NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Innovation for Our Energy Future

NREL's Research Support Facility: An Energy Performance Update

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Commercial Buildings Research Group

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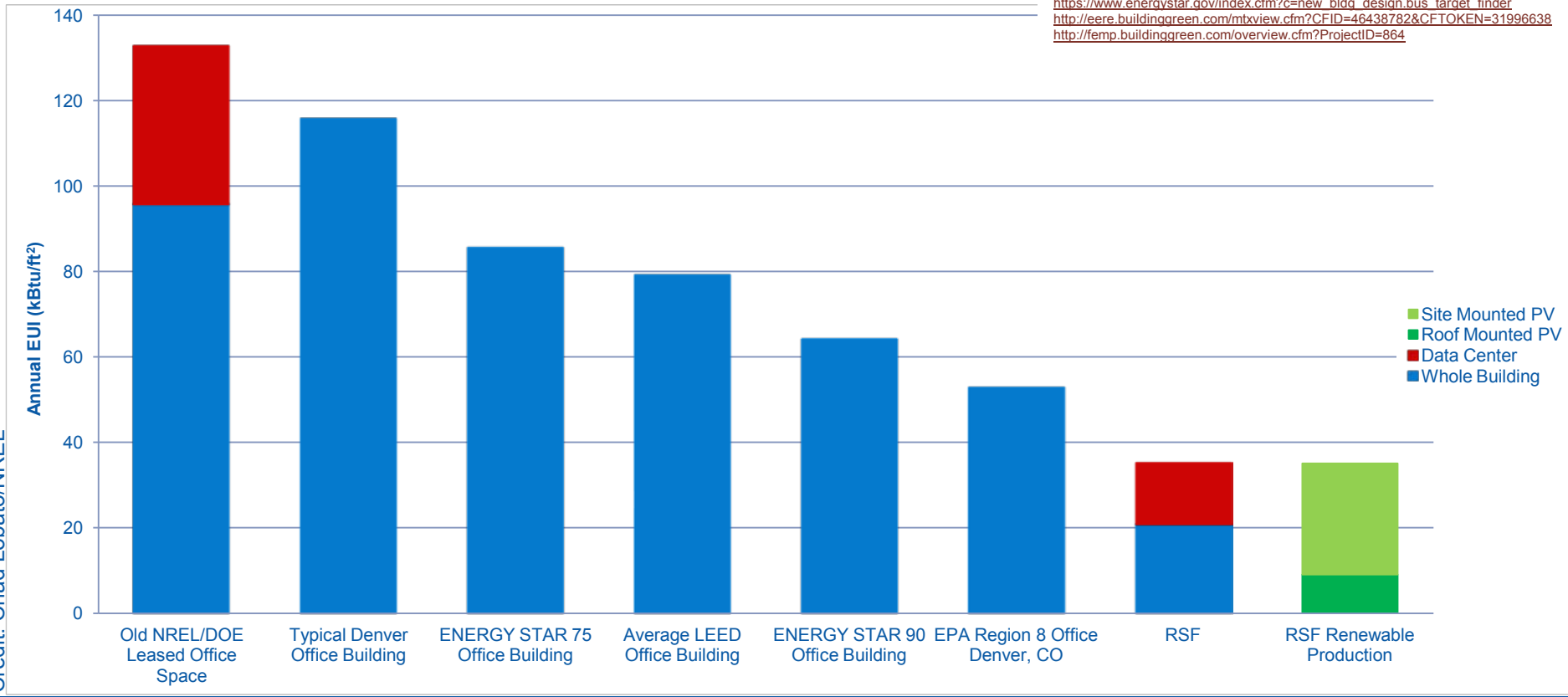
NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Energy Efficiency Design Requirements

- 25 kBtu/ft^2/yr for standard office space occupant density and data center loads
  - Demand side energy use goal, not including renewables
  - Normalized up to 35.1 kBtu/ft^2/yr for better space efficiency and to account for full data center load
- On site renewables sized to offset site energy use to reach net zero annual use

References:
https://www.energystar.gov/index.cfm?c=new_bldg_design.bus_target_finder
http://eere.buildinggreen.com/mtxview.cfm?CFID=46438782&CFTOKEN=31996638
http://femp.buildinggreen.com/overview.cfm?ProjectID=864



Credit: Chad Lobato/NREL

Performance Statements

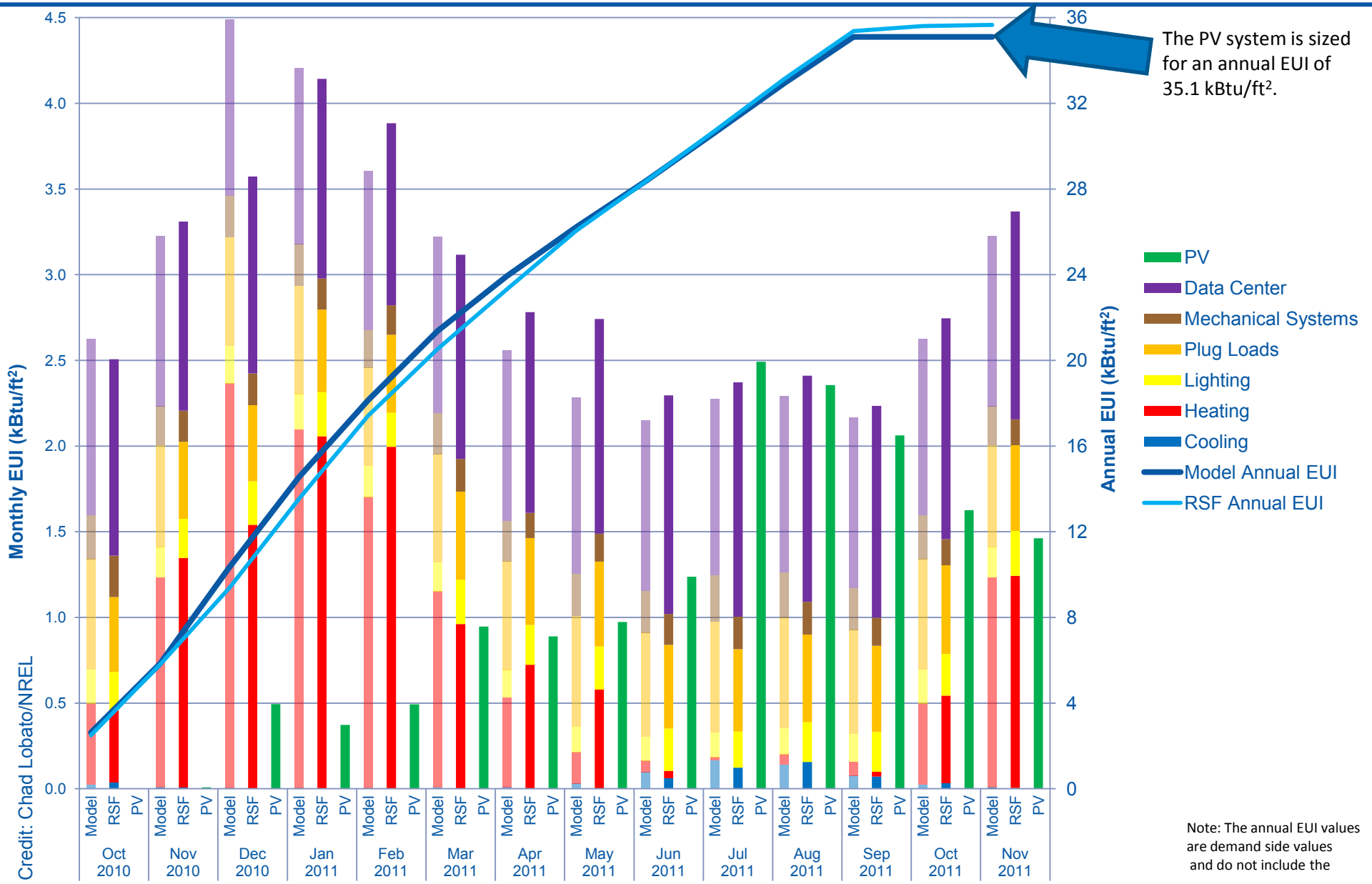
- The RSF complex (RSF, RSF II, parking garage, and associated site lighting) was designed to produce more on-site renewable energy than it uses over the course of a typical weather year, when accounted for at the site.
- For the first year of occupancy, the measured whole building energy use is meeting the predicted annual energy use intensity targets.
  - 35.4 kBtu/ft^2 measured vs. 35.1 kBtu/ft^2 predicted
- Continued performance monitoring and occupant education is required to ensure annual energy use goals will continue to be met.

So How Is It Performing?

For the last 14 months, we have been comparing the measured end uses to the model end uses:

- Annual EUI close to model
  - 35.4 kBtu/ft^2 compared to the goal of 35.1 kBtu/ft^2
- Winter Daytime lighting meeting the model predictions
  - 25-30 kW of lighting (typical office building would use 170 kW)
  - 35-40 kW of lighting during the summer due to high sun angles
  - Addressing nighttime cleaning and staff lighting operation
- Significantly below daytime plug load predictions
  - Staff education programs have engaged occupants as active participants
  - Continuous occupant education needed to reduce nighttime plug loads
- Fans and Pumps meeting the model predictions
  - Nighttime loads half of model predictions
- Datacenter meeting the model predictions during cooler months
  - PUE of 1.1 - 1.15 during cooler months
  - Average PUE of 1.21 for summer 2011
  - Refining hot aisle containment strategy to reduce data center chilled water use
- Rooftop PV meeting model predictions
  - 32,800 kWh Dec production compared to 29,000 kWh modeled
- Heating use close to model
  - Internal gains of occupants and plugs less than modeled
- Cooling use close to model
  - Building cooling is below the model prediction
  - Total cooling, including additional datacenter chilled water use, is slightly higher than predicted

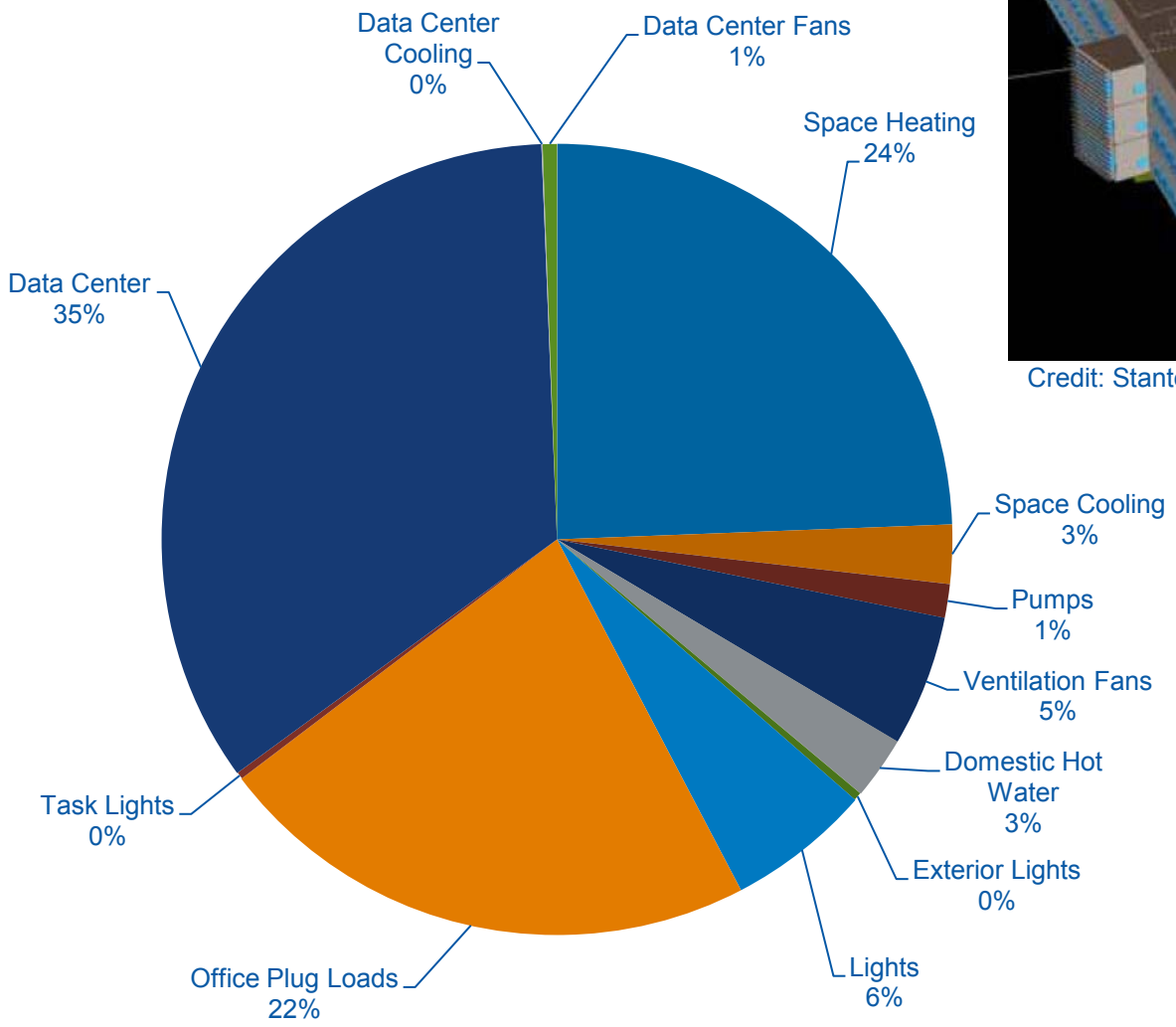
Measured Versus Modeled Monthly and Cumulative EUI



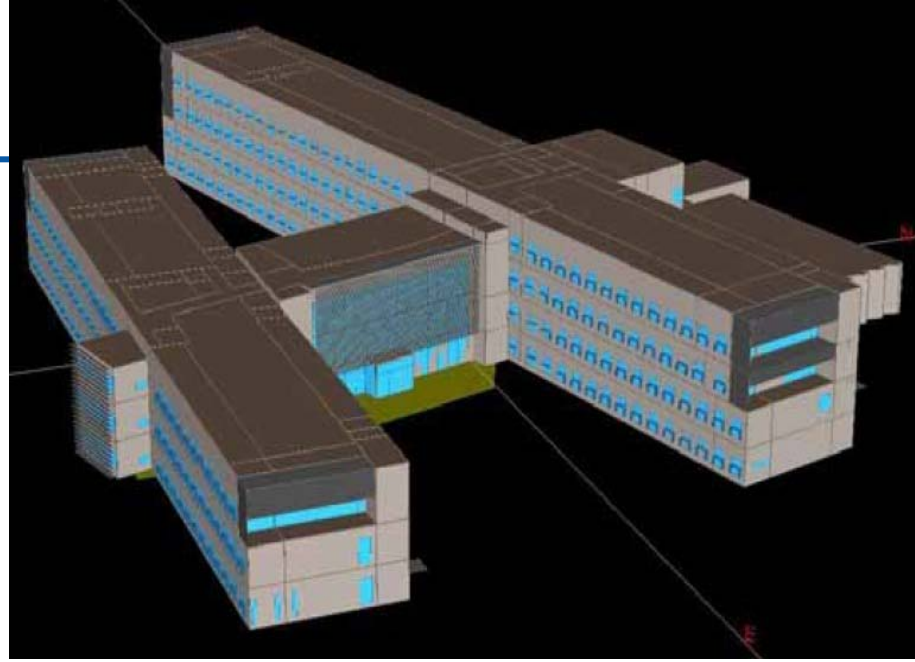
Note: The annual EUI values are demand side values and do not include the

Energy Modeling

NREL RSF Energy Use Breakdown



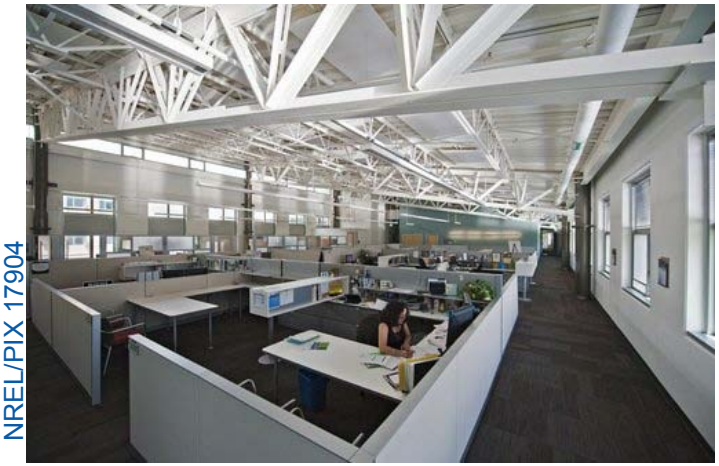
Credit: Chad Lobato/NREL



Credit: Stantec

End Use	kBtu/ft²
Space Heating	8.58
Space Cooling	0.85
Pumps	0.48
Ventilation Fans	1.88
Domestic Hot Water	0.90
Exterior Lights	0.12
Lights	2.07
Office Plug Loads	7.87
Task Lights	0.10
Data Center	12.11
Data Center Cooling	0.02
Data Center Fans	0.20

RSF Complex Update


NREL/PIX 17904

- RSF opened June 2010
- ~80% occupied
  - 14 of 14 wings occupied
  - 650 of 820 occupants
- Roof-mounted PV installed and operational
- Visitor parking lot and PV installation complete
  - PV operational July 2011
- RSF II opened November 2011
- Parking garage construction underway
  - Winter 2011 completion


NREL/PIX 17845

Photovoltaic System

- Power Purchase Agreement (PPA) provides full rooftop array on RSF 1
- Zero energy = building, parking lot and future parking garage arrays

December 2010 – November 2011 Plug Load Power Density

Credit: Matthew Luckwitz/NREL

Power Density (W/ft²)

0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00

0 2 4 6 8 10 12 14 16 18 20 22 24

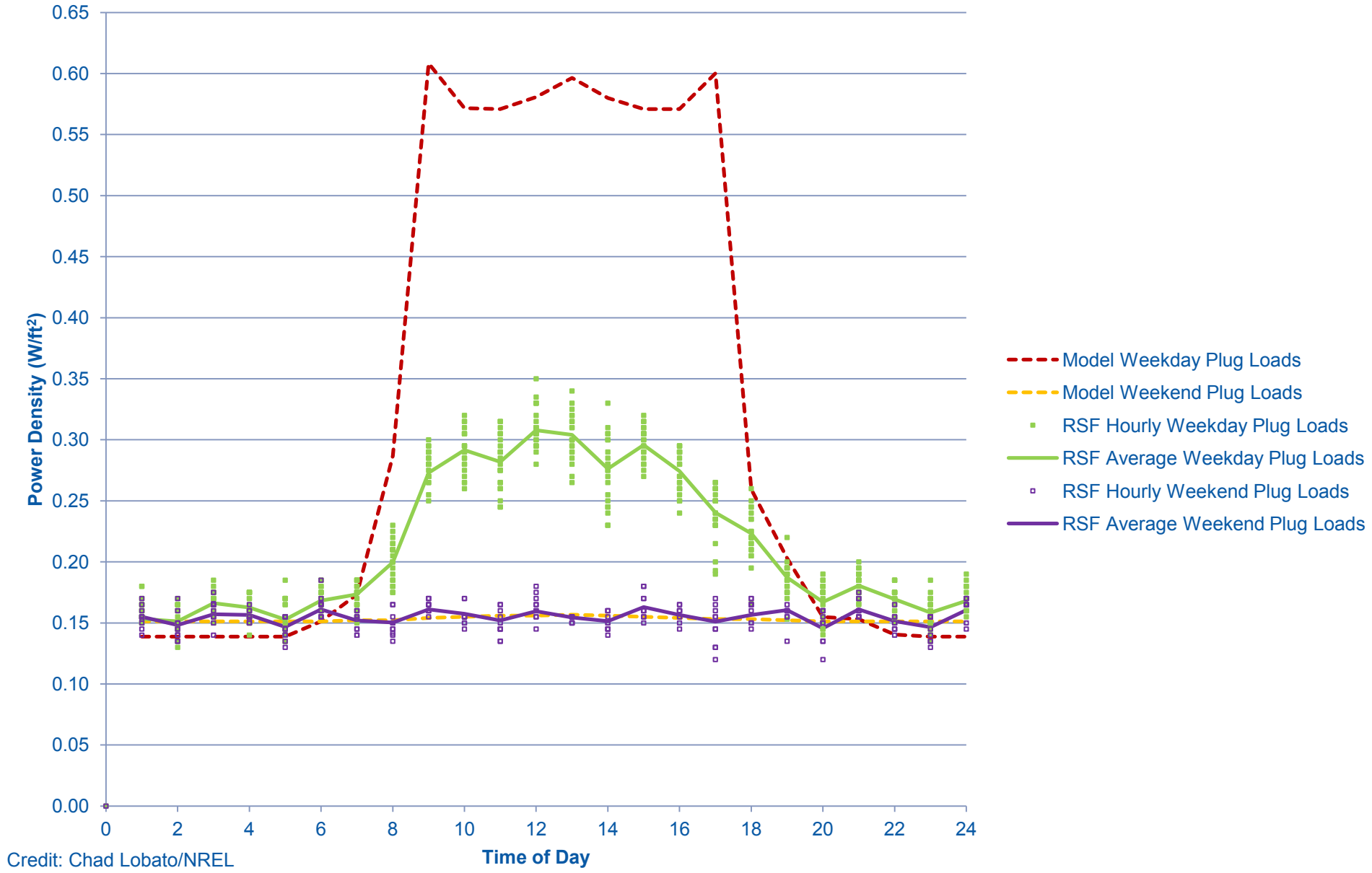
Time of Day

- Model Average
- December 2010
- January 2011
- February 2011
- March 2011
- April 2011
- May 2011
- June 2011
- July 2011
- August 2011
- September 2011
- October 2011
- November 2011

Note: The elevators are included in the plug loads

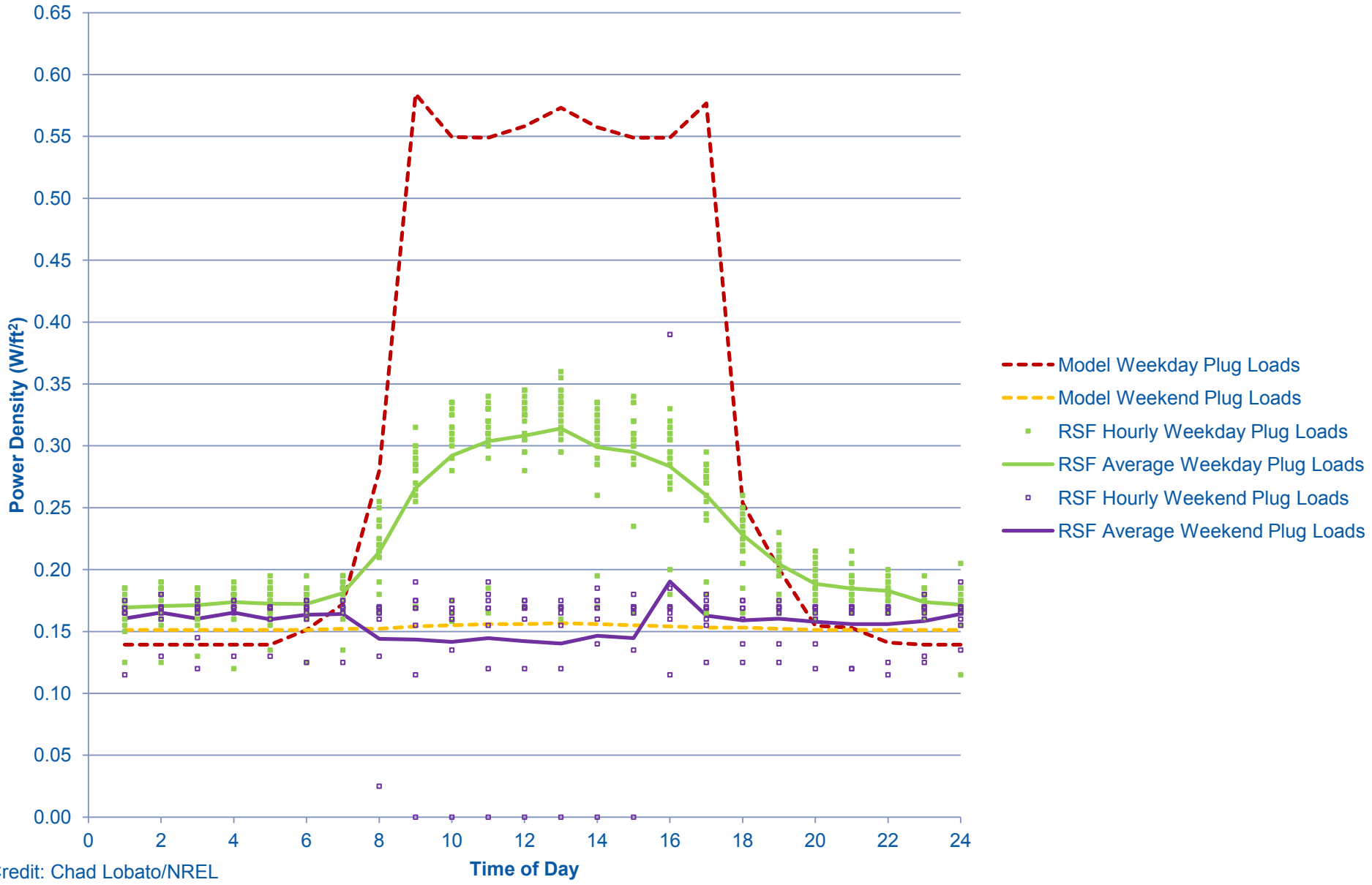
Credit: Chad Lobato/NREL

October 2010 Plug Load Power Density



Credit: Chad Lobato/NREL

November 2010 Plug Load Power Density



Credit: Chad Lobato/NREL

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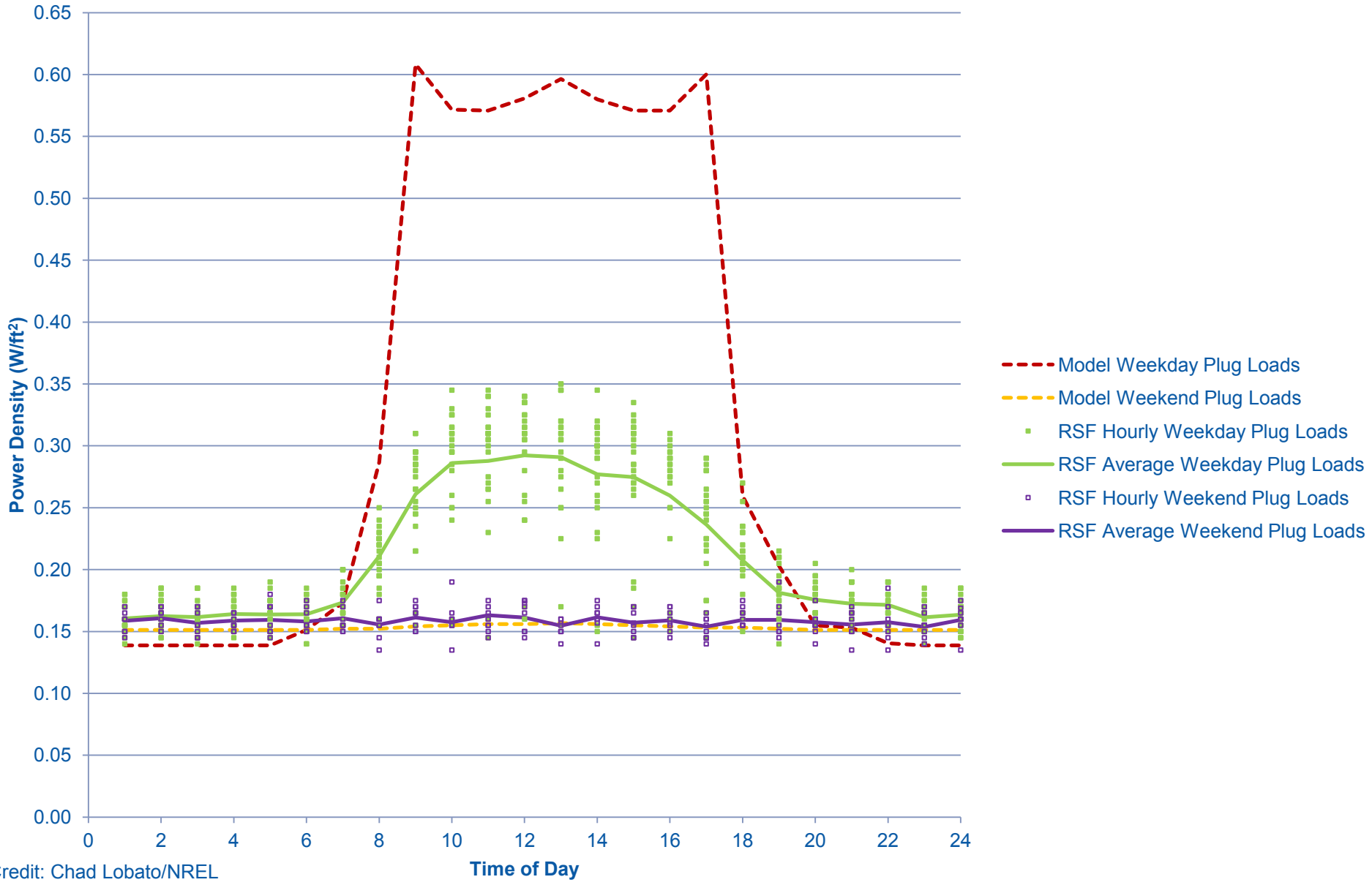
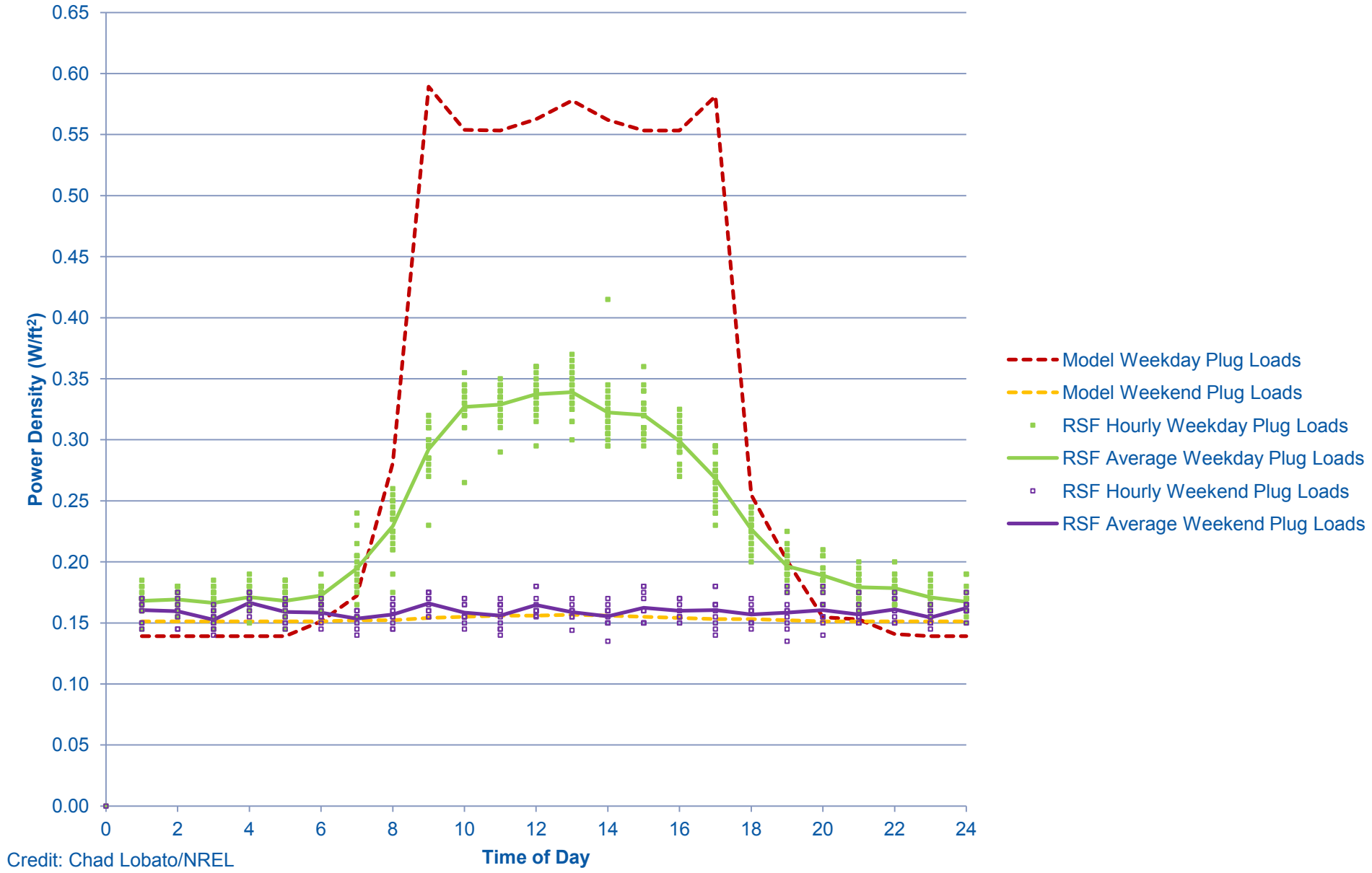


