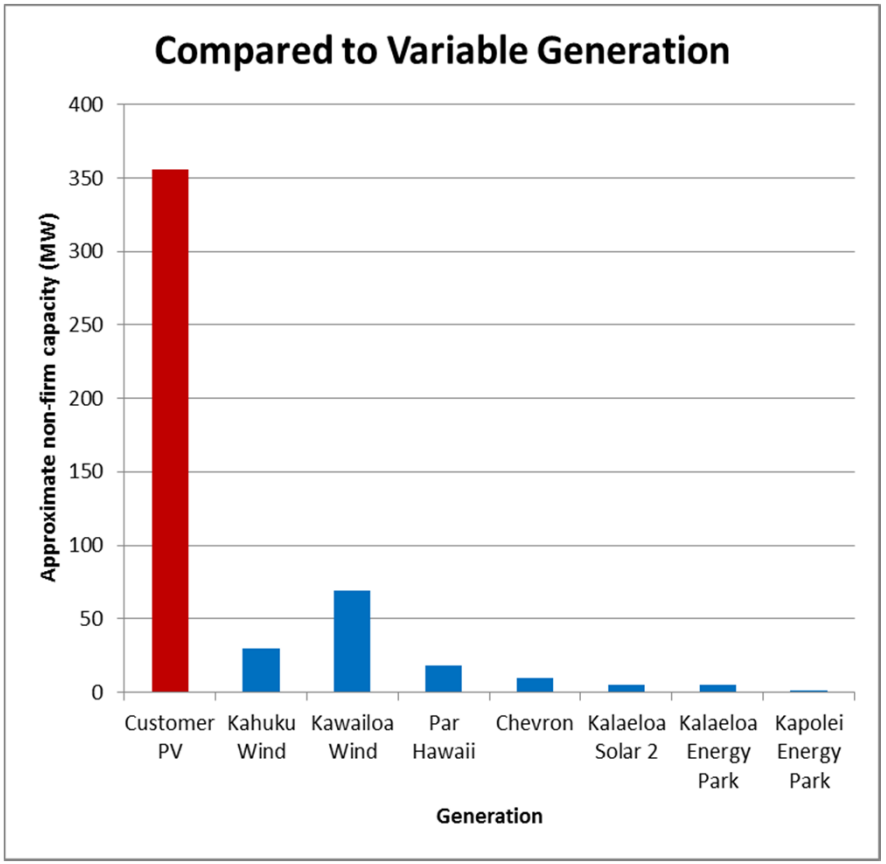
Magnitude of a Power Plant





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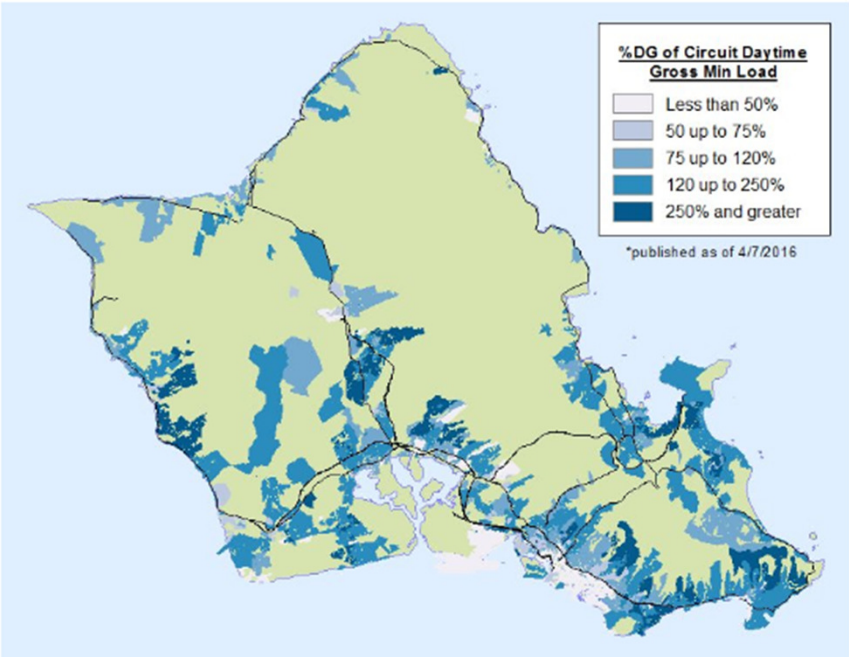
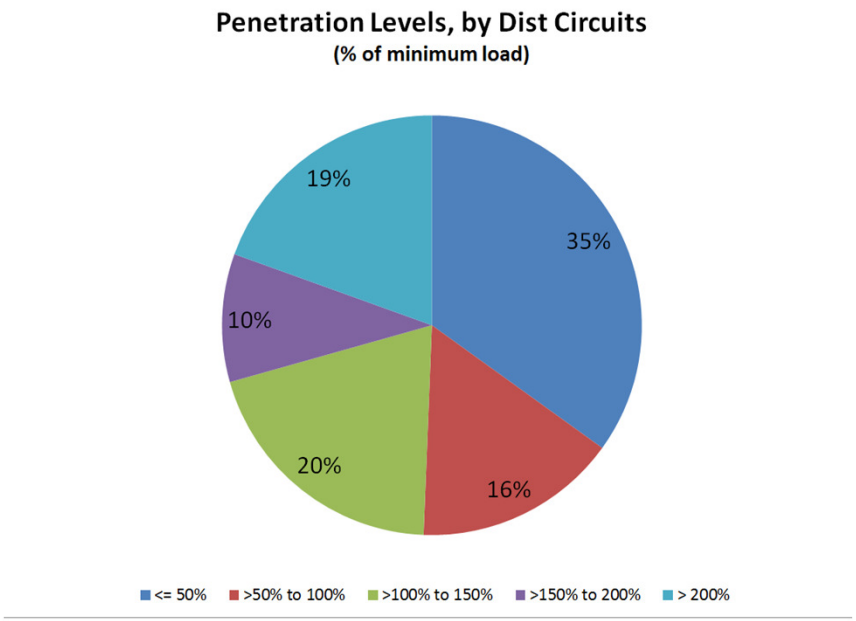
Circuit Penetration





