NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Innovation for Our Energy Future

Solar + LEED

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Integrated Applications Center

October 2011

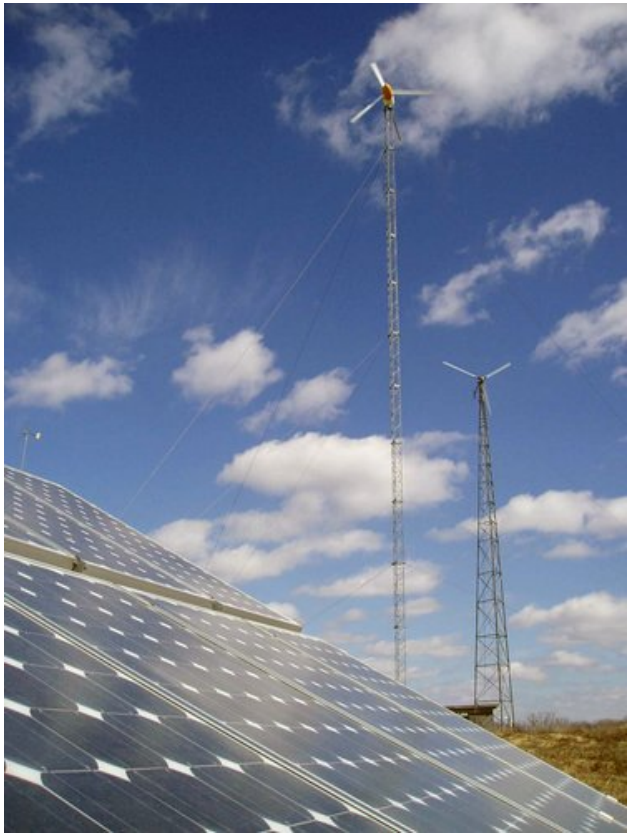
NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

LEED NC 2009

Leadership in Energy and Environmental Design 2009
Green Building Rating System for New Construction and Major Renovations

Solar + LEED

- **Requirements for City of Tucson municipal buildings…**
  - LEED Silver
  - 5% energy from solar
  - 7 points (combined) from EAc1 and EAc2



Solar + LEED

- EA Cr 2 - On-Site Renewable Energy
  - Must retain or replace REC's
- EA Cr1 – Optimize Energy Performance
  - Double dipping
- EA Cr 6 – Green Power
  - For the rest…

EA Cr 2 – On-Site Renewable Energy

% Renewable	Points
1%	1
3%	2
5%	3
7%	4
9%	5
11%	6
13%	7

How much solar do I need?

EA Cr 2 – On-Site Renewable Energy

- **Building Energy Use**

CBECS Average (annual)

85 kBtu/sf (25 kWh/sf)

5% solar = 1.25 kWh/sf

ASHRAE 90.1 – 2004 (annual)

50 kBtu/sf (15 kWh/sf)

5% solar = 0.75 kWh/sf

EA Cr 2 – On-Site Renewable Energy

- **Code compliant building, 5% PV**
  - 20,000 sf building: 1,000,000 kBtu = 290,000 kWh
  - 5% = 14,500 kWh = 9 kW system in Tucson
  - (28) 320-watt panels… 600 sf roof space
    (60”x 40” panel with 30% additional)
  - Cost ($6.00/W) = $54,000
    Less federal tax credit (30%) = - $16,200
    Less state tax credit (10%) = - $5,400
    Less TEP incentive ($1.50/W)= - $13,500 (Sell RECs)
    Buy RECs (200% for 20 yrs @ 1¢/kWh) = + $5,800
  - Net cost = $24,700
  - Energy savings = $1,270/yr
  - Simple payback = 20 yrs (5% ROI)
  - Unit cost = $1.24/sf