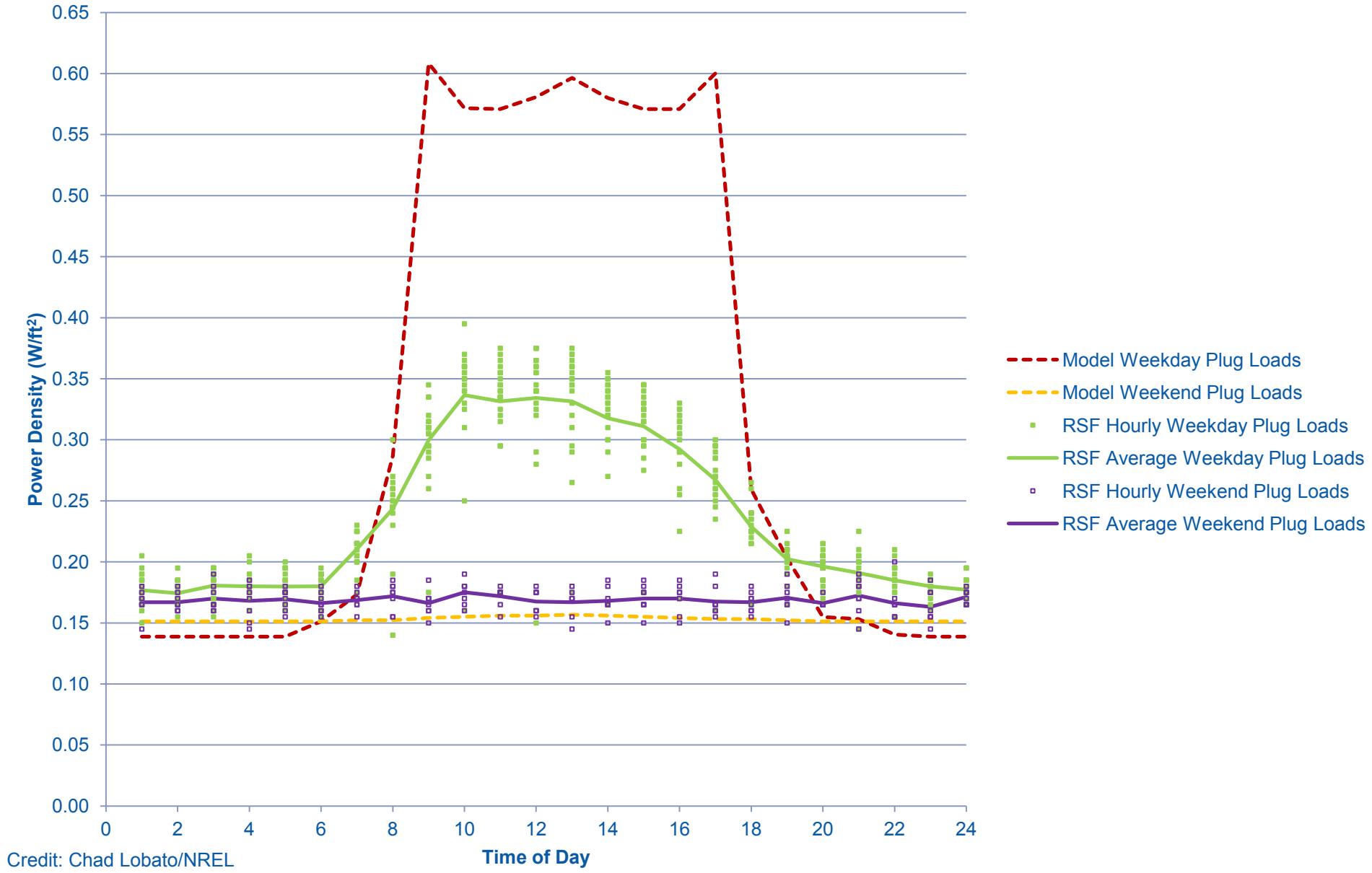
Credit: Chad Lobato/NREL

January 2011 Plug Load Power Density



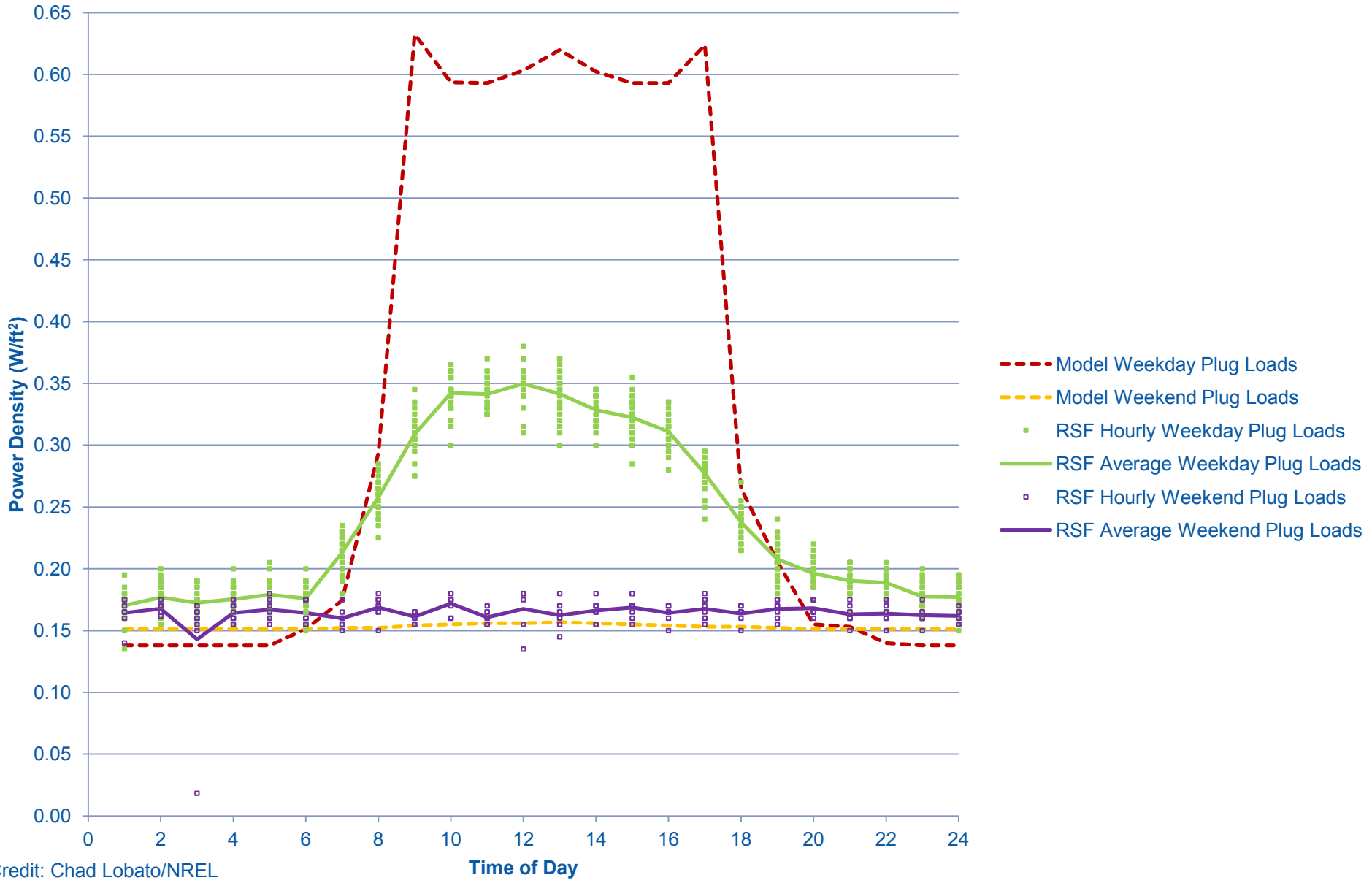
Credit: Chad Lobato/NREL

February 2011 Plug Load Power Density



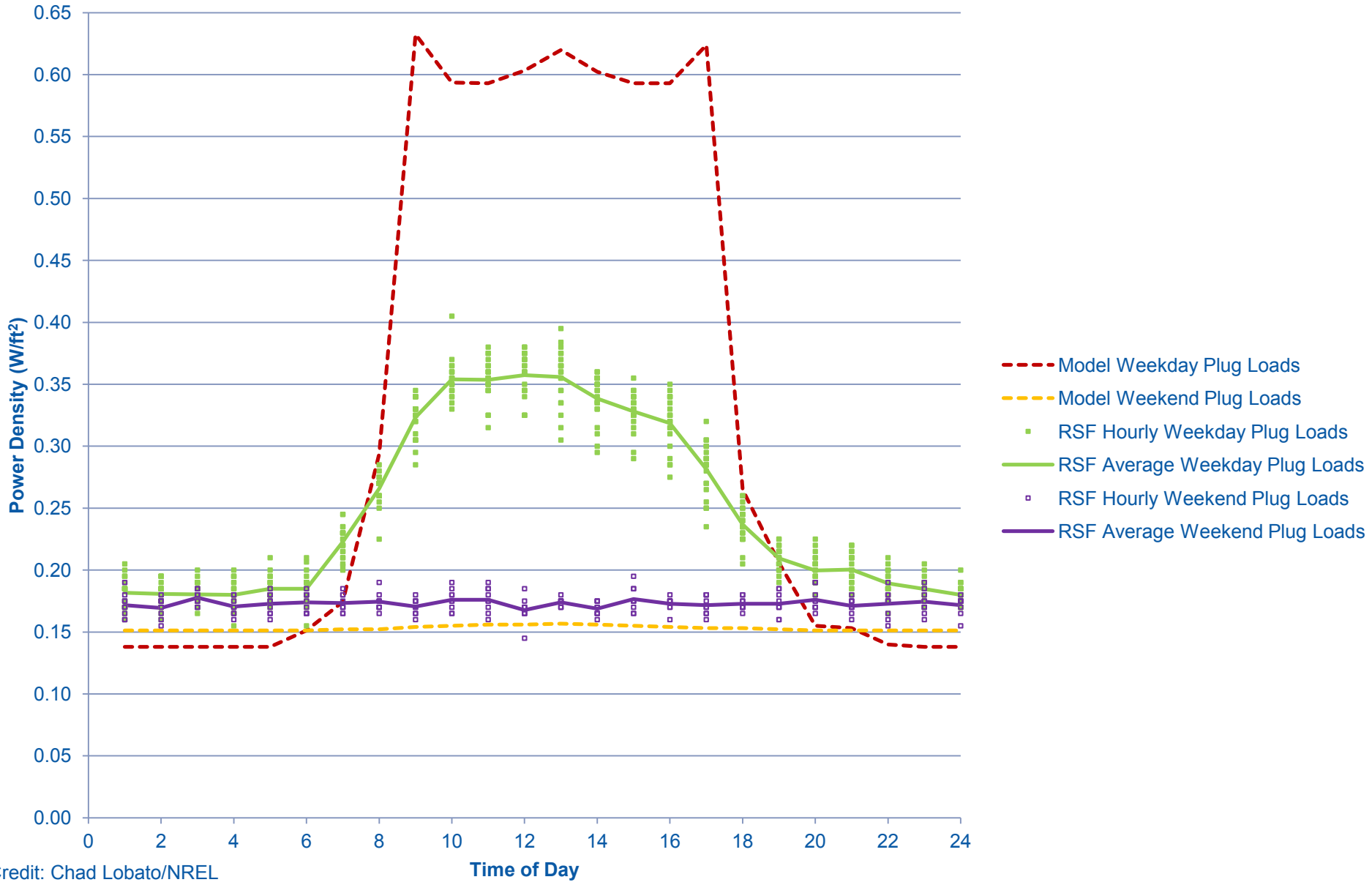
Credit: Chad Lobato/NREL

March 2011 Plug Load Power Density



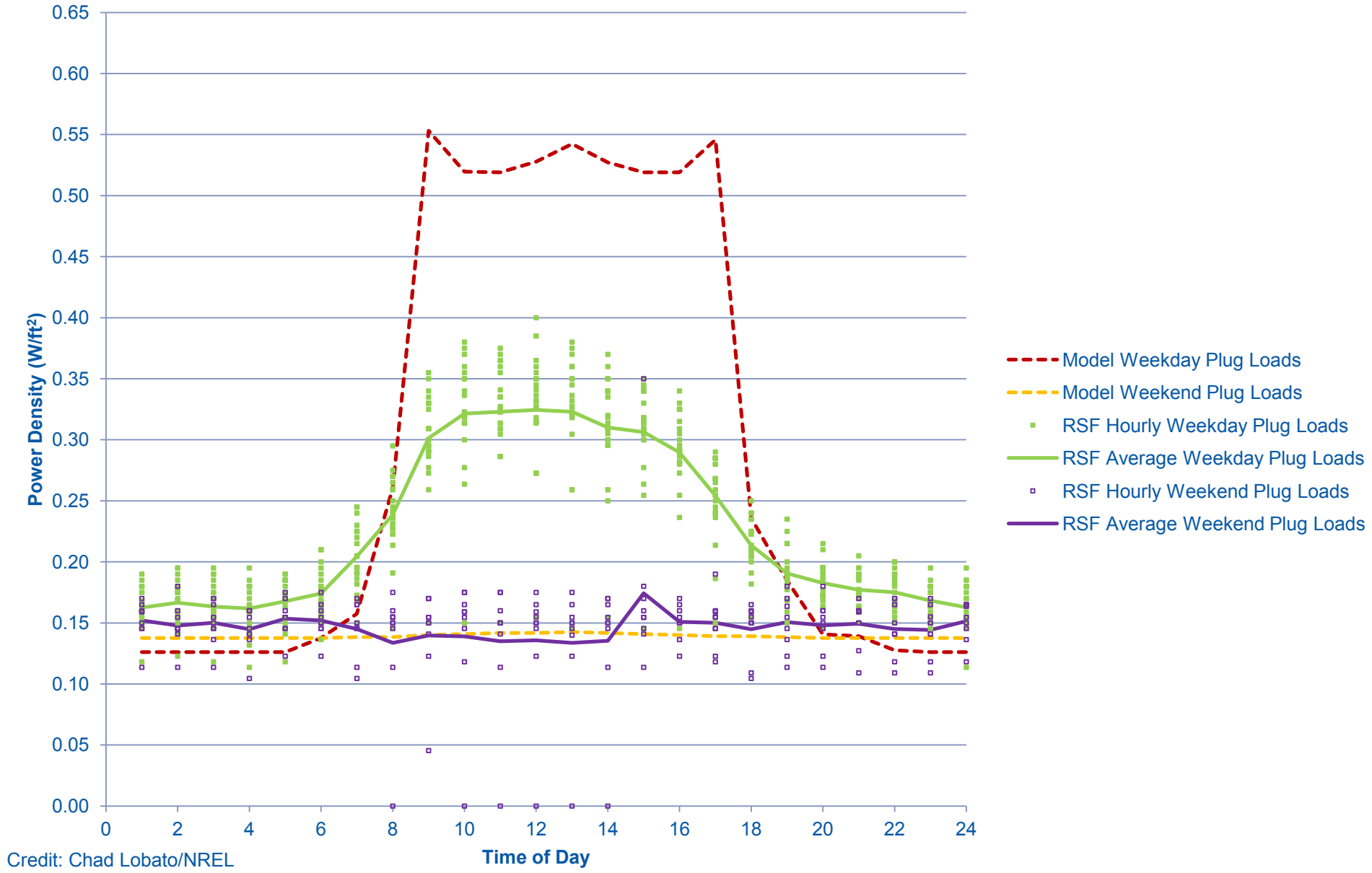
Credit: Chad Lobato/NREL

April 2011 Plug Load Power Density



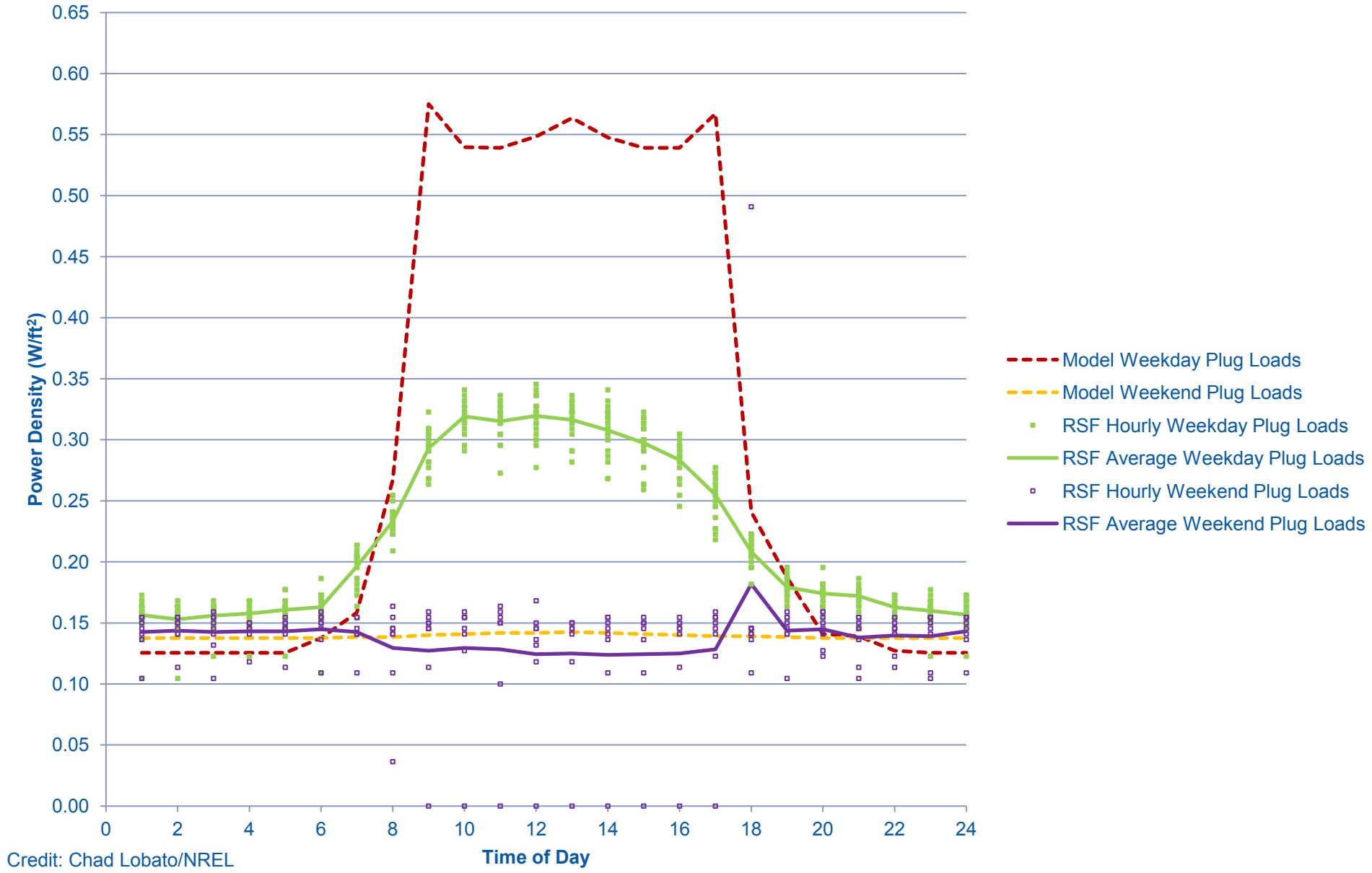
Credit: Chad Lobato/NREL

May 2011 Plug Load Power Density



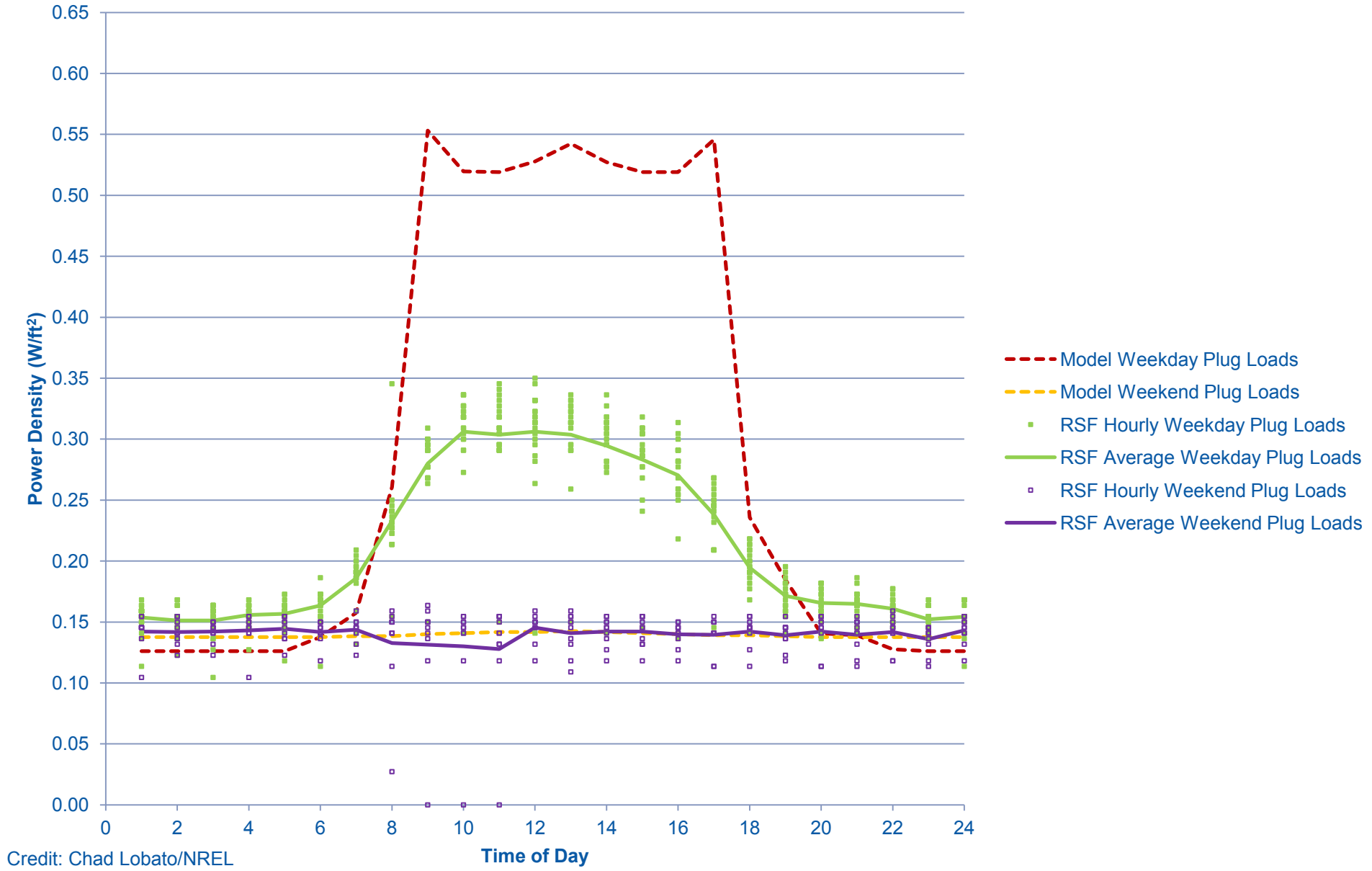
Credit: Chad Lobato/NREL

June 2011 Plug Load Power Density



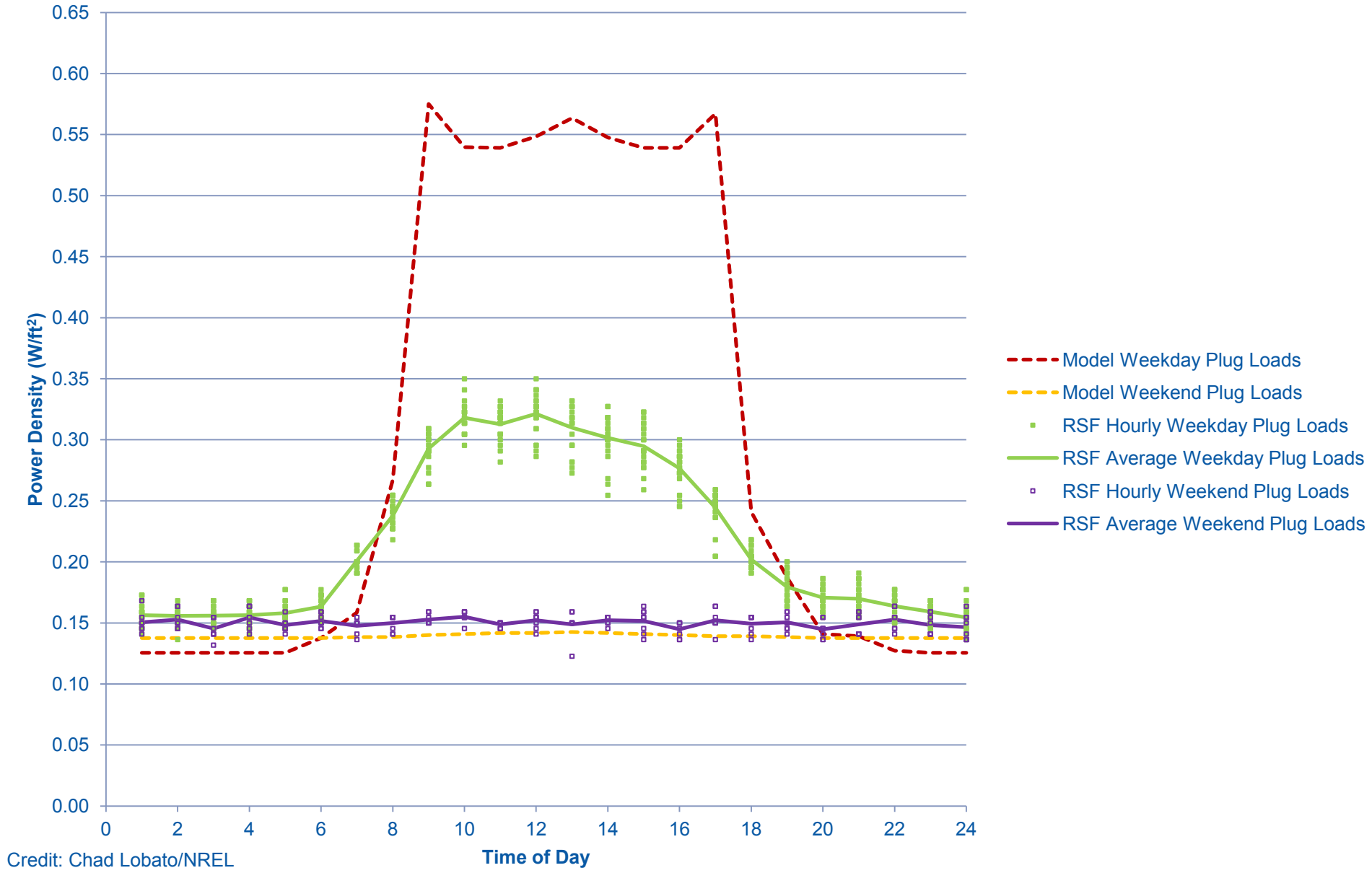
Credit: Chad Lobato/NREL

July 2011 Plug Load Power Density



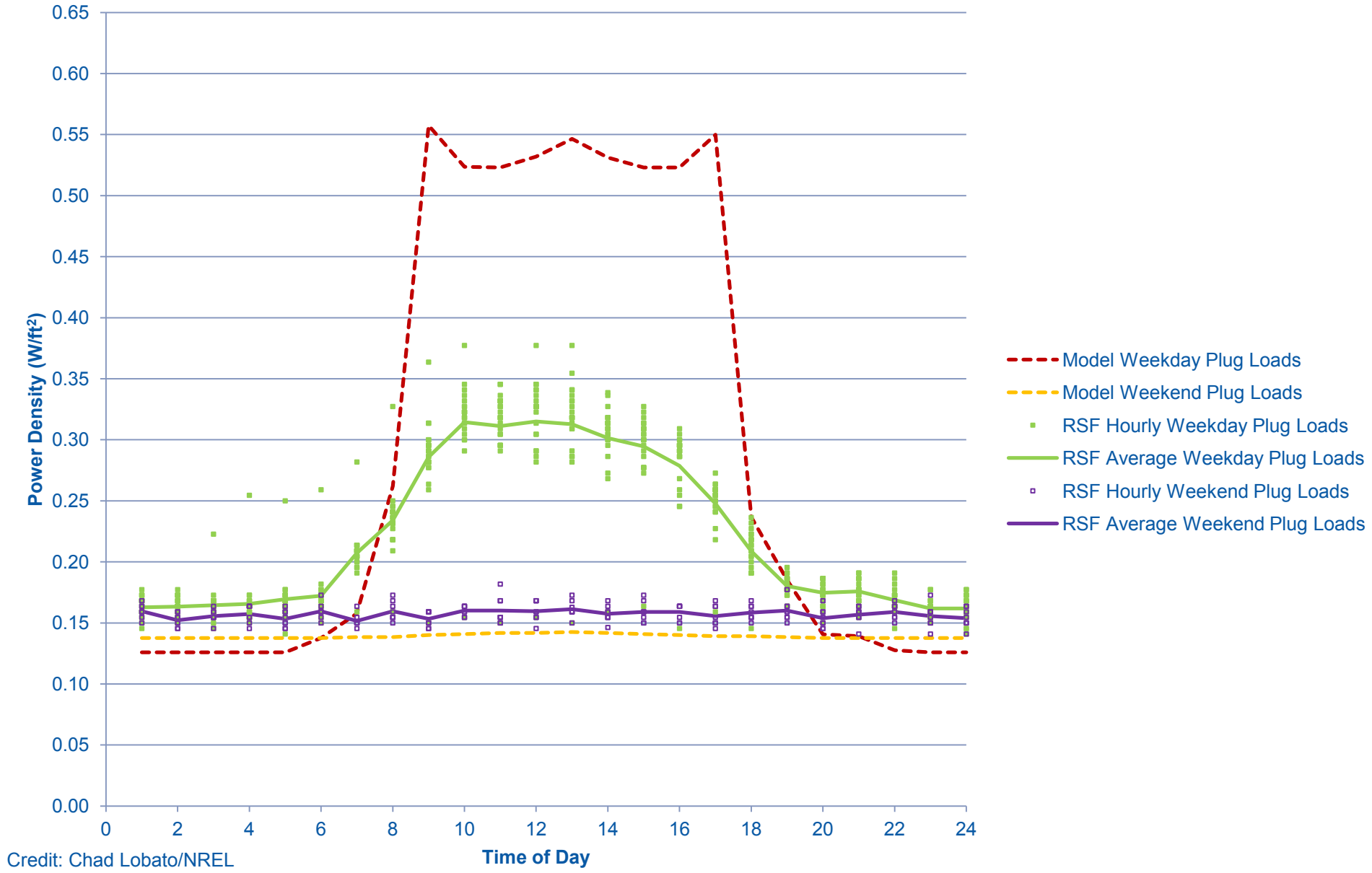
Credit: Chad Lobato/NREL

August 2011 Plug Load Power Density



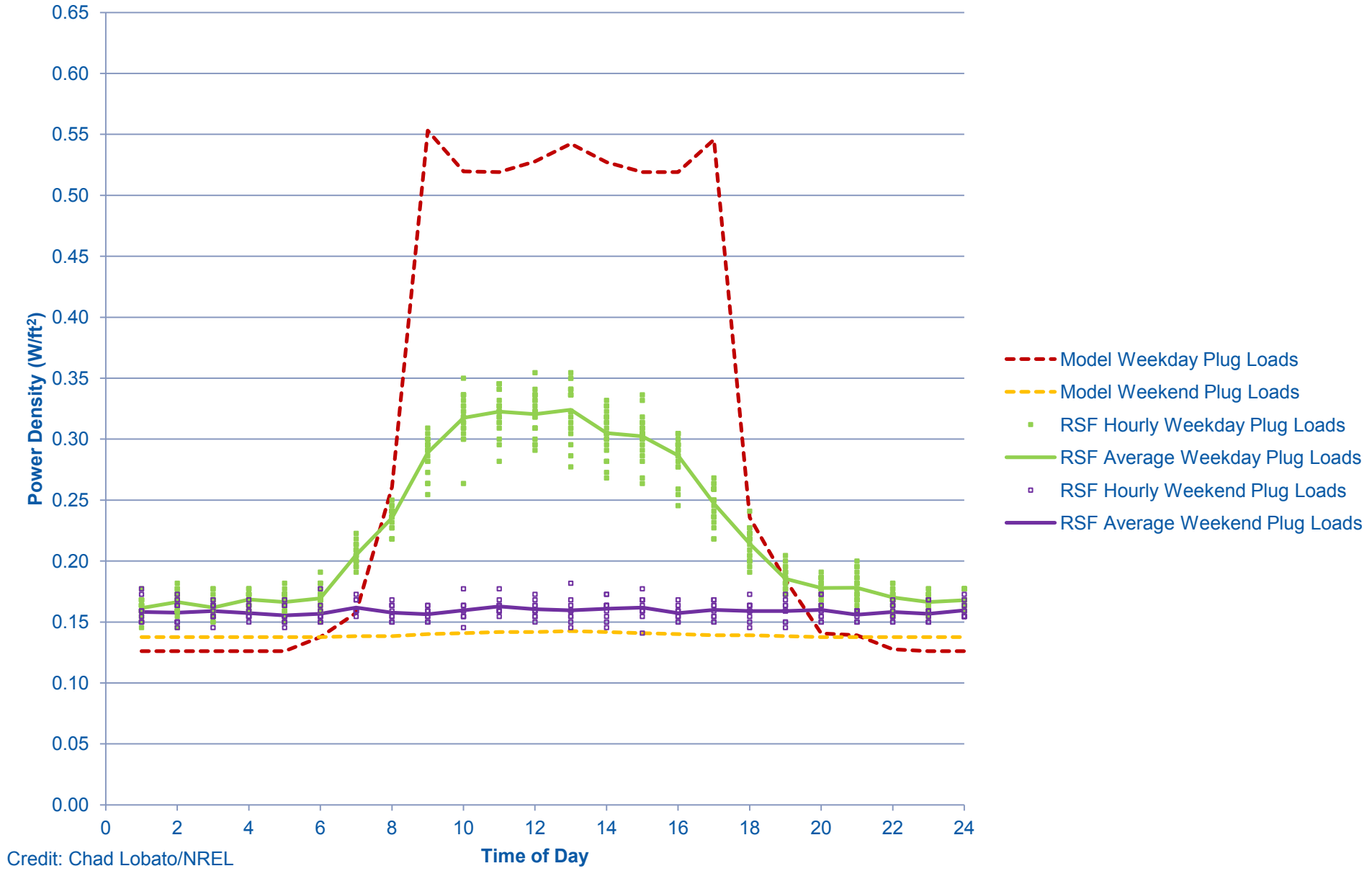
Credit: Chad Lobato/NREL

September 2011 Plug Load Power Density



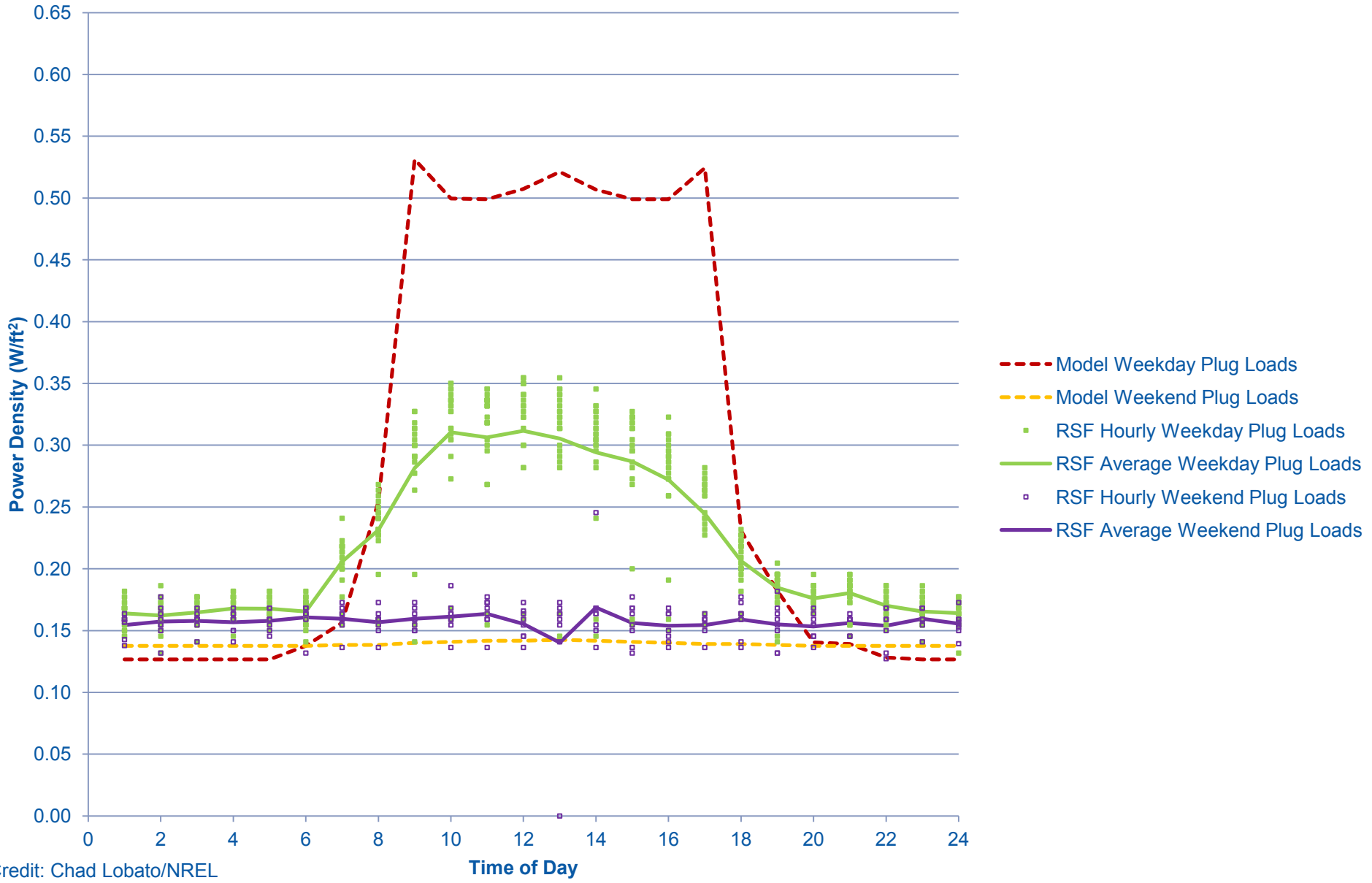
Credit: Chad Lobato/NREL

October 2011 Plug Load Power Density