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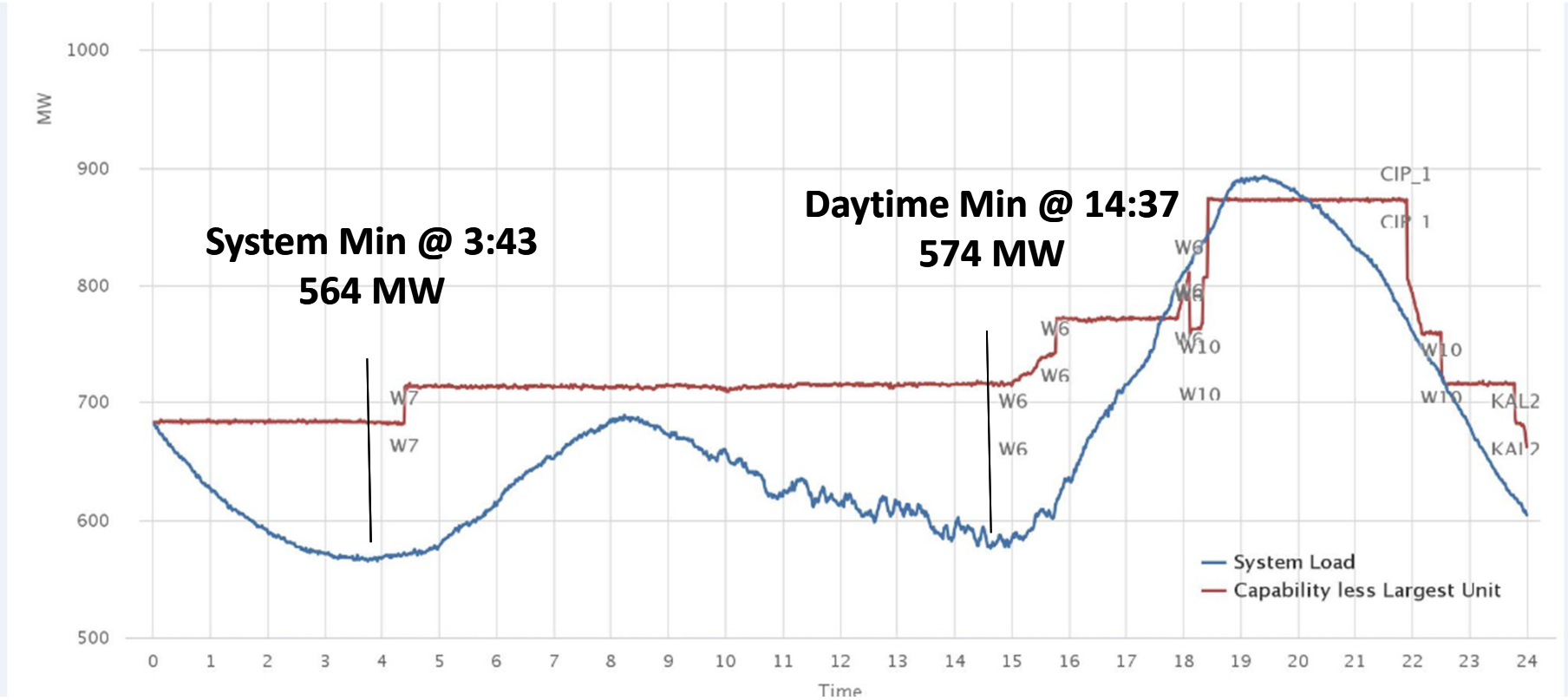
Day Minimum As Low As Evening Minimum