EA Cr 2 – On-Site Renewable Energy

- **Energy efficient building (30% savings), 5% PV**
  - 20,000 sf building: 700,000 kBtu = 205,000 kWh
  - 5% = 10,250 kWh = 6.5 kW system in Tucson
  - (20) 320-watt panels… 430 sf roof space
    (60”x 40” panel with 30% additional)
  - Cost ($6.50/W) = $42,250
    Less federal tax credit (30%) = - $12,675
    Less state tax credit (10%) = - $4,225
    Less TEP incentive ($1.50/W) = - $9,750 (Sell REC’s)
    Buy REC’s (200% for 20 yrs @ 1¢/kWh) = + $4,100
  - Net cost = $19,700
  - Energy savings = $920/yr
  - Simple payback = 21 yrs (5% ROI)
  - Unit cost = $0.99/sf

EA Cr 2 – On-Site Renewable Energy

- **Energy efficient building (30% savings), 13% PV**
  - 20,000 sf building: 700,000 kBtu = 205,000 kWh
  - 13% = 26,670 kWh = 16 kW system in Tucson
  - (50) 320-watt panels… 1,100 sf roof space
    (60”x 40” panel with 30% additional)
  - Cost ($6.00/W) = $96,000
    Less federal tax credit (30%) = - $28,800
    Less state tax credit (10%) = - $9,600
    Less TEP incentive ($1.50/W) = - $24,000 (Sell REC’s)
    Buy REC’s (200% for 20 yrs @ 1¢/kWh) = + $10,000
  - Net cost = $43,600
  - Energy savings = $2,250/yr
  - Simple payback = 20 yrs (5% ROI)
  - Unit cost = $2.40/sf

EA Cr 1 – Optimize Energy Performance

% Savings	Points
12%	1
14%	2
16%	3
18%	4
20%	5
22%	6
24%	7
26%	8
28%	9
30%	10
32%	11
etc…	
48%	19

EA Cr 1 – Optimize Energy Performance

- Energy Efficient Building, 5% PV
  - Baseline: 290,000 kWh
  - Proposed: 205,000 kWh
  - PV production: 10,250 kWh

} 30% savings = 10 pts EA Cr 1

} 5% RE = 3 pts EA Cr2

- Renewable Energy is deducted from EA Credit 1…
  - Double dipping!!
- Net energy: 194,750 kWh or 33% savings = **11 points!!**
- Total EAc1 + EAc2 = 11 + 3 = **14 points**

EA Cr 1 – Optimize Energy Performance

- Energy Efficient Building, 13% PV
  - Baseline: 290,000 kWh
  - Proposed: 205,000 kWh

  } 30% savings = 10 pts EA Cr 1

  - PV production: 26,670 kWh

  } 13% RE = 7 pts EA Cr2

- Net energy: 178,330 kWh or 38% savings = 14 points!!

- Total EAc1 + EAc2 = 14 + 7 = **21 points**

- **Point increase = 7**
- **Cost increase = $23,900**

} **$3,400 per point**

Compare to …

- Recycled content (2 points) …. $5,000??
- Low VOC paint (1 point) … $5,000??
- White Roof (1 point) … $20,000??
- Bike Racks (1 point) … $3,000??

Options …

- **Direct Purchase**
  - Private owners
  - No ongoing fees
  - Owner responsible for maintenance
  - Available cash
- **Leased System**
  - Public/private clients
  - Fixed rate, guaranteed minimum production
  - Low, or no, initial costs
- **Power Purchase Agreement**
  - Public/private clients
  - Variable rate, incentive to maximize production
  - Low, or no, initial costs

LEED 2012

- Reduced Points

% Renewable	Points
3%	1
5%	2
10%	3

- Community Solar (Solar Gardens):
  - Explicitly Allowable
  - Must have ownership interest
  - In same utility service area

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NREL Research Support Facility