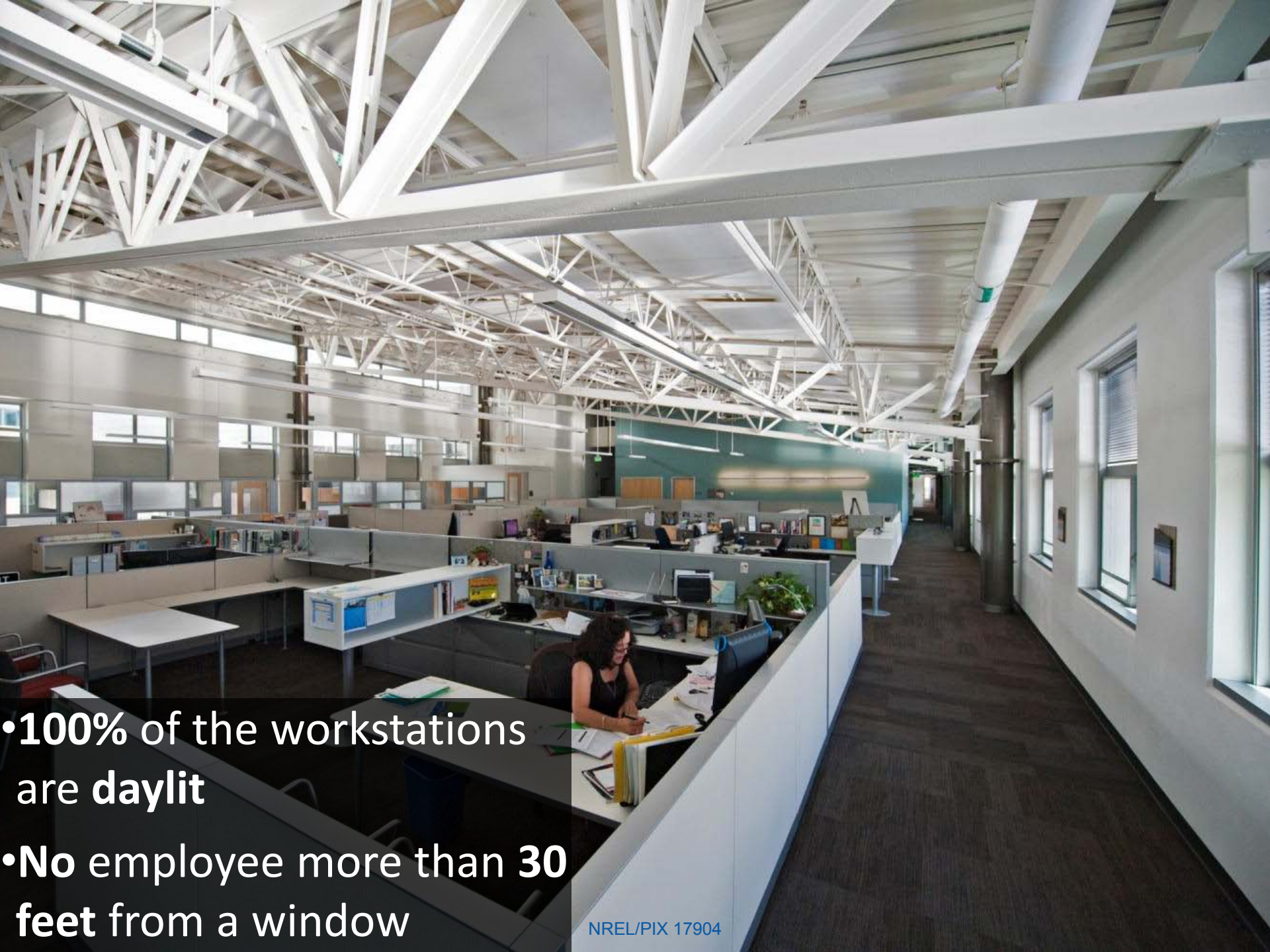


Credit: Chad Lobato/NREL

November 2011 Plug Load Power Density



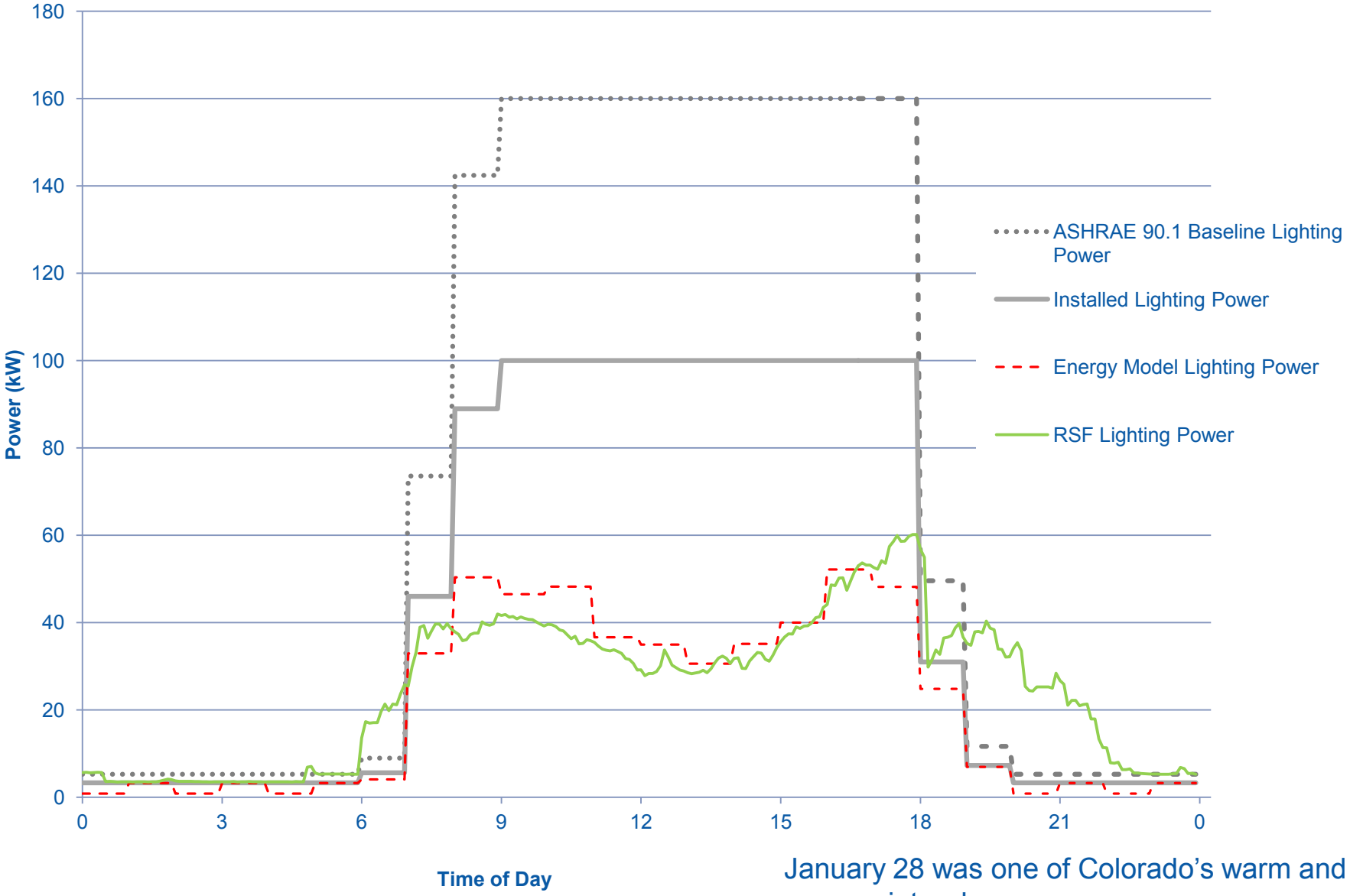
Credit: Chad Lobato/NREL



- **100%** of the workstations are **daylit**
- **No** employee more than **30 feet** from a window

NREL/PIX 17904

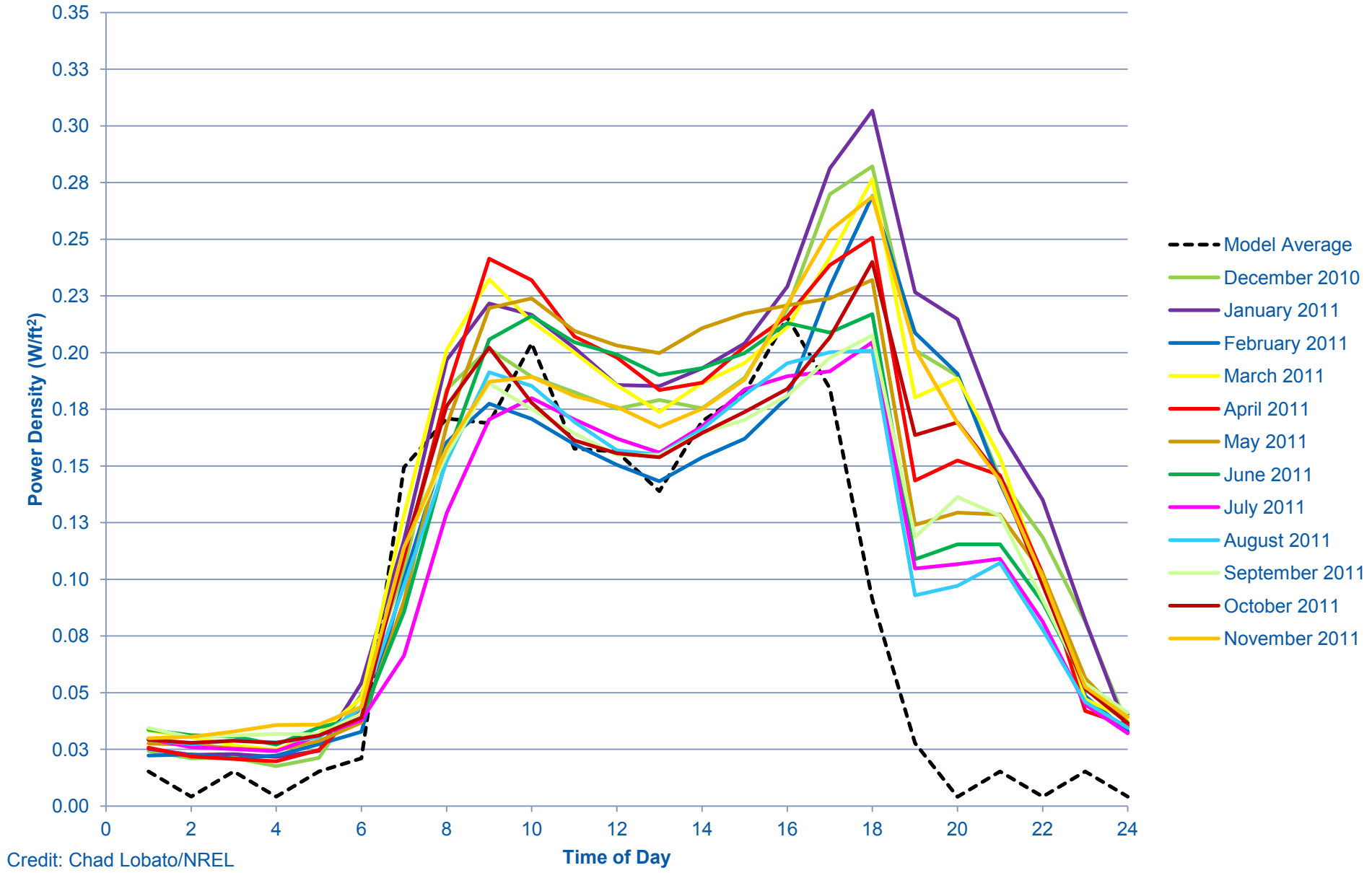
January 28, 2011 Lighting and Daylighting



January 28 was one of Colorado's warm and sunny winter days.

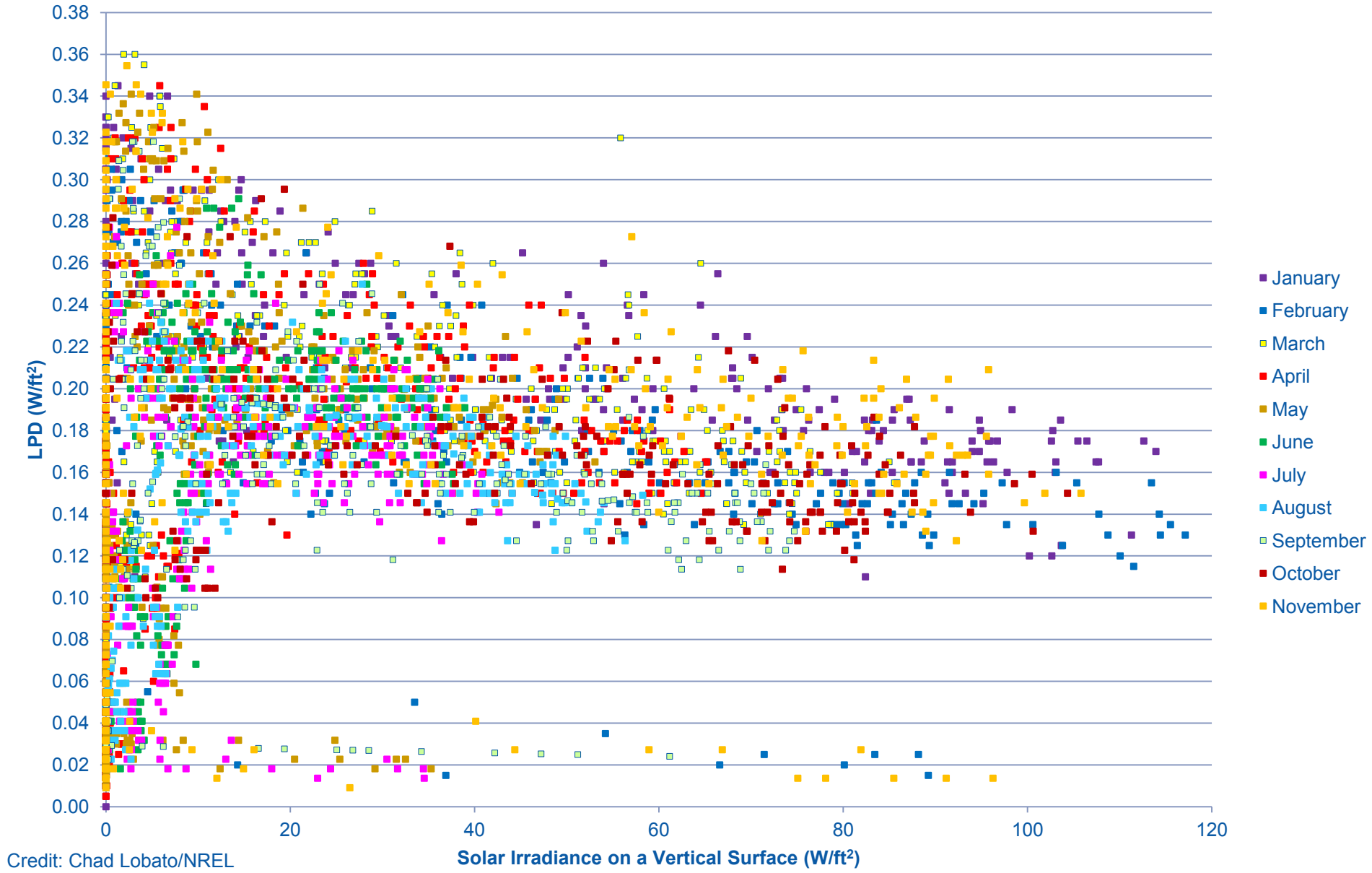
Credit: Chad Lobato/NREL

December 2010 – November 2011 Lighting Power Density



Credit: Chad Lobato/NREL

RSF Weekday Daylighting Performance



Credit: Chad Lobato/NREL

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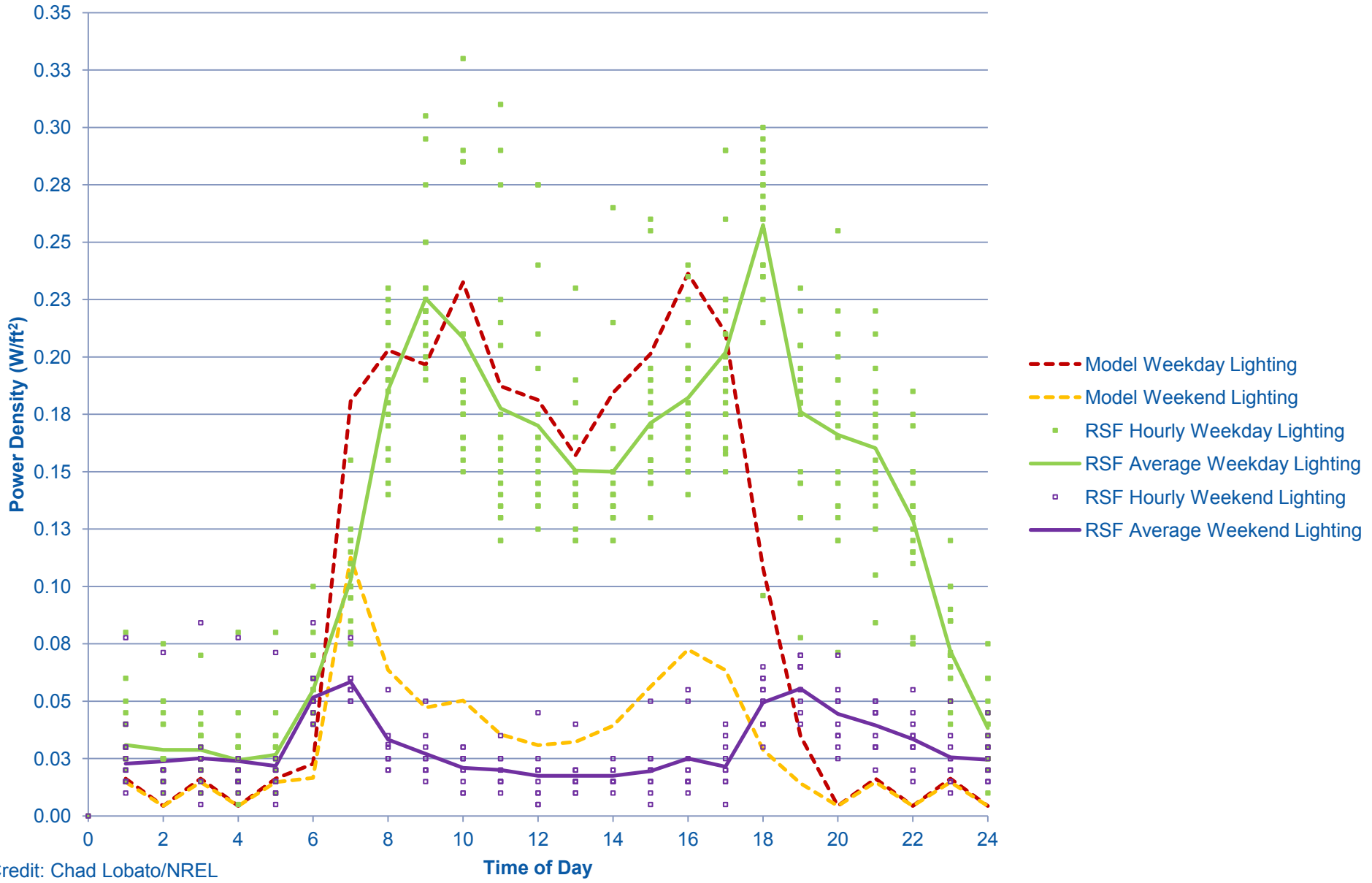

Credit: Chad Lobato/NREL

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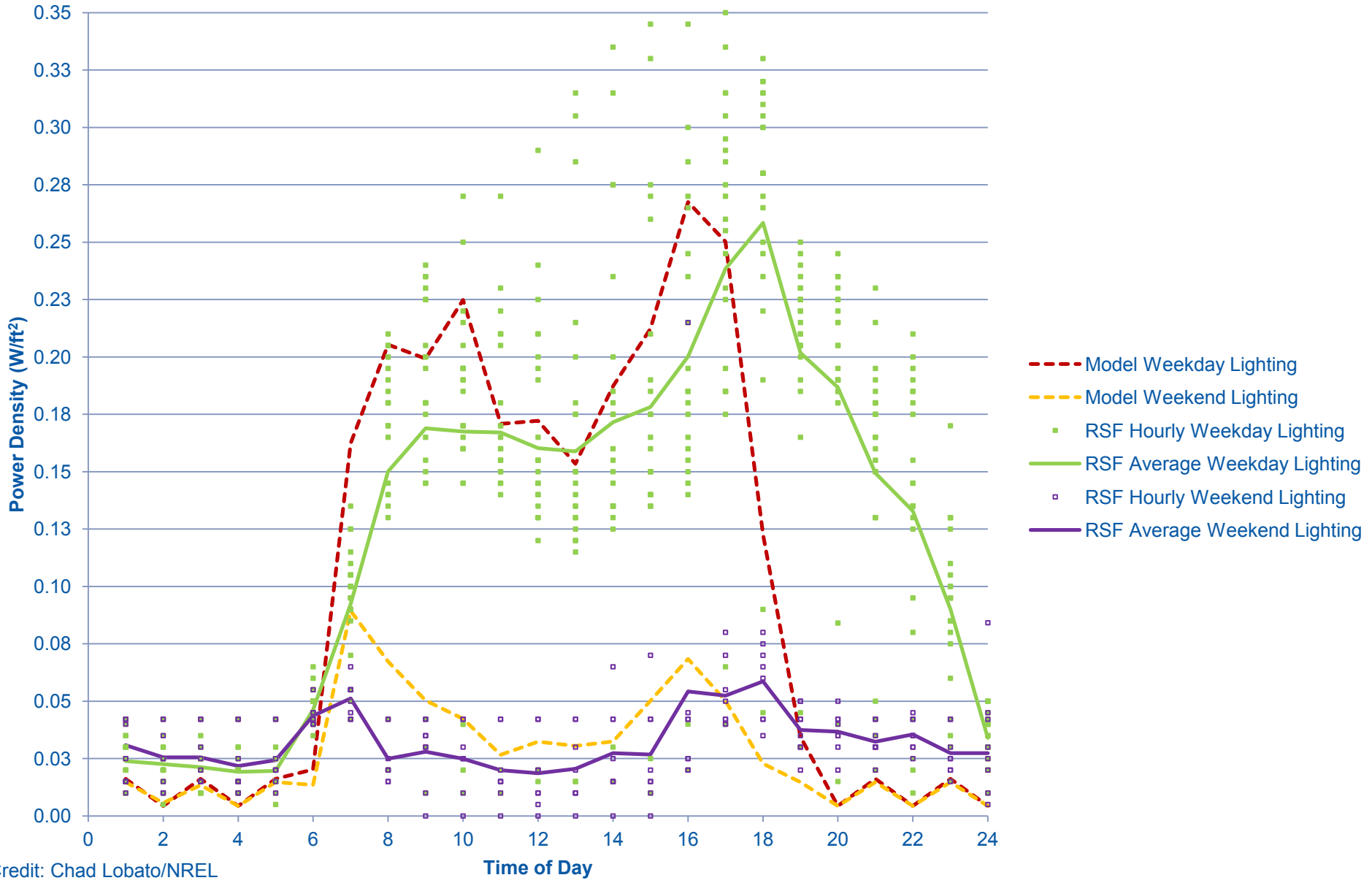

Credit: Chad Lobato/NREL

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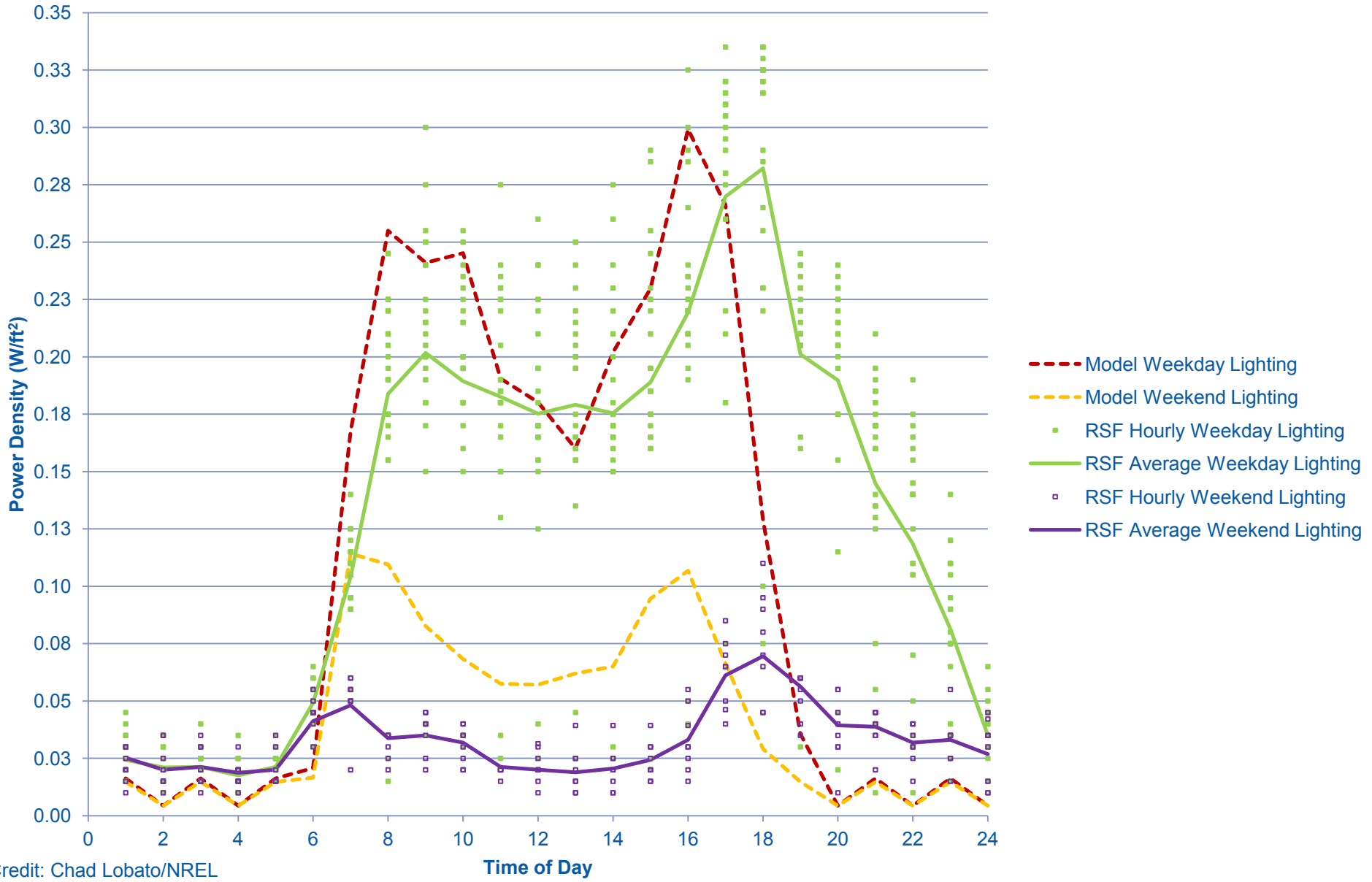

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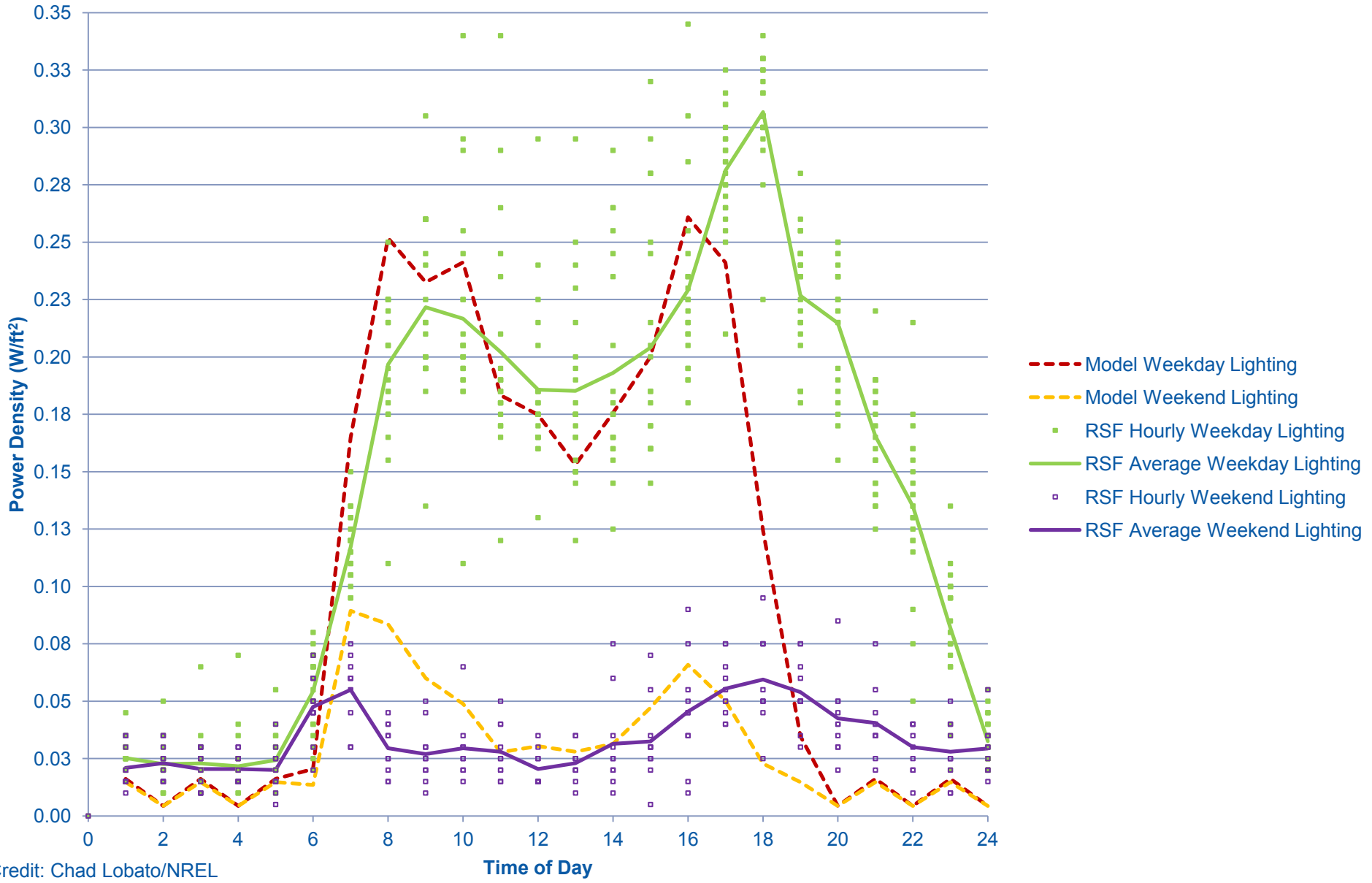

