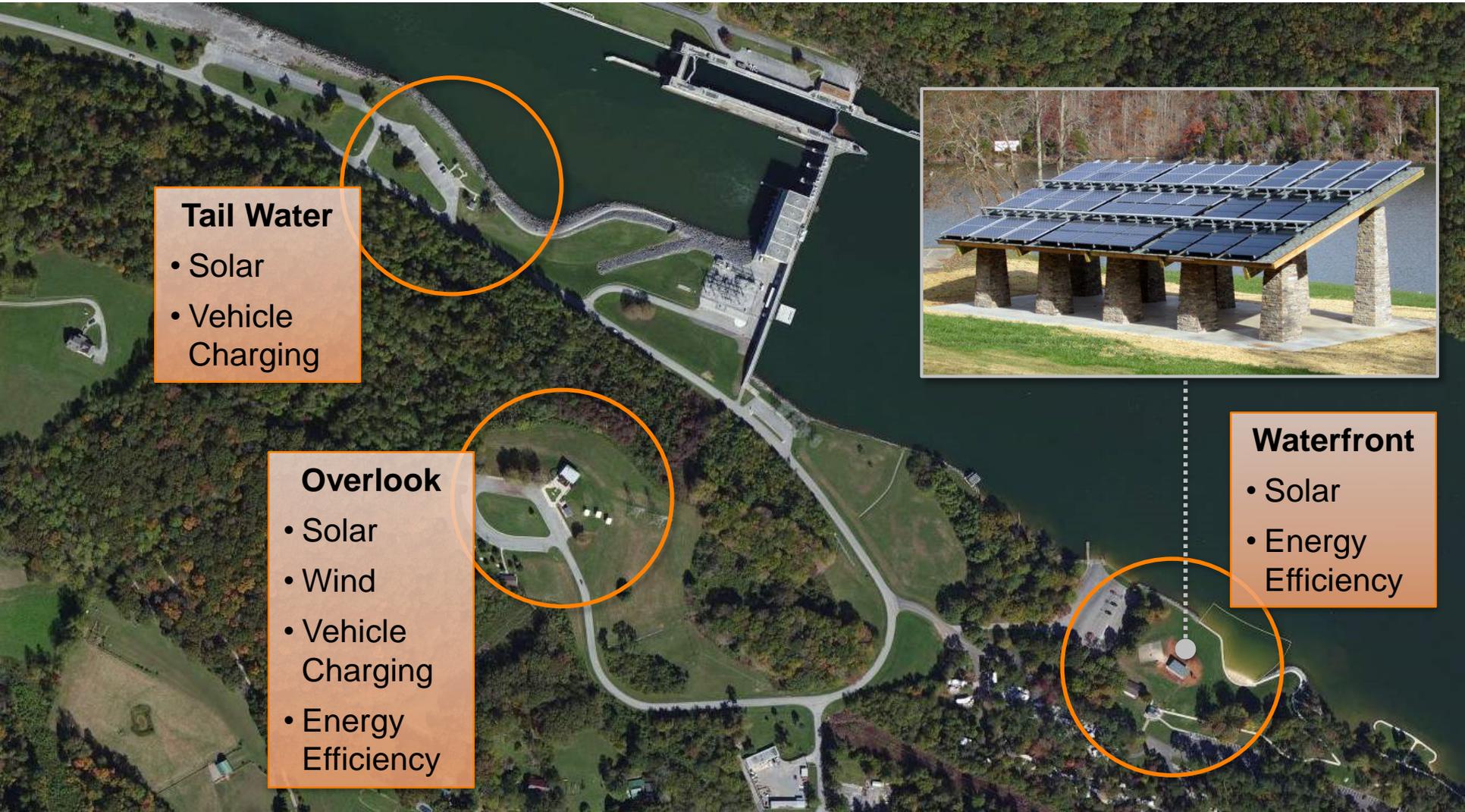


TVA Melton Hill Dam Sustainable Recreation Area

Field monitoring and analysis of renewable and efficient technologies



Tail Water

- Solar
- Vehicle Charging

Overlook

- Solar
- Wind
- Vehicle Charging
- Energy Efficiency



Waterfront

- Solar
- Energy Efficiency

1. Energy Generation and Consumption
2. Renewable Energy Performance
3. Solar Thermal Water Heater Performance
4. Environmental Benefits
5. Sample Power Profiles



1. Energy Generation and Consumption



Annual Energy Generation & Consumption

| Annual Energy | 2012 (MWh) | 2013 (MWh) | 2014** (MWh) | 2015*** (MWh) |
|---|---------------|---------------|-----------------|------------------|
| Generation* | 34.0 | 31.6 | 30.4 | 25.8 |
| Consumption | 177.0 | 151.4 | 159.1 | 117.0 |
| Net (consumed) | 143.0 | 119.8 | 128.7 | 91.1 |
| Generation offsets consumption by... | 19.2% | 20.9% | 19.1% | 22.1% |

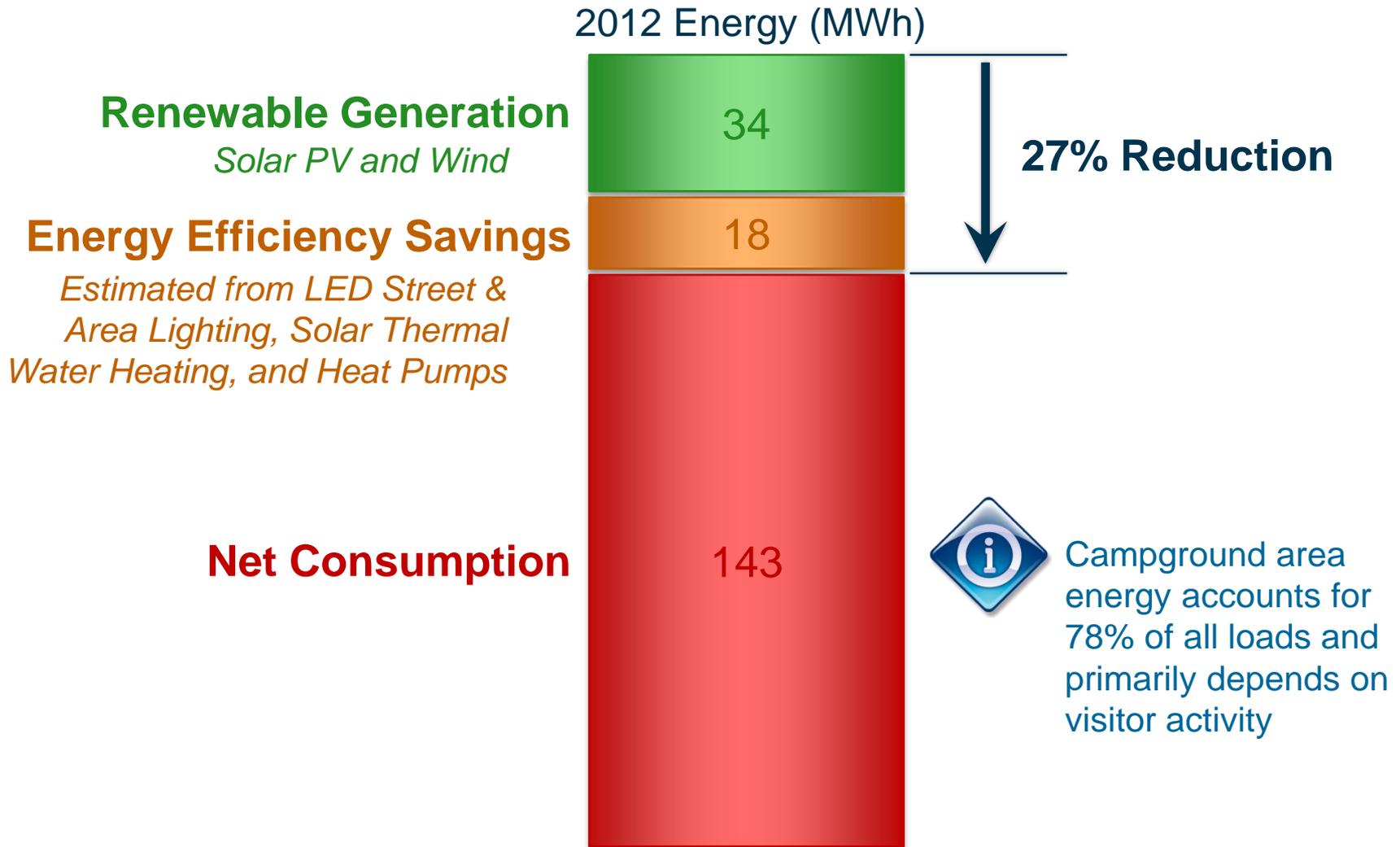
* Generation = Solar + Wind. In each full year, wind power generated 0.2MWh.

** Inverter failures on two PV systems caused lower than normal solar generation in 2014.

*** Data in 2015 is through the end of Sep.

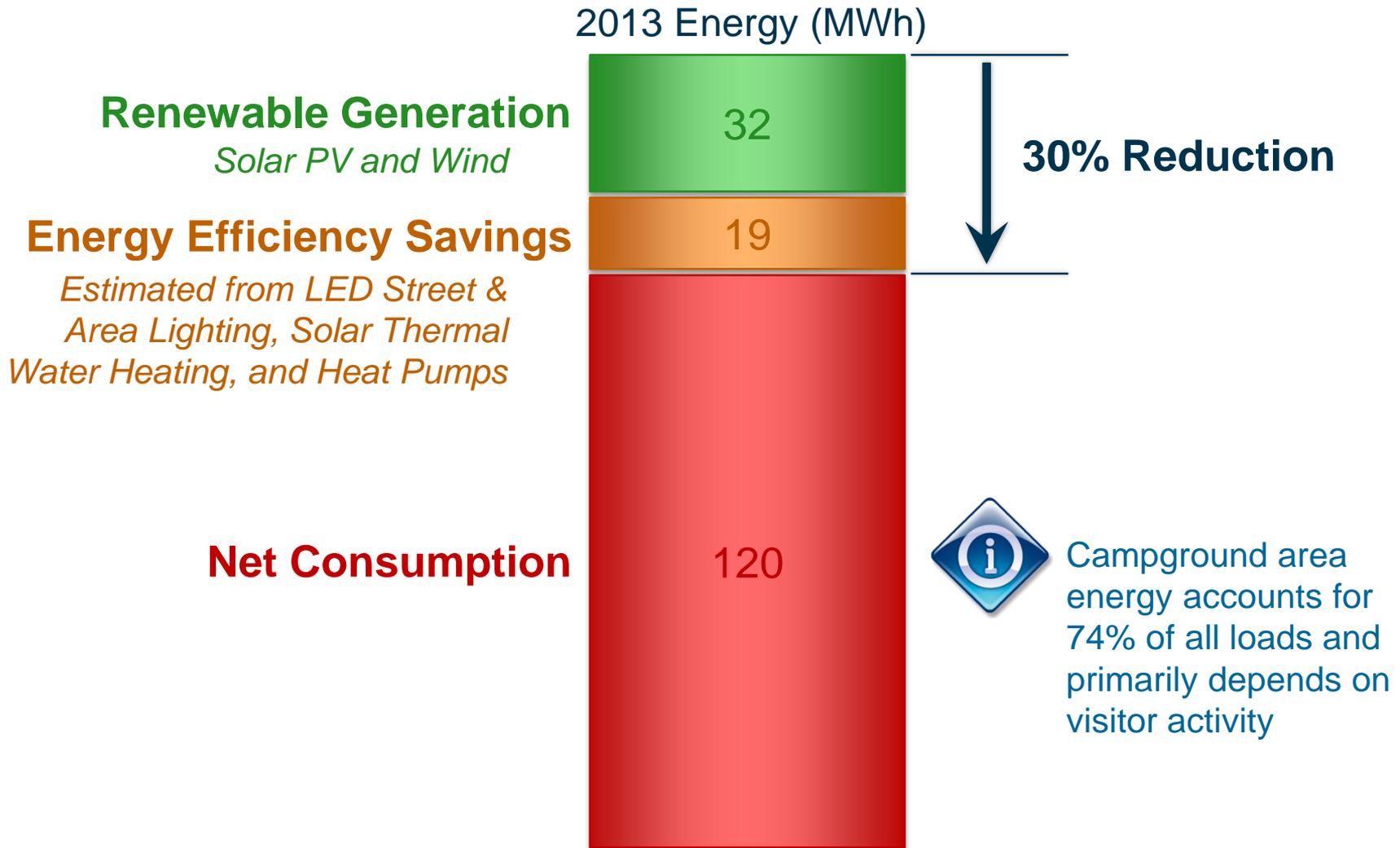
Net Energy Reduced by 27% for 2012

A combination of renewable generation and energy efficiency savings



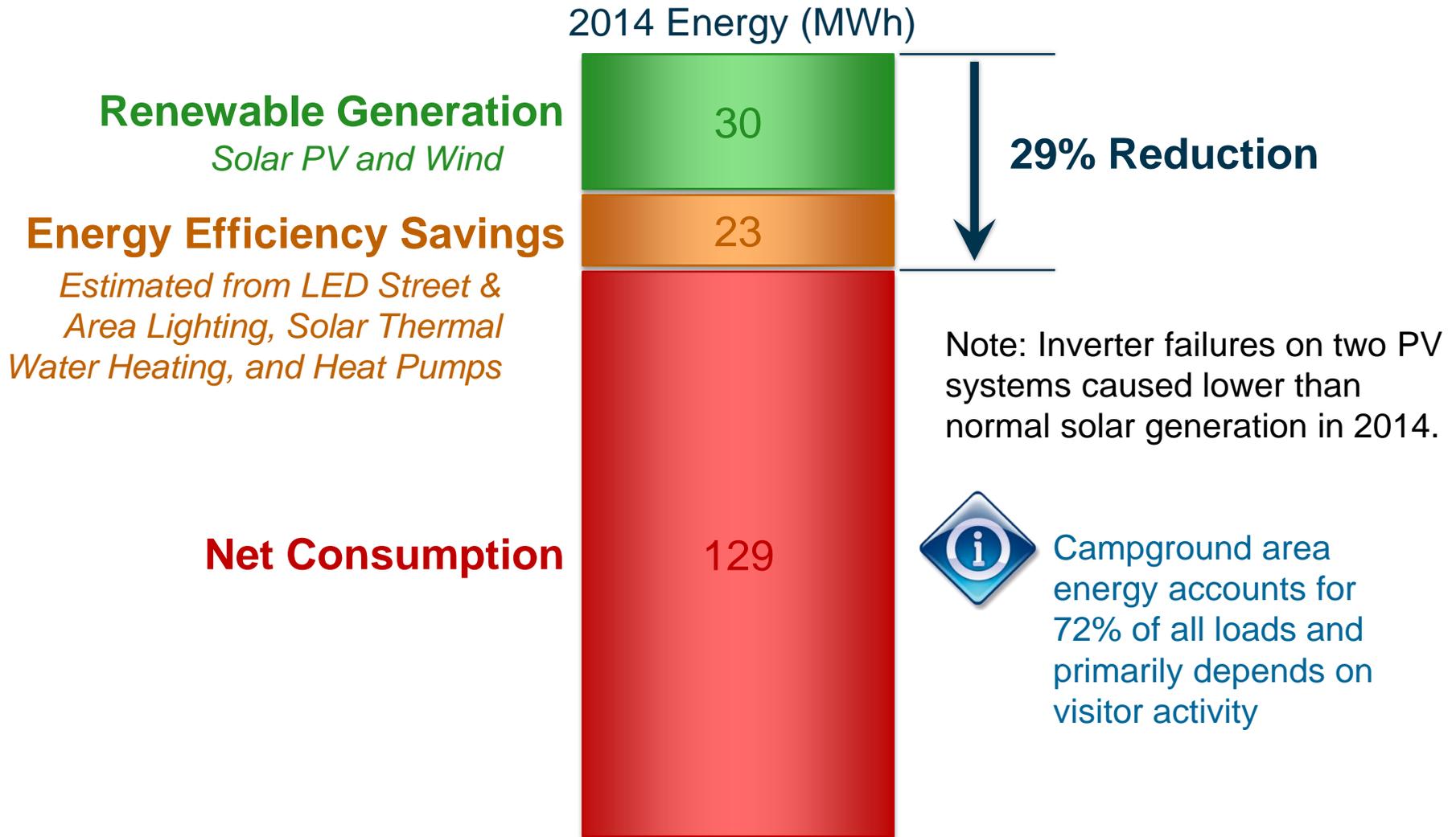
Net Energy Reduced by 30% for 2013

A combination of renewable generation and energy efficiency savings

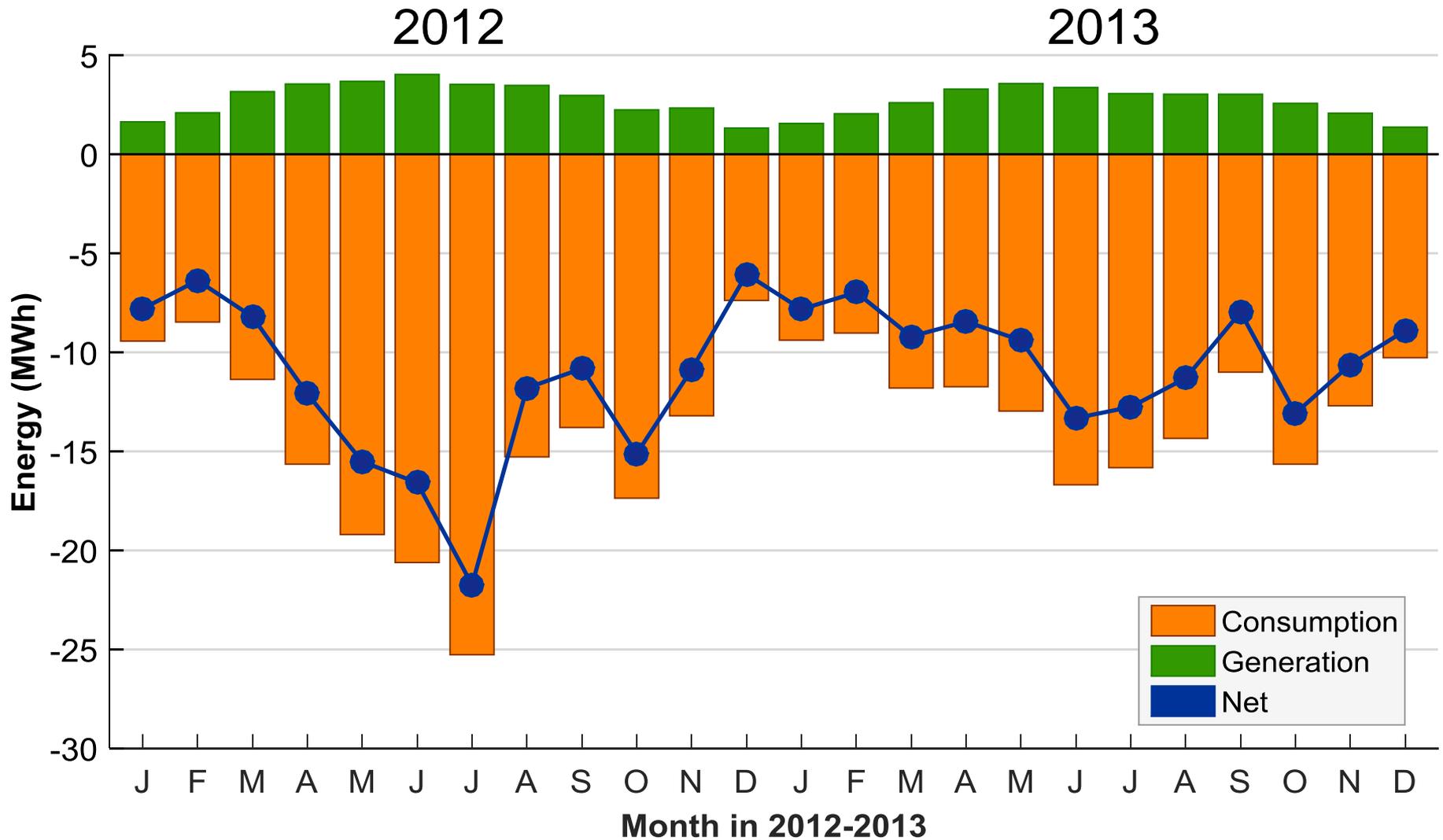


Net Energy Reduced by 29% for 2014

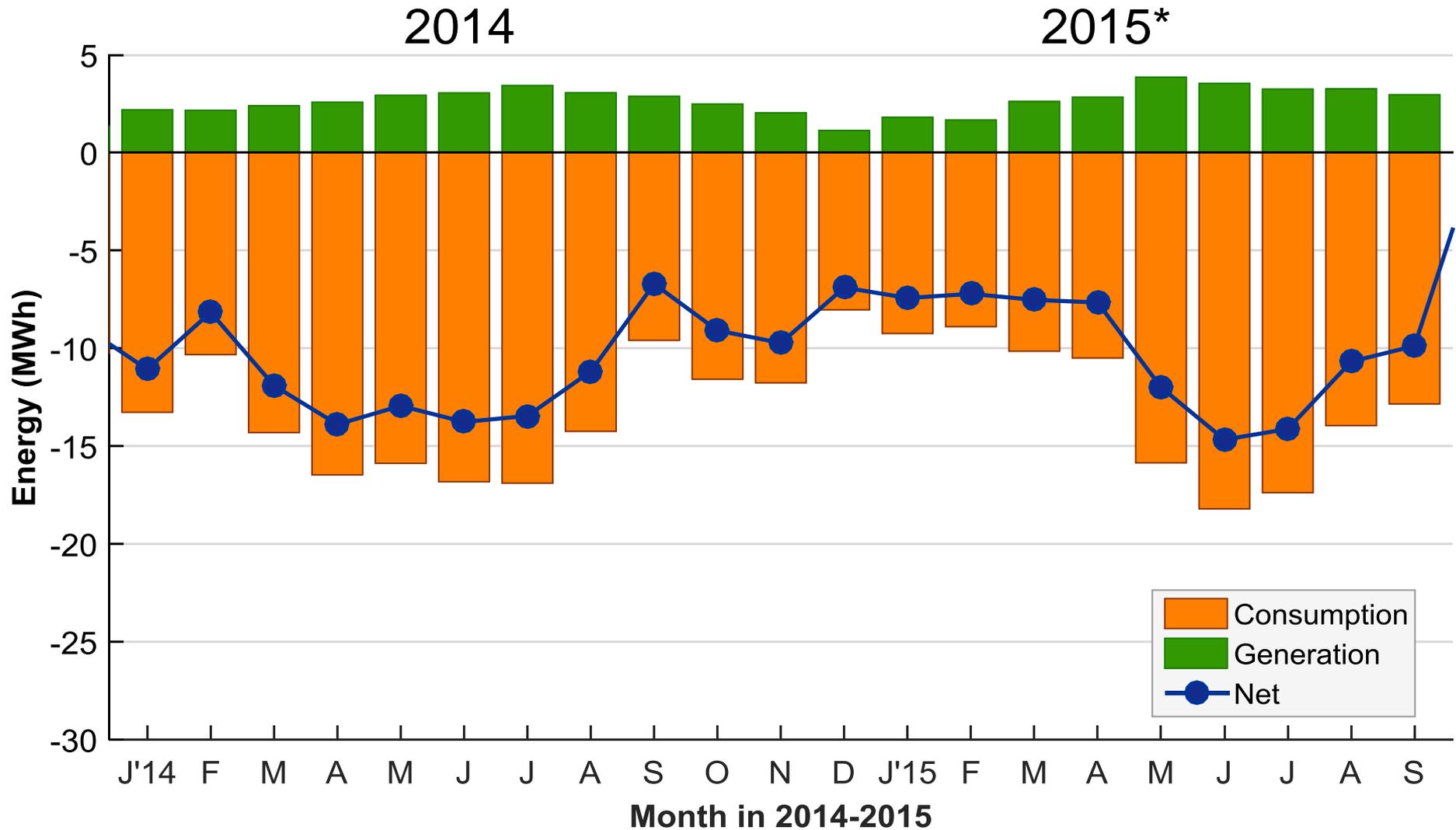
A combination of renewable generation and energy efficiency savings