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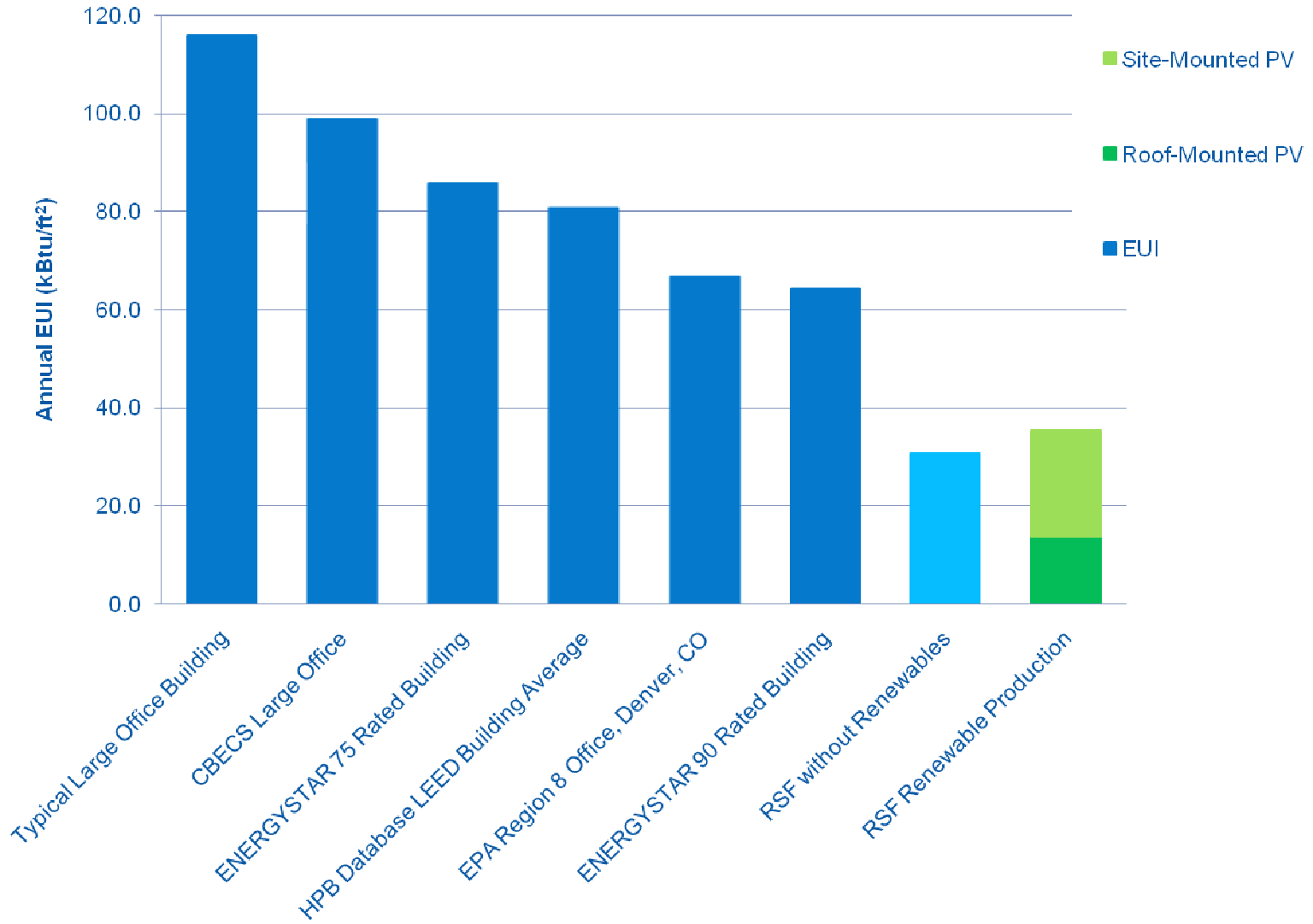
DOE/NREL Research Support Facility: Project Goals

- More than 800 people in DOE office space on NREL's campus
- 220,000 ft^2
- Energy goals:
  - 25 kBtu/ft^2
  - 50% energy savings
  - LEED Platinum
- Replicable:
  - Process
  - Technologies
  - Cost

Credit: Haselden Construction

- Site net zero energy building
  - Includes plugs loads and datacenter
- Firm fixed price of ~$64 million
  - $259/ft^2 construction cost (not including $27/ft^2 for PV from PPA)
- Open first phase June 10, 2010