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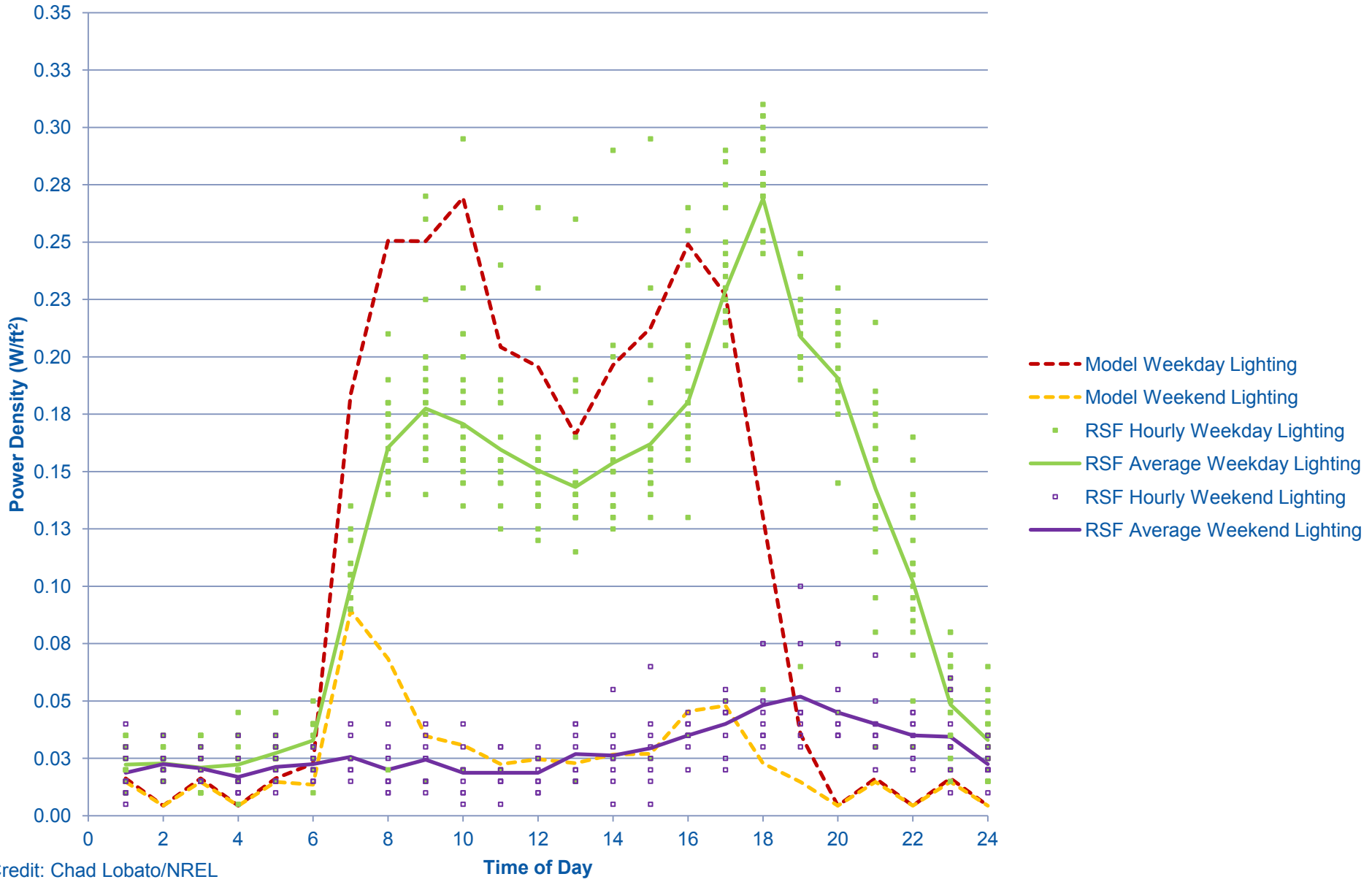

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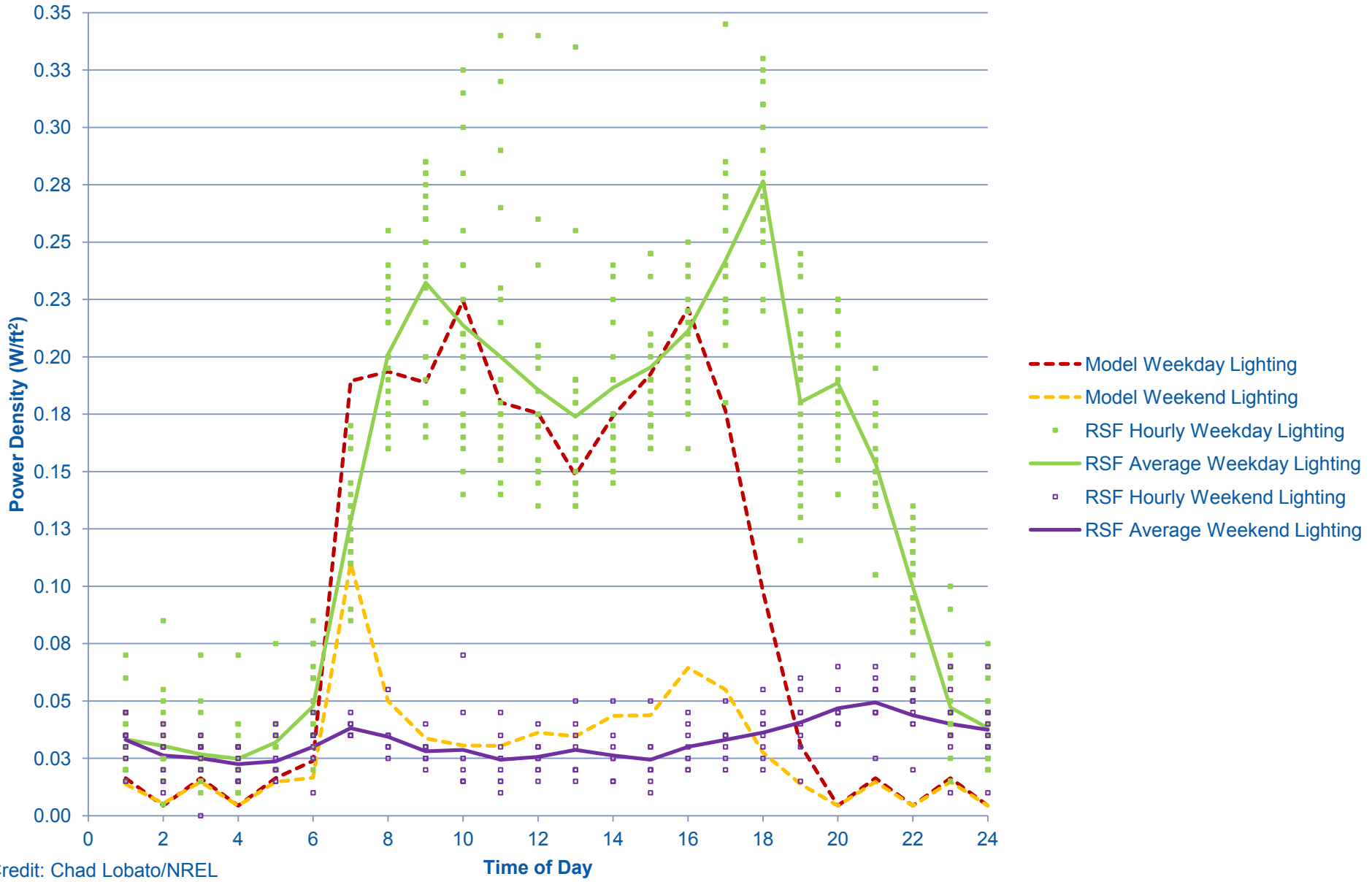

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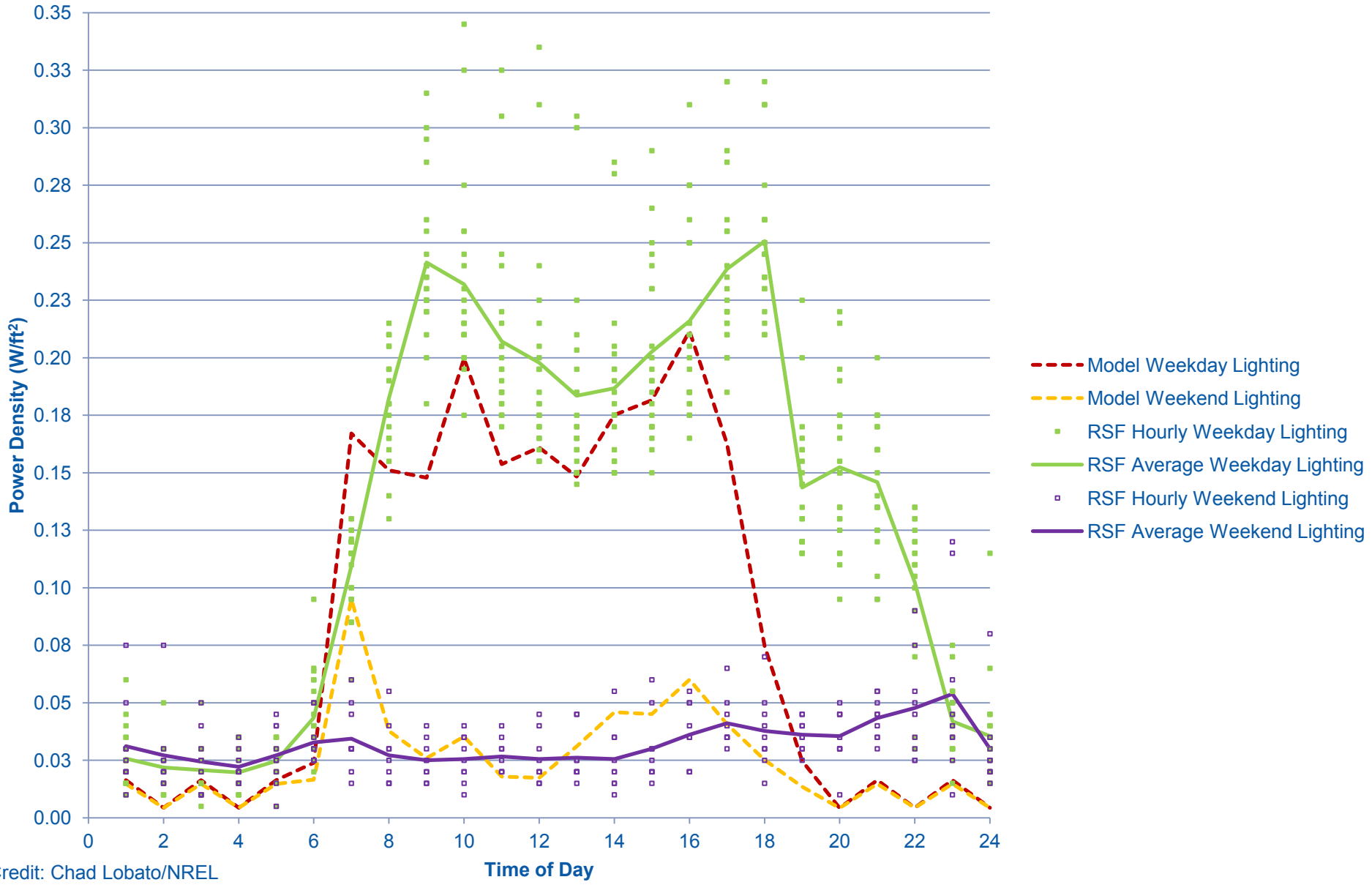

Credit: Chad Lobato/NREL

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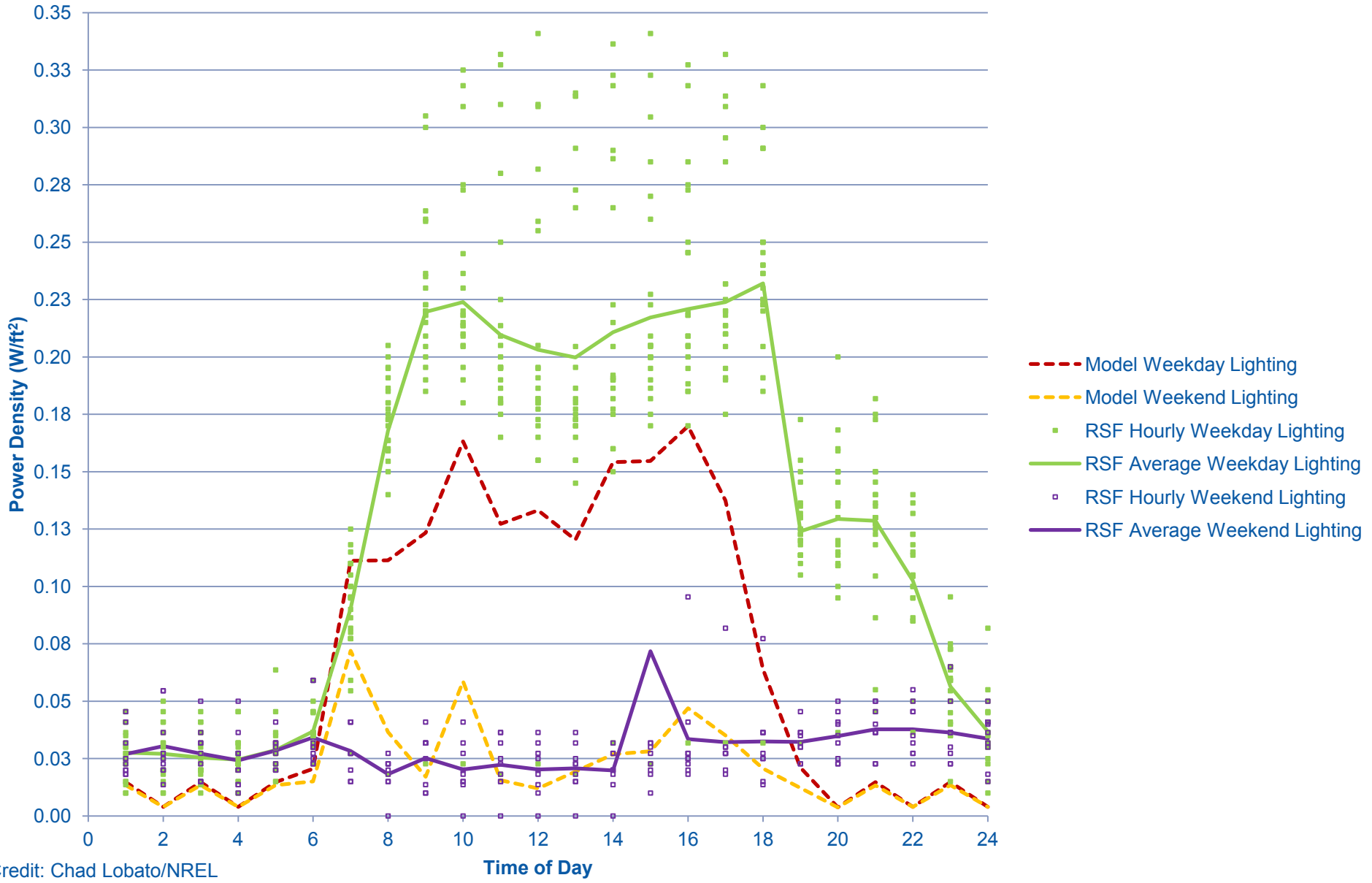

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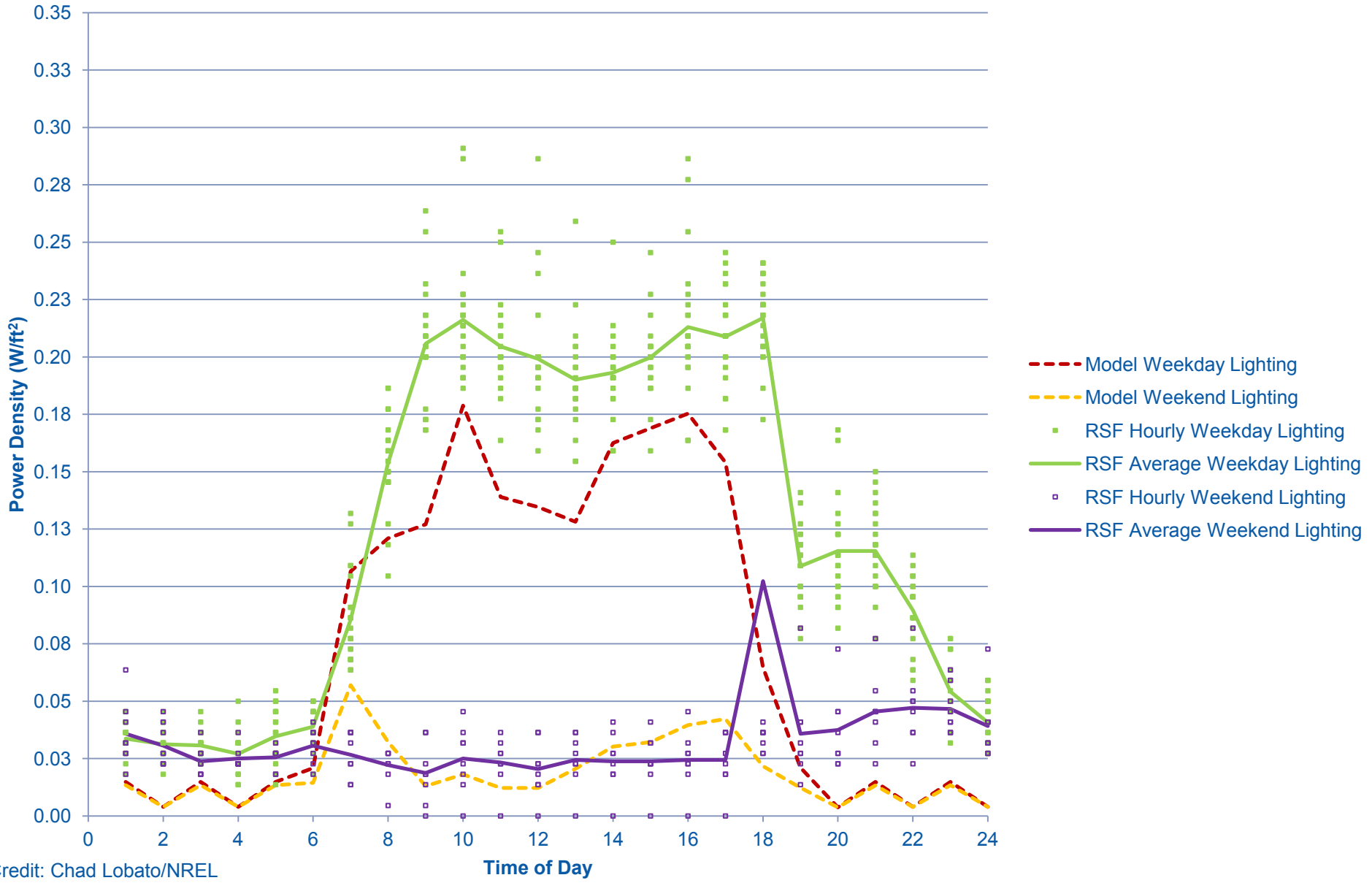
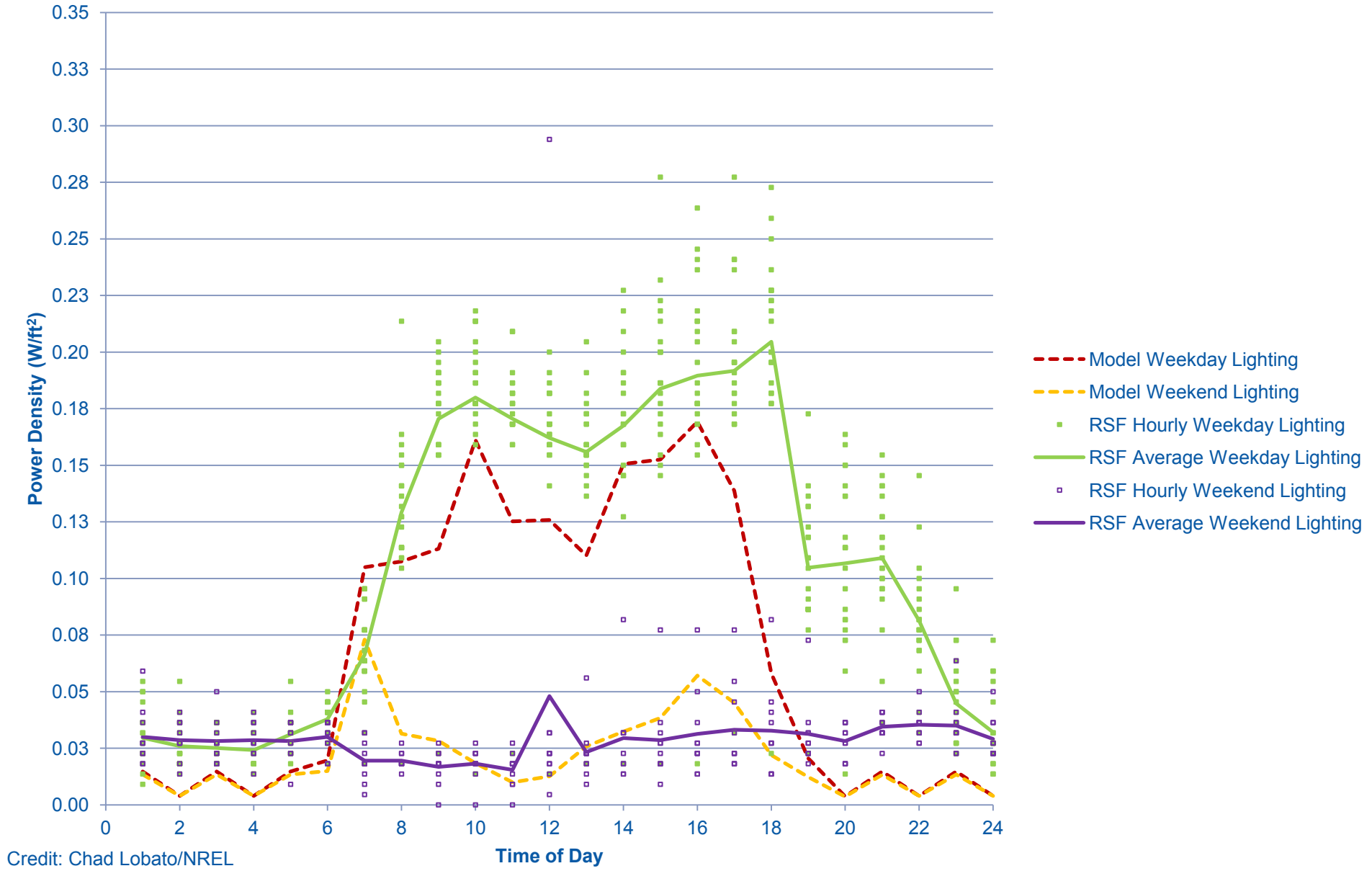
June 2011 Lighting Power Density



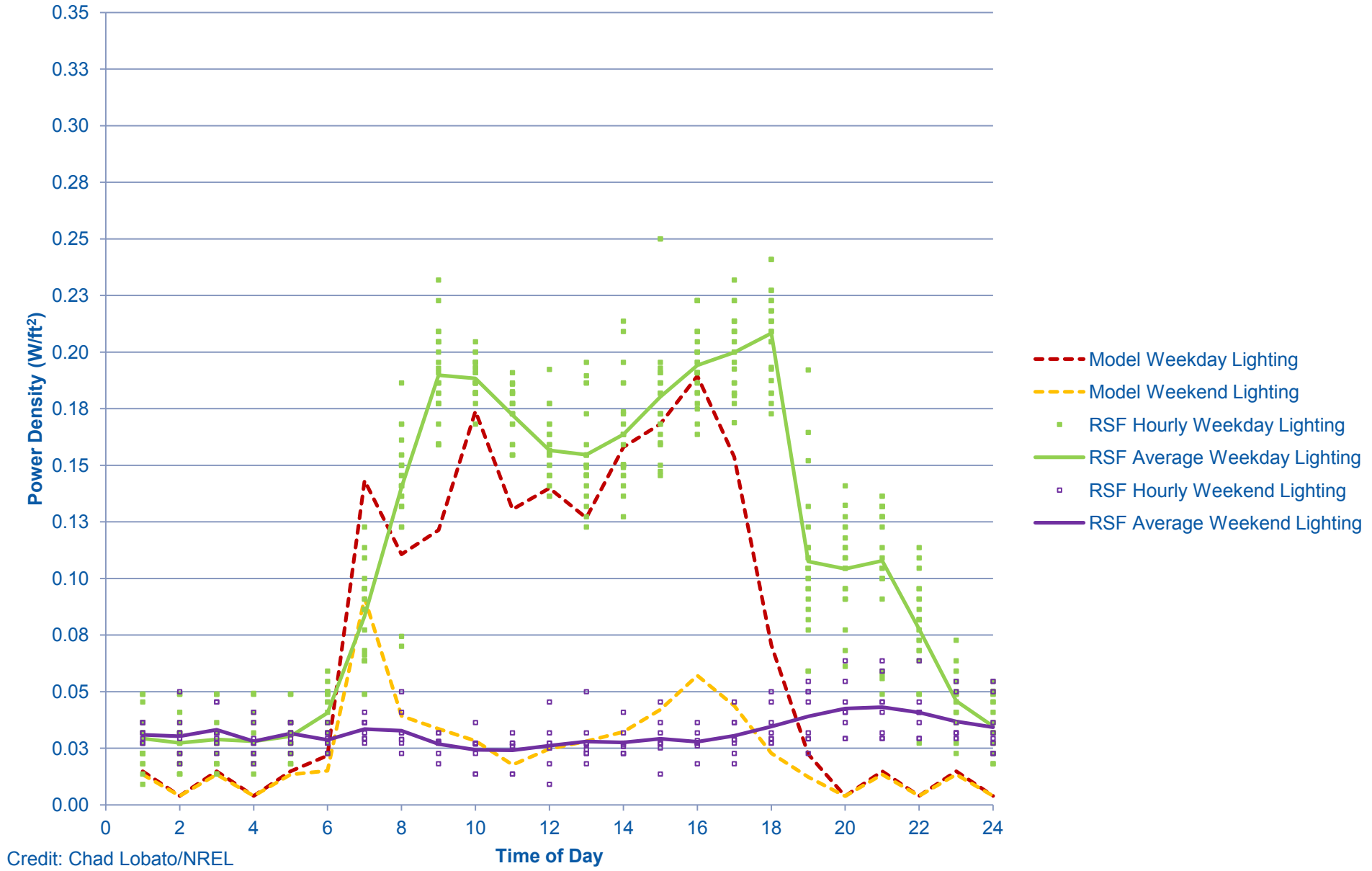
Credit: Chad Lobato/NREL

July 2011 Lighting Power Density



Credit: Chad Lobato/NREL

August 2011 Lighting Power Density



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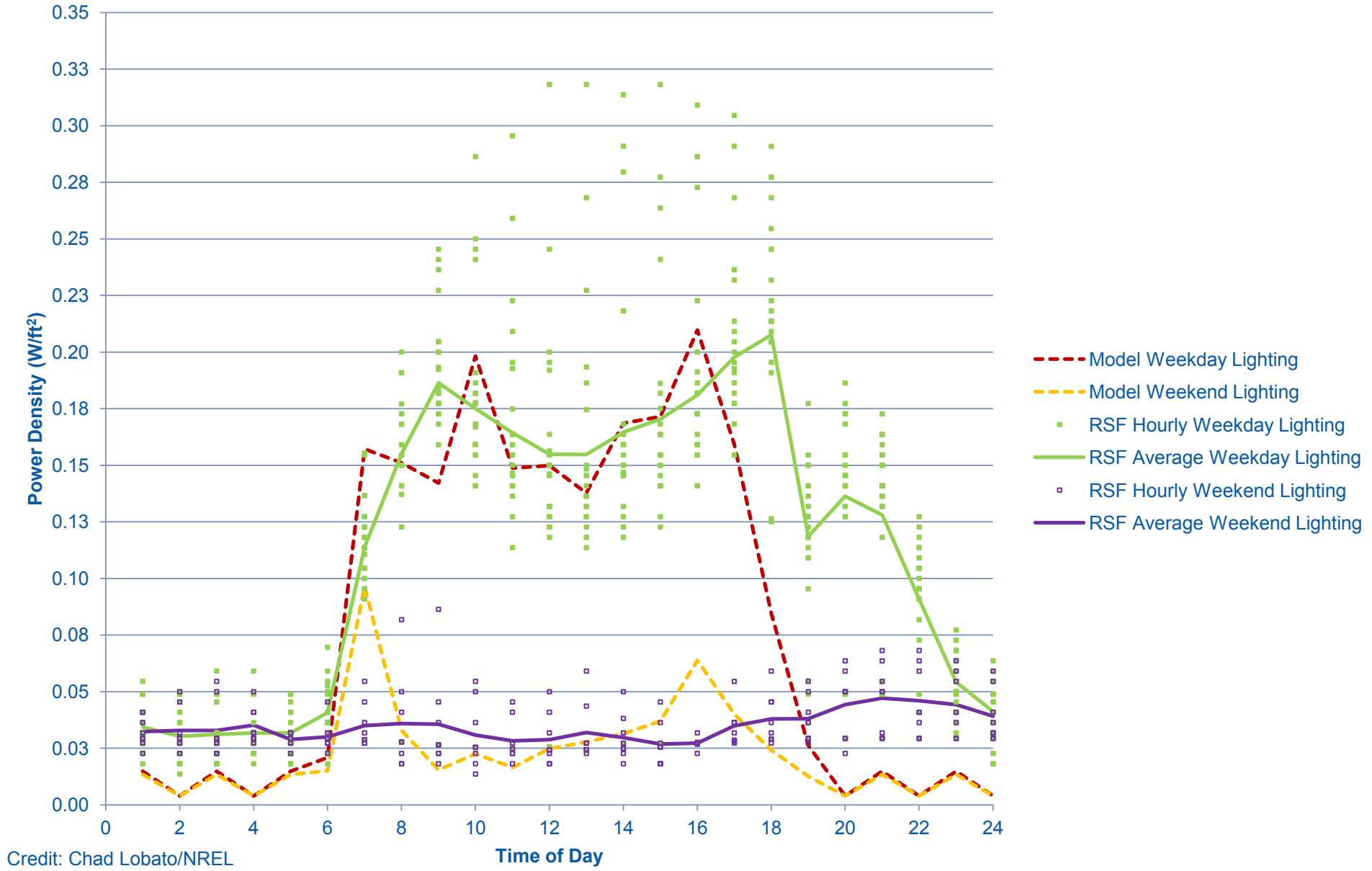
September 2011 Lighting Power Density



Credit: Chad Lobato/NREL

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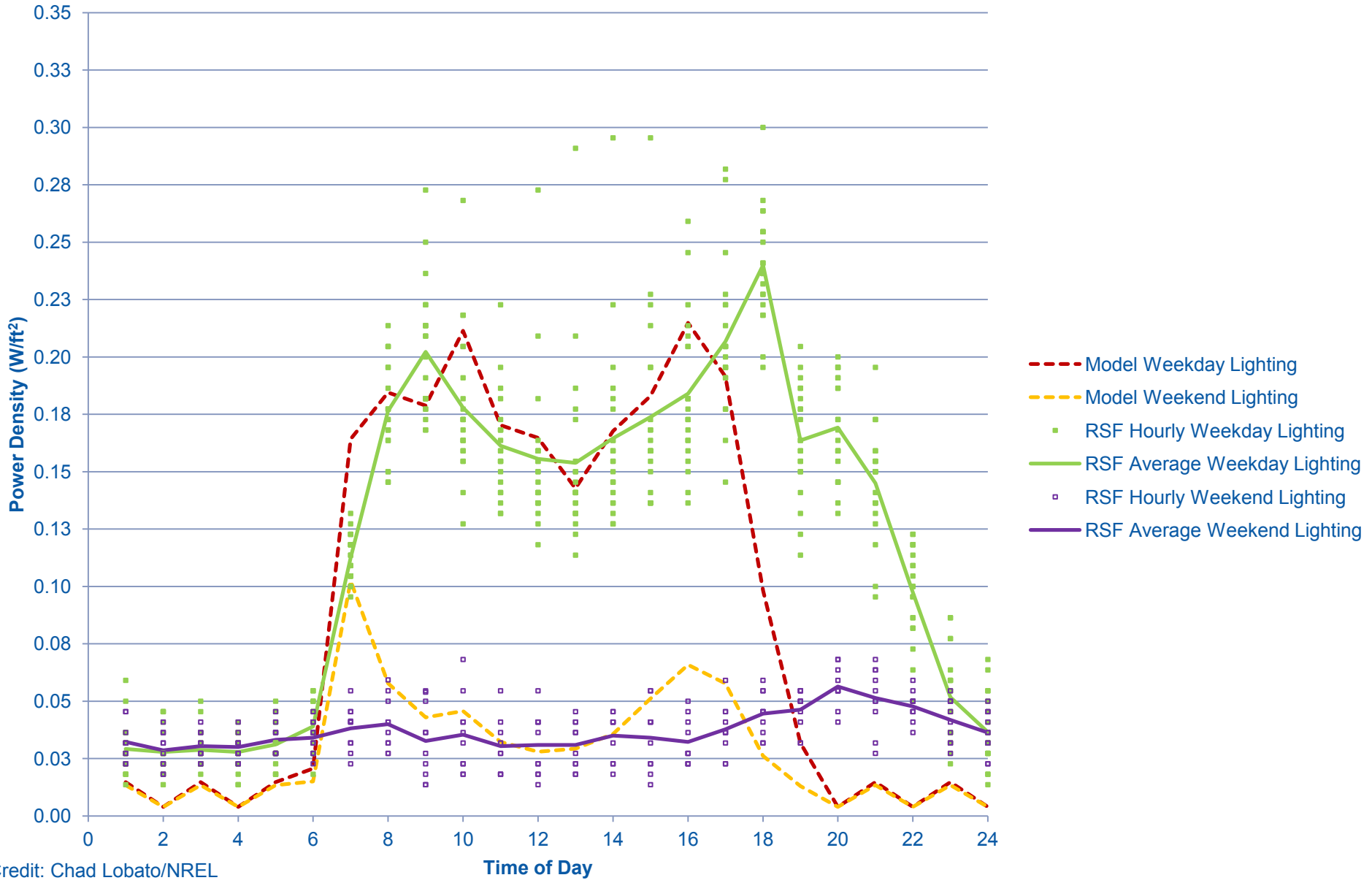