System Load on Feb. 7, 2016



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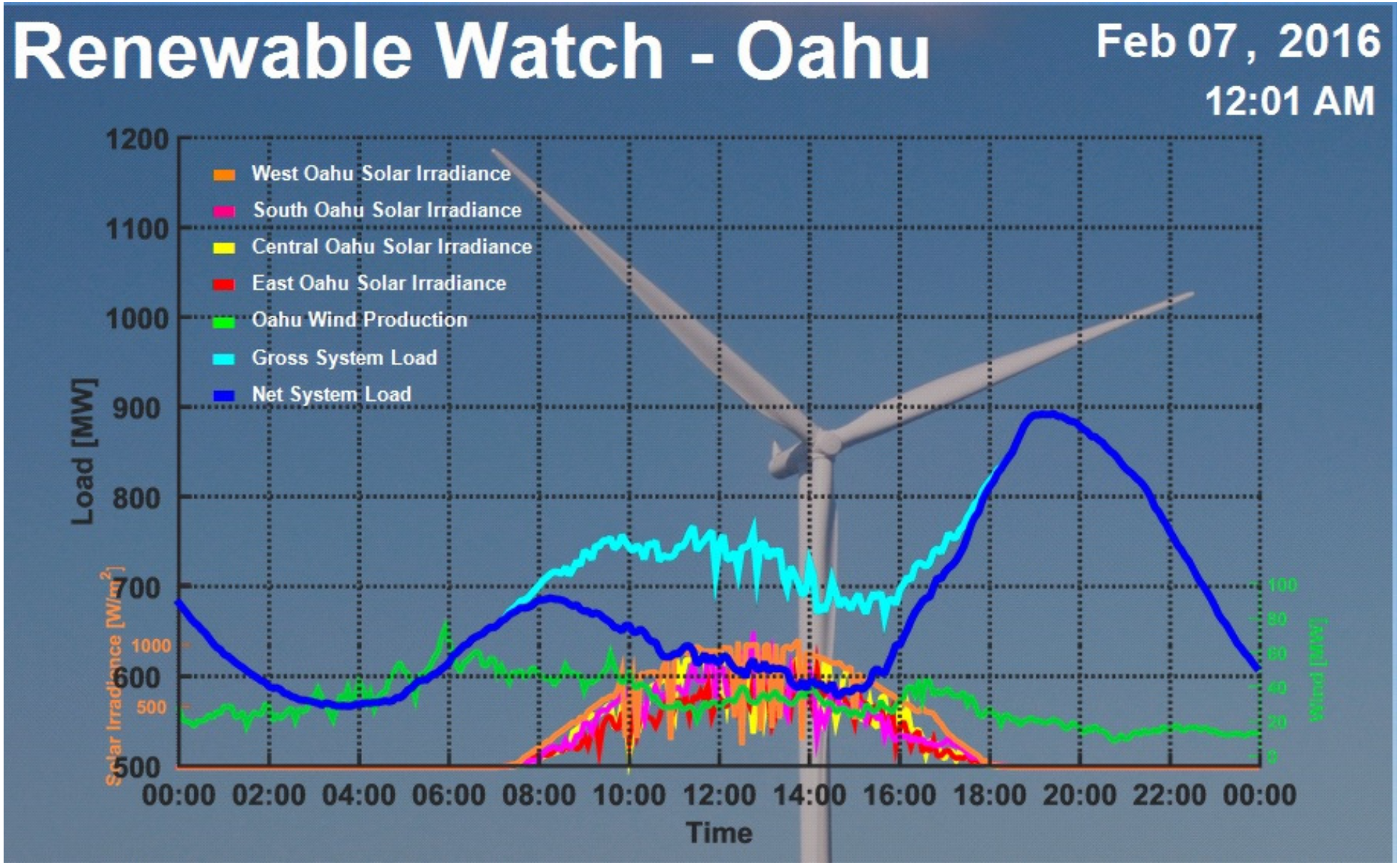