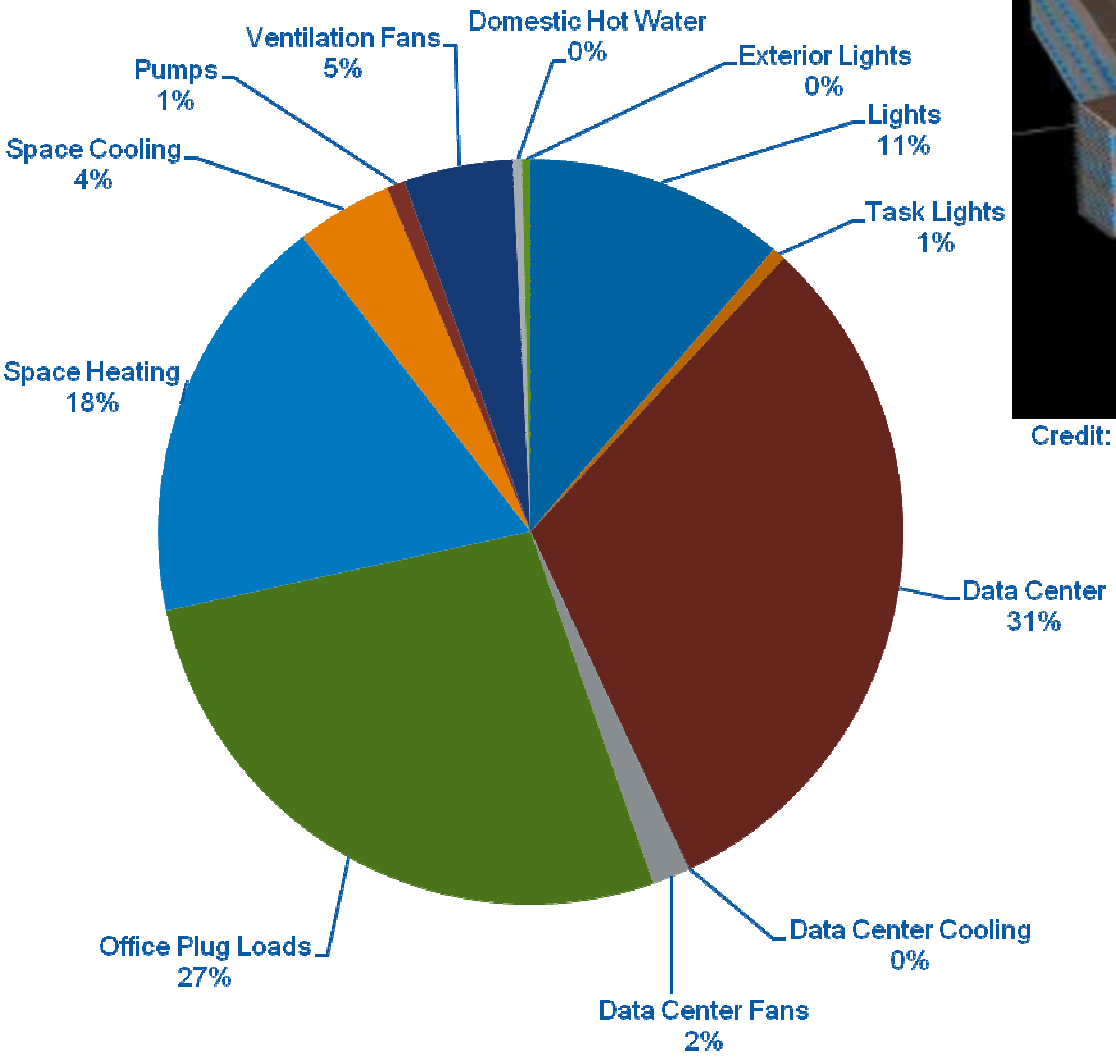
RSF Performance Target



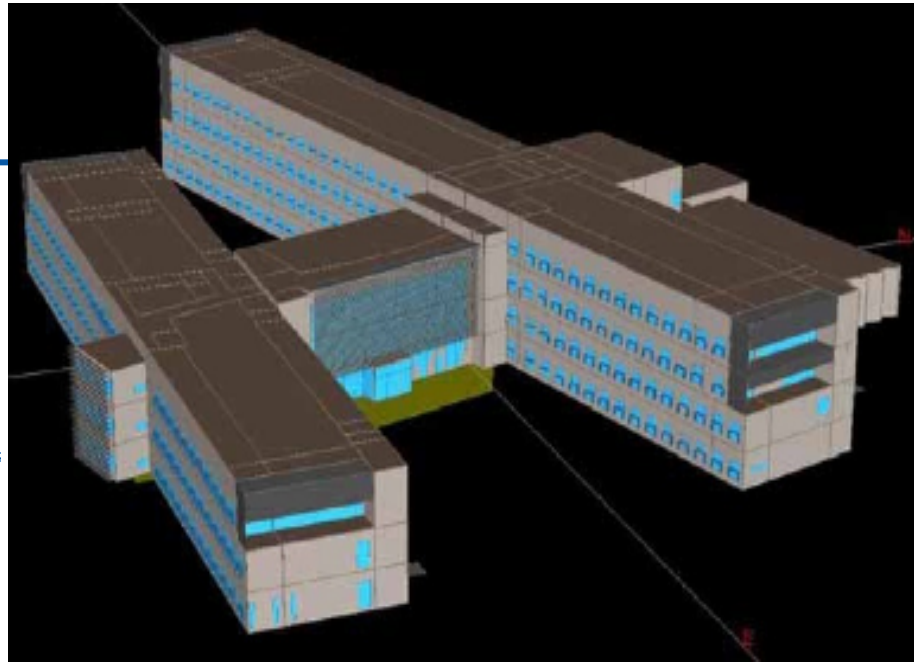
Credit: Chad Lobato/NREL

Energy Modeling

NREL RSF Energy Use Breakdown