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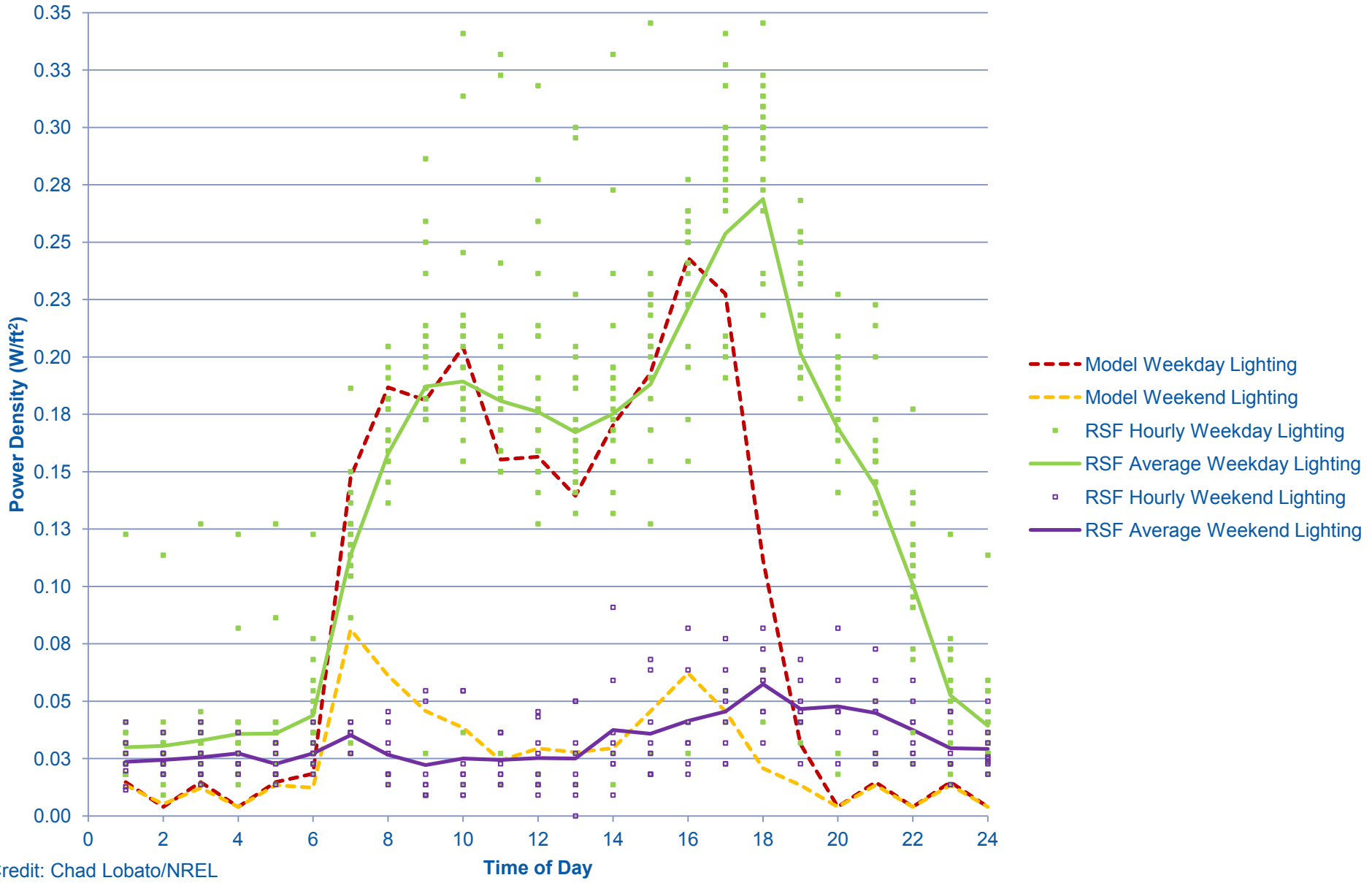
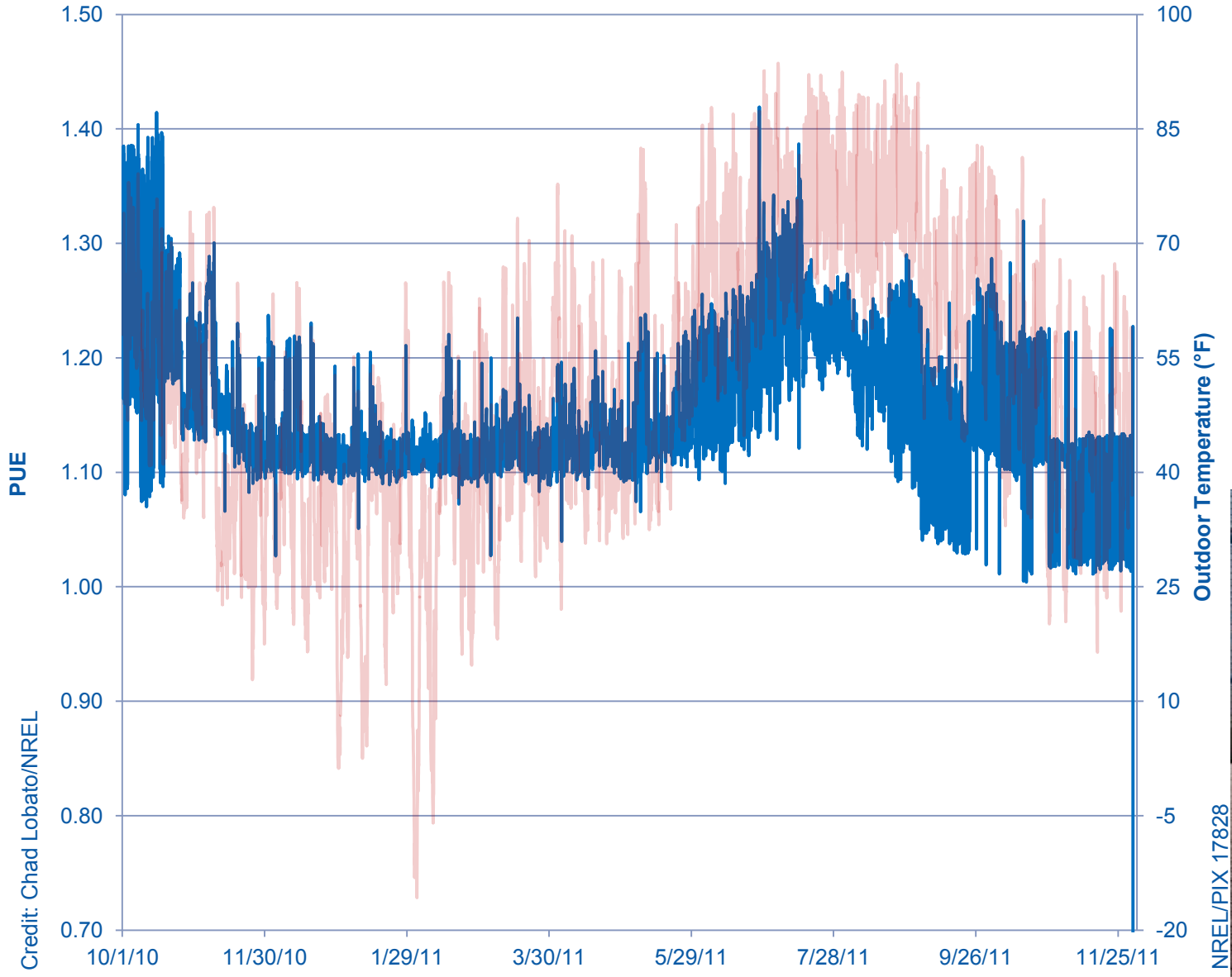


Credit: Chad Lobato/NREL

Data Center PUE



Credit: Chad Lobato/NREL

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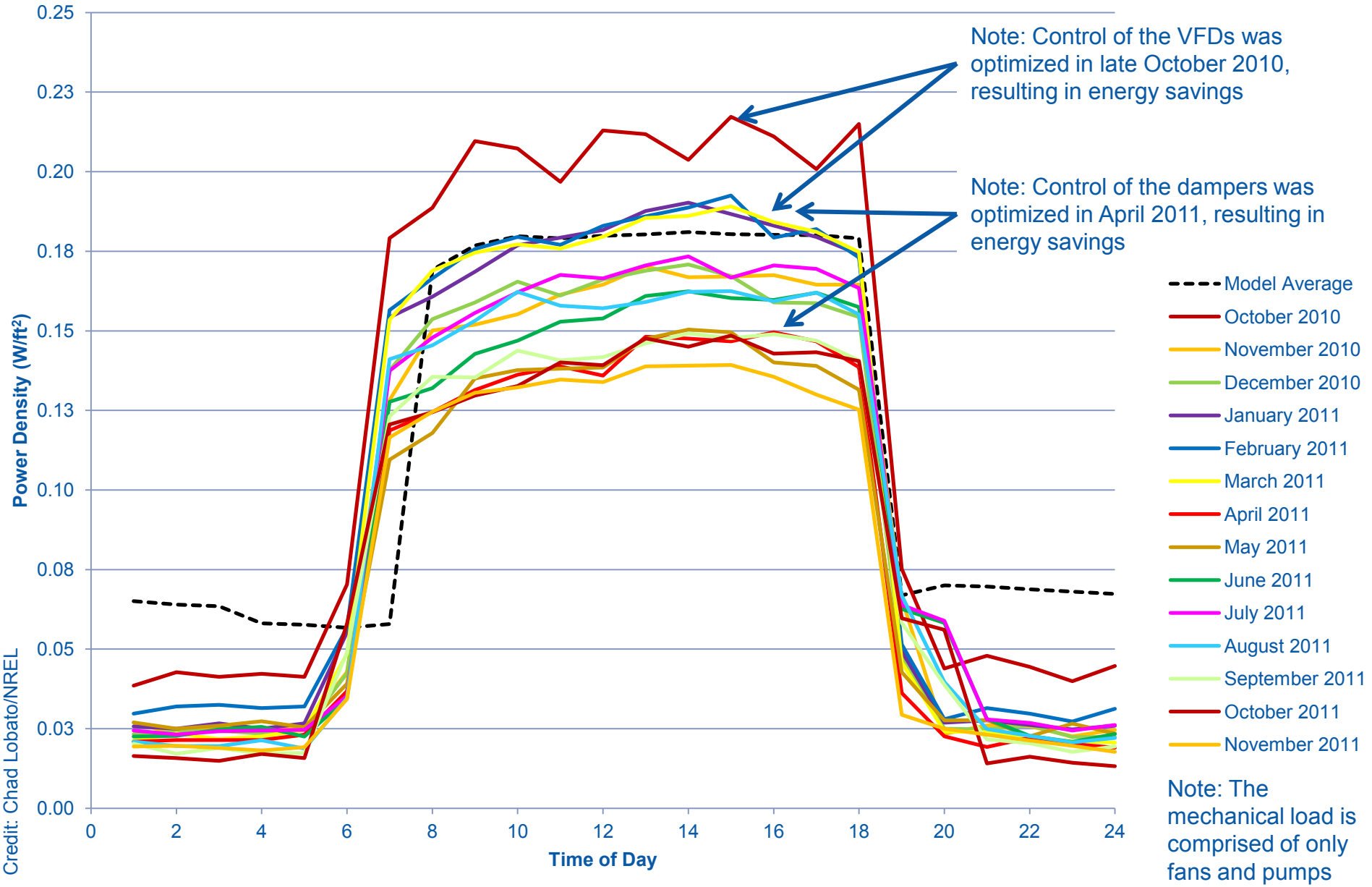
October 2010 – November 2011 Mechanical System Power Density



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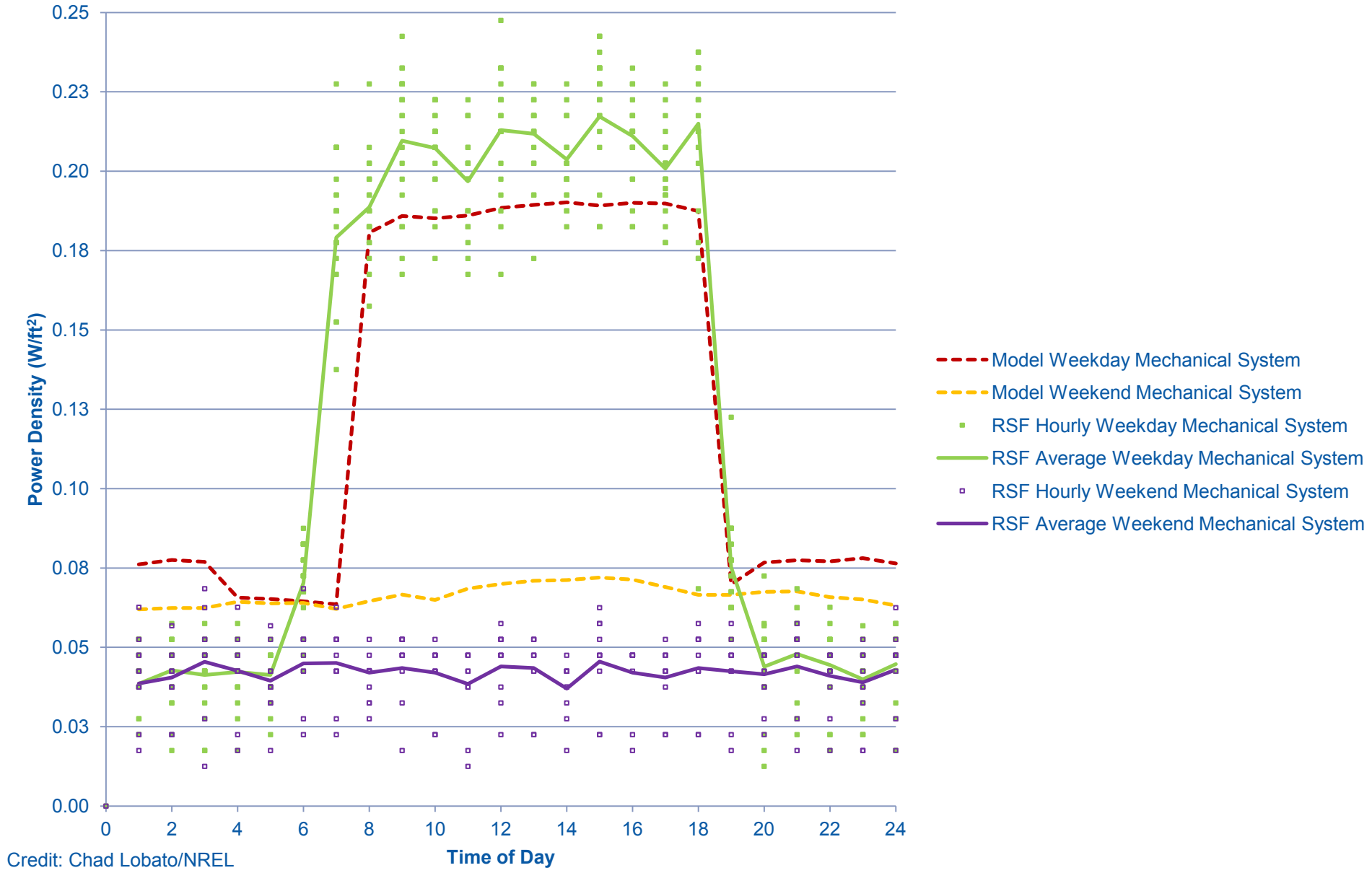

Credit: Chad Lobato/NREL

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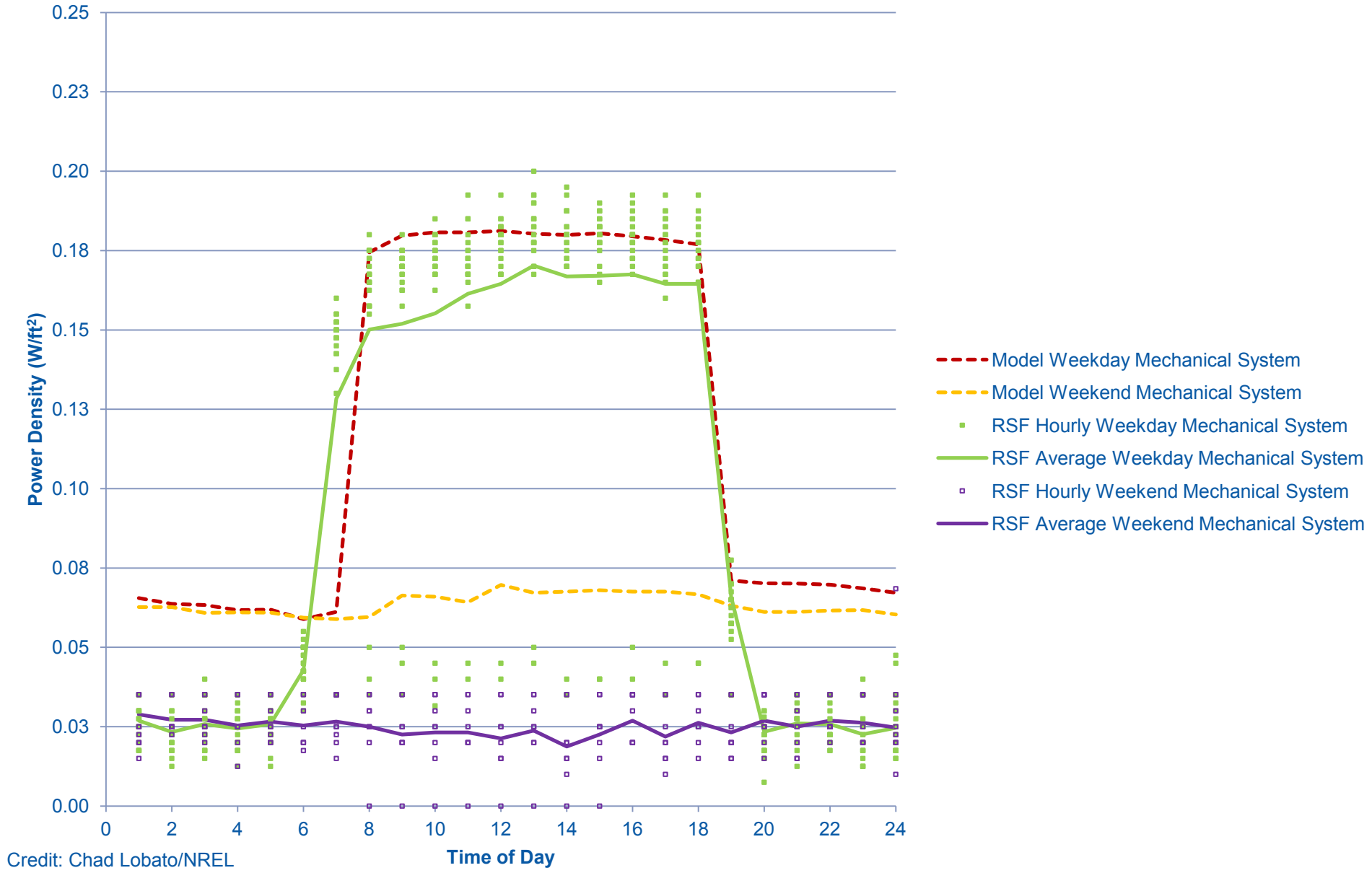

Credit: Chad Lobato/NREL

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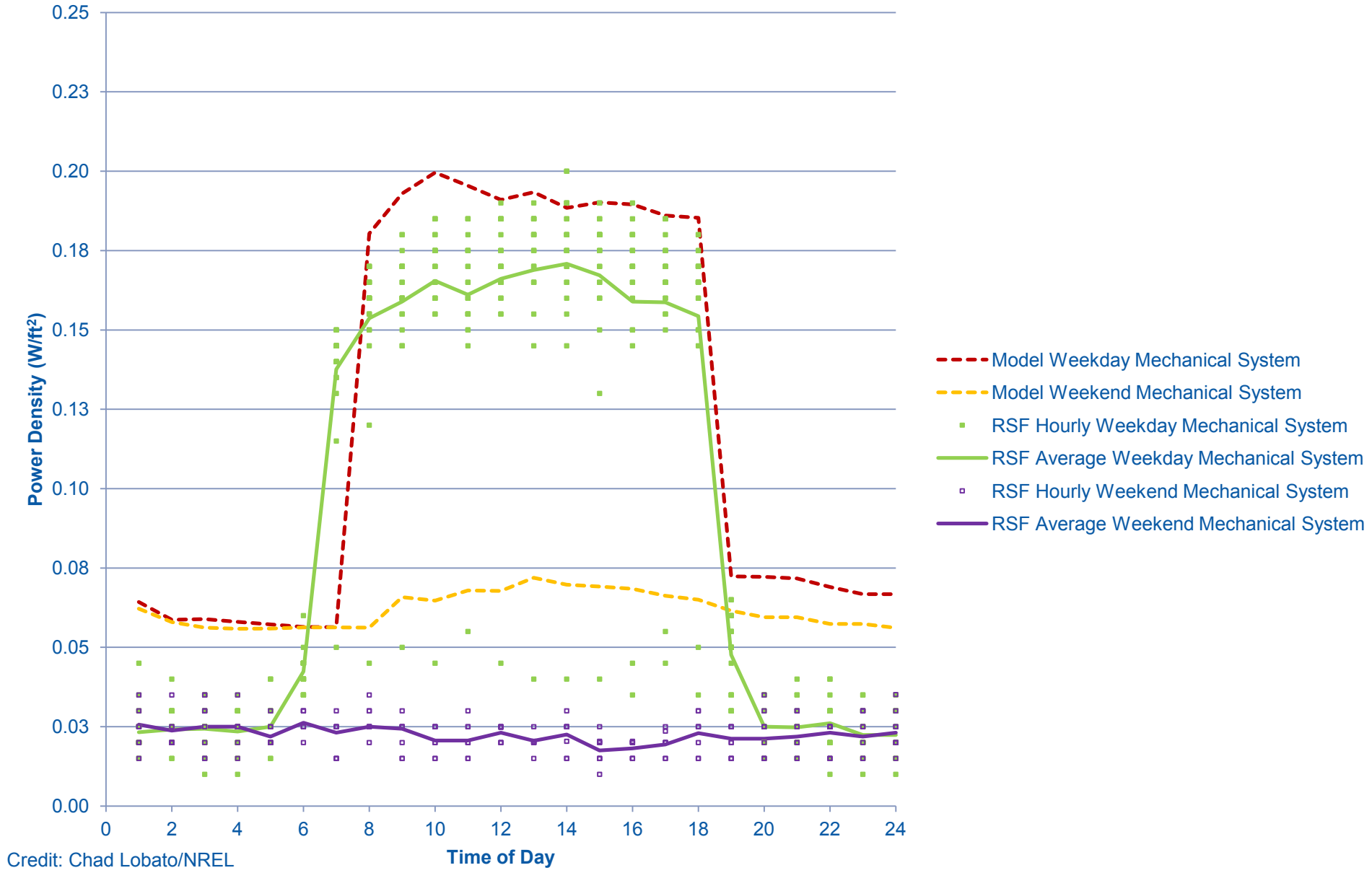
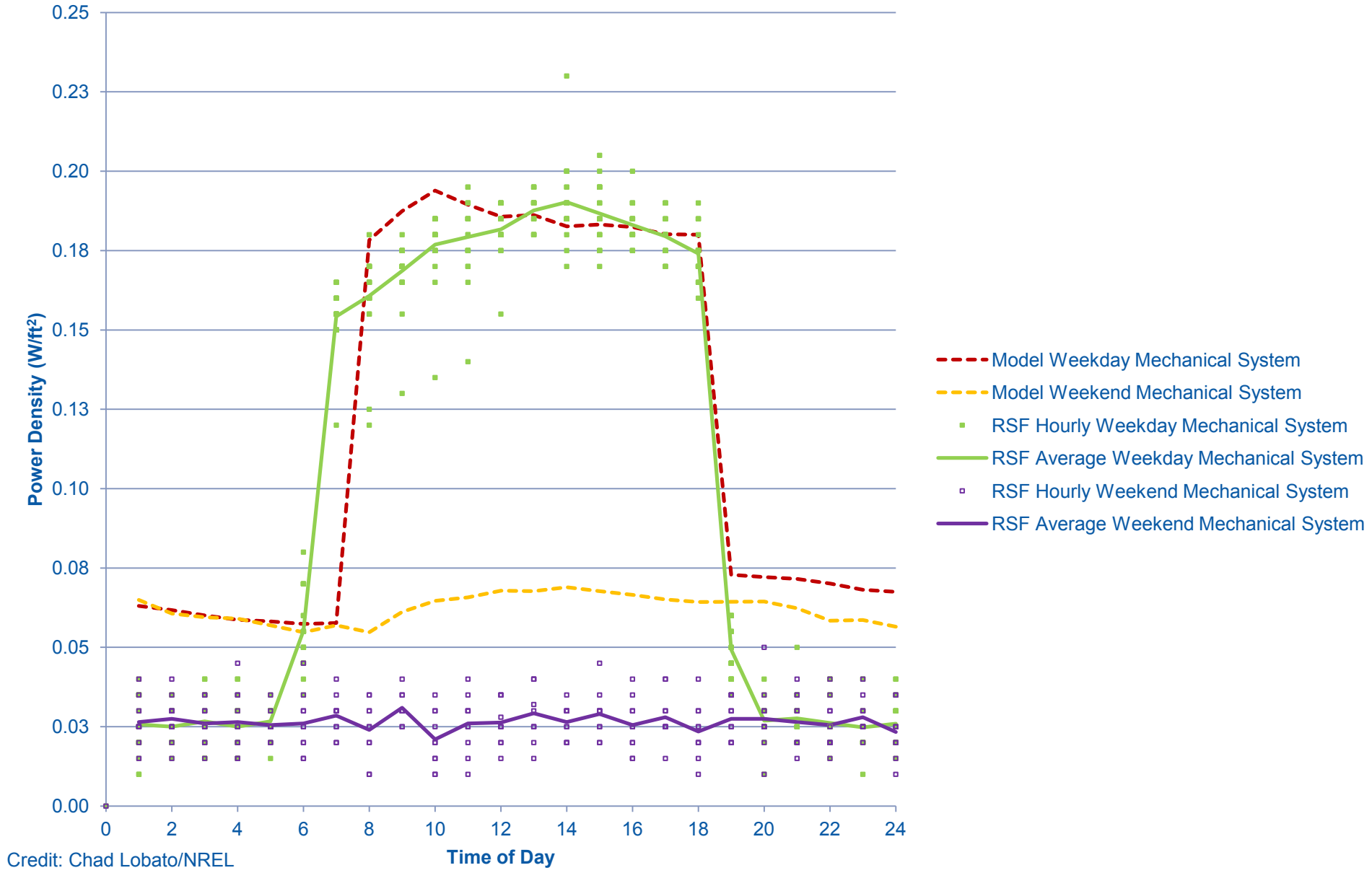