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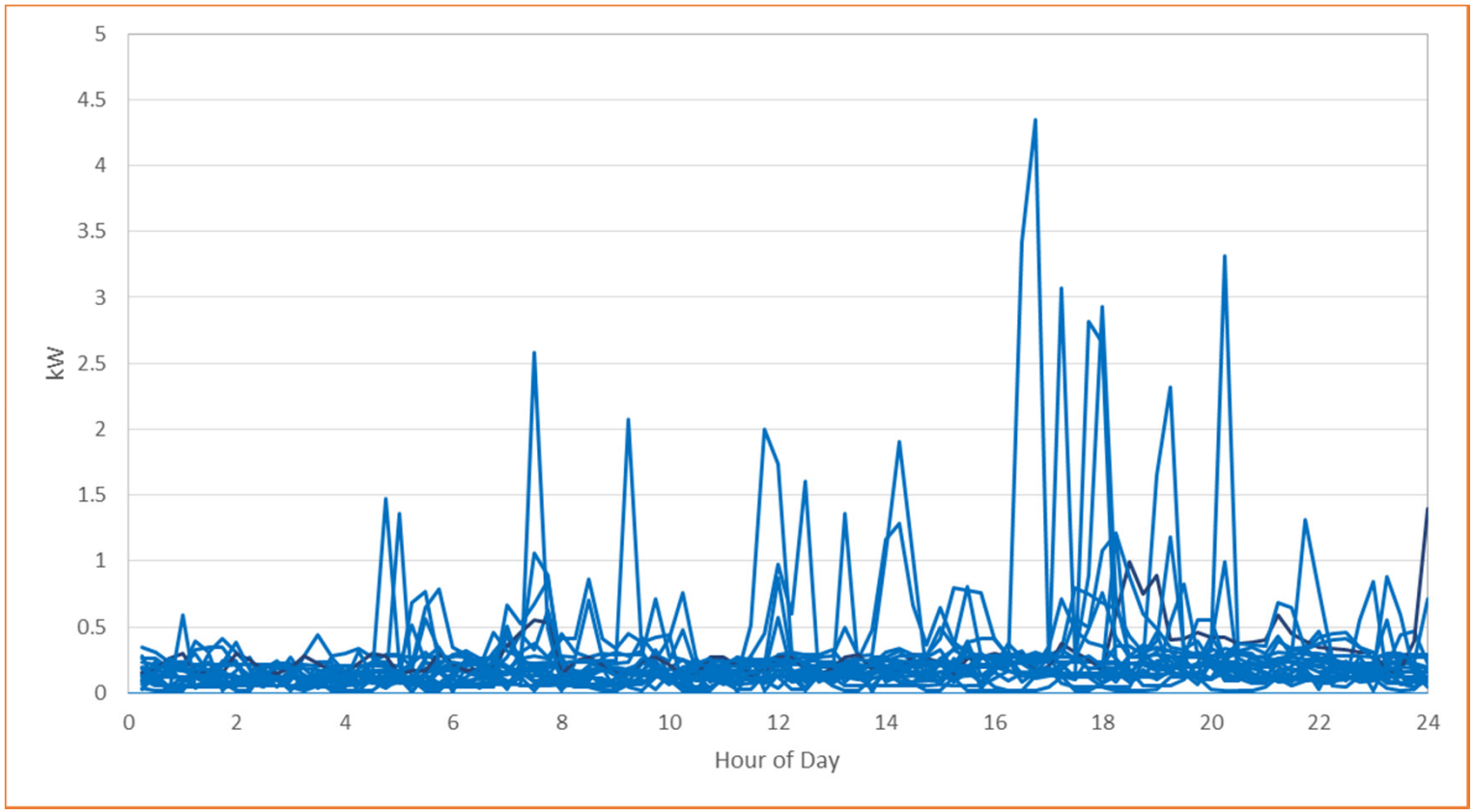
Issues with Traditional Stratification (by Billed Energy)

- Increased variability from mixture of NEM and non-NEM
  - Especially within low-use strata
- Precision of ratio estimate depends on demand-energy correlation, which is lower for NEM and mixtures
- Very dissimilar customer load shape (particularly daytime hours)