Monthly Generation, Consumption, and Net for Entire Recreation Area, 2012-2013



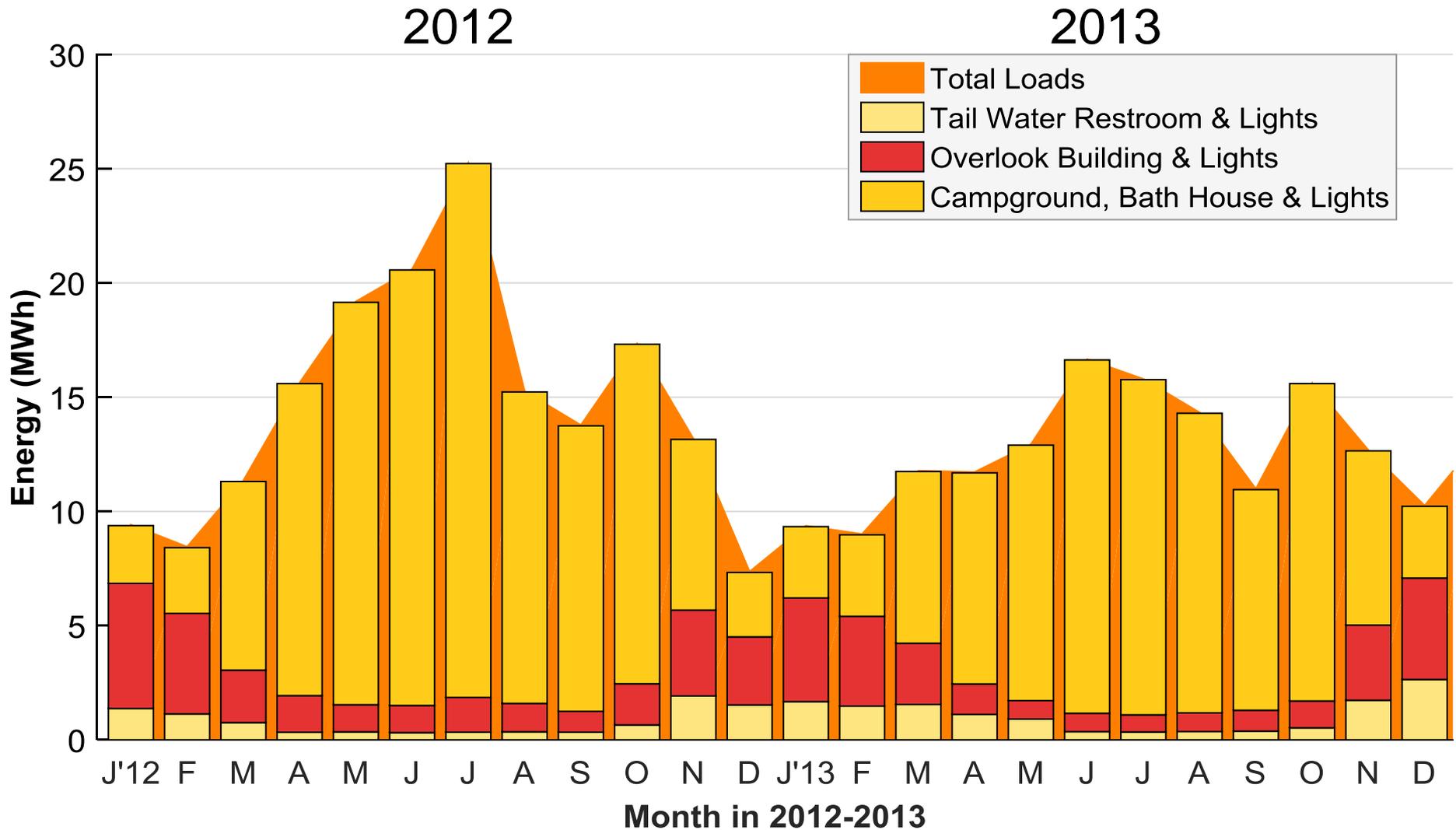
Monthly Generation, Consumption, and Net for Entire Recreation Area, 2014-Sep 2015



* Data in 2015 is through the end of Sep.

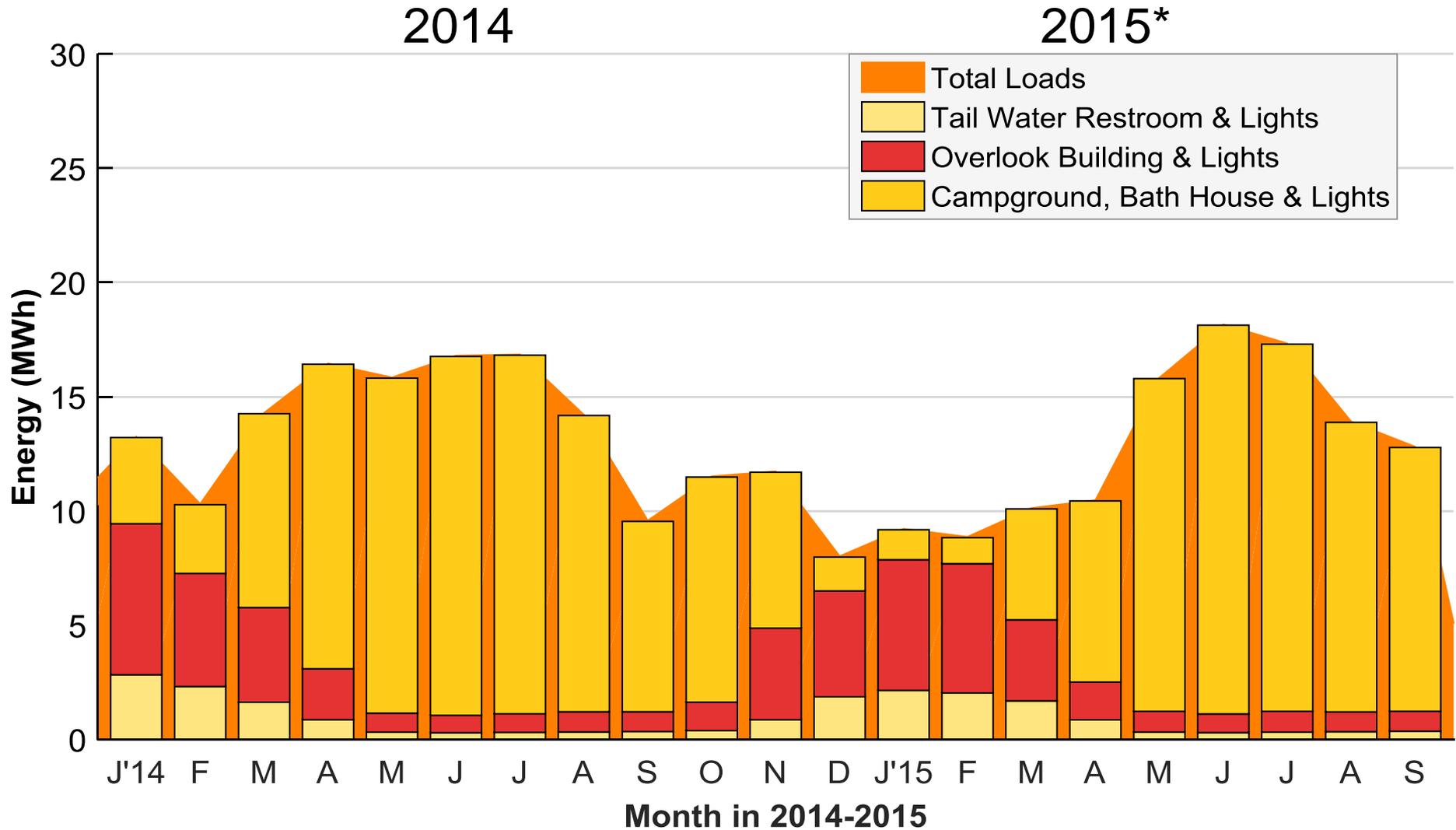
Monthly Energy Consumption: By Area, 2012-2013

Shown as stacked bars with shaded area for overall load in background



Monthly Energy Consumption: By Area, 2014-Sep 2015

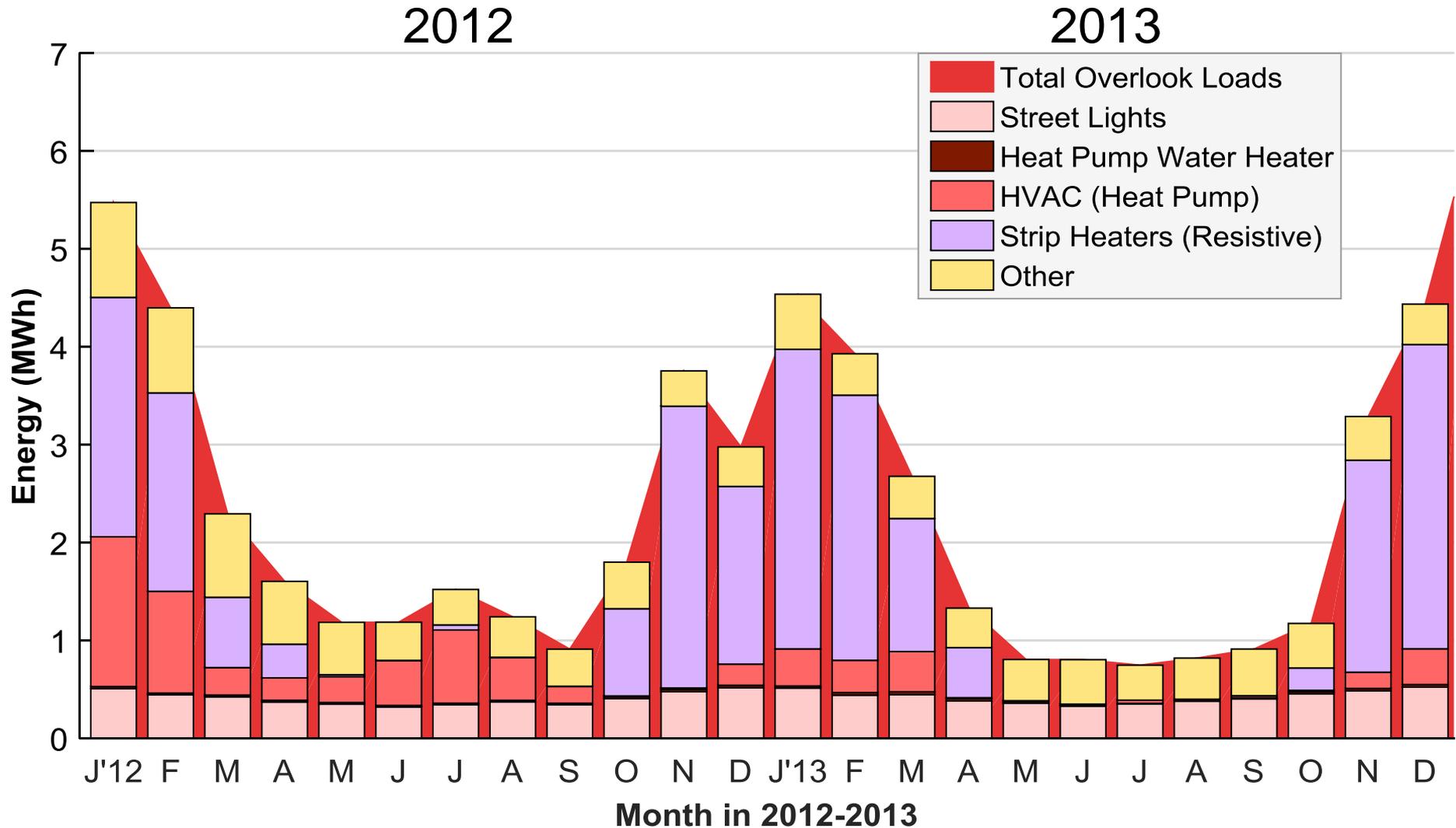
Shown as stacked bars with shaded area for overall load in background



* Data in 2015 is through the end of Sep.

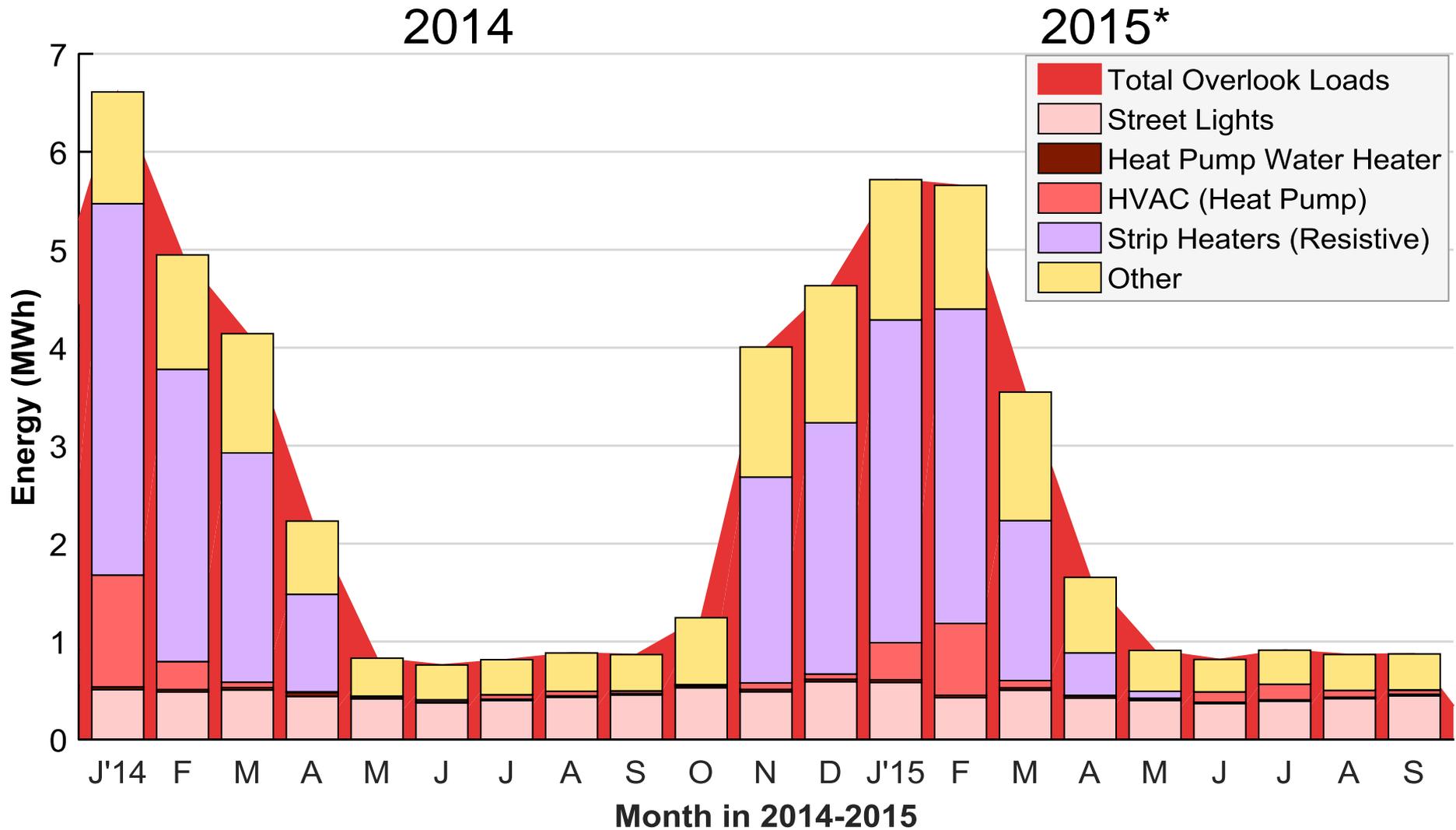
Monthly Energy Consumption: Overlook, 2012-2013

Shown as stacked bars with shaded area for total Overlook loads



Monthly Energy Consumption: Overlook, 2014-Sep 2015

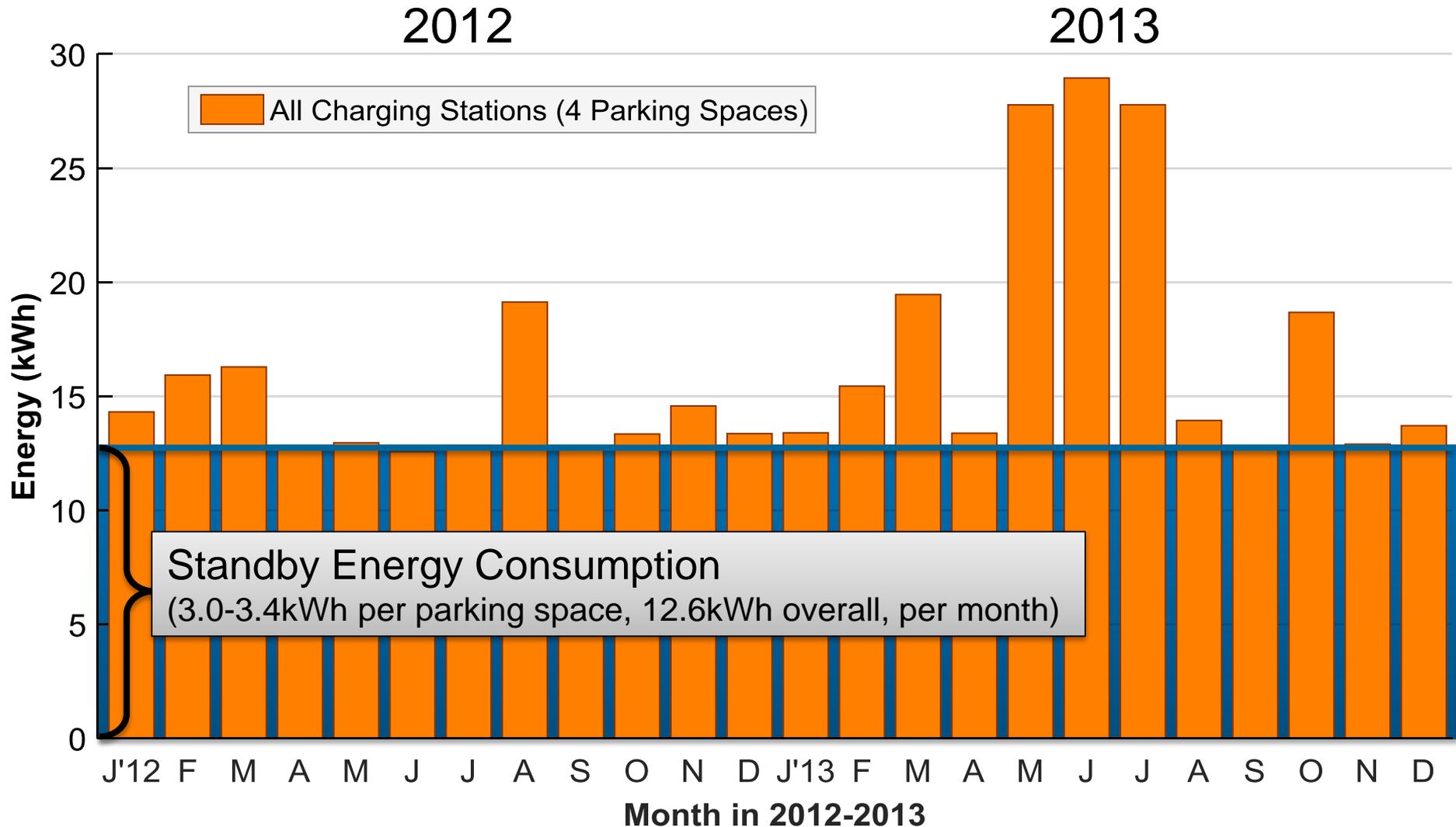
Shown as stacked bars with shaded area for total Overlook loads



* Data in 2015 is through the end of Sep.