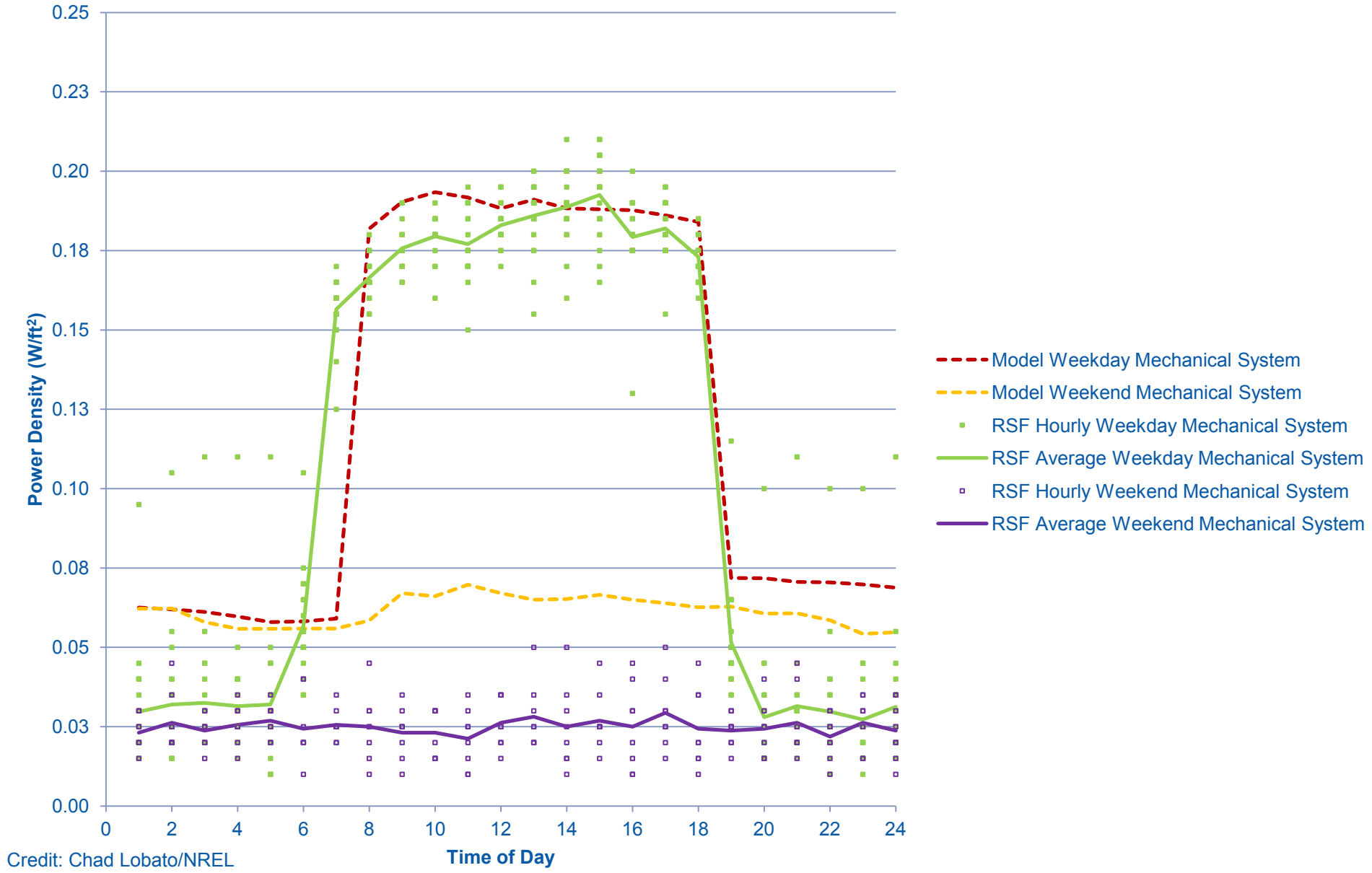
Credit: Chad Lobato/NREL

January 2011 Mechanical System Power Density



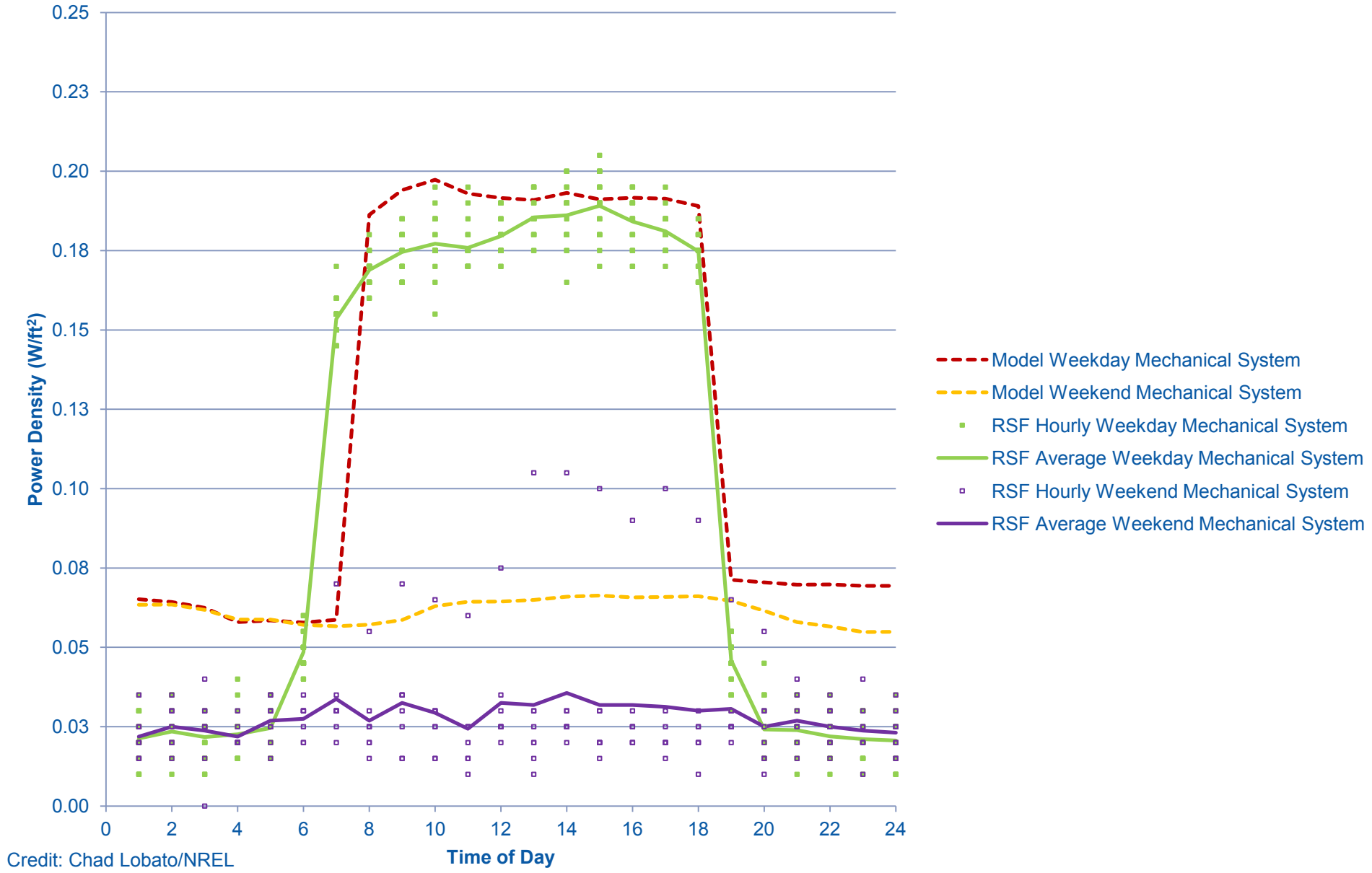
Credit: Chad Lobato/NREL

February 2011 Mechanical System Power Density



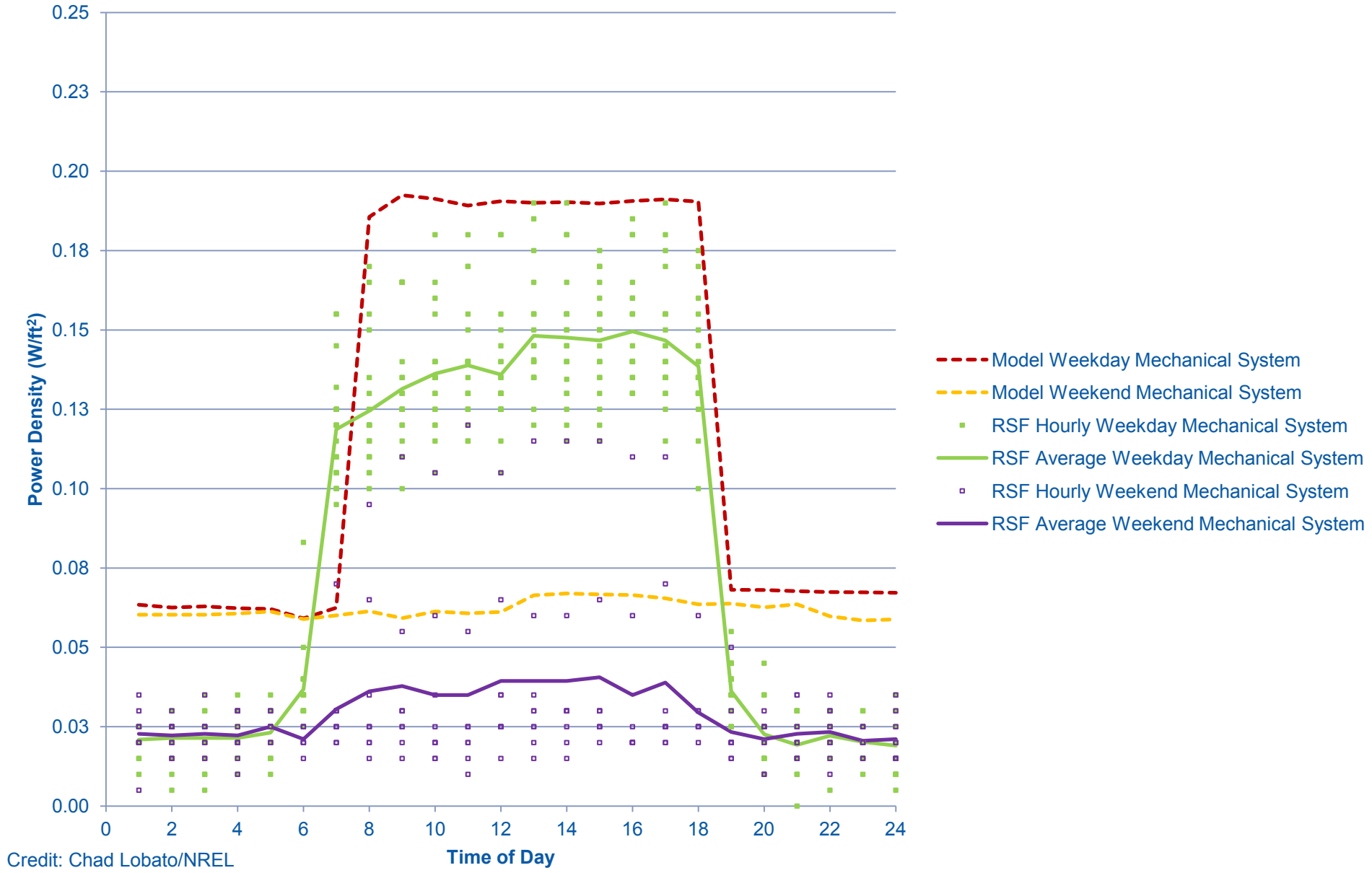
Credit: Chad Lobato/NREL

March 2011 Mechanical System Power Density



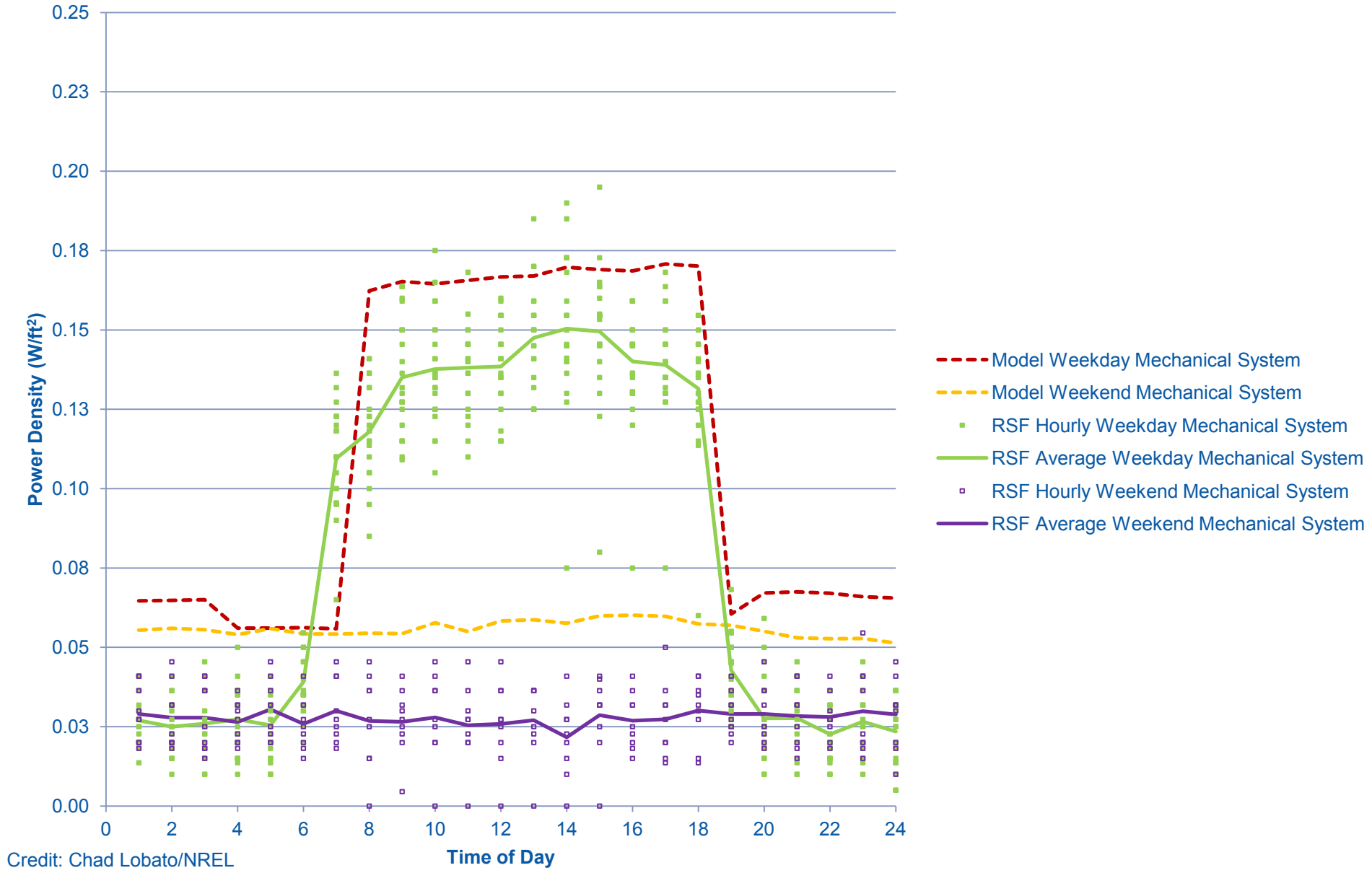
Credit: Chad Lobato/NREL

April 2011 Mechanical System Power Density



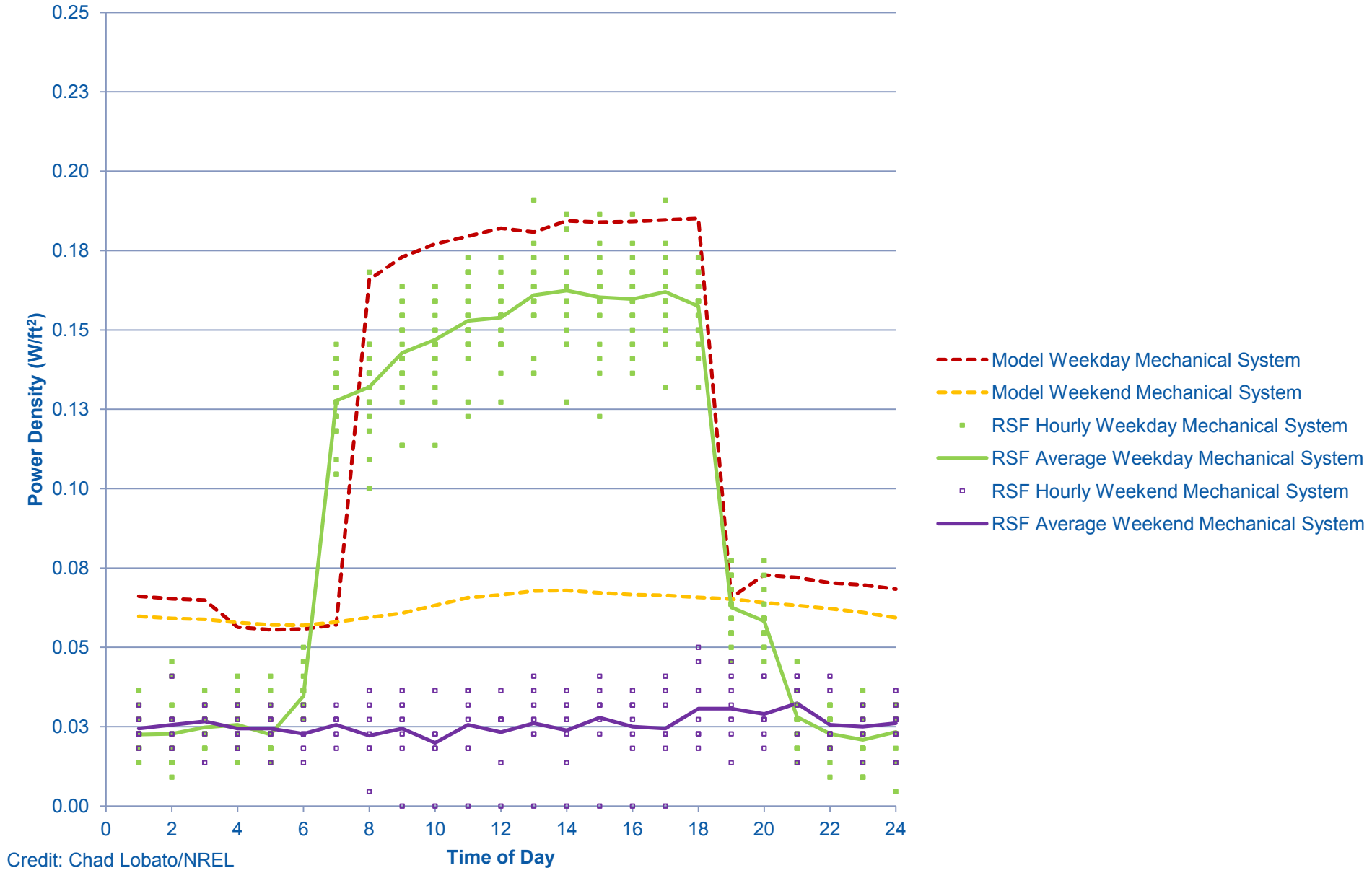
Credit: Chad Lobato/NREL

May 2011 Mechanical System Power Density



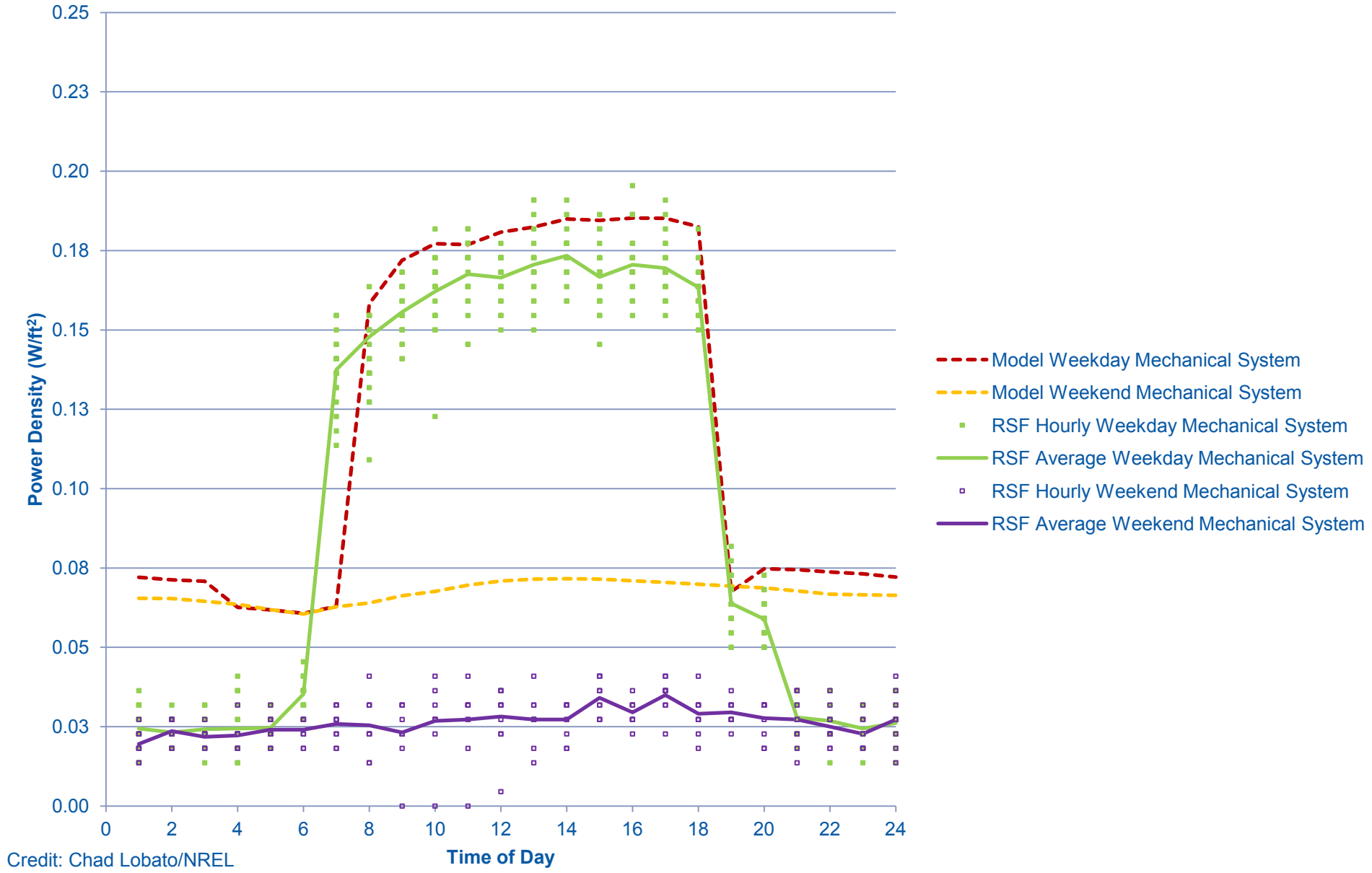
Credit: Chad Lobato/NREL

June 2011 Mechanical System Power Density



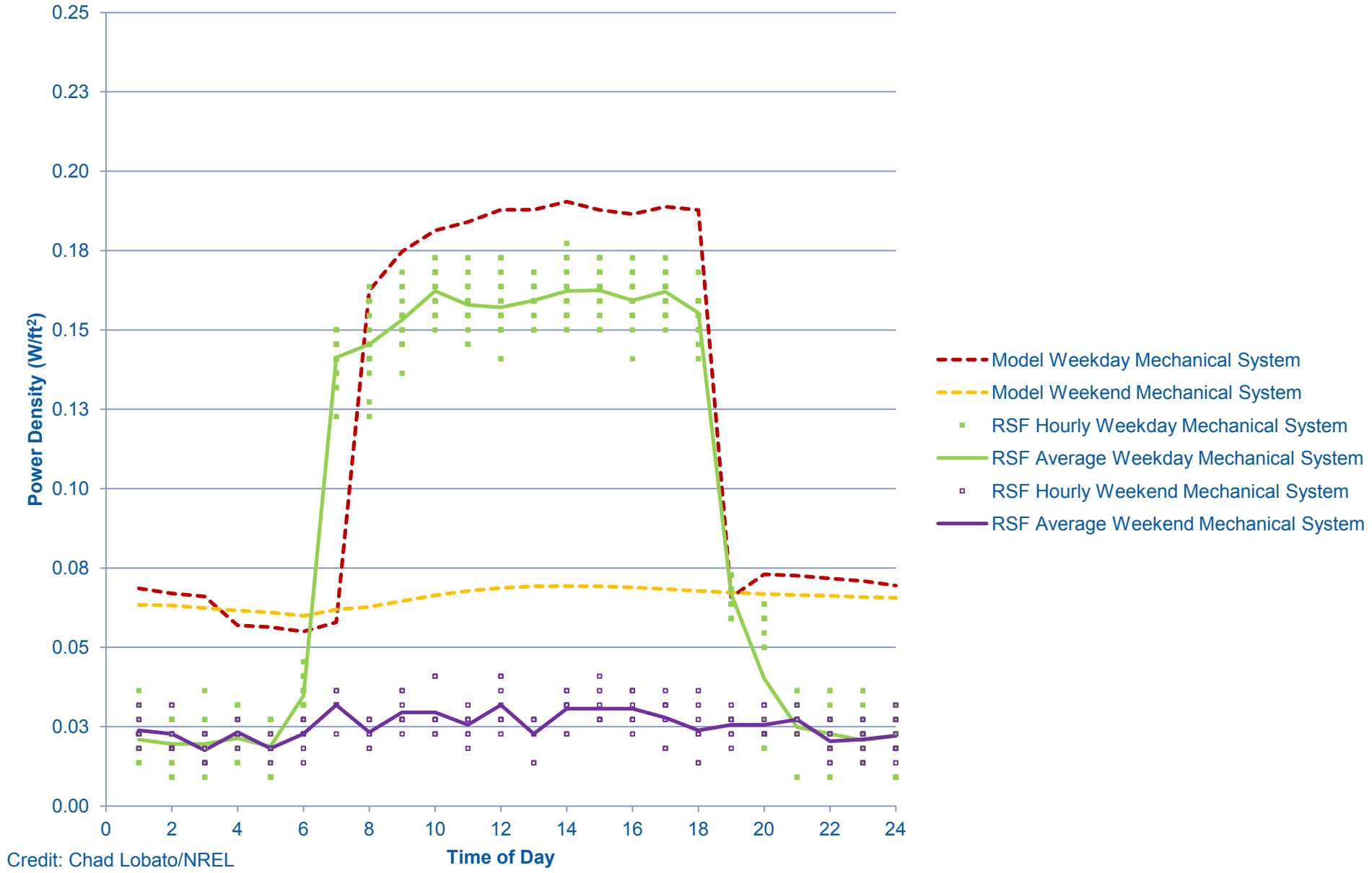
Credit: Chad Lobato/NREL

July 2011 Mechanical System Power Density



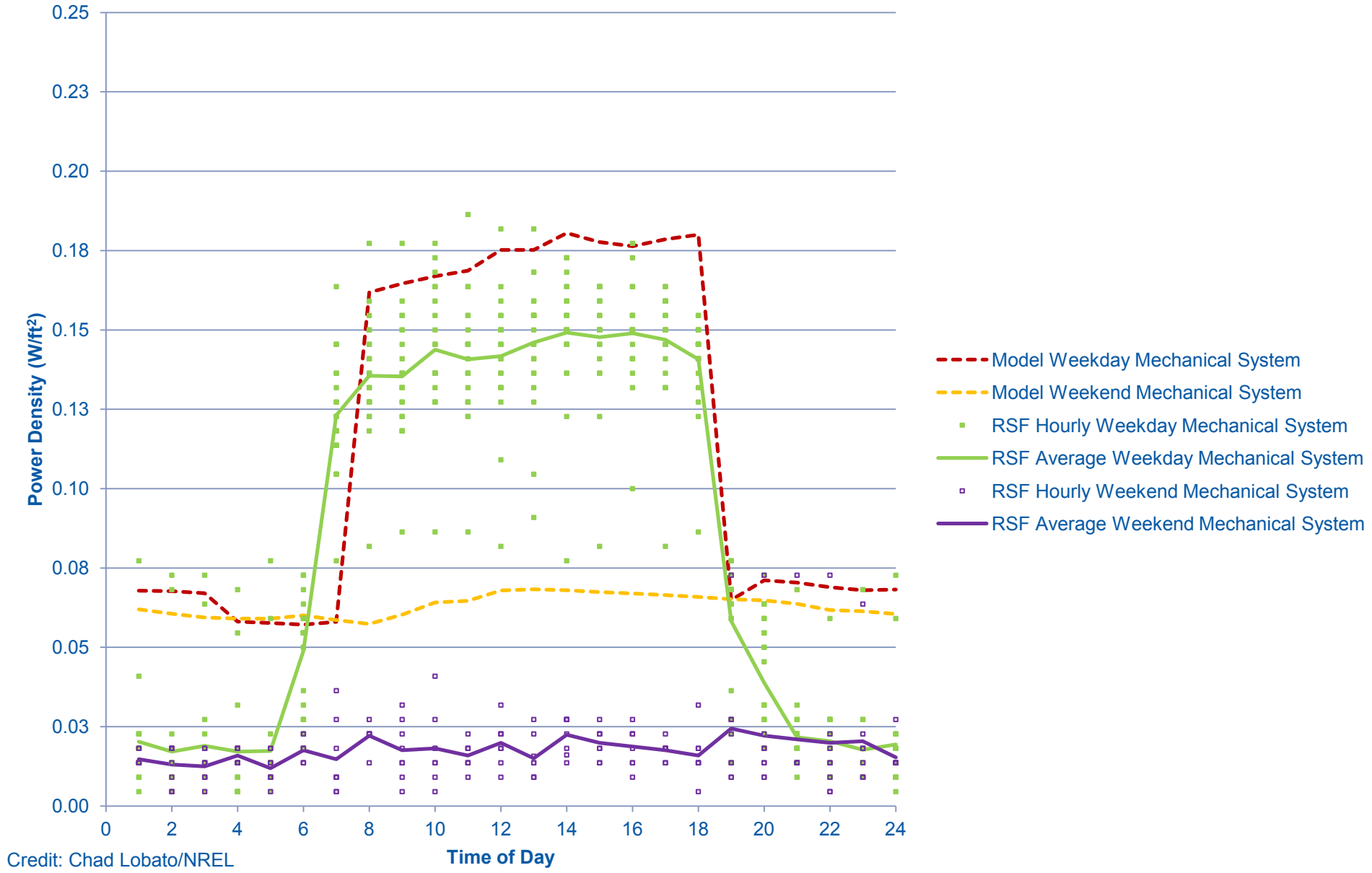
Credit: Chad Lobato/NREL

August 2011 Mechanical System Power Density



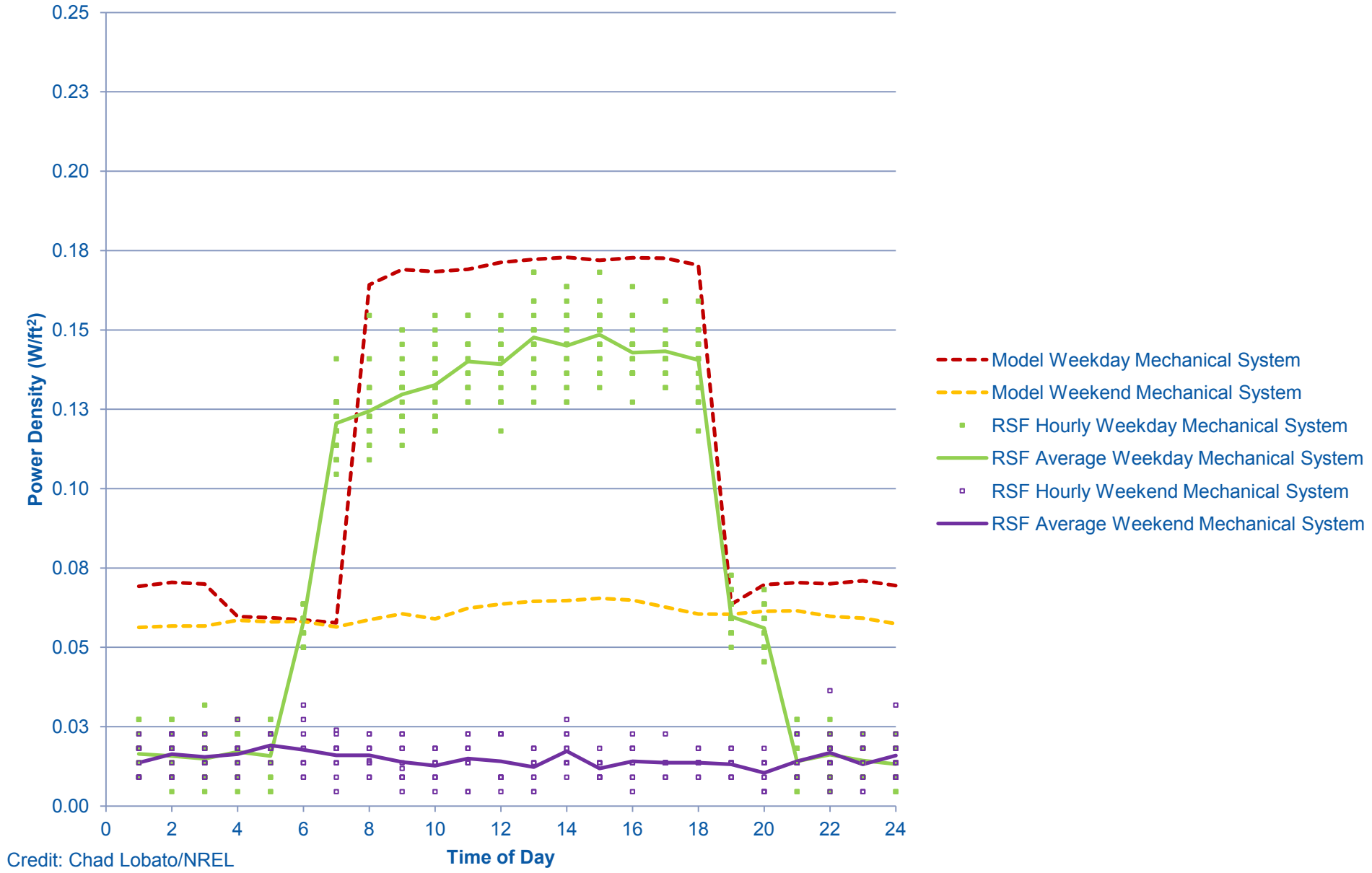