Load Shapes – 20 Non-NEM customers with 100-200 kWh in August



Note magnitude on y-axis

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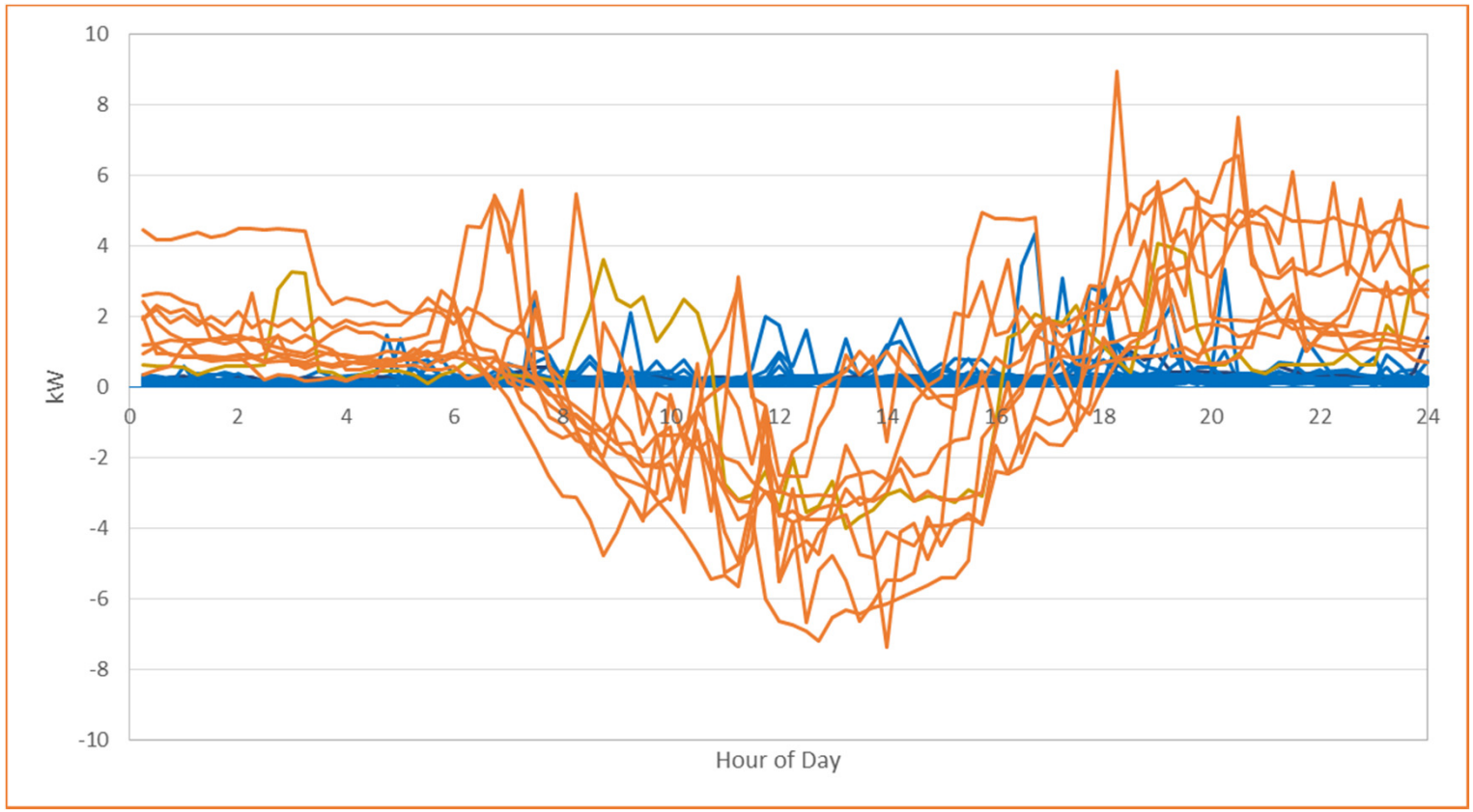
Now add 10 NEM customers with 100-200 kWh in August



Note magnitude on y-axis

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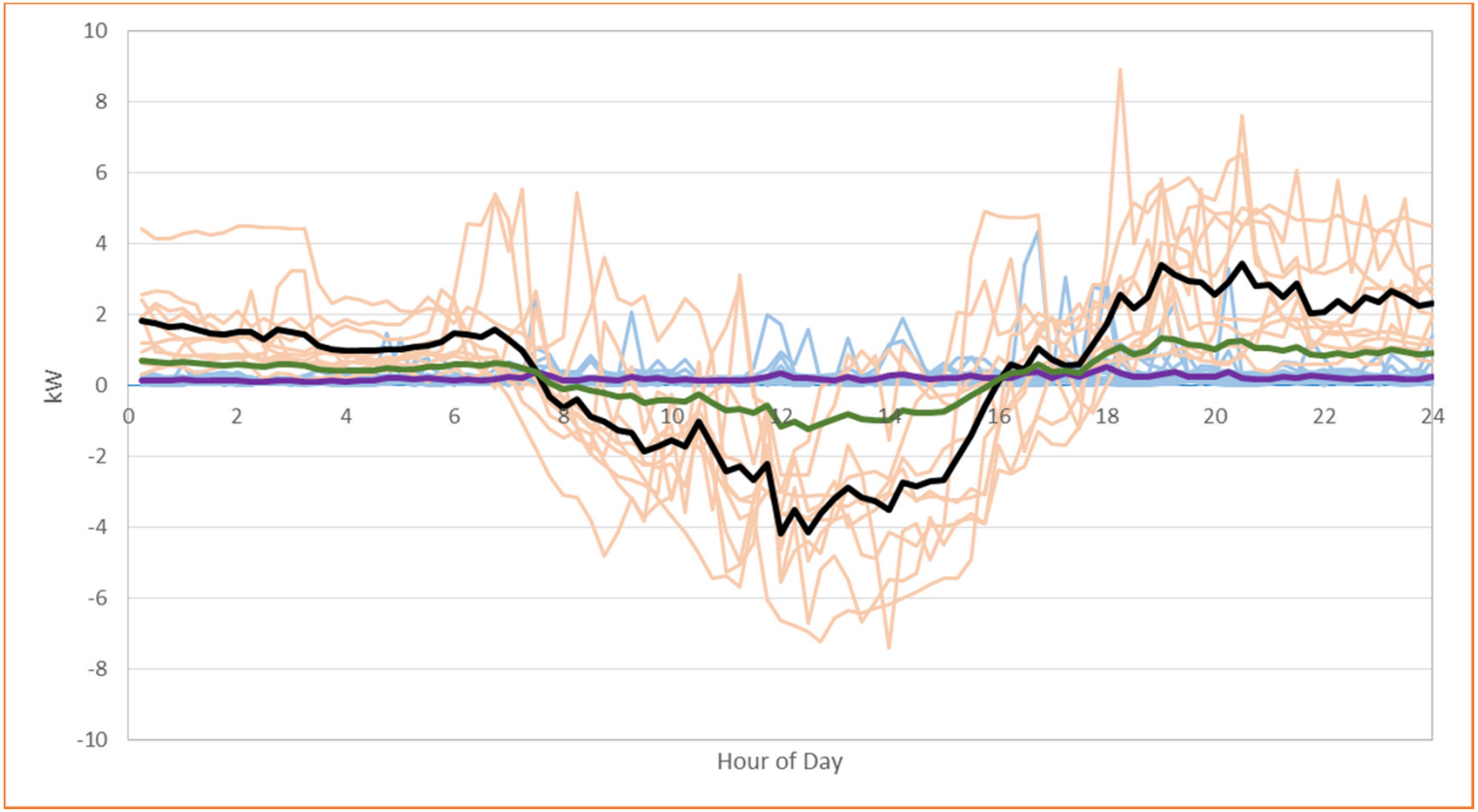
Compare the Average Load Shapes