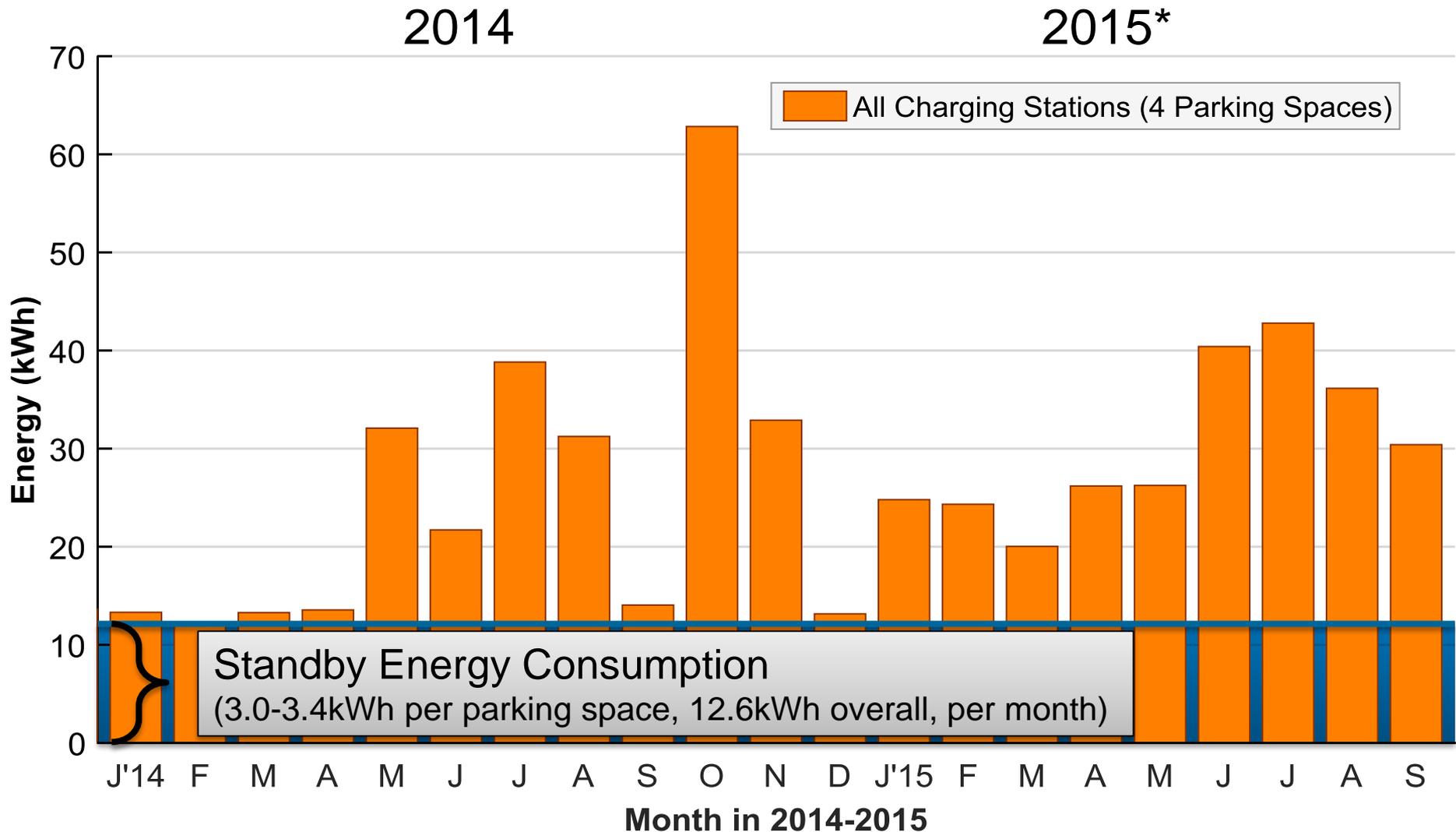
Monthly Consumption: Charging Stations, 2012-2013

Few vehicle charging instances observed; most occurred in 2013



Monthly Consumption: Charging Stations, 2014-Sep 2015

9 months above 30 kWh in 2014-2015, compared to 0 months in 2012-2013



* Data in 2015 is through the end of Sep.

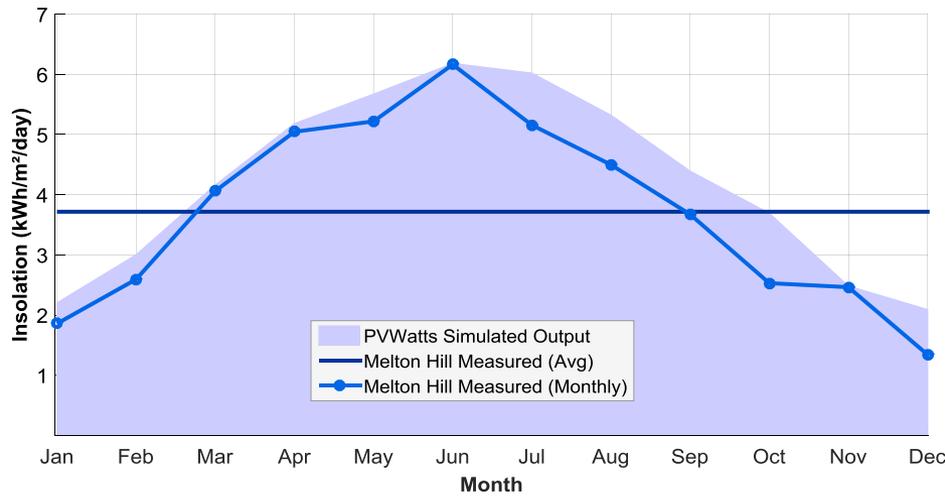
2. Renewable Energy Performance



Monthly Global Horizontal Insolation, 2012-2013

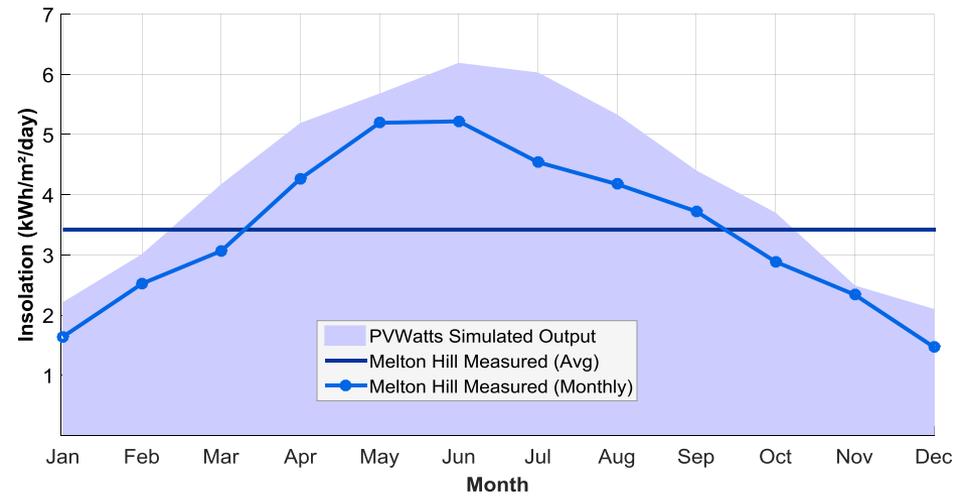
With NREL's PVWatts predicted insolation shown in background

2012



Average **3.72** kWh/m²/day

2013



Average **3.42** kWh/m²/day

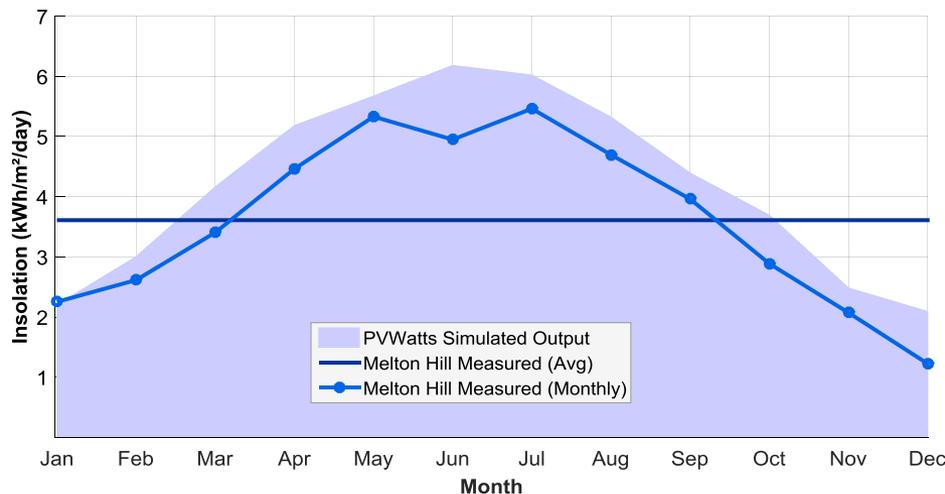
8.1% reduction from 2012

(Oak Ridge weather station shows comparable 8.8% reduction from 2012)

Monthly Global Horizontal Insolation, 2014-Sep 2015

With NREL's PVWatts predicted insolation shown in background

2014

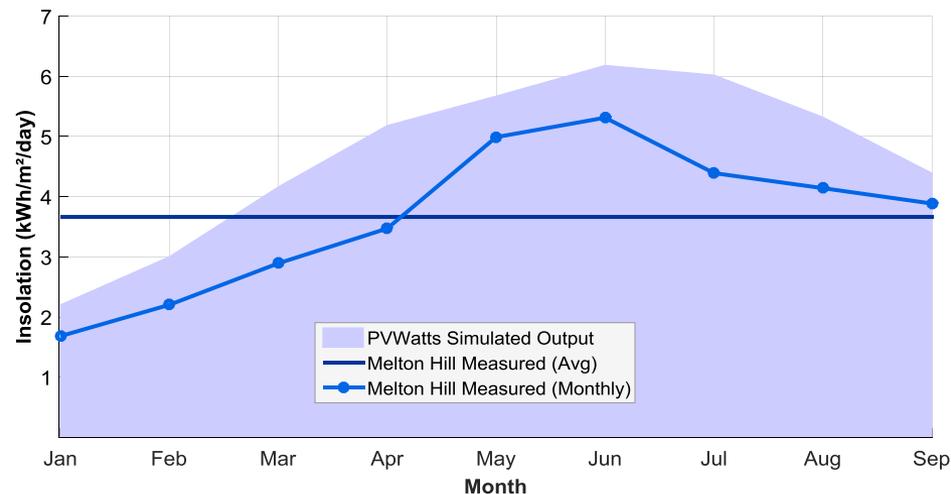


Average **3.61** kWh/m²/day

5.6% increase from 2013

(Oak Ridge weather station shows comparable 6.5% increase from 2013)

2015



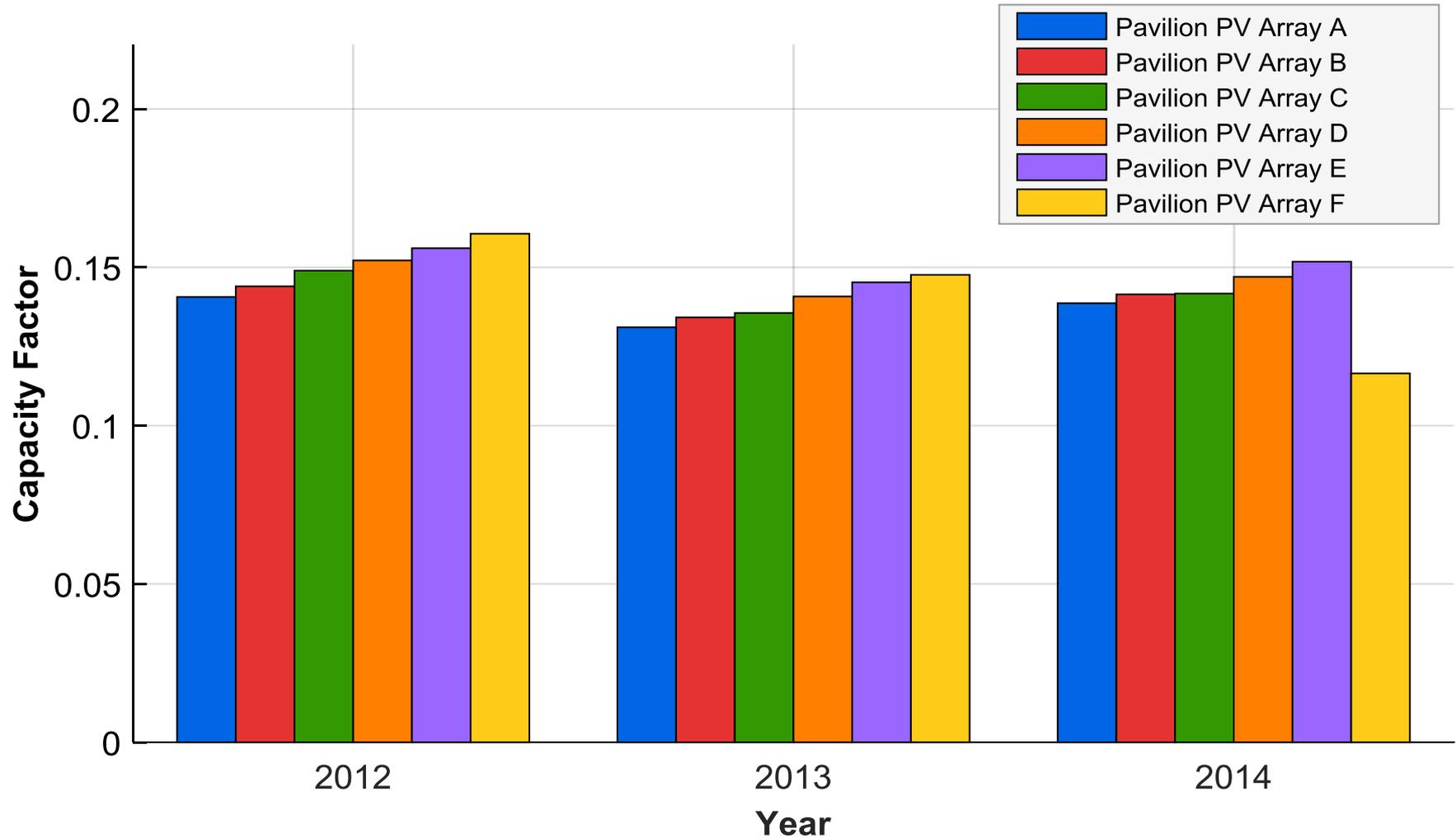
Average **3.66** kWh/m²/day

11.4% reduction from Jan-Sep 2014

(Oak Ridge weather station shows comparable 5.5% reduction from Jan-Sep 2014)

Annual Capacity Factors per System, 2012-2014

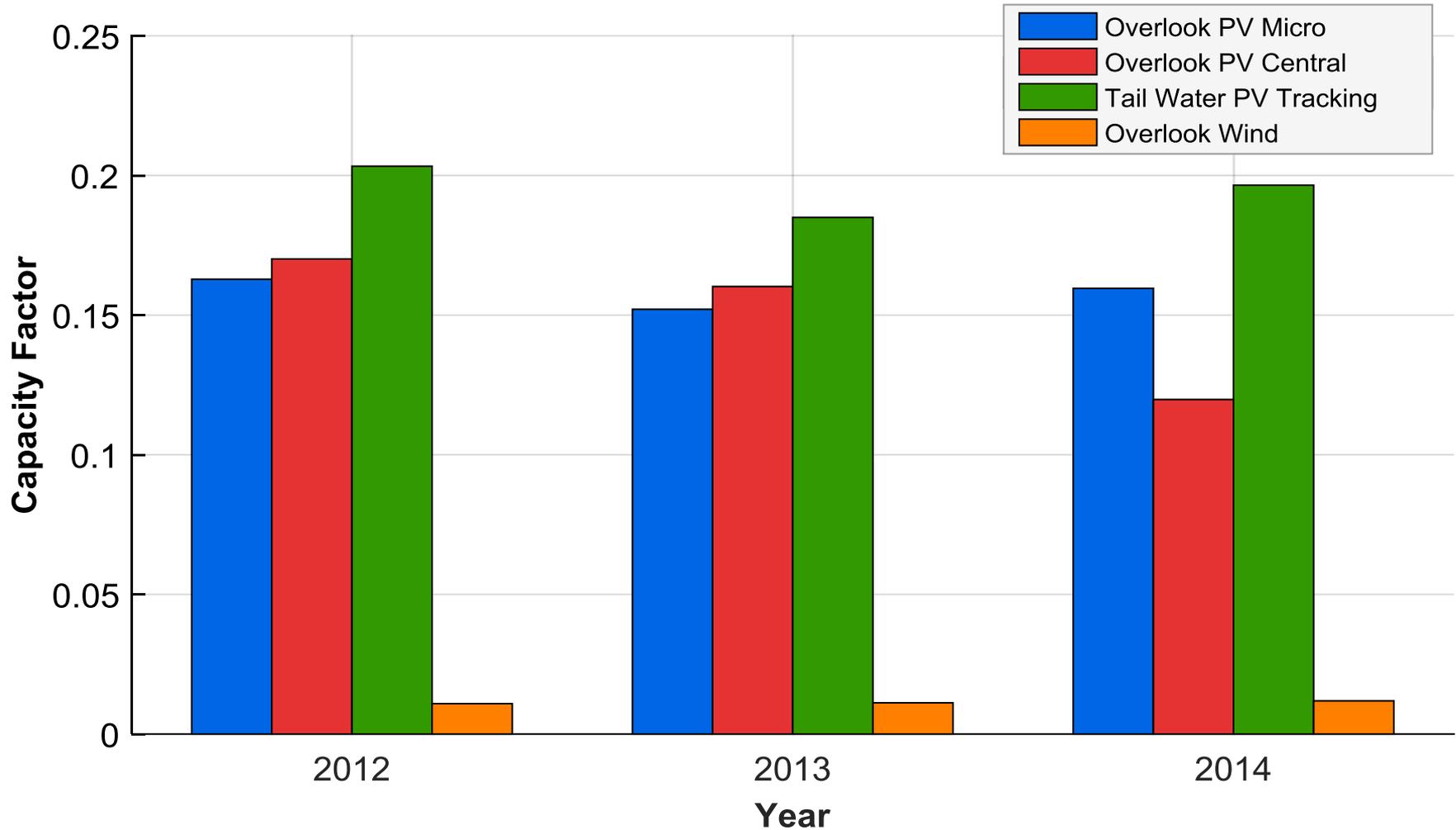
Pavilion Systems



Note: Capacity Factor for Array F was lower than normal in 2014 due to an inverter failure, lasting from 6/30/2014 to 9/12/2014.