Credit: Chad Lobato/NREL



Credit: Stantec

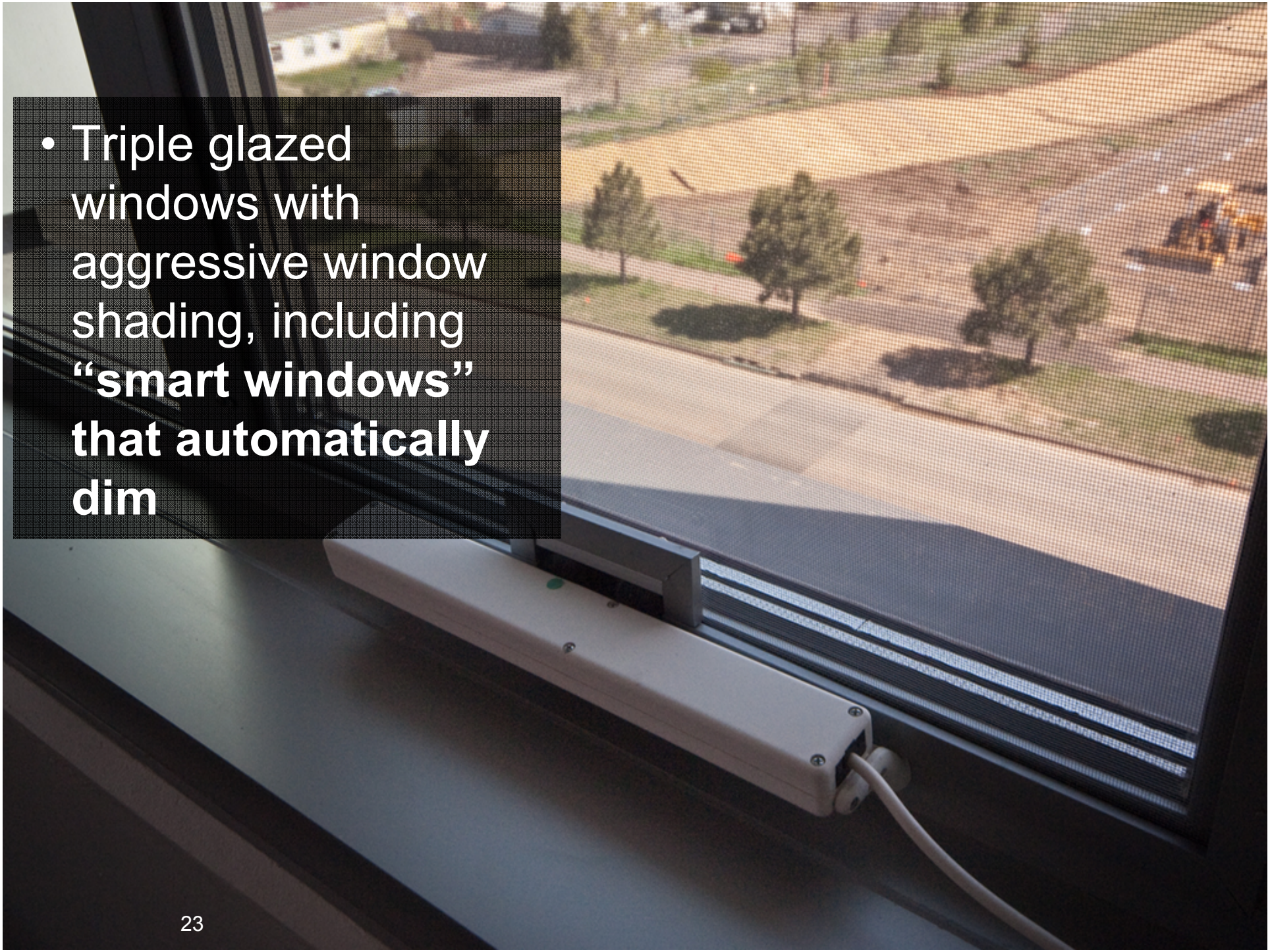
End Use	kBtu/ft²
Lights	3.85
Task lights	0.19
Data center	10.60
Data center cooling	0.01
Data center fans	0.55
Office plug loads	9.16
Space heating	6.11
Space cooling	1.42
Pumps	0.27
Ventilation fans	1.61
Domestic hot water	0.13
Exterior lights	0.12