Black is Average of the NEM shapes
Purple is Average of the Non-NEM shapes
Green is overall average

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Correlations by Billed Energy (kWh) and PV System Size (kW)

Billed Energy

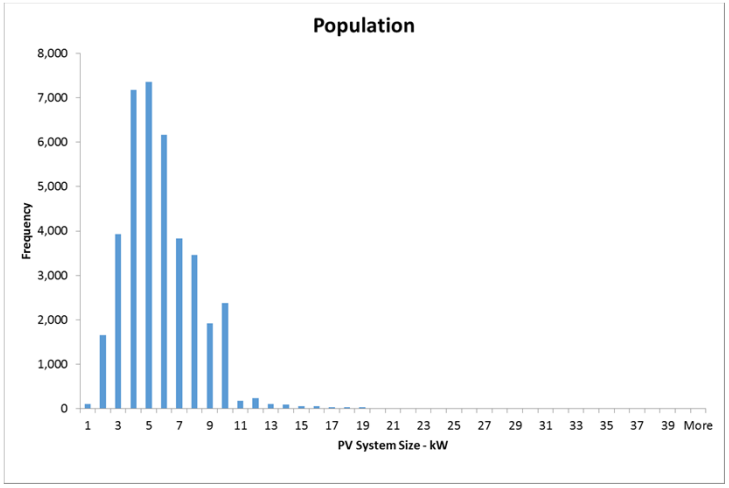
	Correlations with Billing Energy			
Month and Year	Daytime Peak	Evening Peak	Group Peak	**Group Minimum**
JUN 2014	0.44	0.60	0.53	**0.31**
JUL 2014	0.52	0.42	0.42	**0.21**
AUG 2014	0.54	0.54	0.53	**0.36**
SEP 2014	0.41	0.56	0.50	**0.35**
OCT 2014	0.32	0.64	0.60	**0.25**
NOV 2014	0.42	0.71	0.70	**0.07**
DEC 2014	0.39	0.67	0.67	**0.14**
JAN 2015	0.40	0.66	0.53	**-0.03**
FEB 2015	0.58	0.63	0.66	**0.14**
MAR 2015	0.19	0.59	0.51	**0.16**
APR 2015	0.33	0.49	0.42	**0.24**
MAY 2015	0.57	0.53	0.42	**0.25**