Annual Capacity Factors per System, 2012-2014

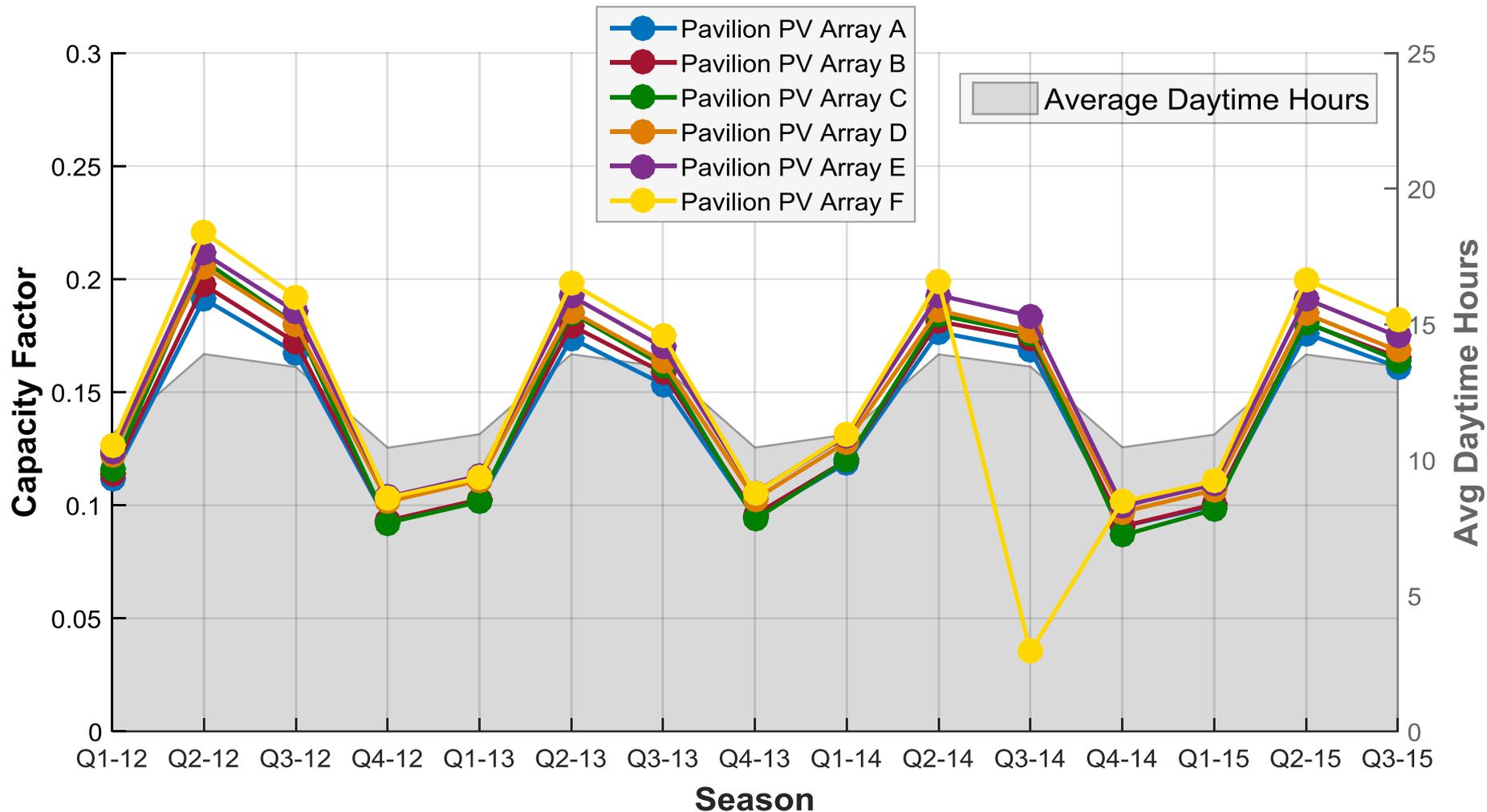
Overlook & Tail Water Systems



Note: Capacity Factor for Overlook PV Central was lower than normal in 2014 due to an inverter failure, lasting from 3/18/2014 to 6/5/2014.

Seasonal Capacity Factors per System, 2012–Q3 2015

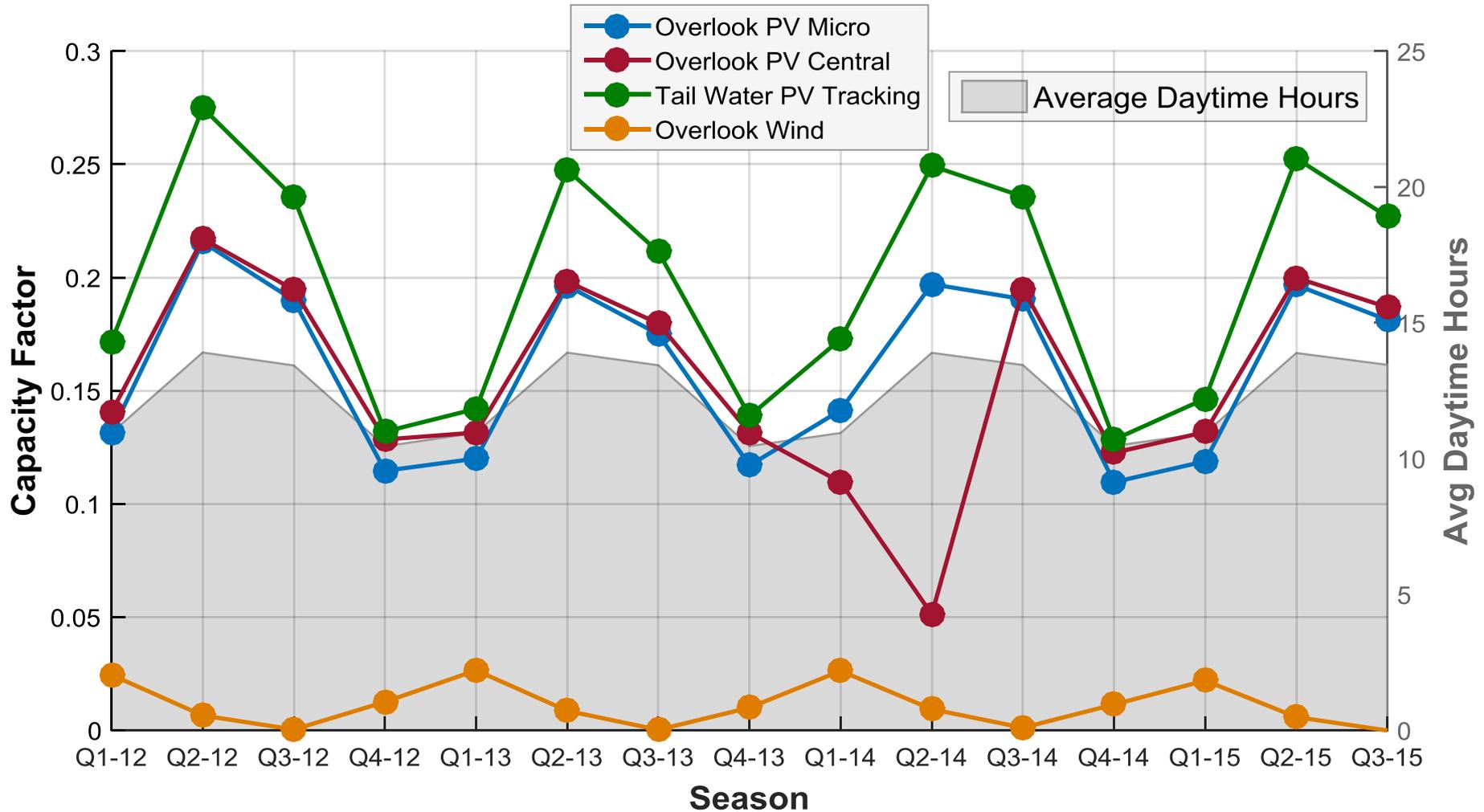
Pavilion Systems



Note: Capacity Factor for Array F was lower than normal in Q3 2014 due to an inverter failure, lasting from 6/30/2014 to 9/12/2014.

Seasonal Capacity Factors per System, 2012–Q3 2015

Overlook & Tail Water Systems



Note: Capacity Factor for Overlook PV Central was lower than normal in Q1 and Q2 2014 due to an inverter failure, lasting from 3/18/2014 to 6/5/2014.

Performance Ratio Definition

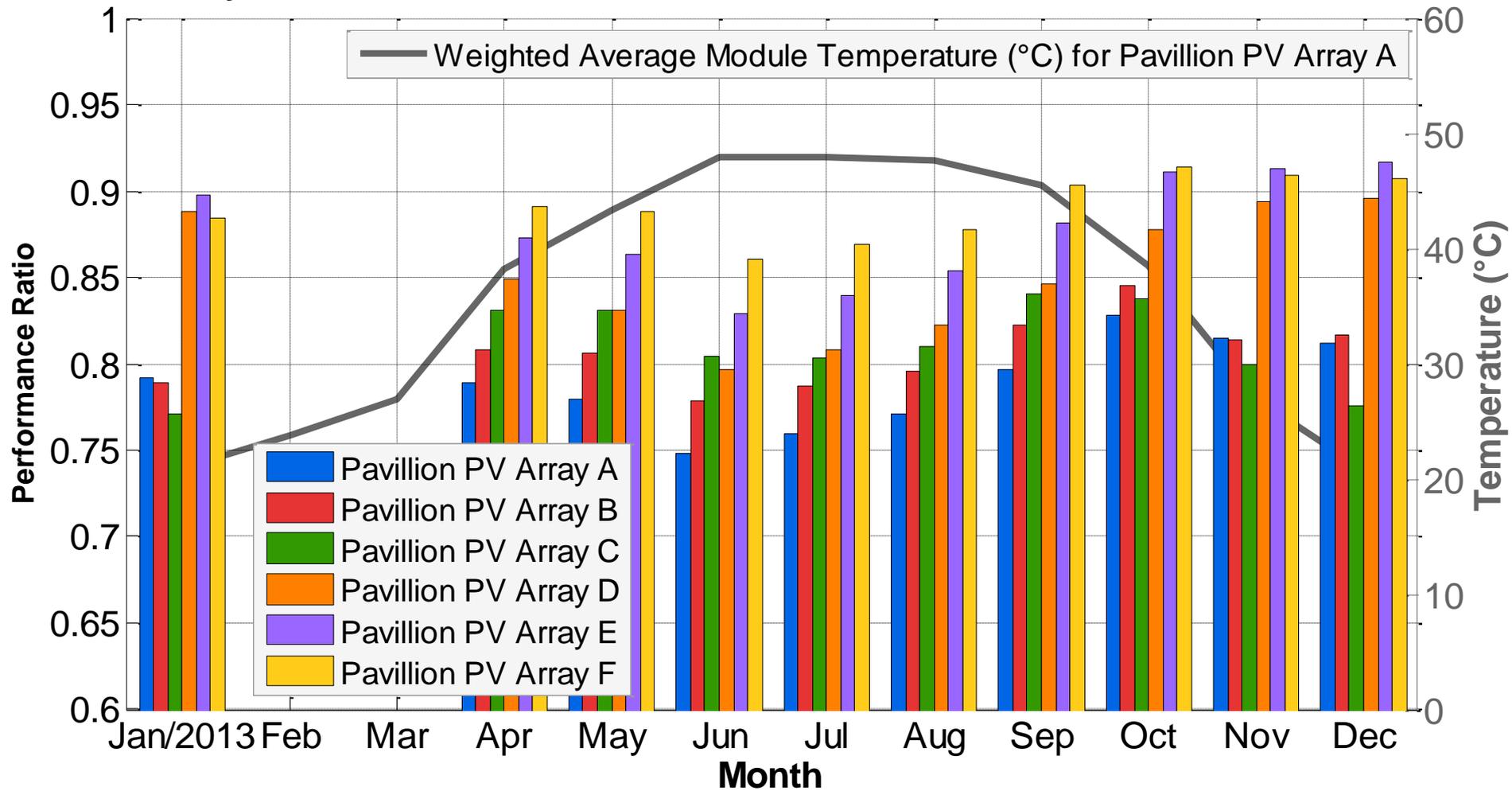
Quantifies how well a system performs given the available solar resource

$$\text{Performance Ratio} = \frac{\text{Energy Output (kWh)} / \text{System Rating (kW)}}{\text{Solar Insolation (Wh/m}^2\text{)} / 1000 \text{ (W/m}^2\text{)}}$$

- Represents how well a PV system performed given the available solar resource
- Useful metric to compare the total energy output of different PV systems
- A factor of 1.0 indicates optimum PV system performance
- Typical values range between 0.7 and 1.0

Monthly Performance Ratio Per System, 2013

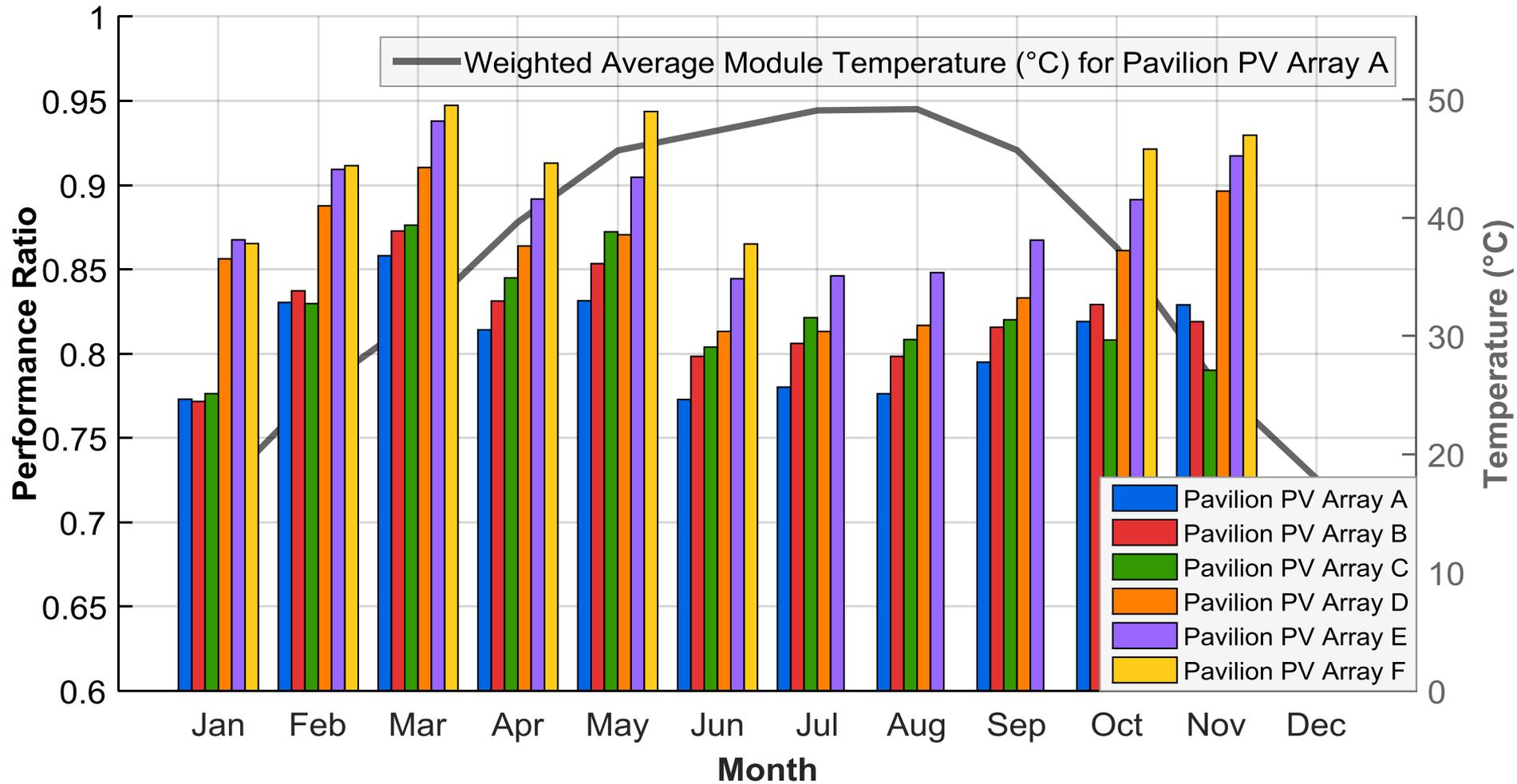
Pavilion Systems



Note: No data in Feb-Mar 2013 due to a communication outage.

Monthly Performance Ratio Per System, 2014

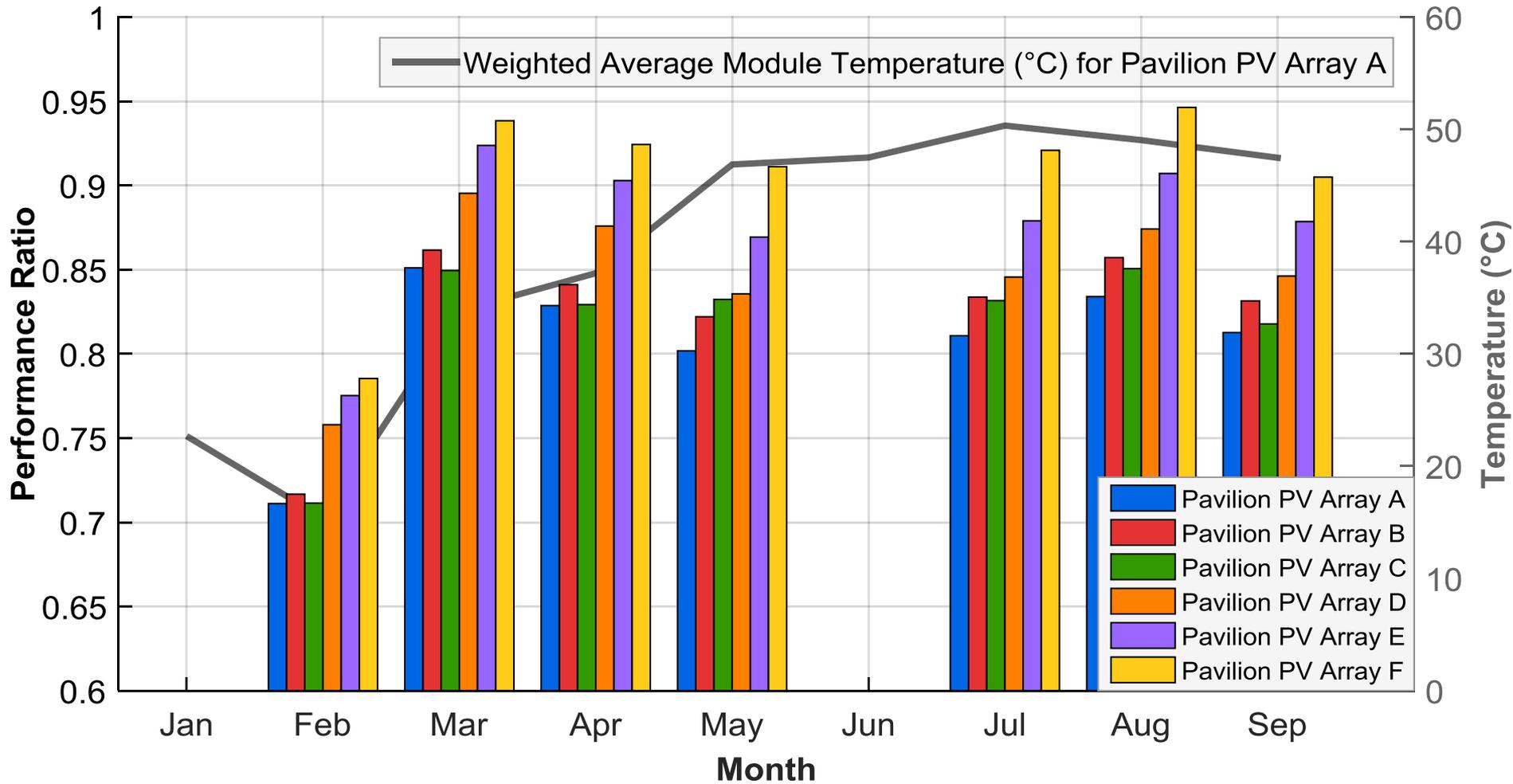
Pavilion Systems



Note: No data in Dec 2014 due to a communication outage.