Key Design Strategies

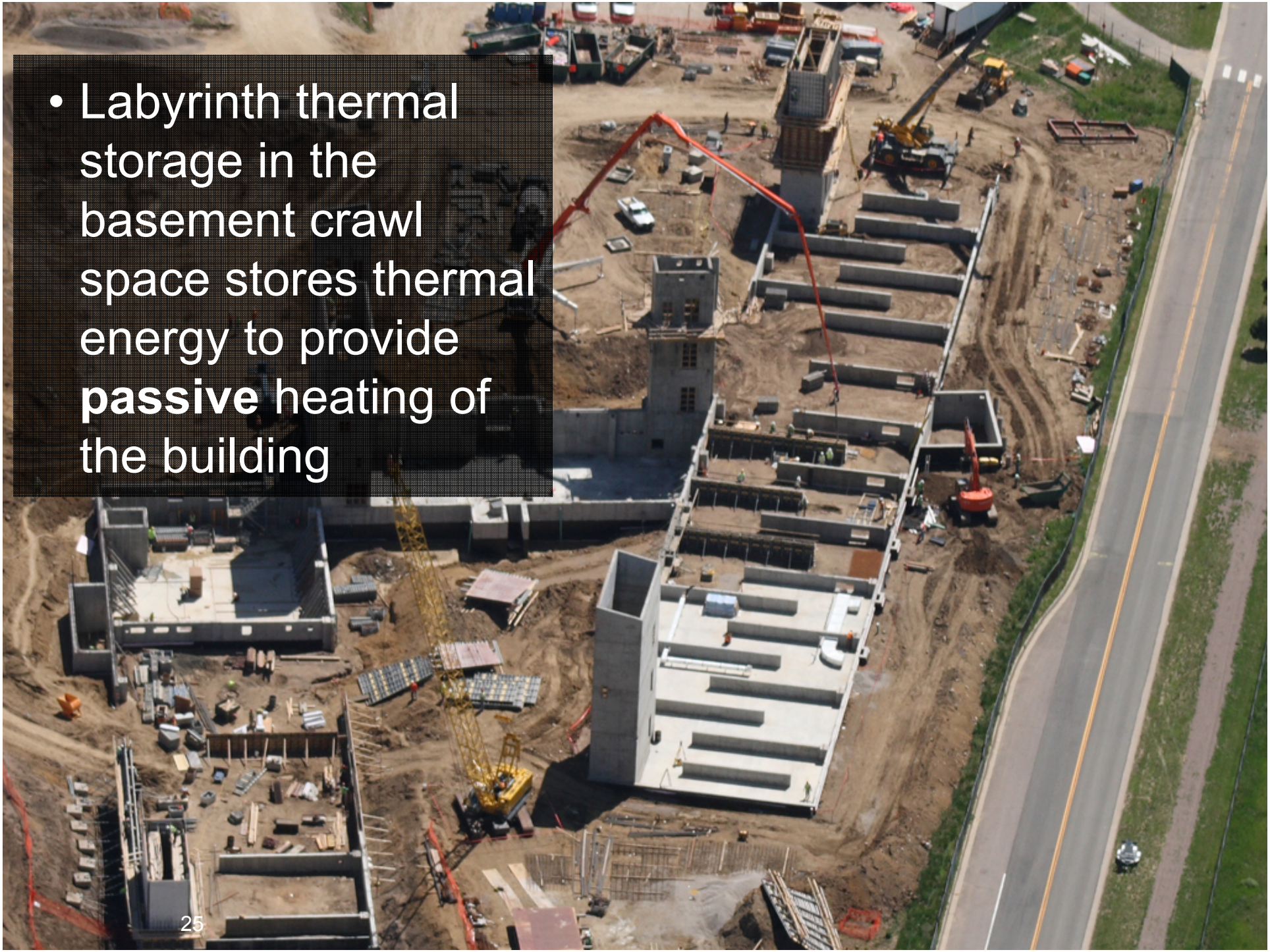
1. Orientation
2. Daylighting with high performance electrical lighting
3. Continuous insulation precast wall panels with thermal mass
4. Operable windows for natural ventilation
5. Radiant heating and cooling
6. Outdoor air preheating
   - Transpired solar collector
   - Datacenter waste heat
   - Exhaust air energy recovery
   - Crawl space thermal storage
7. Aggressive plug load control strategies
8. Data center outdoor air economizer with hot aisle containment
9. Roof top and parking lot based PV