Credit: Chad Lobato/NREL

September 2011 Mechanical System Power Density



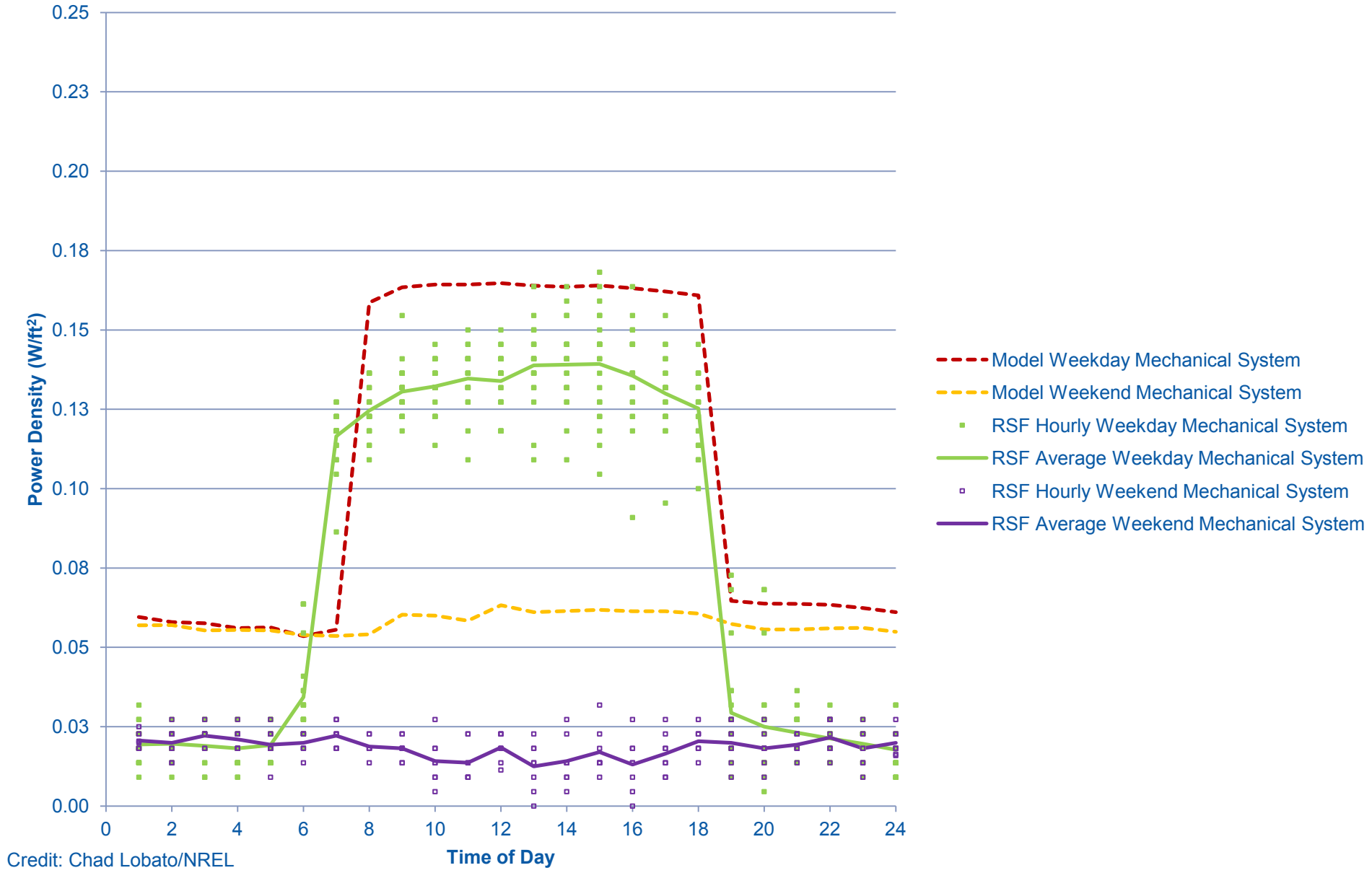
Credit: Chad Lobato/NREL

October 2011 Mechanical System Power Density



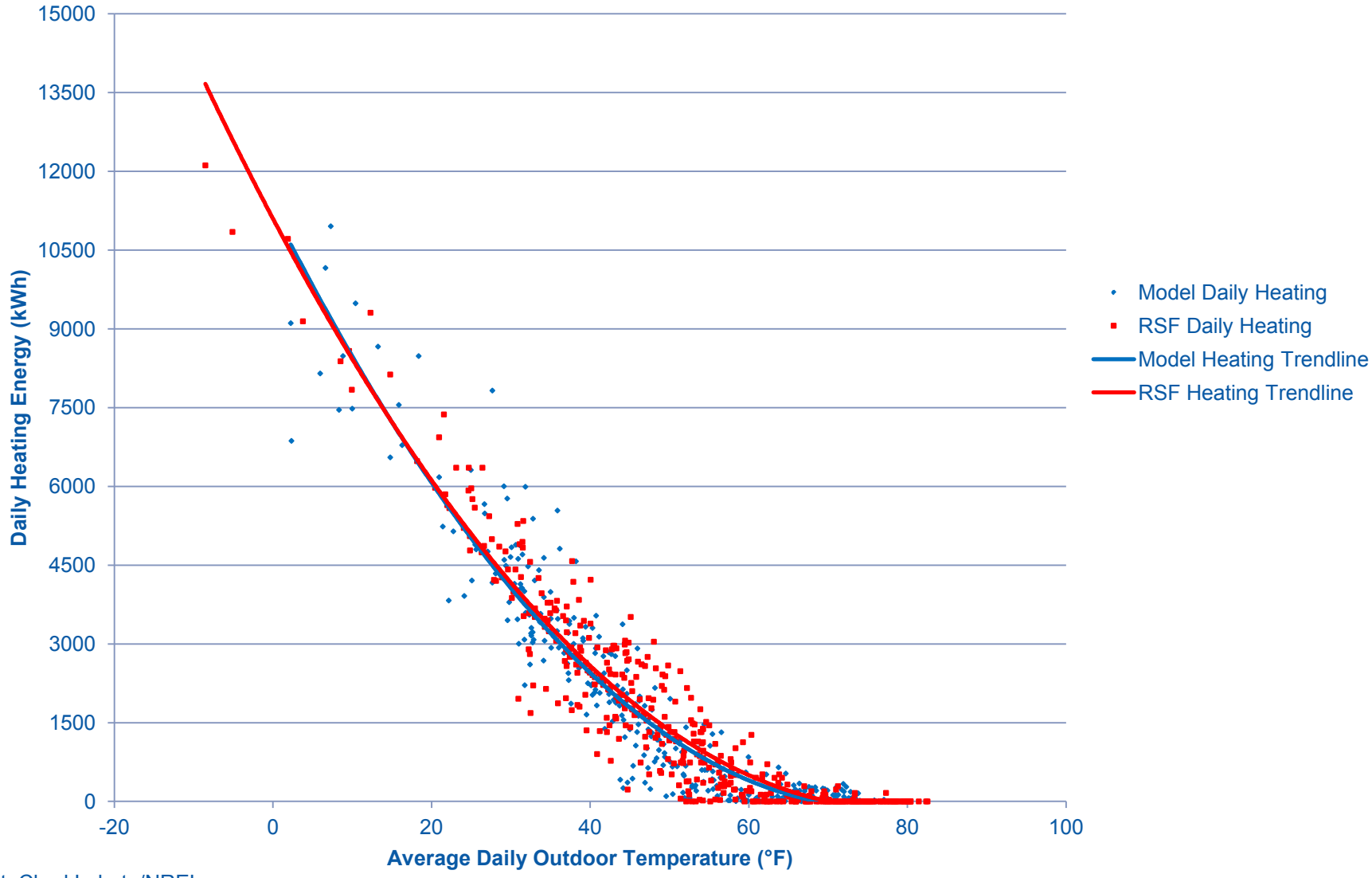
Credit: Chad Lobato/NREL

November 2011 Mechanical System Power Density



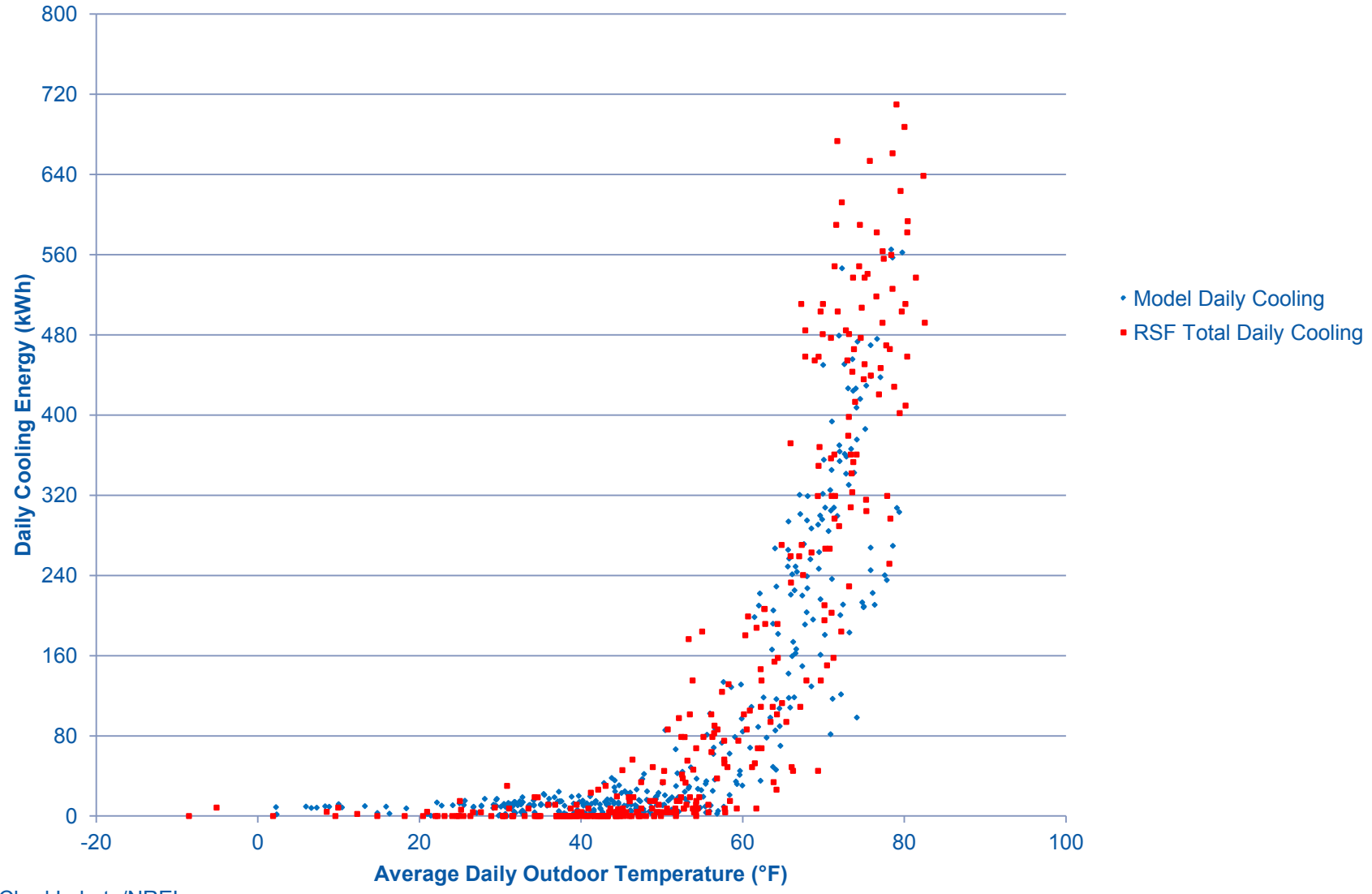
Credit: Chad Lobato/NREL

October 2010 – November 2011 Daily Heating Energy



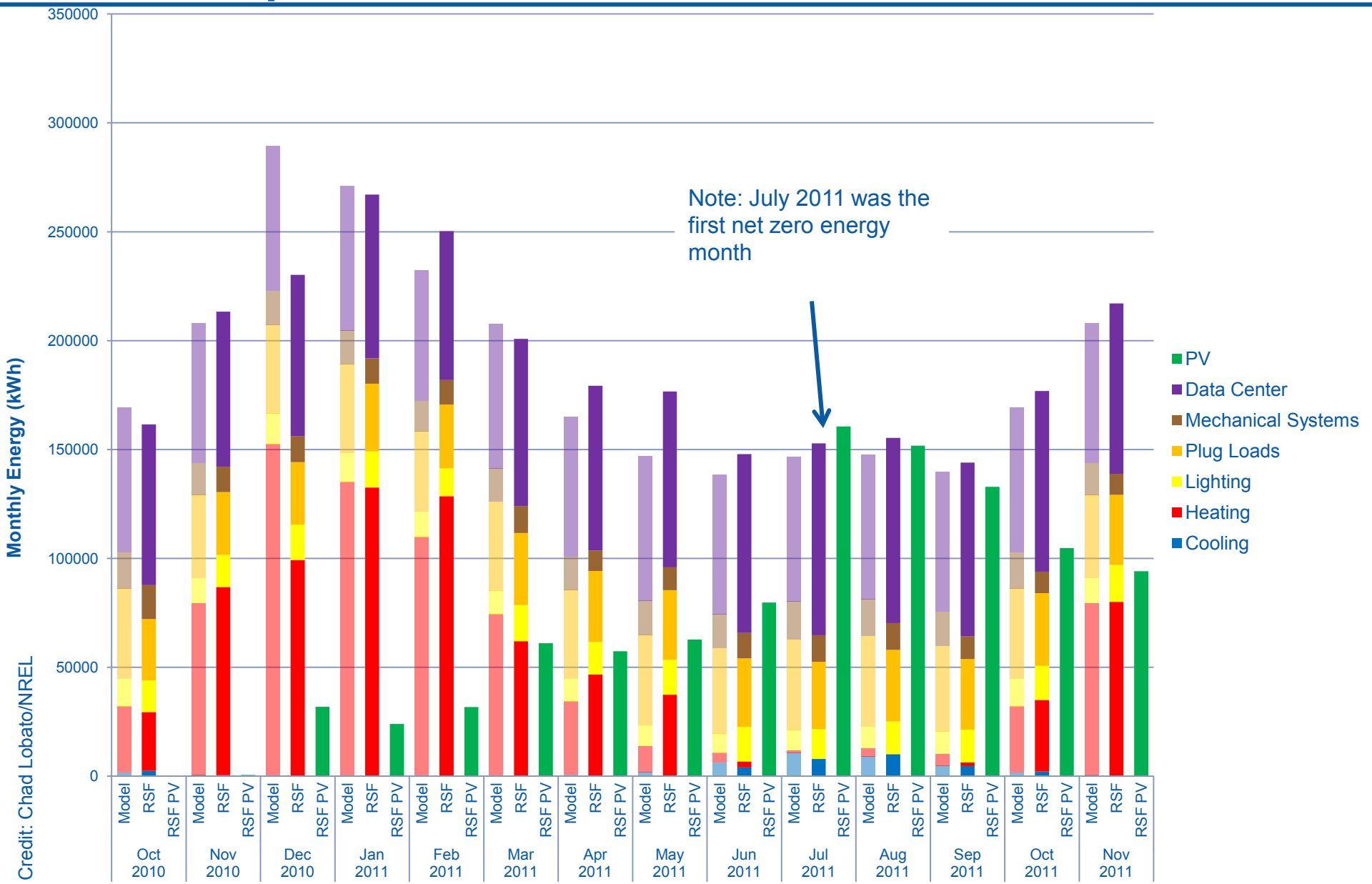
Credit: Chad Lobato/NREL

2011 YTD Daily Cooling Energy



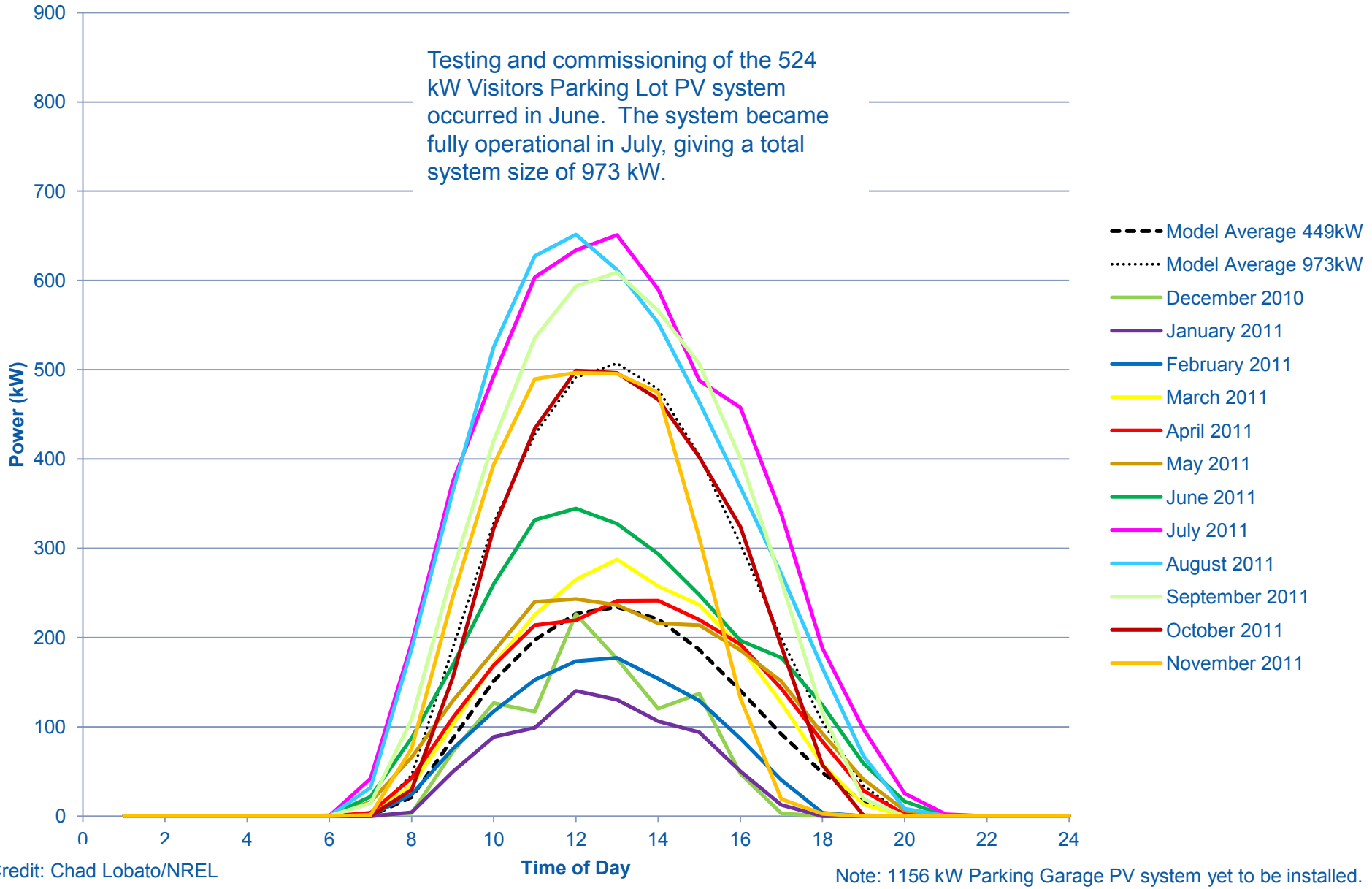
Credit: Chad Lobato/NREL

Measured Versus Modeled Monthly End Use Energy Consumption



Credit: Chad Lobato/NREL

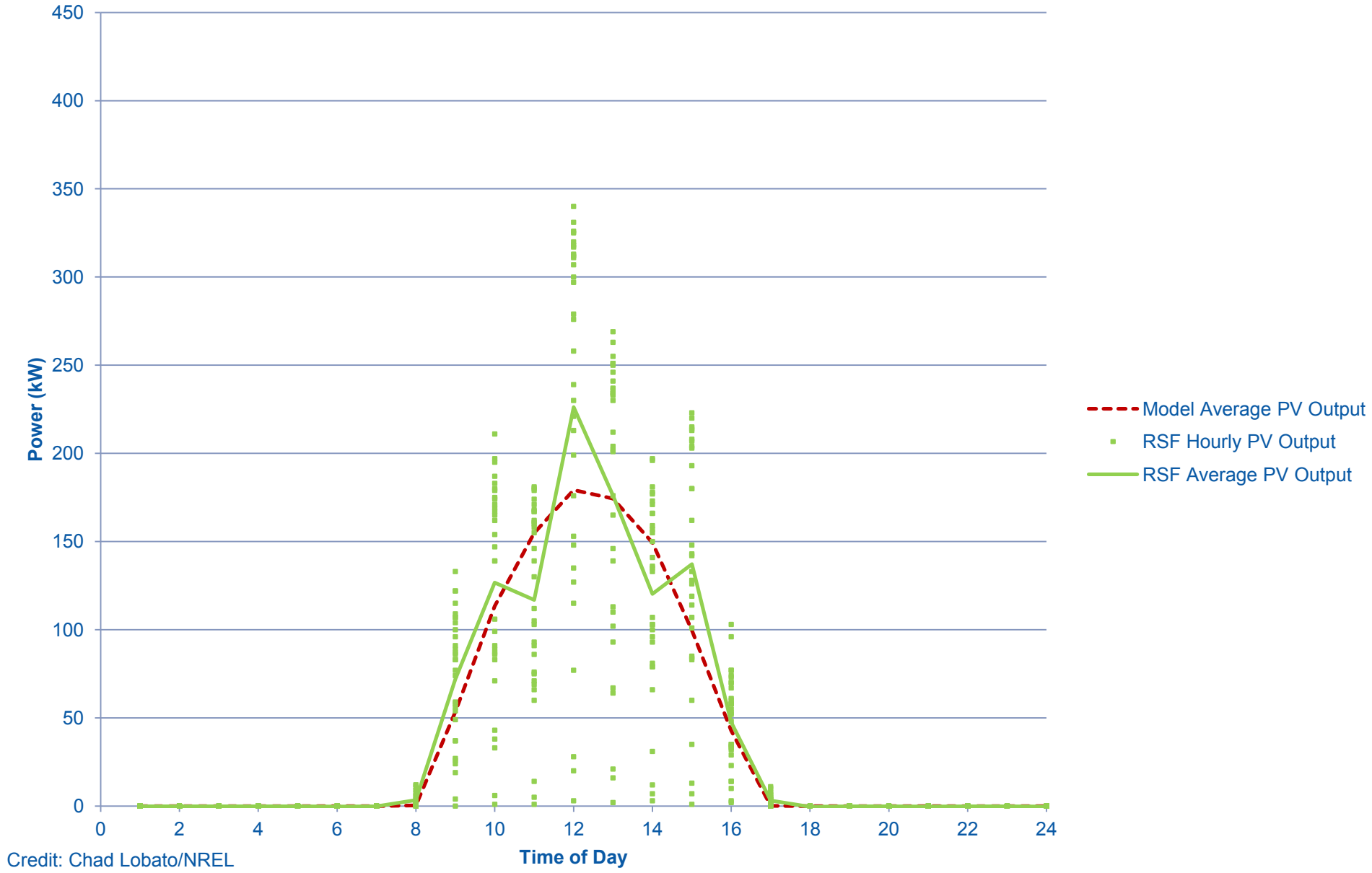
December 2010 – November 2011 PV System Power Output



Credit: Chad Lobato/NREL

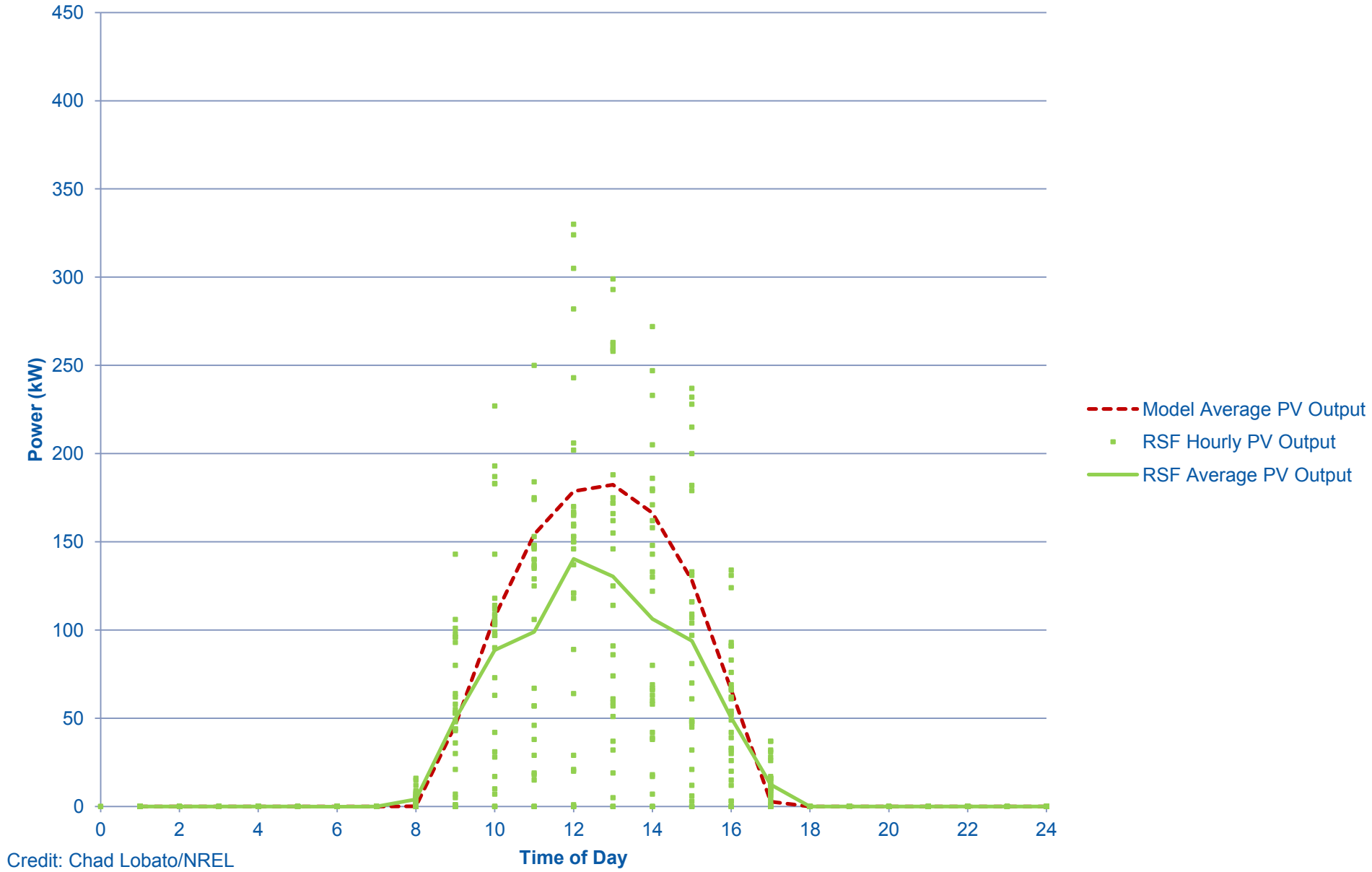
Note: 1156 kW Parking Garage PV system yet to be installed.