Monthly Performance Ratio Per System, Jan-Sep 2015

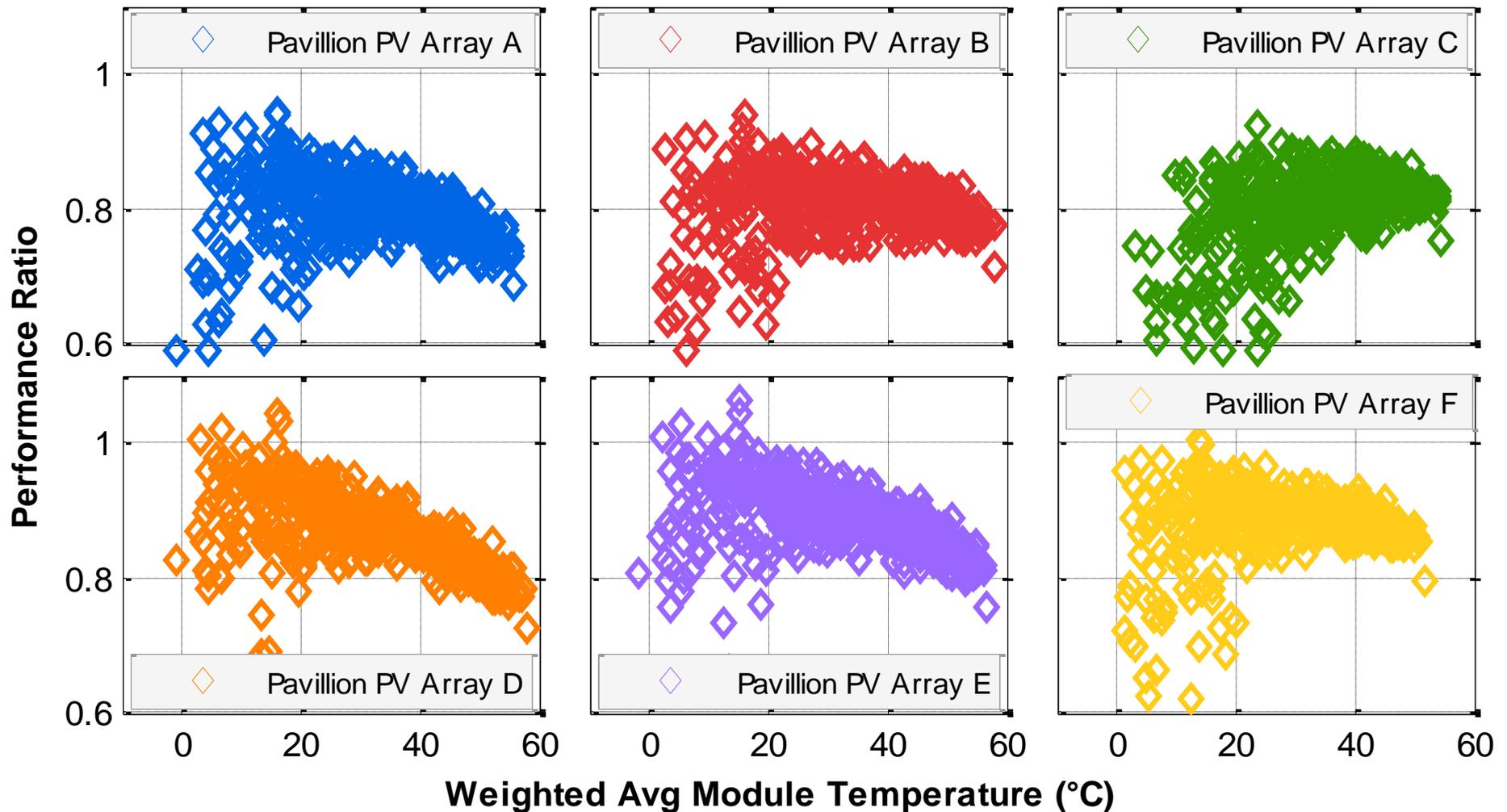
Pavilion Systems



Note: No data in Jan and Jun 2015 due to communication outages.

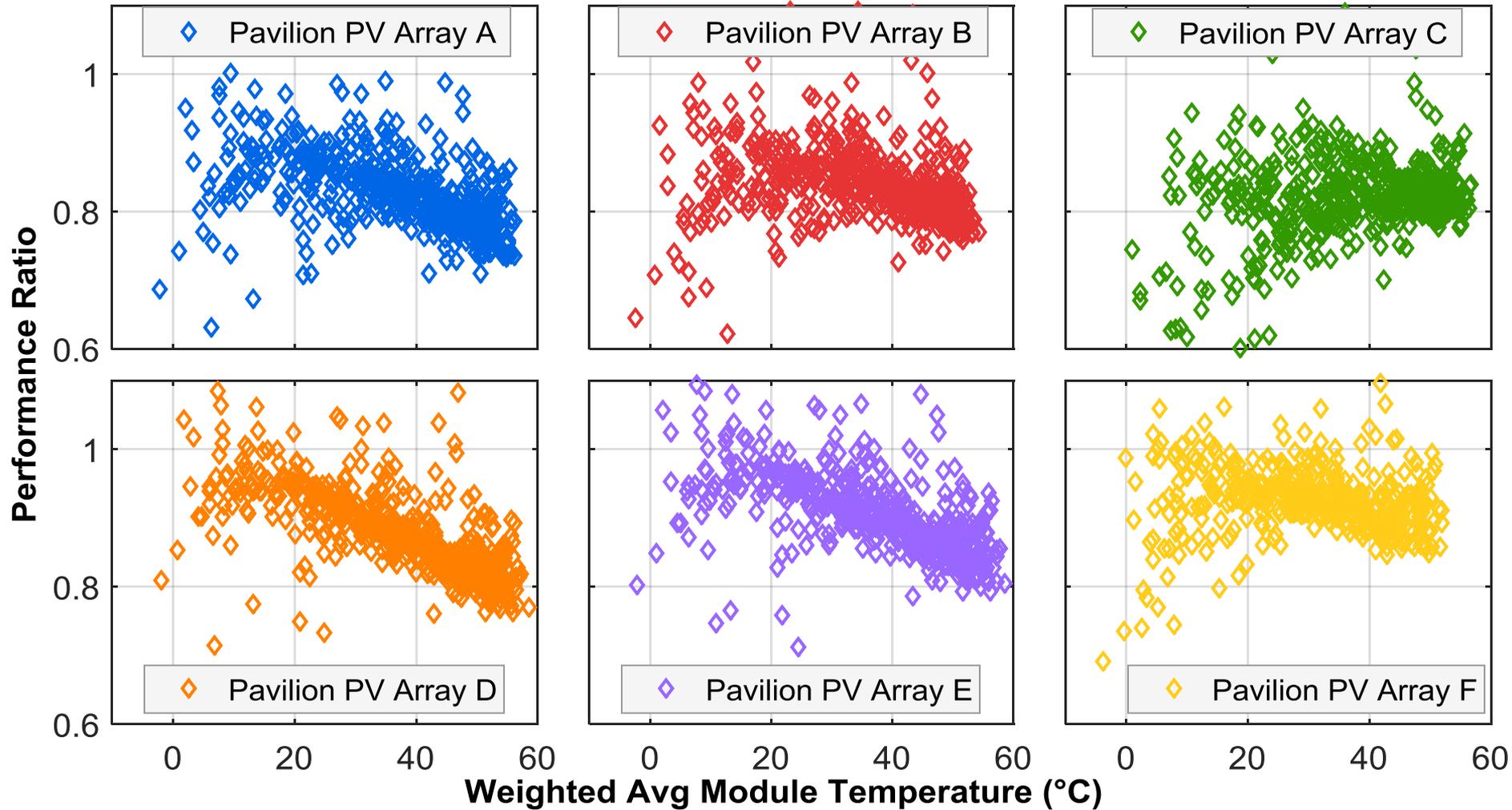
Daily Performance Ratio vs. Temperature, Oct 2012-Dec 2013

Pavillion Systems



Daily Performance Ratio vs. Temperature, 2014-Sep 2015

Pavilion Systems

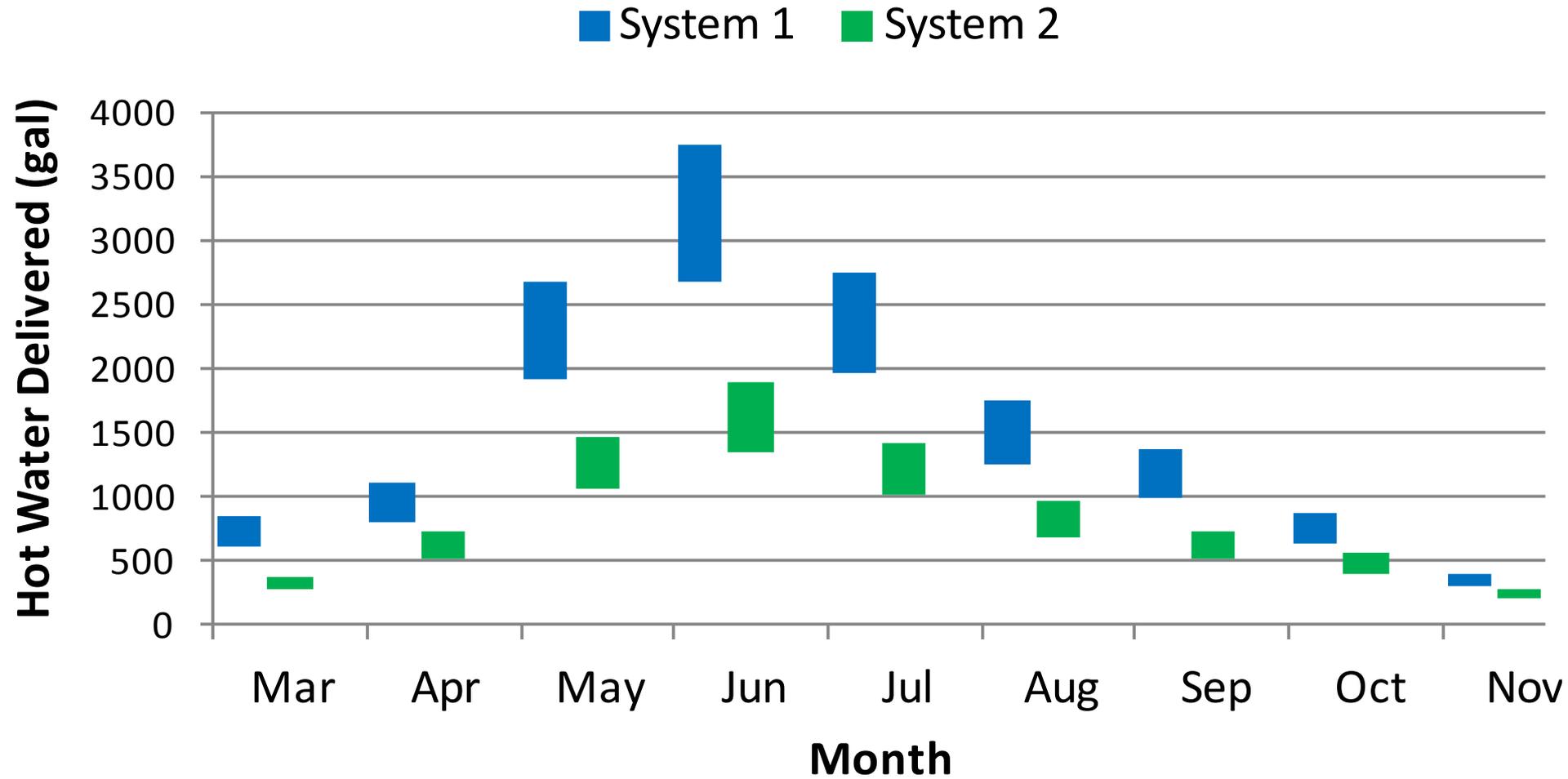


3. Solar Thermal Water Heater Performance



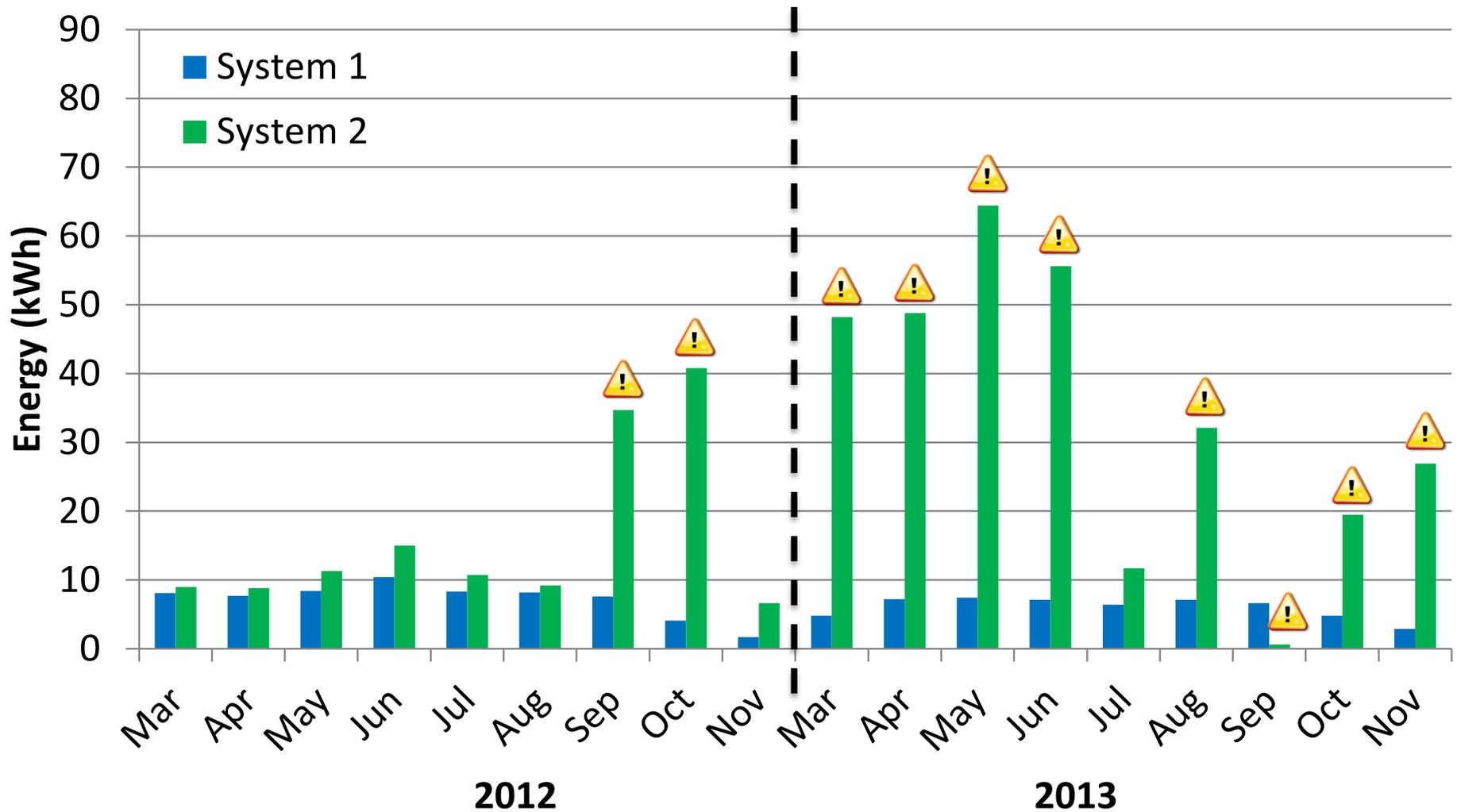
Monthly Hot Water Delivered

For 2012 camping season, colored bars show estimated volume range



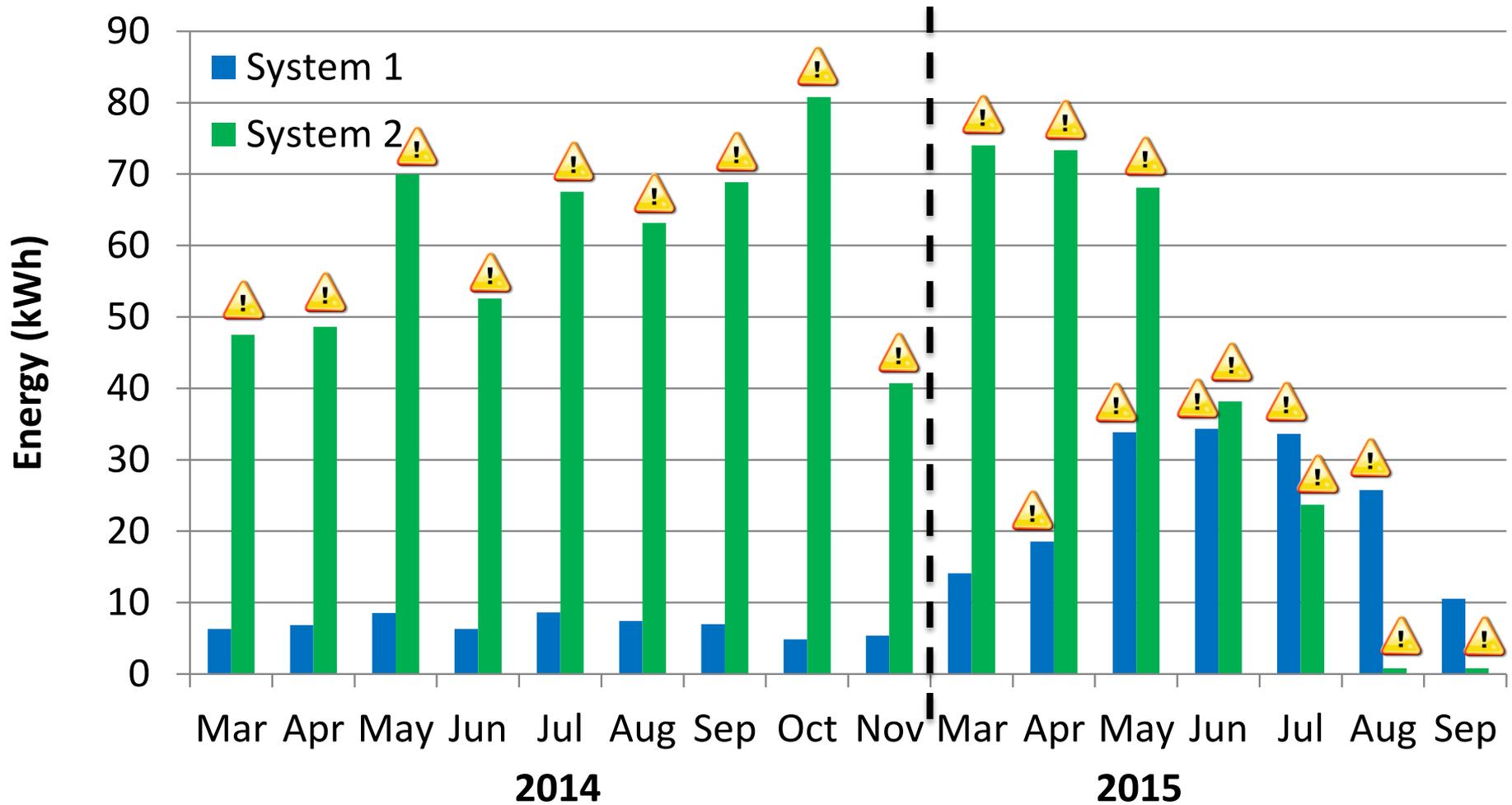
Circulation Pump Energy Consumption

By month, 2012-2013 camping seasons; unexpected energy for System 2



Circulation Pump Energy Consumption

By month, 2014-2015* camping seasons; unexpected energy for both systems**

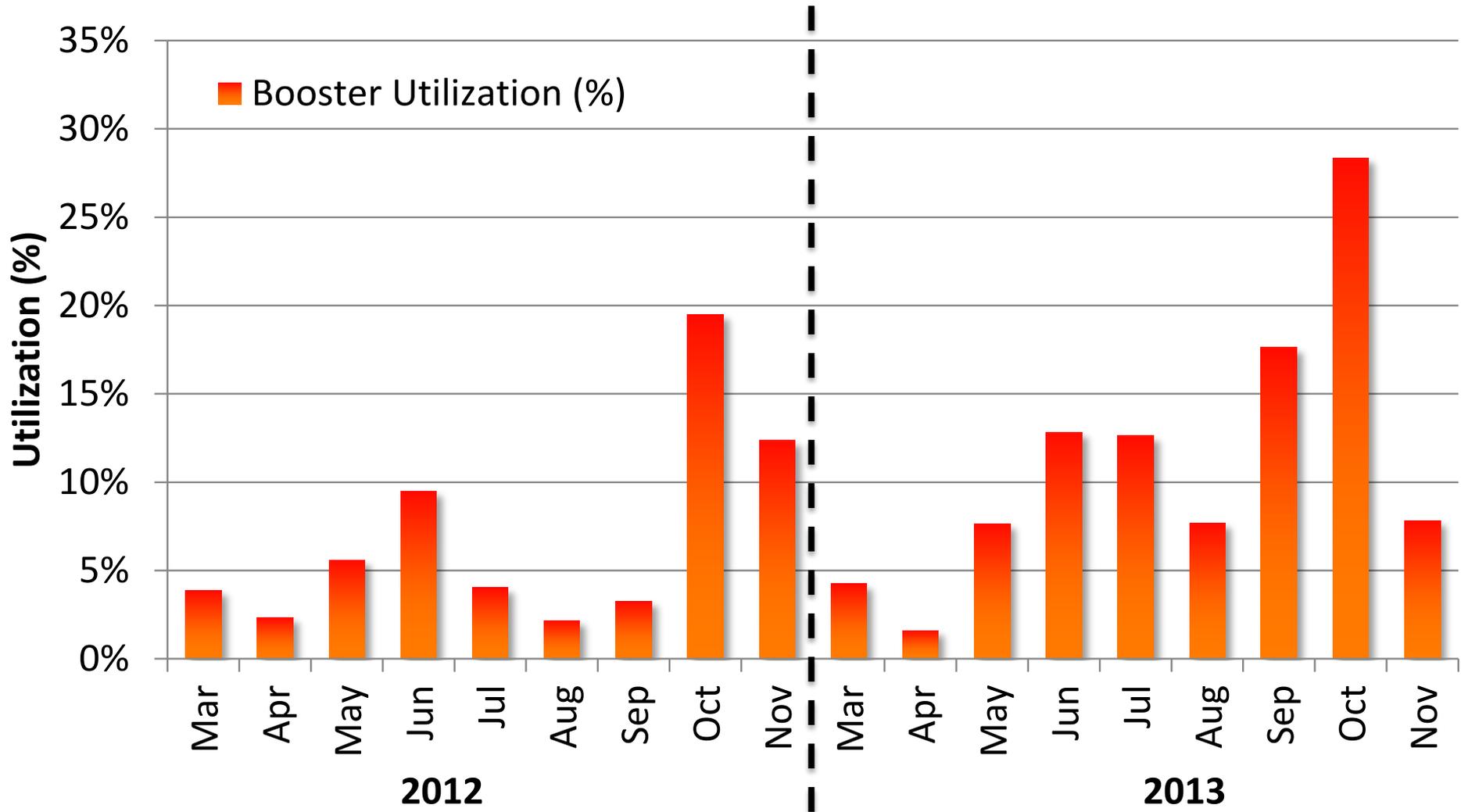


* Data in 2015 is through the end of Sep.