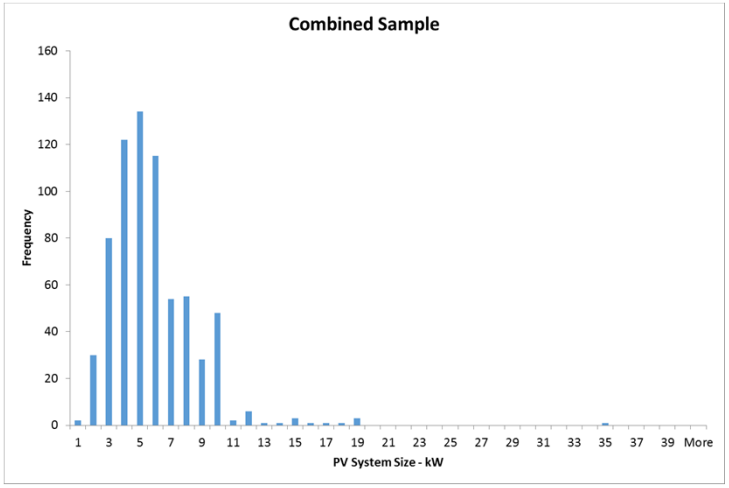
System Size

	Correlations with PV System Size in kW			
Month and Year	Daytime Peak	Evening Peak	Group Peak	**Group Minimum**
JUN 2014	-0.11	0.52	0.57	**-0.73**
JUL 2014	-0.04	0.51	0.54	**-0.64**
AUG 2014	-0.06	0.53	0.55	**-0.59**
SEP 2014	-0.10	0.55	0.56	**-0.49**
OCT 2014	-0.06	0.59	0.59	**-0.51**
NOV 2014	-0.11	0.58	0.55	**-0.64**
DEC 2014	0.27	0.56	0.56	**-0.59**
JAN 2015	0.08	0.60	0.50	**-0.72**
FEB 2015	0.42	0.55	0.58	**-0.67**
MAR 2015	-0.02	0.54	0.56	**-0.69**
APR 2015	-0.46	0.57	0.54	**-0.76**
MAY 2015	0.08	0.52	0.55	**-0.75**

Sample for Exploratory Study

- Combination of interval data from two sources matched the population distribution fairly well
- Combined sample was post-stratified and weighted to match the current population





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Post Stratification

Stratum	Population Count	Stratum Weight	System Size Low End (kW)	System Size High End(kW)	Random Sample Count	AMI Sample Count	Total Sample Count
1	5,680	0.1462	0	<= 3	12	100	112
2	7,174	0.1846	> 3	<= 4	12	110	122
3	10,239	0.2635	> 4	<= 5.5	24	168	192
4	8,534	0.2196	> 5.5	<= 7.5	13	116	129
5	6,350	0.1634	> 7.5	<= 10	14	99	113
6	886	0.0228	> 10	<= 72	0	20	20
Total	38,863				75	613	688

About the Data

- Data collection: June 1, 2014 – May 31, 2015
- Hourly integrated 15-minute intervals
- Combined Operational Random Sample and AMI initial phase rollout
- n = 688 PV systems
- N = 38,863 PV systems (as of Nov. 6, 2015)

NEM Contribution to the Monthly Evening System Peaks (Total Load)

Month and Year	Date of Evening Peak	Time of Evening Peak	Total Group Load (kW)	90% CI +/- (kW)	Relative Precision
June 2014	30	8:00 PM	77,990	4,508	5.8%
July 2014	21	7:45 PM	95,609	4,866	5.1%
August 2014	12	7:30 PM	88,013	5,068	5.8%
September 2014	22	7:00 PM	91,300	5,337	5.8%
October 2014	6	7:00 PM	89,129	5,096	5.7%
November 2014	4	6:30 PM	84,925	6,281	7.4%
December 2014	9	6:45 PM	73,642	4,889	6.6%
January 2015	19	7:00 PM	76,411	4,984	6.5%
February 2015	3	7:00 PM	75,157	5,221	6.9%
March 2015	2	7:15 PM	68,375	4,119	6.0%
April 2015	23	7:15 PM	75,168	4,449	5.9%
May 2015	4	7:30 PM	68,159	4,169	6.1%

This table defines Evening as 17:00 through midnight

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NEM Contribution to the Monthly Daytime System Peaks (Total Load)

Month and Year	Date of Daytime Peak	Time of Daytime Peak	Total Group Load (kW)	90% CI +/- (kW)	Relative Precision
June 2014	2	2:00 PM	-22,974	8,061	35.1%
July 2014	21	3:00 PM	-23,079	5,805	25.2%
August 2014	12	3:00 PM	-62,499	6,036	9.7%
September 2014	29	3:00 PM	-36,602	5,439	14.9%
October 2014	7	2:15 PM	15,073	4,073	27.0%
November 2014	6	3:00 PM	-22,521	3,743	16.6%
December 2014	10	3:00 PM	6,697	3,633	54.2%
January 2015	23	2:45 PM	-9,806	3,524	35.9%
February 2015	3	9:45 AM	26,239	2,960	11.3%
March 2015	31	3:00 PM	3,346	3,183	95.2%
April 2015	24	3:00 PM	-81,770	4,088	5.0%
May 2015	28	3:00 PM	-7,247	4,212	58.1%