December 2010, RSF Roof-Mounted PV Power Output



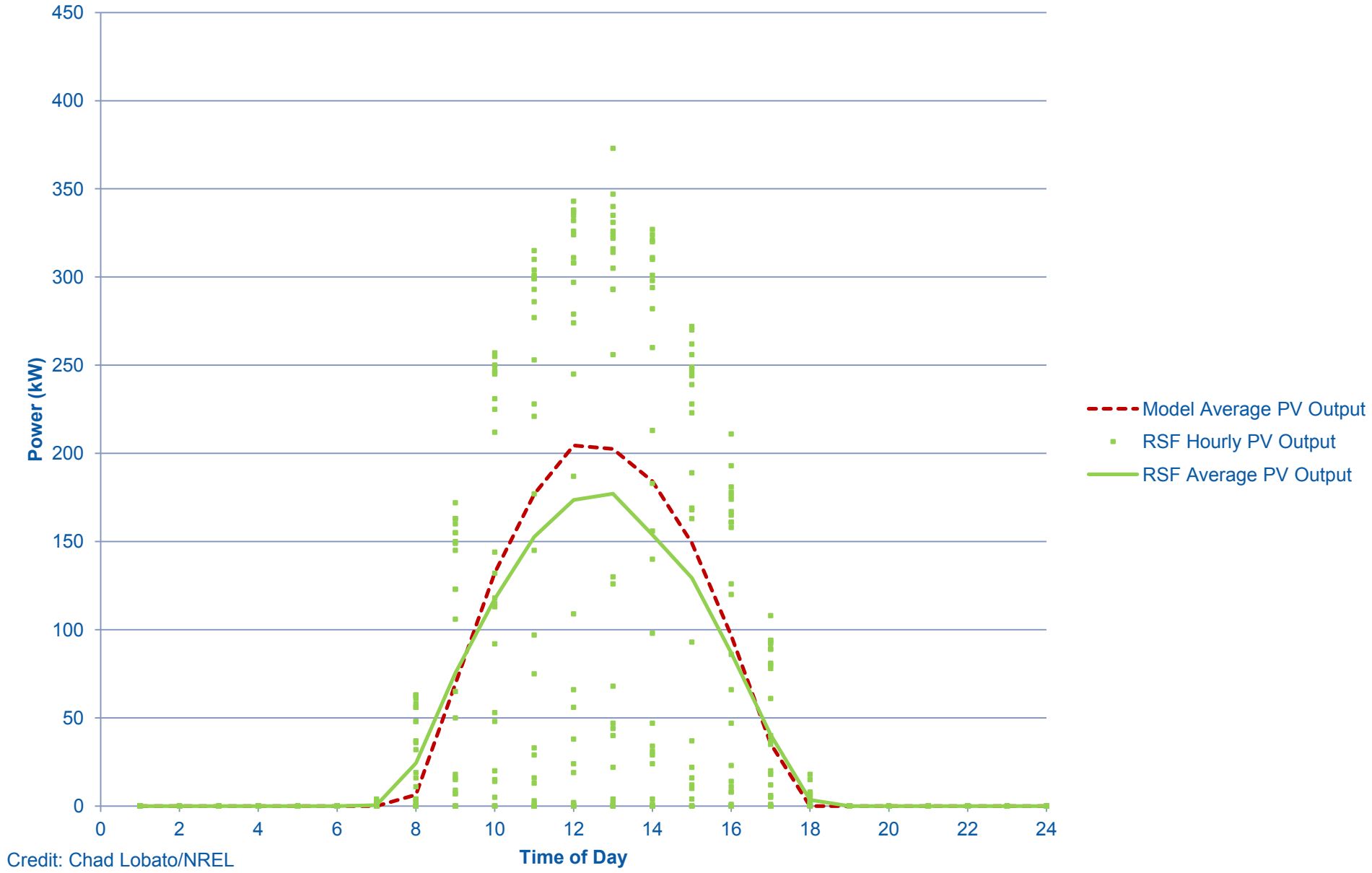
Credit: Chad Lobato/NREL

January 2011, RSF Roof-Mounted PV Power Output



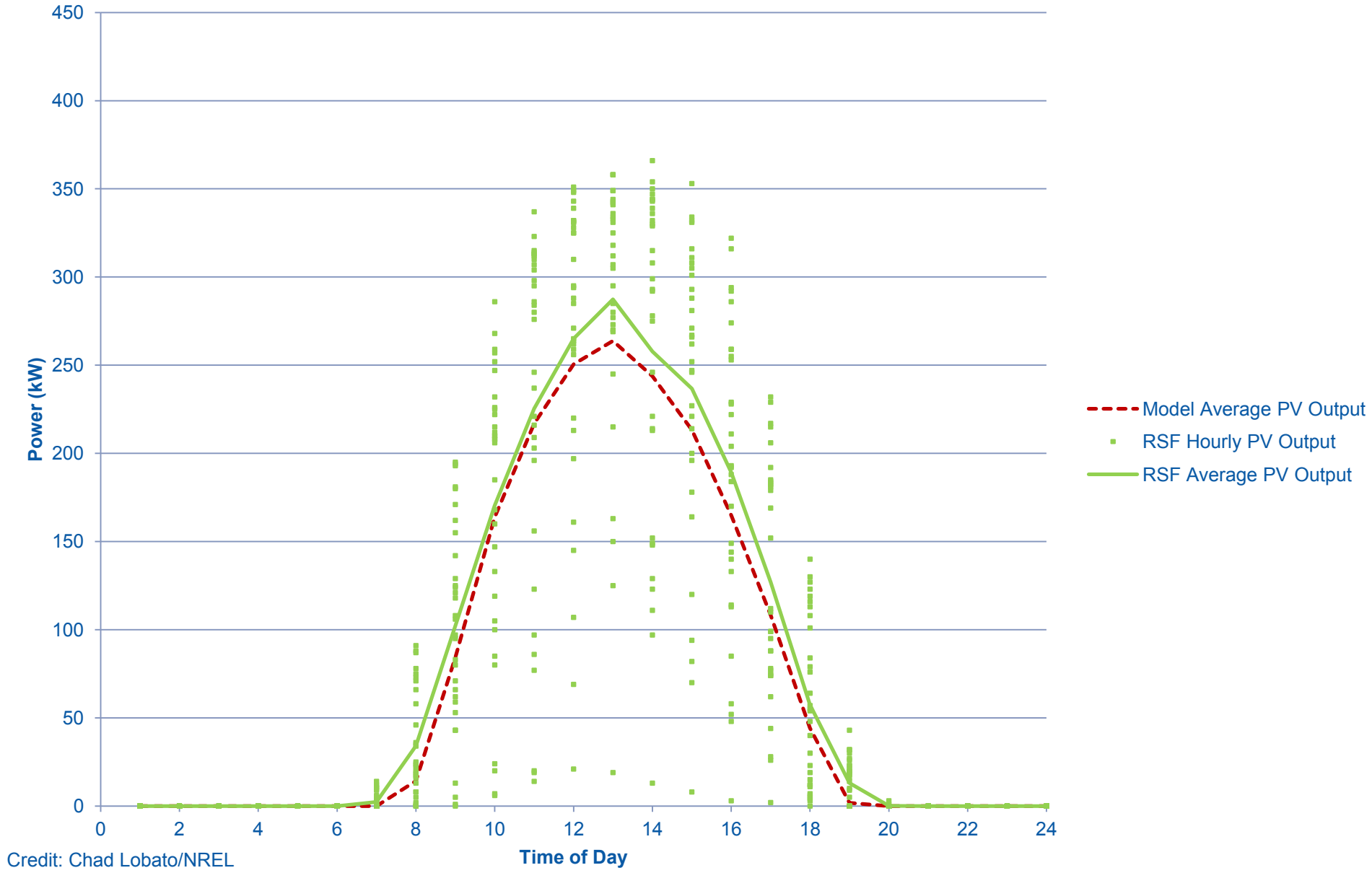
Credit: Chad Lobato/NREL

February 2011, RSF Roof-Mounted PV Power Output



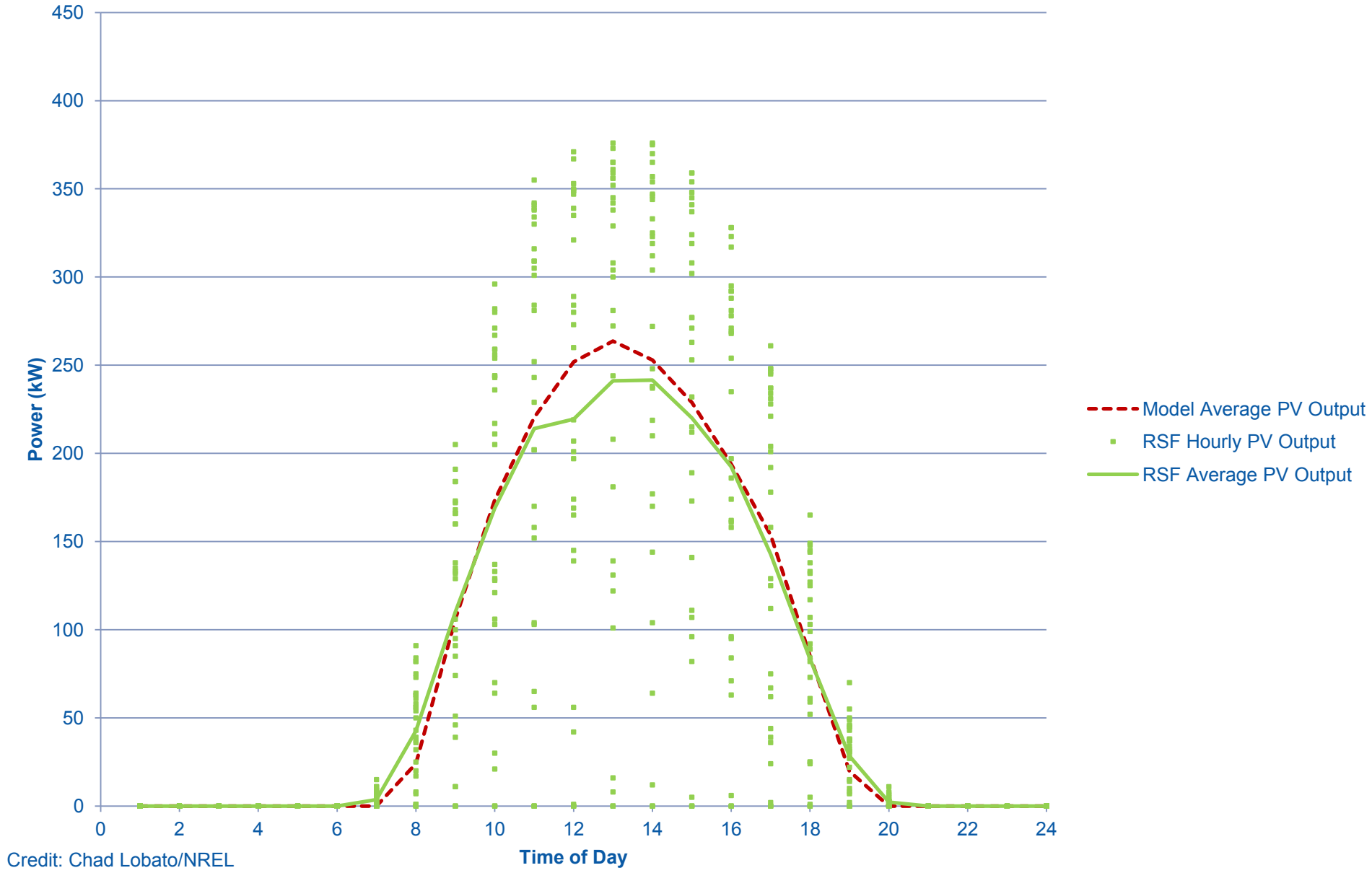
Credit: Chad Lobato/NREL

March 2011, RSF Roof-Mounted PV Power Output



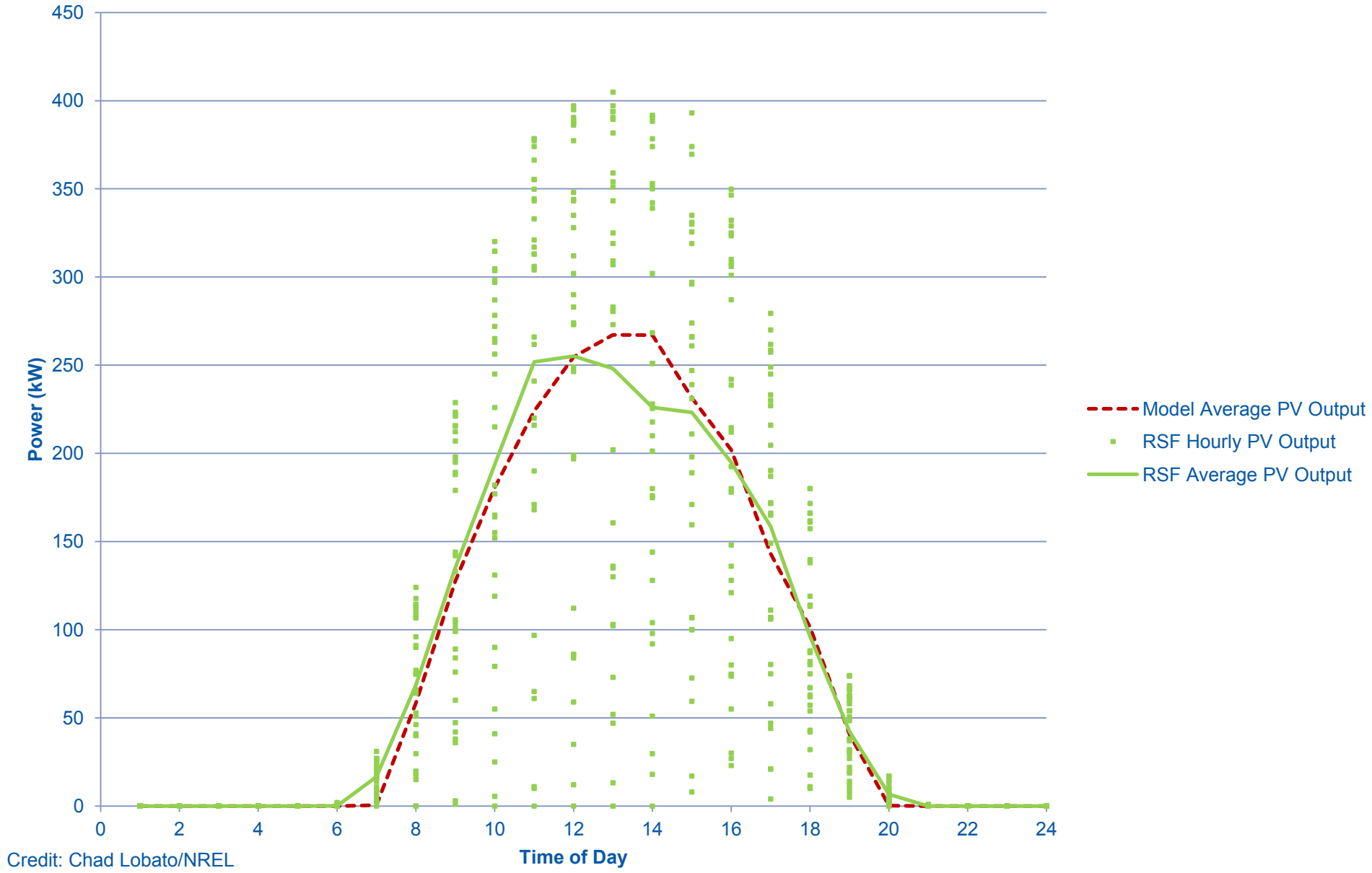
Credit: Chad Lobato/NREL

April 2011, RSF Roof-Mounted PV Power Output



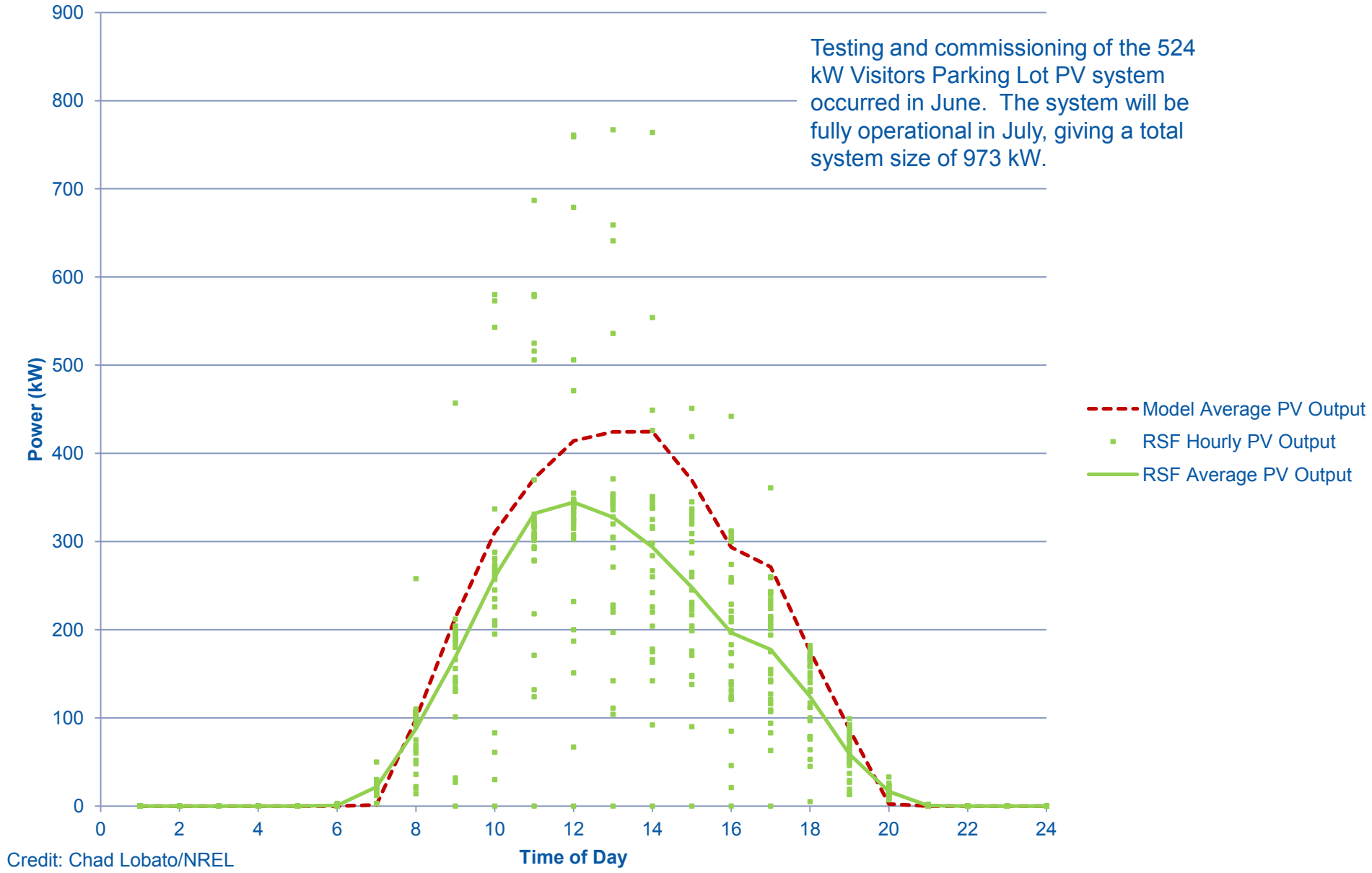
Credit: Chad Lobato/NREL

May 2011, RSF Roof-Mounted PV Power Output



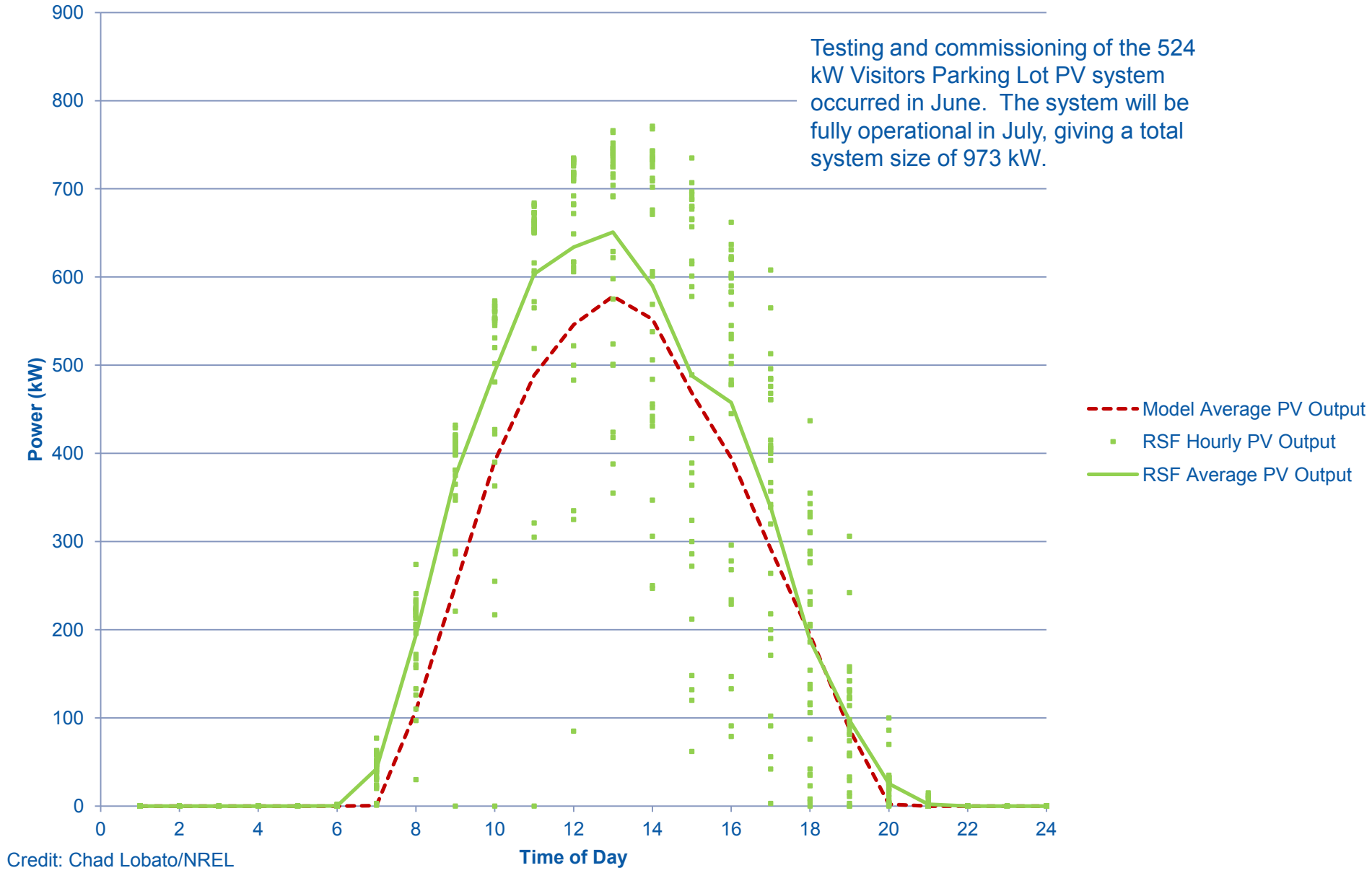
Credit: Chad Lobato/NREL

June 2011, RSF Roof-Mounted PV Power Output



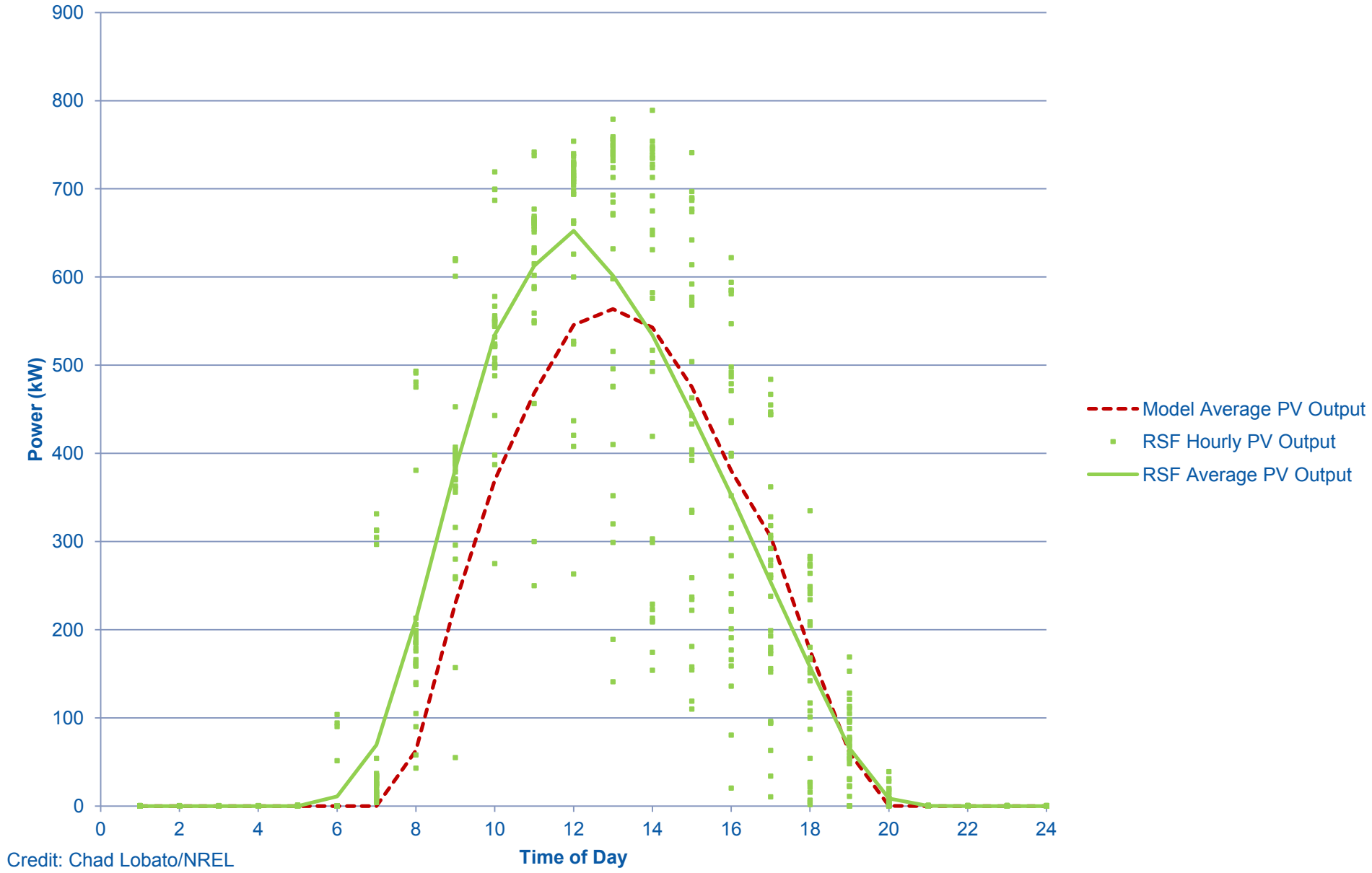
Credit: Chad Lobato/NREL

July 2011, RSF Roof and Site Mounted PV Power Output



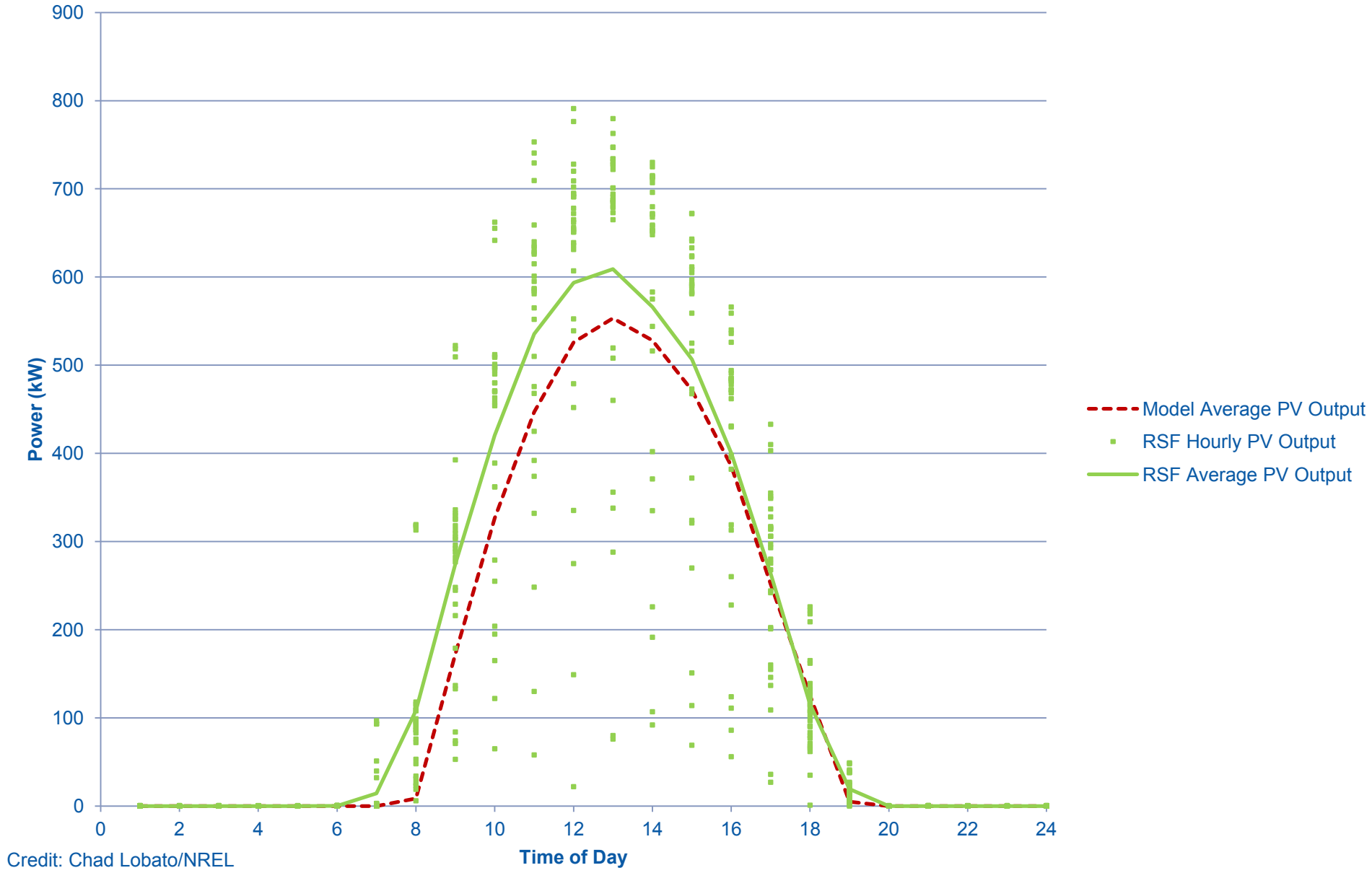
Credit: Chad Lobato/NREL

August 2011, RSF Roof and Site Mounted PV Power Output



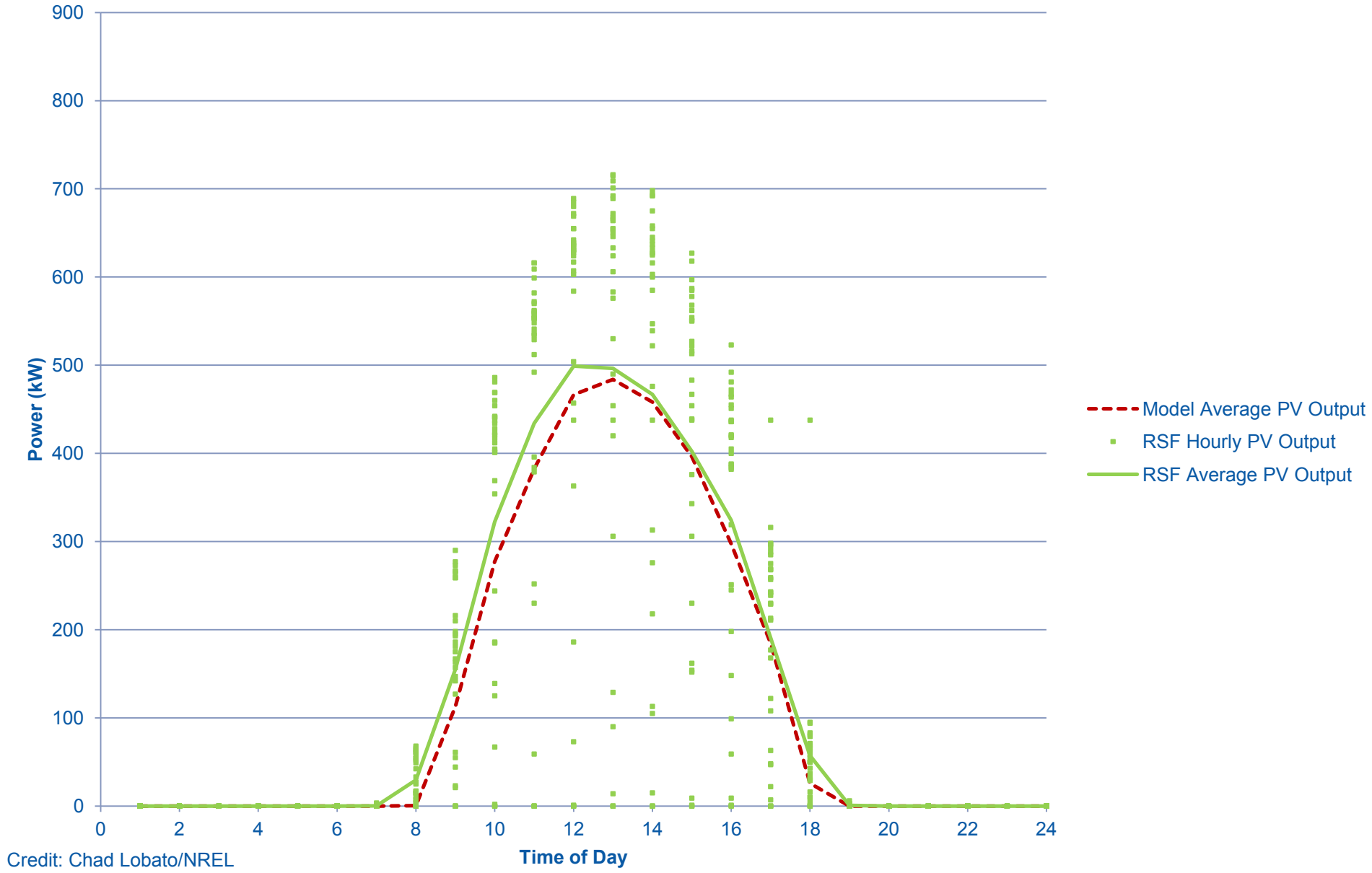
Credit: Chad Lobato/NREL

September 2011, RSF Roof and Site Mounted PV Power Output



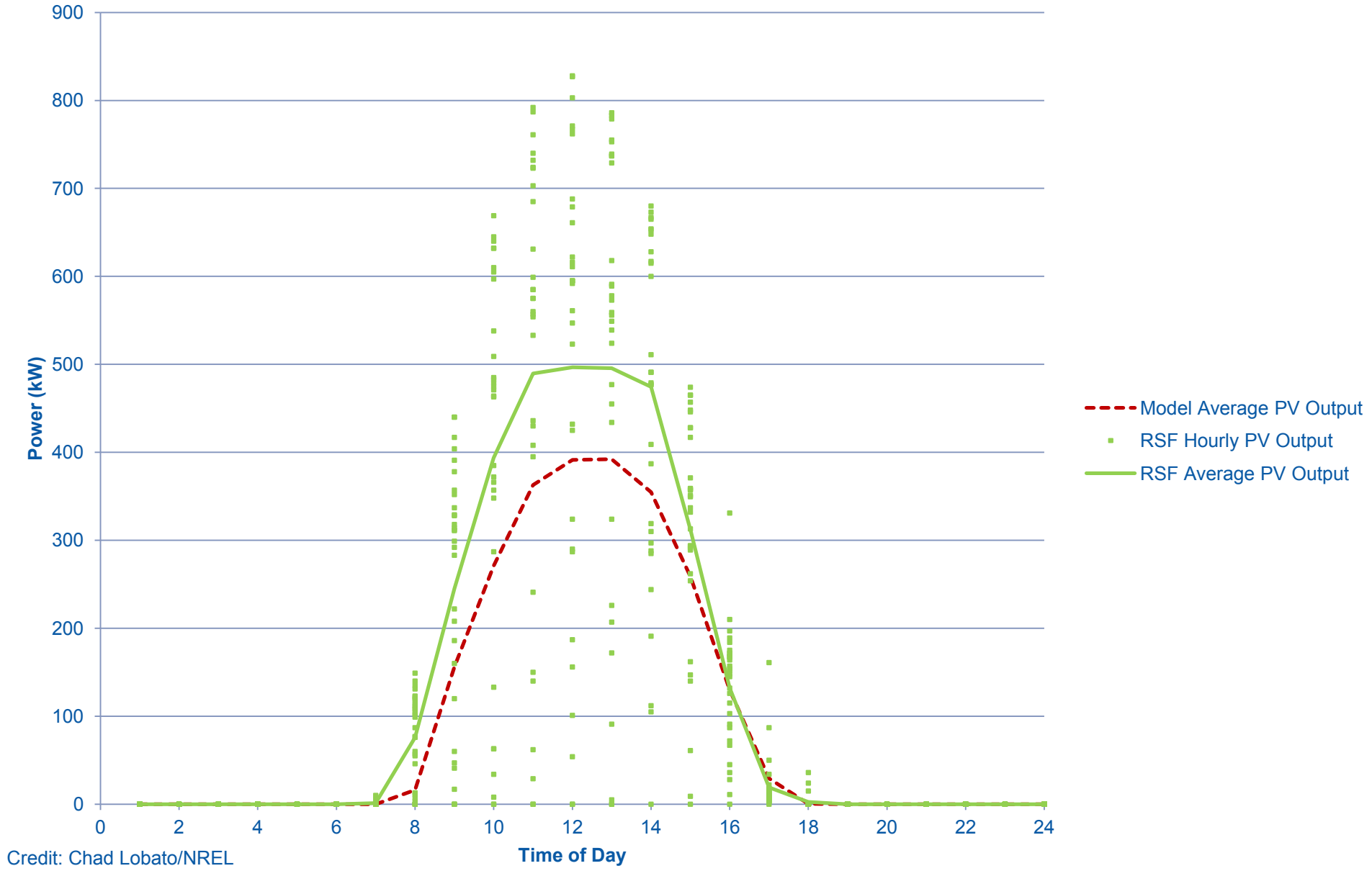
Credit: Chad Lobato/NREL

October 2011, RSF Roof and Site Mounted PV Power Output



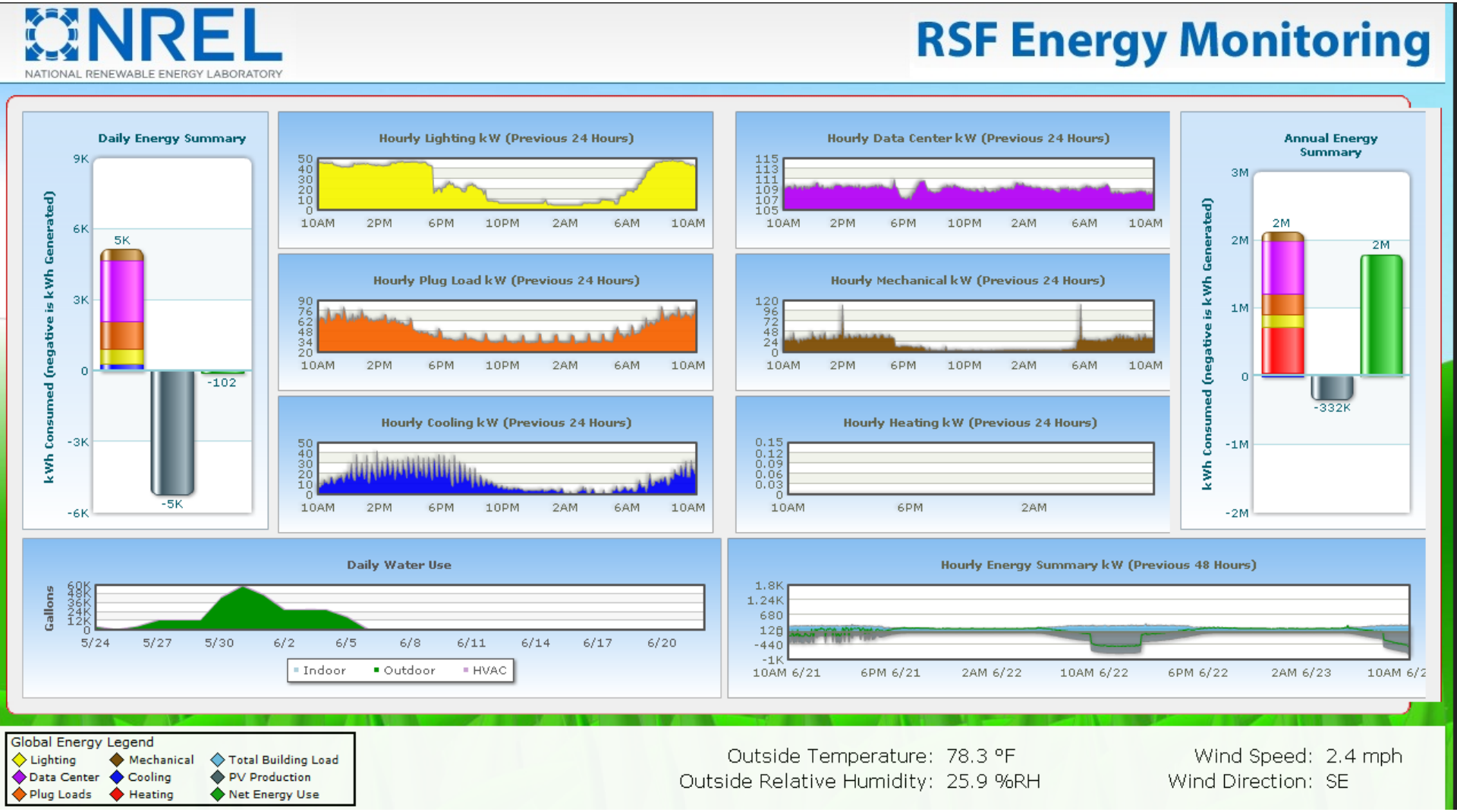
Credit: Chad Lobato/NREL

November 2011, RSF Roof and Site Mounted PV Power Output

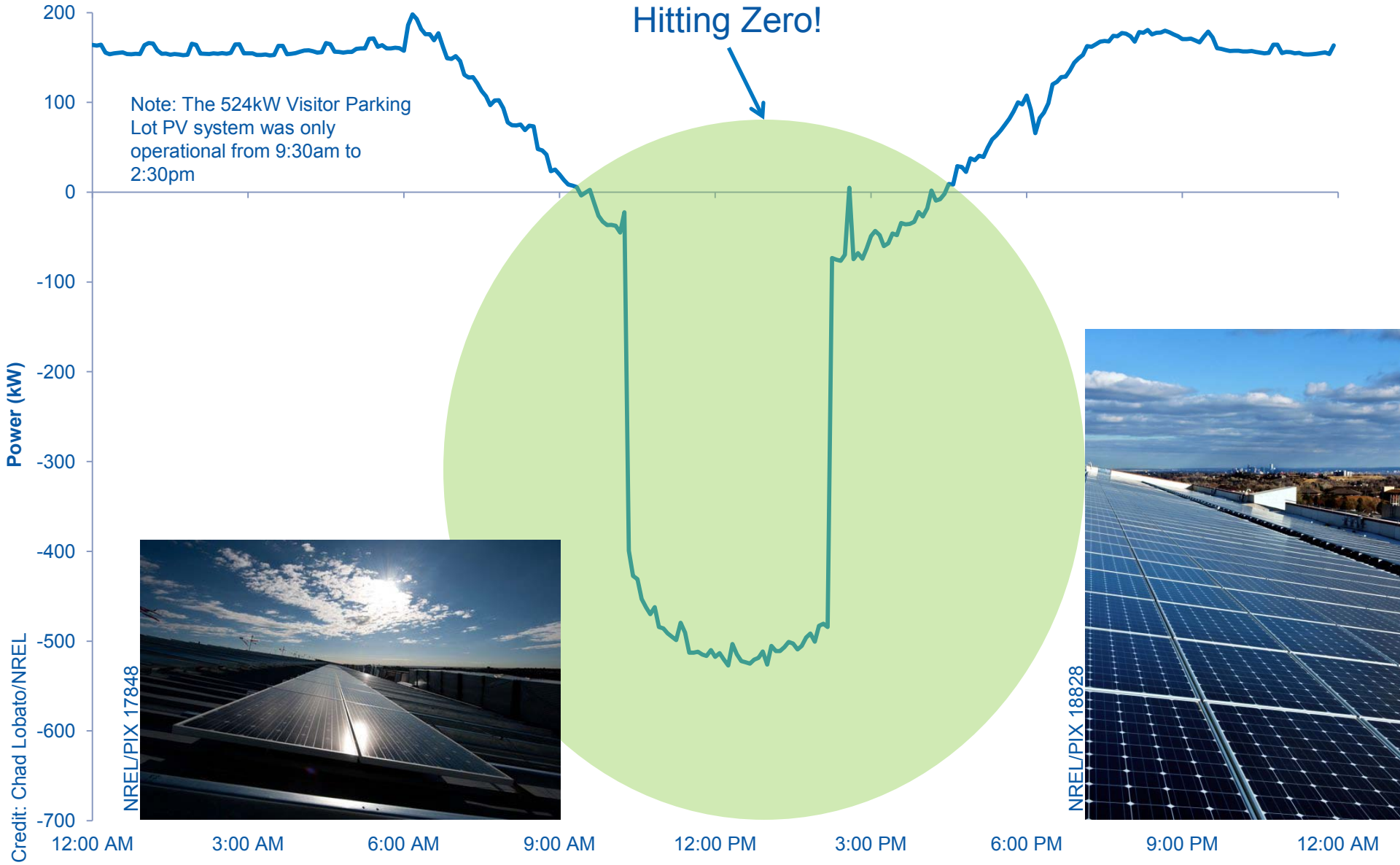


Credit: Chad Lobato/NREL

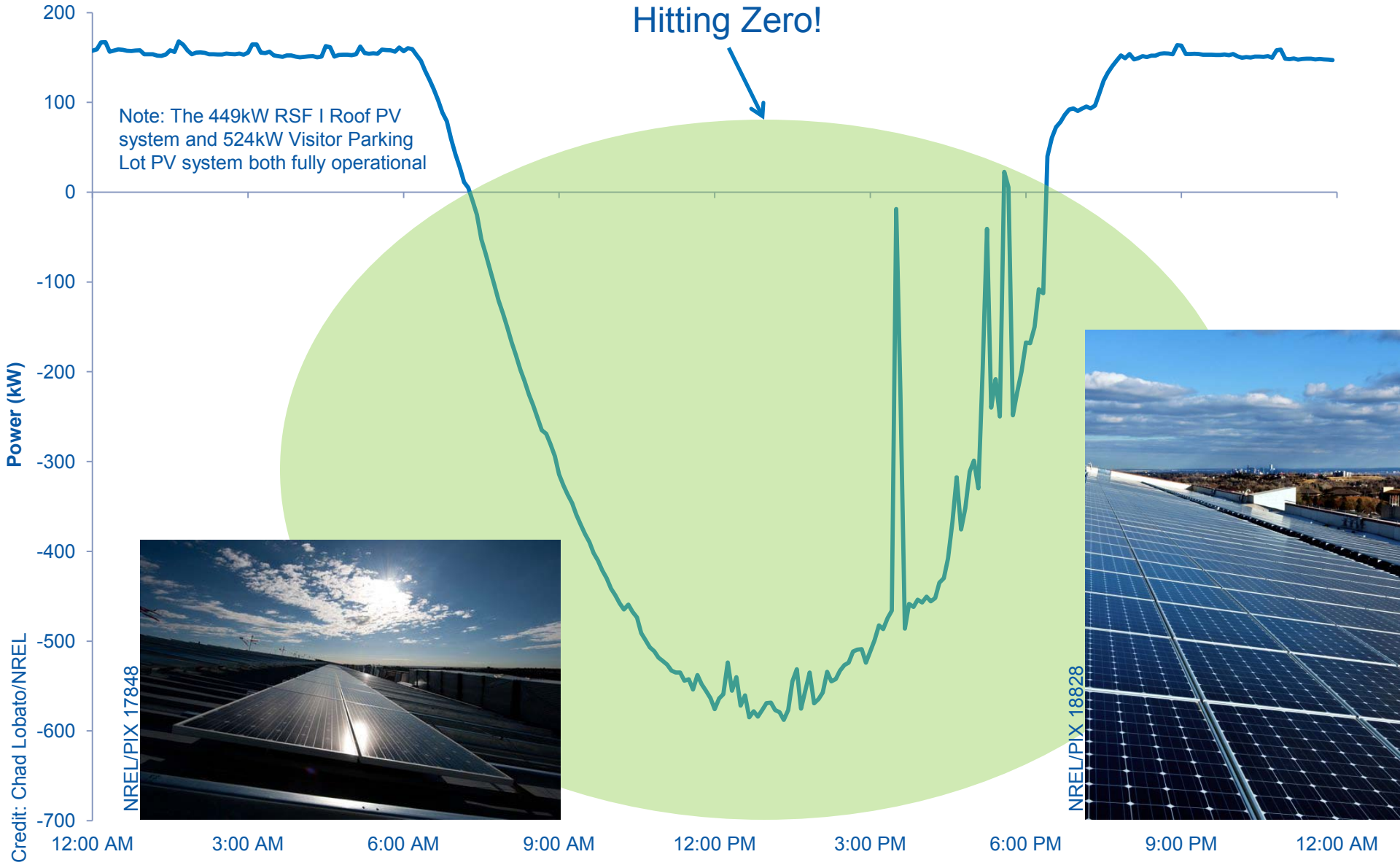
First day of Net zero – June 23, 2011



First day of Net zero – June 23, 2011



973-kW Roof and Site Mounted PV Installed and Operational July 2011



RSF is a living laboratory and researchers use **real-time building performance data** to study building energy use.

NREL/PIX 17408