** System 2 pump failed on 7/17/15; System 1 pump was turned off due to poor running condition 9/11/2015.

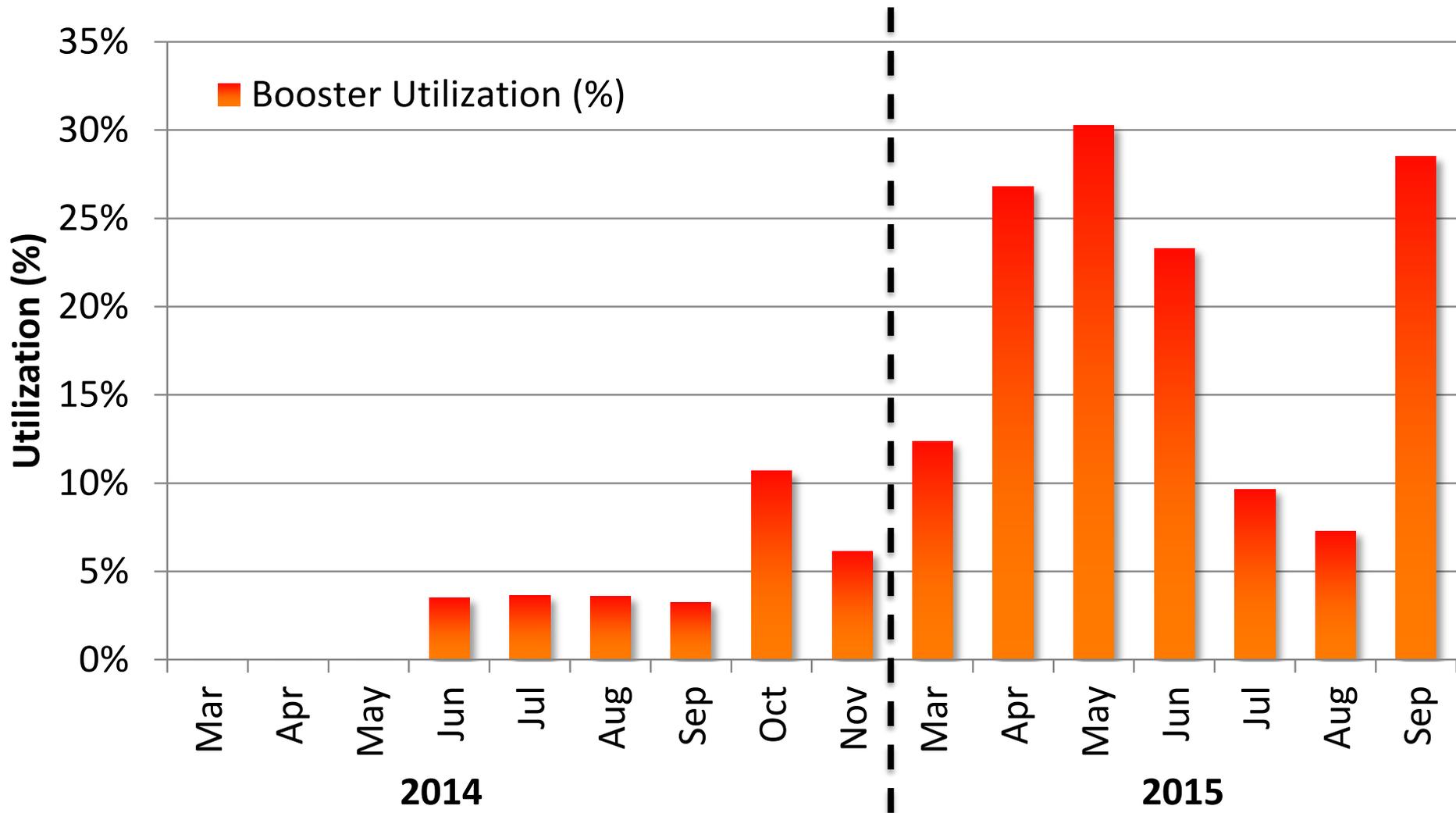
Booster Heater Utilization, 2012-2013

Tankless; percentage of time resistive element "on" during water flow



Booster Heater Utilization, 2014-Sep 2015

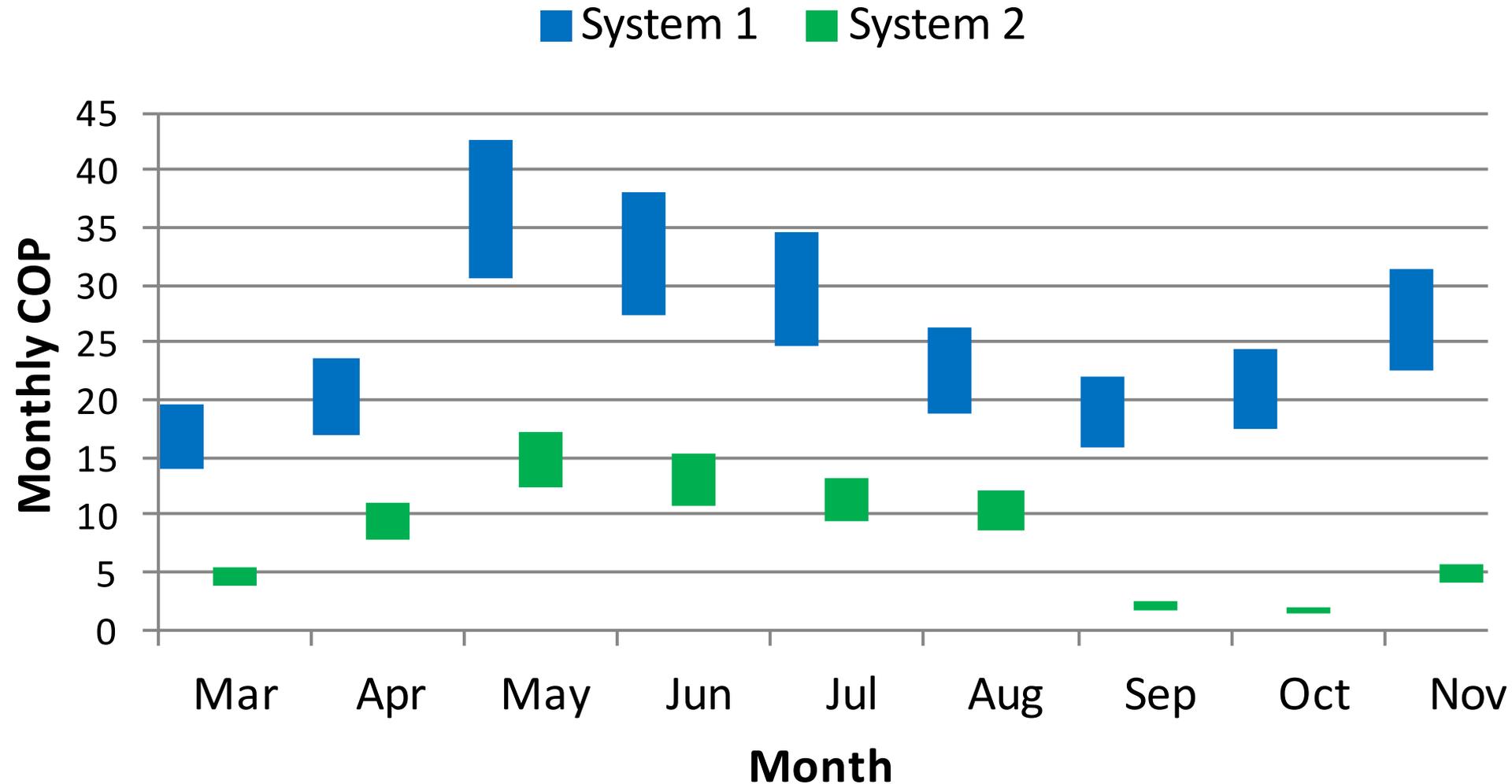
Tankless; percentage of time resistive element "on" during water flow



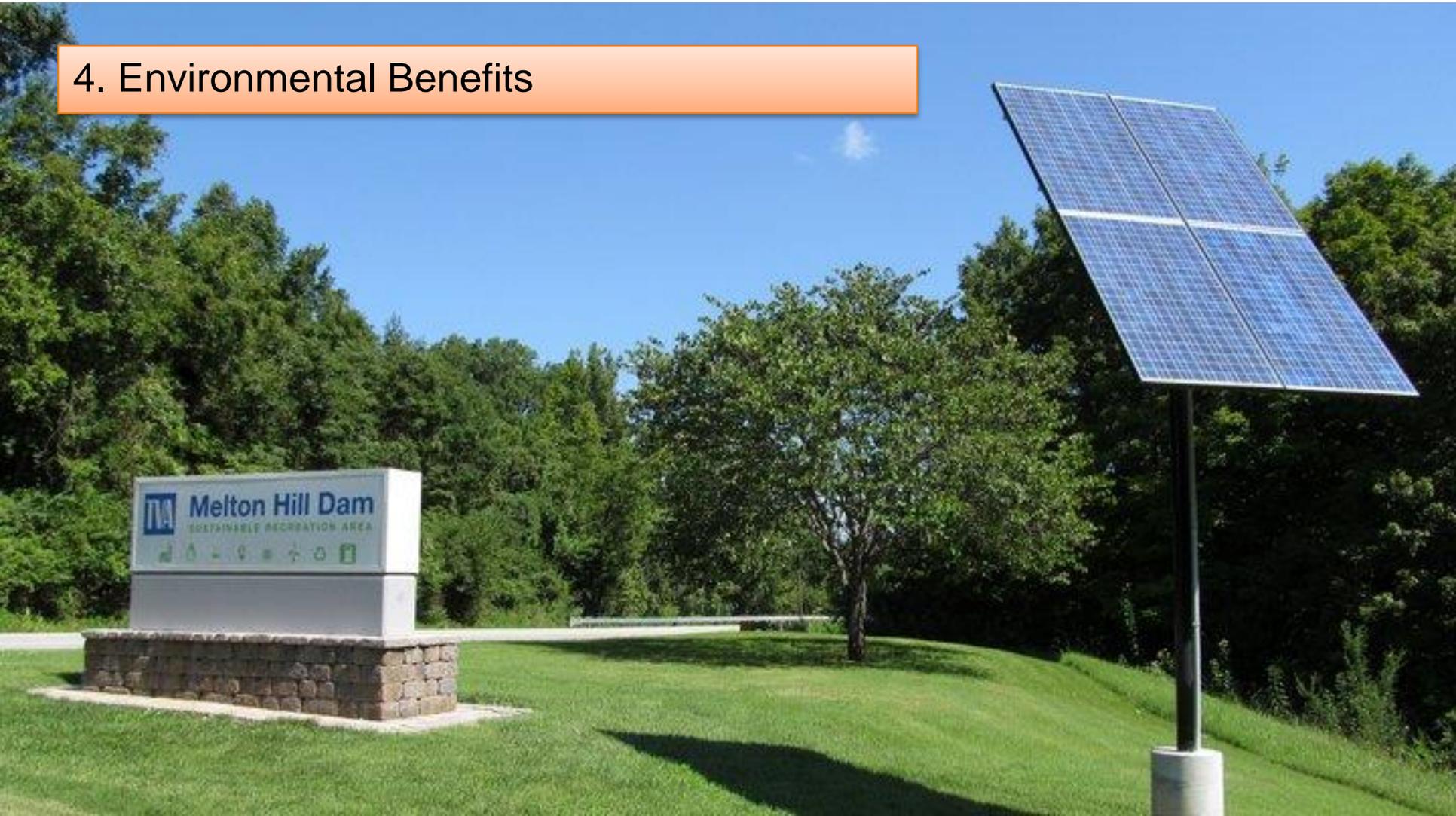
Note: System 2 pump failed on 7/17/15, and System 1 pump was turned off due to poor running condition 9/11/2015.

Monthly Coefficient of Performance

For 2012 camping season, colored bars show estimated COP range



4. Environmental Benefits



Equivalents

Based on renewable energy generated in 2012-2015*

| | Item | Conversion Basis | Units | 2012 | 2013 | 2014 | 2015* |
|---|-------------|--------------------------|-------------------|-------|------|------|-------|
|  | Gasoline | 33.4 kWh/gal | gal | 1,020 | 946 | 910 | 773 |
|  | Light Bulbs | 60-W lamp for 8 hr/day | Number of lamps | 193 | 180 | 173 | 147 |
|  | Laptops | 35-W laptop for 8 hr/day | Number of laptops | 332 | 309 | 297 | 252 |

* Data in 2015 is through the end of Sep.

Reduced Emissions

Based on renewable energy generated in 2012-2015*



| Emission | Conversion Basis (lb/kWh) | 2012 (lb) | 2013 (lb) | 2014 (lb) | 2015* (lb) |
|-----------------|---------------------------|-----------|-----------|-----------|------------|
| CO ₂ | 1.92 | 65,400 | 60,700 | 58,333 | 49,602 |
| SO ₂ | 5.42x10 ⁻³ | 185 | 171 | 165 | 140 |
| NO _x | 1.51x10 ⁻³ | 51 | 48 | 46 | 39 |

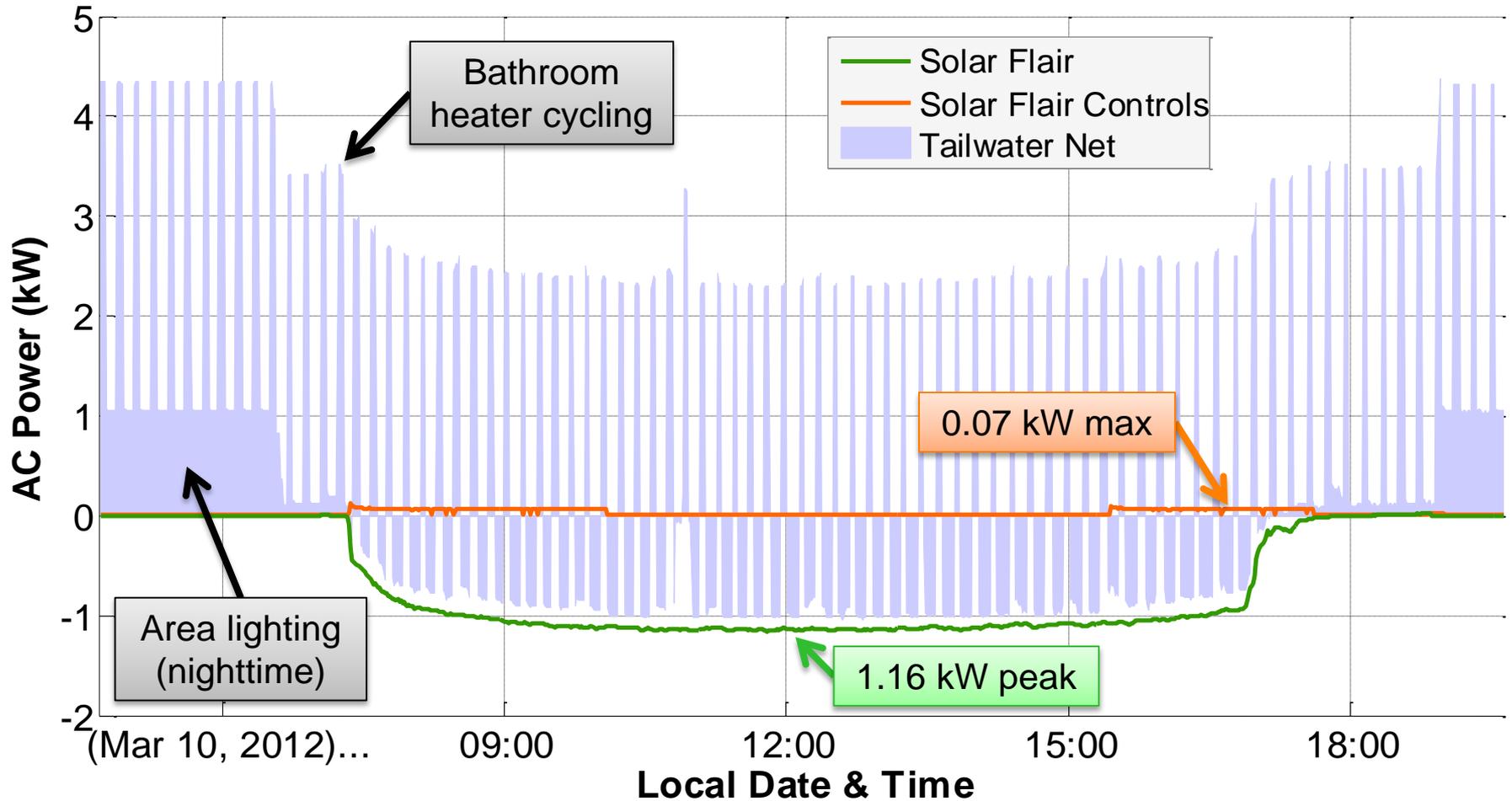
* Data in 2015 is through the end of Sep.