This table defines daytime as midnight through 17:00

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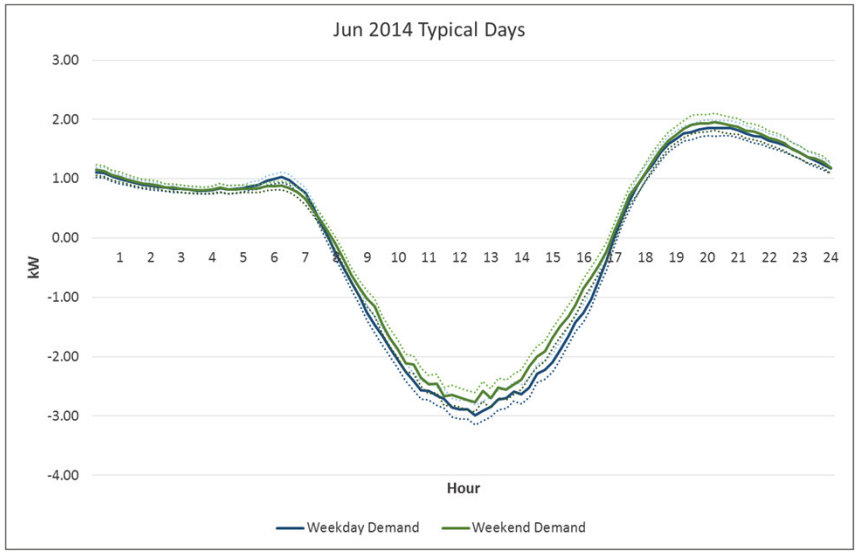
NEM Group Minimums (Total Load)

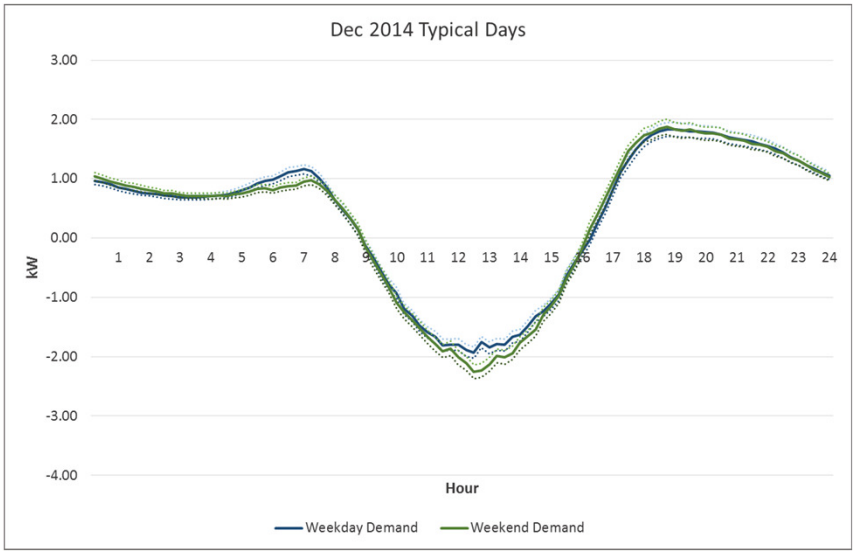
Month and Year	Date of NEM Group Minimum	Time of NEM Group Minimum	Total Group Load (kW)	90% CI +/- (kW)	Relative Precision
June 2014	20	1:30 PM	-132,424	4,923	3.7%
July 2014	24	12:15 PM	-132,954	4,206	3.2%
August 2014	6	1:15 PM	-131,844	4,469	3.4%
September 2014	11	12:15 PM	-122,822	4,553	3.7%
October 2014	28	12:30 PM	-119,199	3,943	3.3%
November 2014	25	12:30 PM	-119,684	3,555	3.0%
December 2014	5	11:45 AM	-109,941	3,942	3.6%
January 2015	26	1:00 PM	-127,168	3,805	3.0%
February 2015	18	1:00 PM	-133,232	3,479	2.6%
March 2015	27	12:30 PM	-149,500	3,360	2.2%
April 2015	9	1:15 PM	-151,305	3,333	2.2%
May 2015	19	12:30 PM	-146,360	3,493	2.4%

NEM Group Peaks (Total Load)

Month and Year	Date of NEM Group Peak	Time of NEM Group Peak	Total Group Load (kW)	90% CI +/- (kW)	Relative Precision
June 2014	29	8:30 PM	88,040	5,576	6.3%
July 2014	21	8:00 PM	97,266	4,771	4.9%
August 2014	25	7:45 PM	91,463	5,138	5.6%
September 2014	14	7:45 PM	102,466	5,324	5.2%
October 2014	6	8:00 PM	95,333	4,935	5.2%
November 2014	2	6:45 PM	89,601	5,770	6.4%
December 2014	7	6:45 PM	78,865	5,614	7.1%
January 2015	25	7:30 PM	77,890	4,752	6.1%
February 2015	3	7:30 PM	78,459	5,386	6.9%
March 2015	11	8:00 PM	78,293	4,843	6.2%
April 2015	26	7:15 PM	81,635	4,602	5.6%
May 2015	21	8:30 PM	73,880	4,408	6.0%

Solar Irradiation Seasonal Change (Average Customer)





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Future Sample Design Recommendations

- Define total rate class population
- Split that population into NEM and non-NEM
- Stratify non-NEM group conventionally (based on annual energy use)
- Stratify NEM group based on PV system size (probably only 2 strata)
- Develop weights based on entire population
- Expand entire sample (both NEM and non-NEM strata) using both a combined ratio estimate on billing energy and a mean-per-unit; compare results