4. Sample Power Profiles



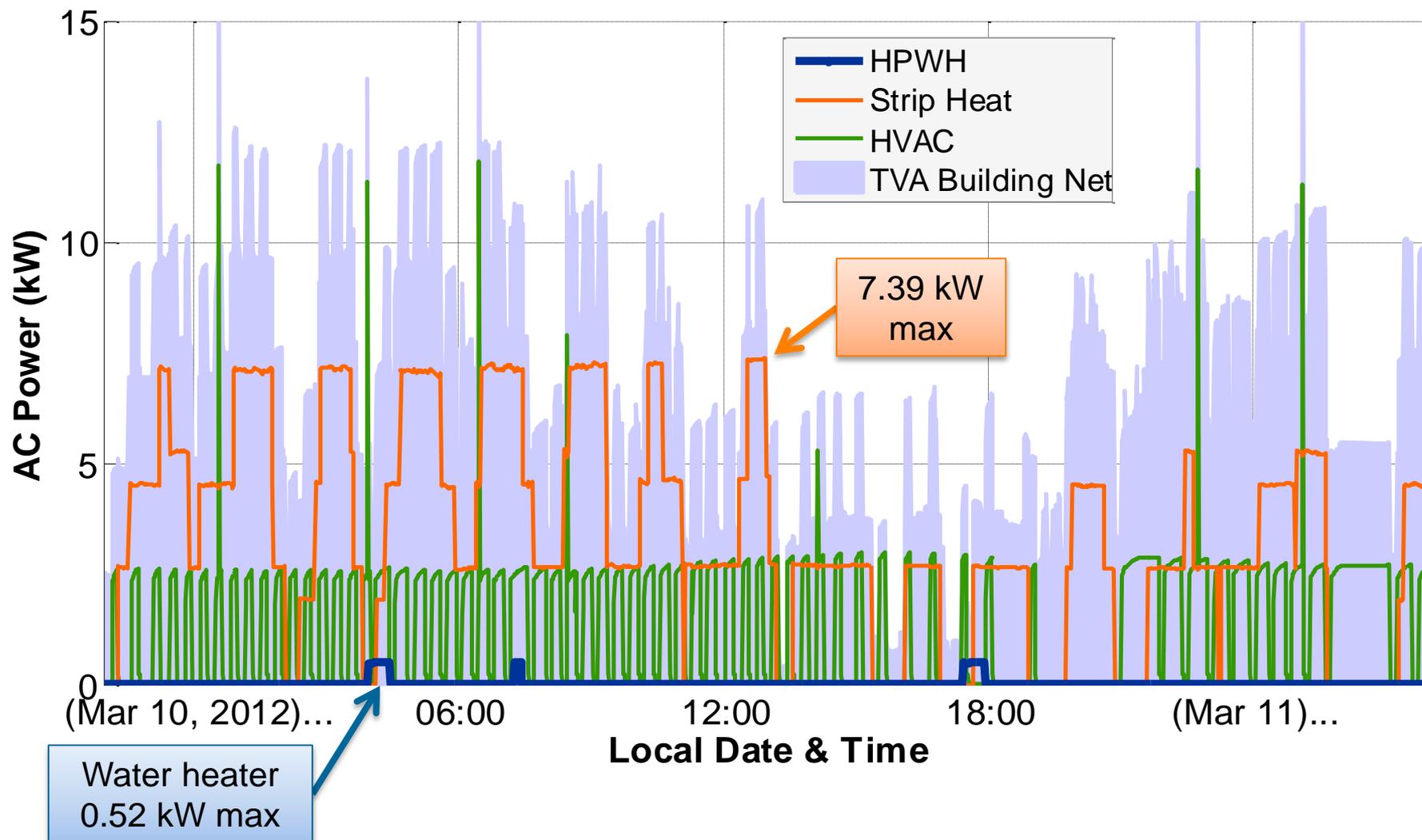
Power Profile: Tailwater Area

Sunny day, but no electric vehicle charging



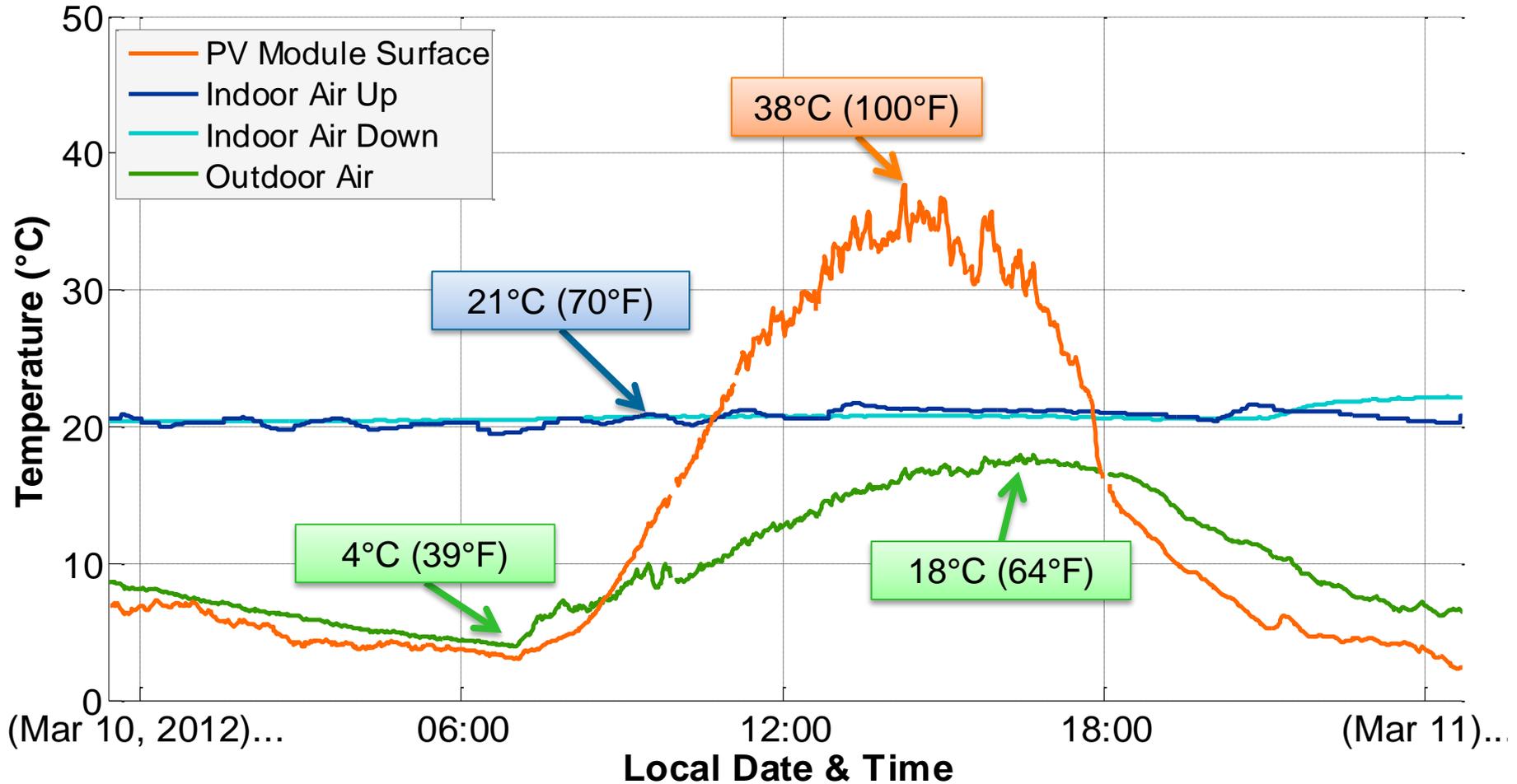
Power Profile: TVA Building at Overlook

Space conditioning systems dominate; minimal hot water usage



Temperature Profile at Overlook

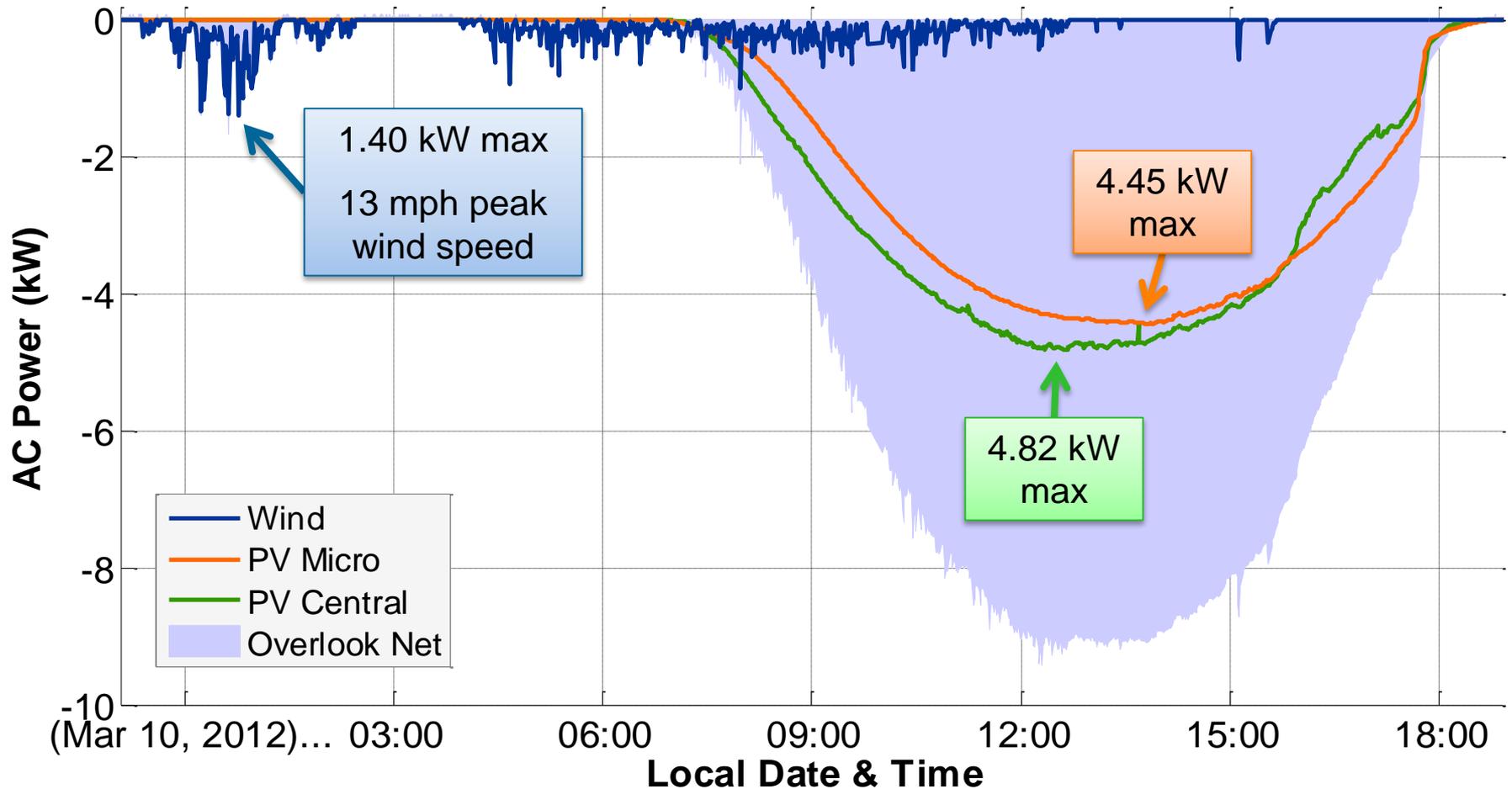
Inside TVA building and at pergola PV system



PV module surface temperature measured on back side of module via surface-mount thermistor

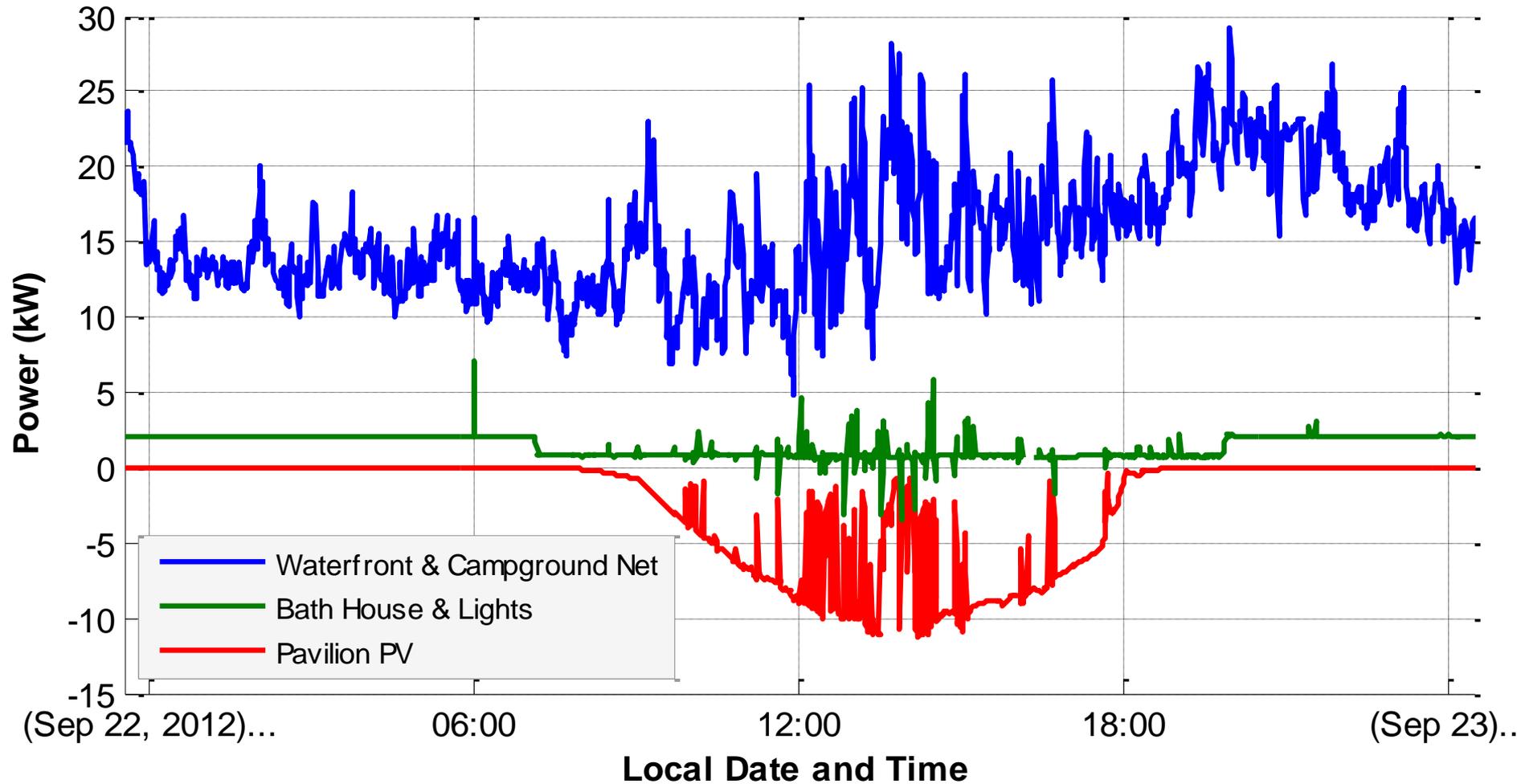
Power Profile: Overlook Renewables

Sunny day with some wind overnight, but no EV charging



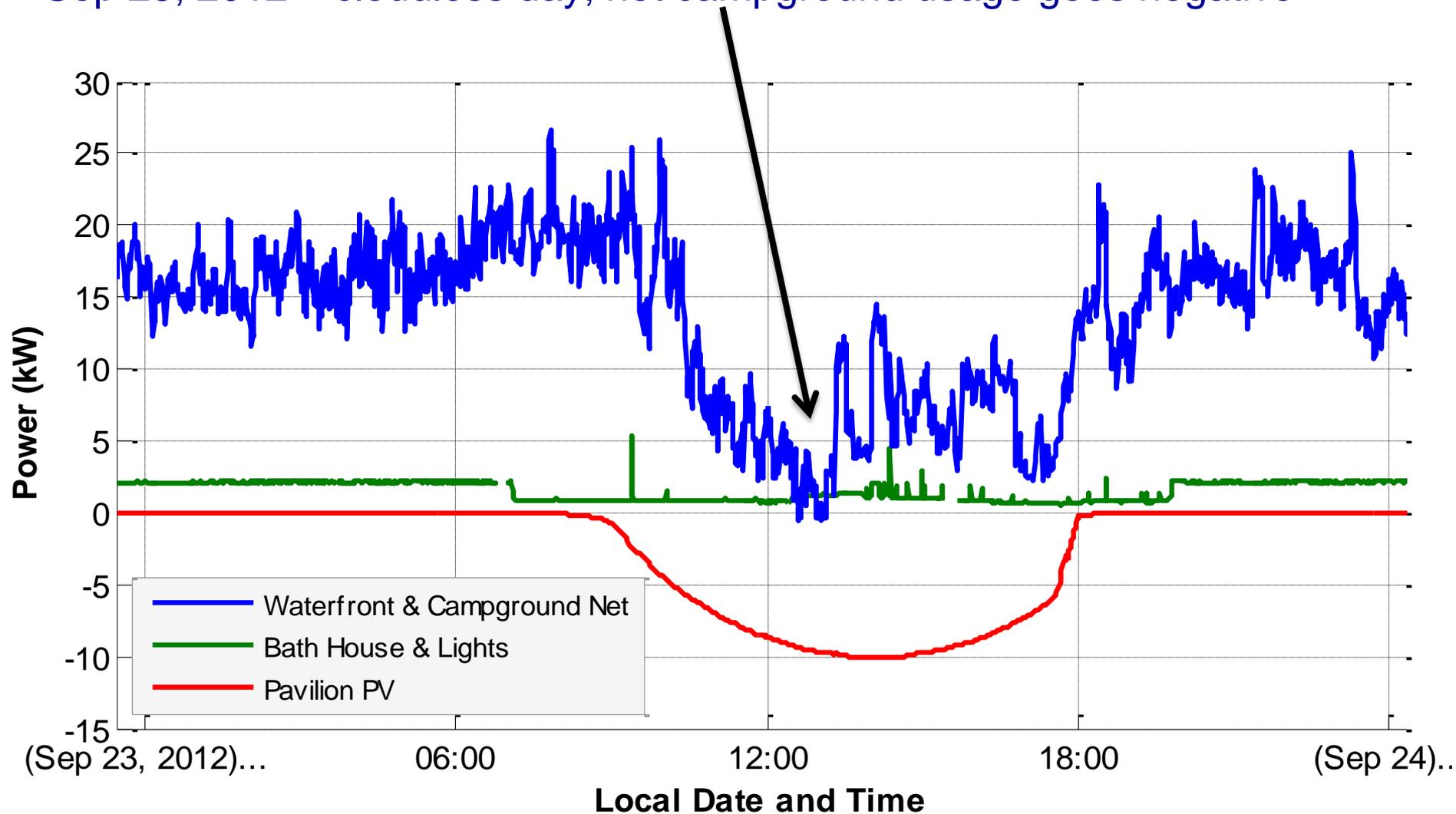
Power Profile: Campground Area with PV

Sep 22, 2012 – partly cloudy day; active campground usage



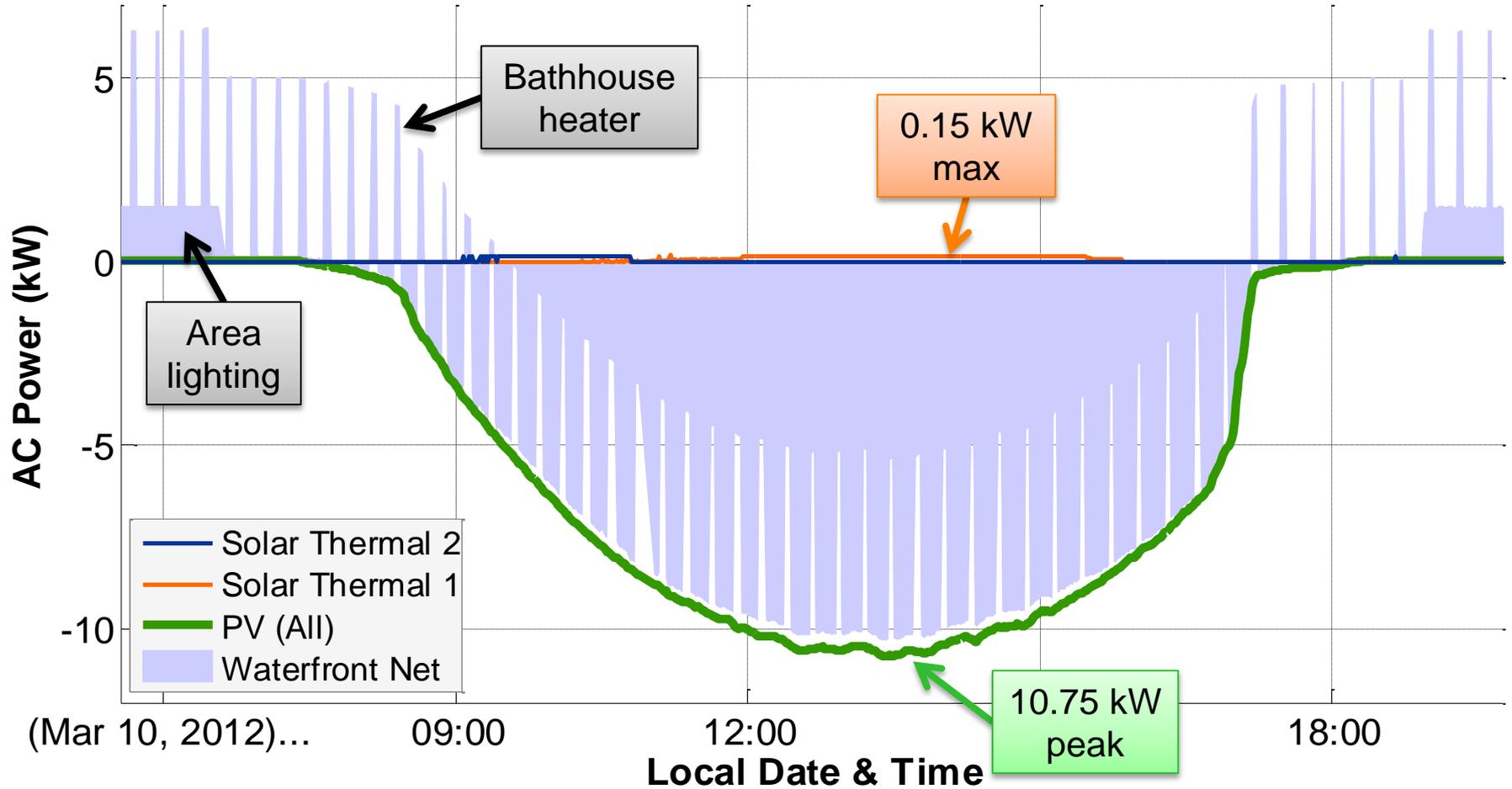
Power Profile: Campground Area with PV

Sep 23, 2012 – cloudless day; net campground usage goes negative



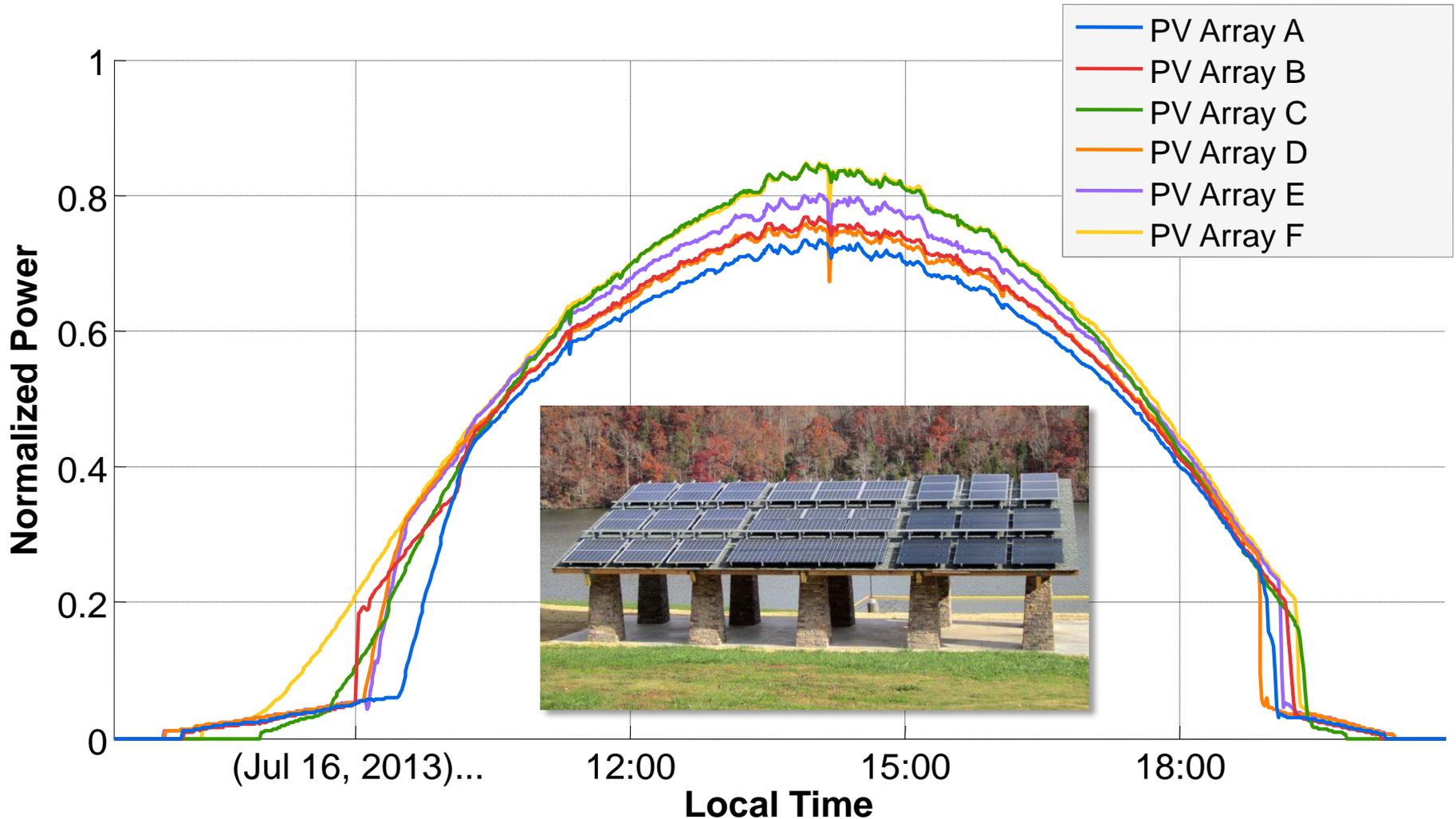
Power Profile: Bathhouse & Pavilion

Sunny day, no backup needed for solar thermal water heating



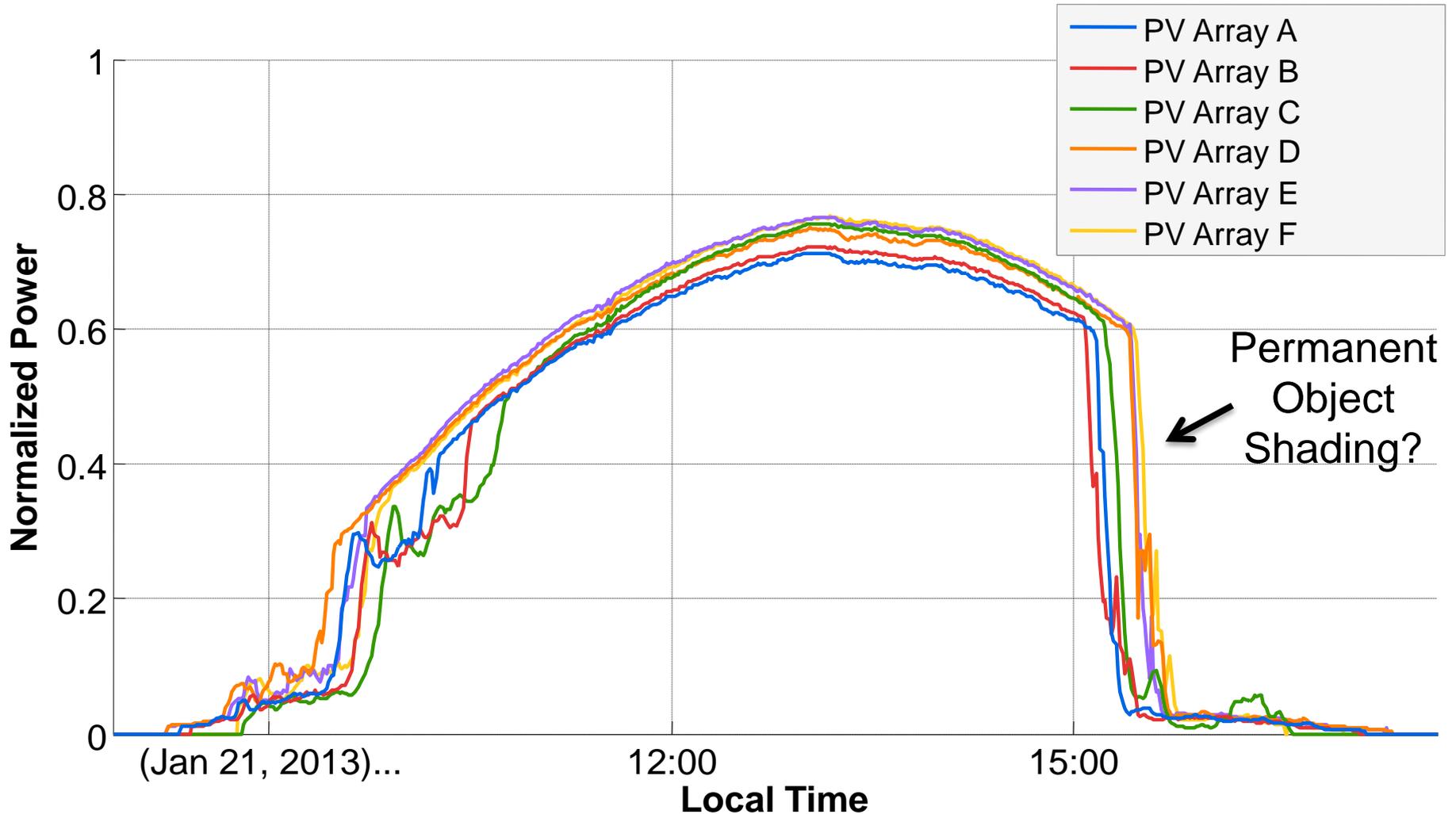
Power Profiles at Pavilion: Clear Day

July 16, 2013 – cloudless day; noticeable divergence in midday powers



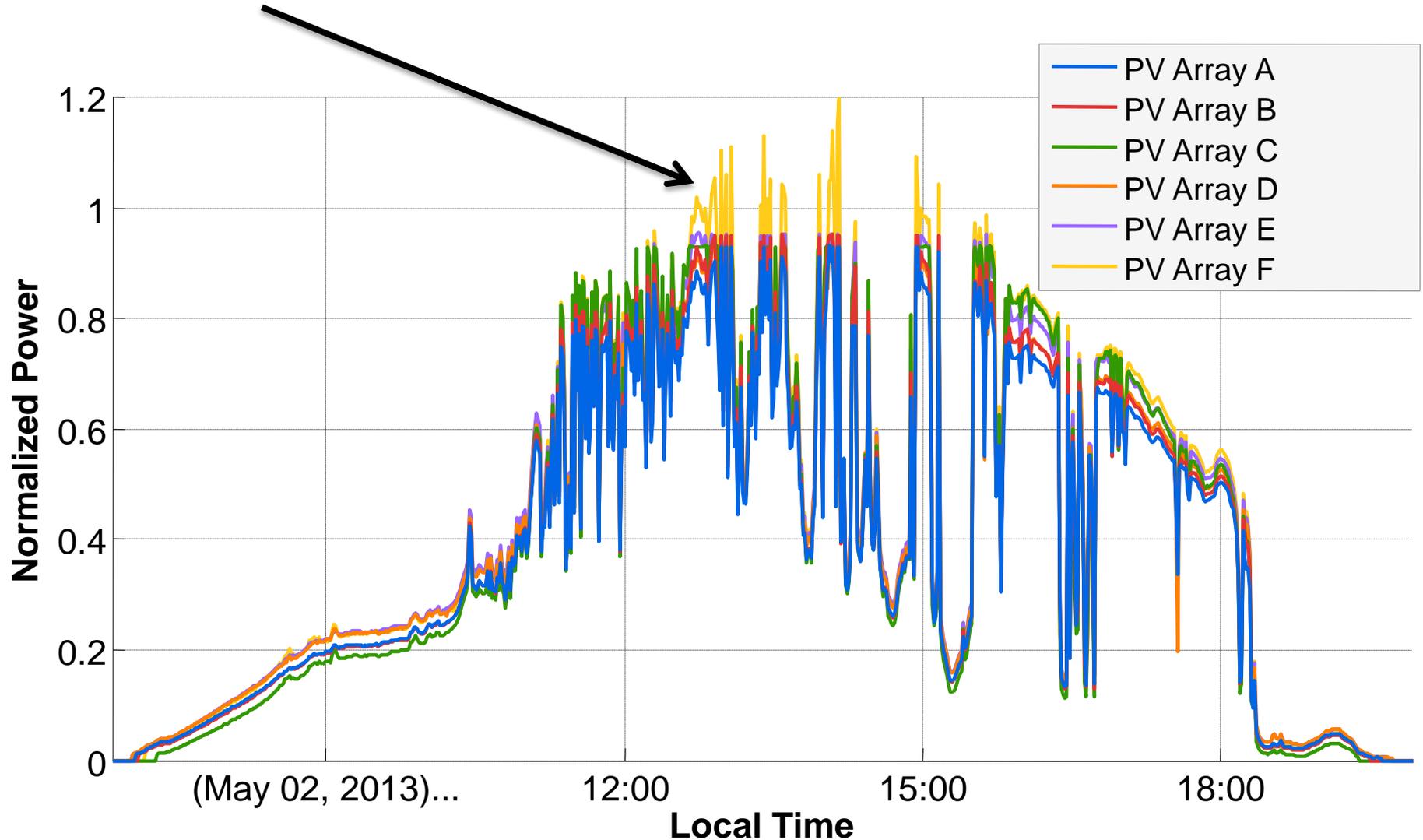
Power Profiles at Pavilion – Shading

Jan 21, 2013 – cloudless day; afternoon shading is prevalent on Pavilion



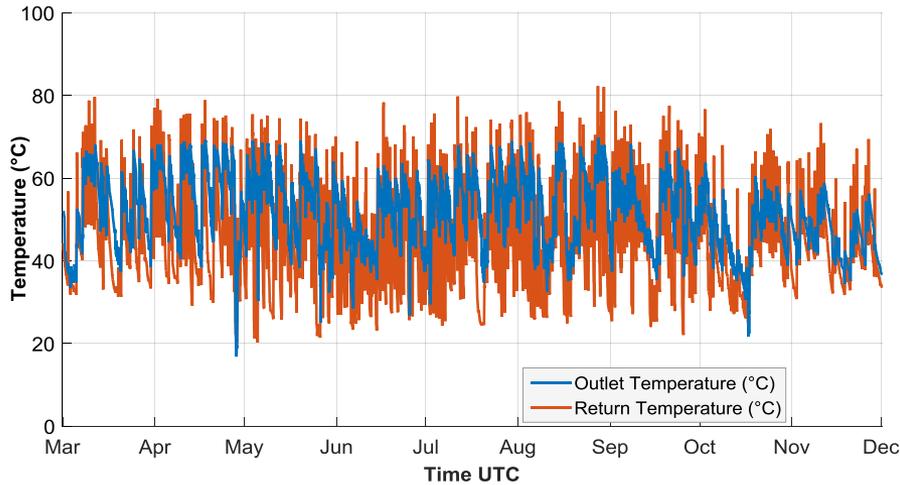
Power Profiles at Pavilion – Enhancement

May 2, 2013 – Pavilion Array F shows increased output, likely from cloud enhancement, because it is undersized relative to inverter (unlike others)

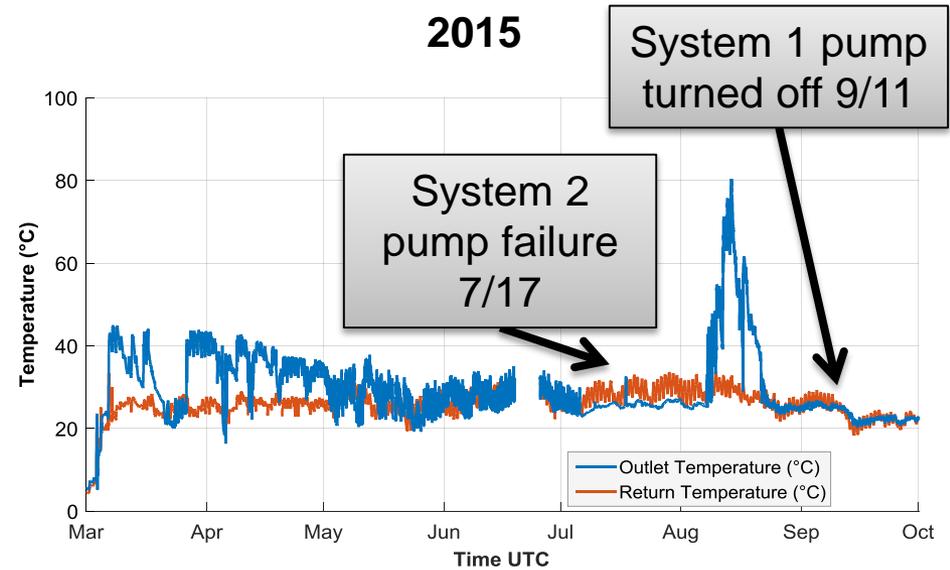


Power Profile: Bathhouse Solar Thermal Water Heating System 1 outlet & return temperatures, 2014 & 2015* camping seasons

2014

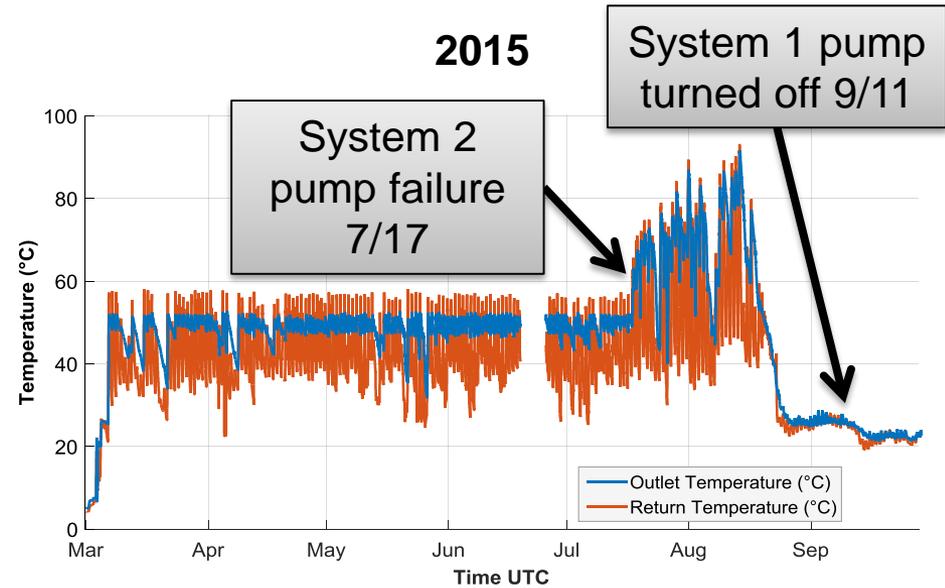
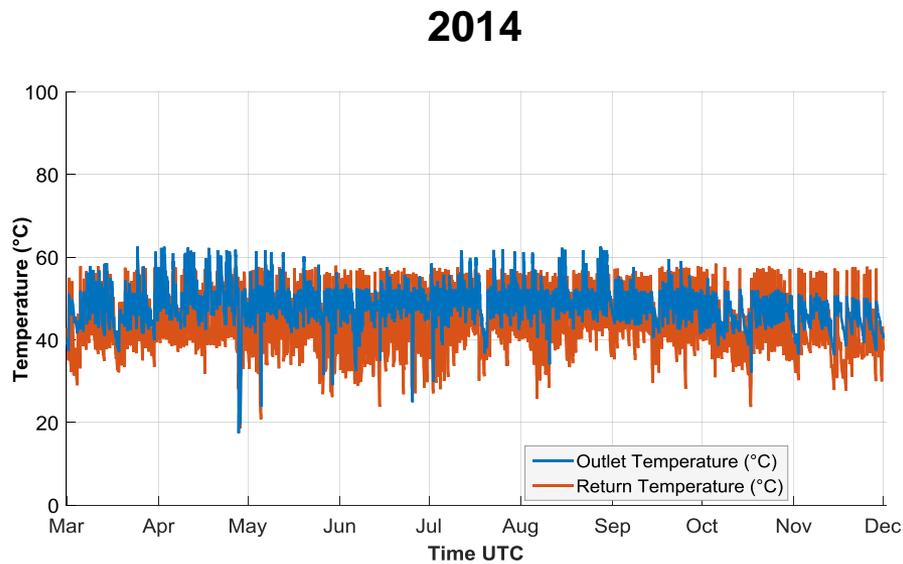


2015



* Data in 2015 is through the end of Sep.

Power Profile: Bathhouse Solar Thermal Water Heating System 2 outlet & return temperatures, 2014 & 2015* camping seasons

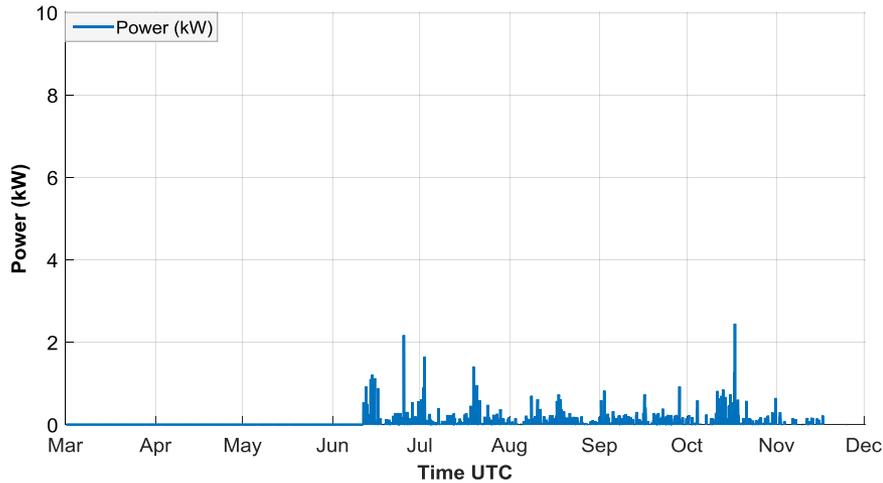


* Data in 2015 is through the end of Sep.

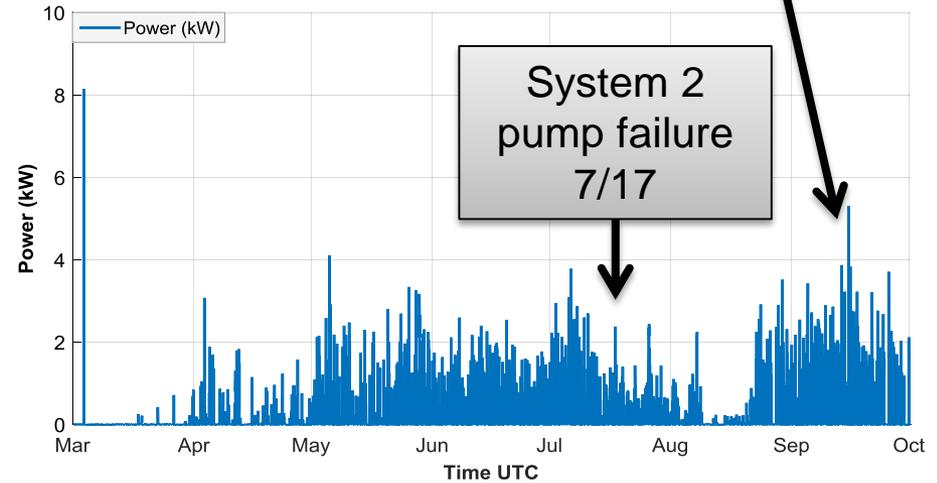
Power Profile: Bathhouse Solar Thermal Water Heating

Tankless water heater power, 2014 & 2015* camping seasons

2014



2015



* Data in 2015 is through the end of Sep.