Building orientation:

- Narrow east-west oriented floor plate (60’ wide) enables **daylighting and natural ventilation**

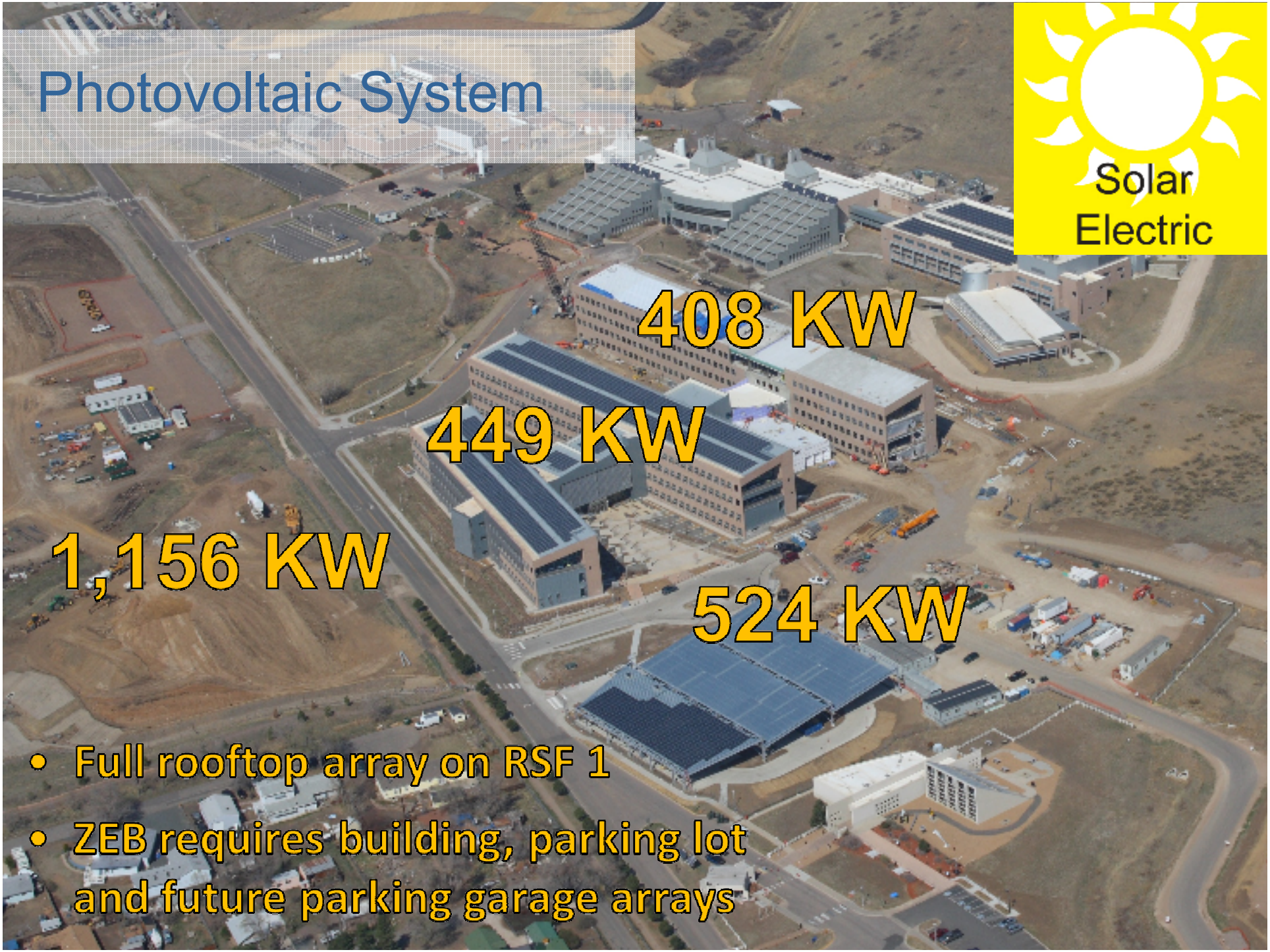

• Triple glazed windows with aggressive window shading, including **“smart windows” that automatically dim**


• The transpired solar collector on the RSF is technology **originally developed at NREL**


• Labyrinth thermal storage in the basement crawl space stores thermal energy to provide **passive** heating of the building

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

Photovoltaic System



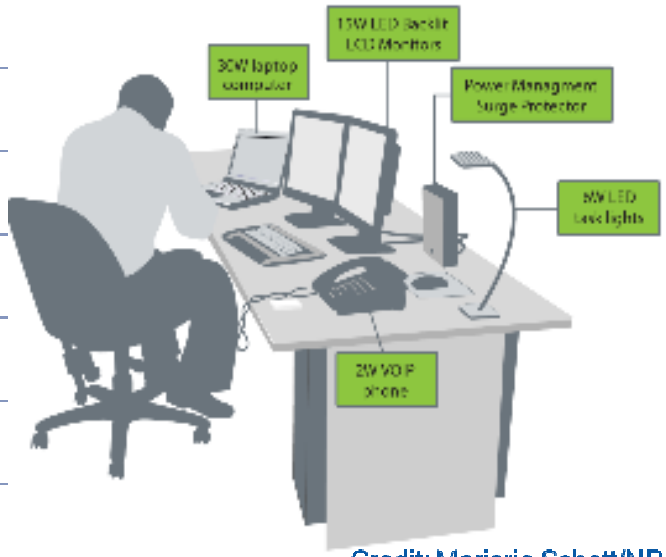
- Full rooftop array on RSF 1
- ZEB requires building, parking lot and future parking garage arrays

So How Is It Performing?

For the last 6 months, we have been comparing the measured end uses to the model end uses:

- ↓ Daytime plug loads
- ✓ Daytime lighting
- ✓ Fans and Pumps
- ✓ Datacenter cooling
- ✓ Rooftop PV
- ✓ Heating
- ? Cooling

October 2010 – April 2011 Plug Load Power Density

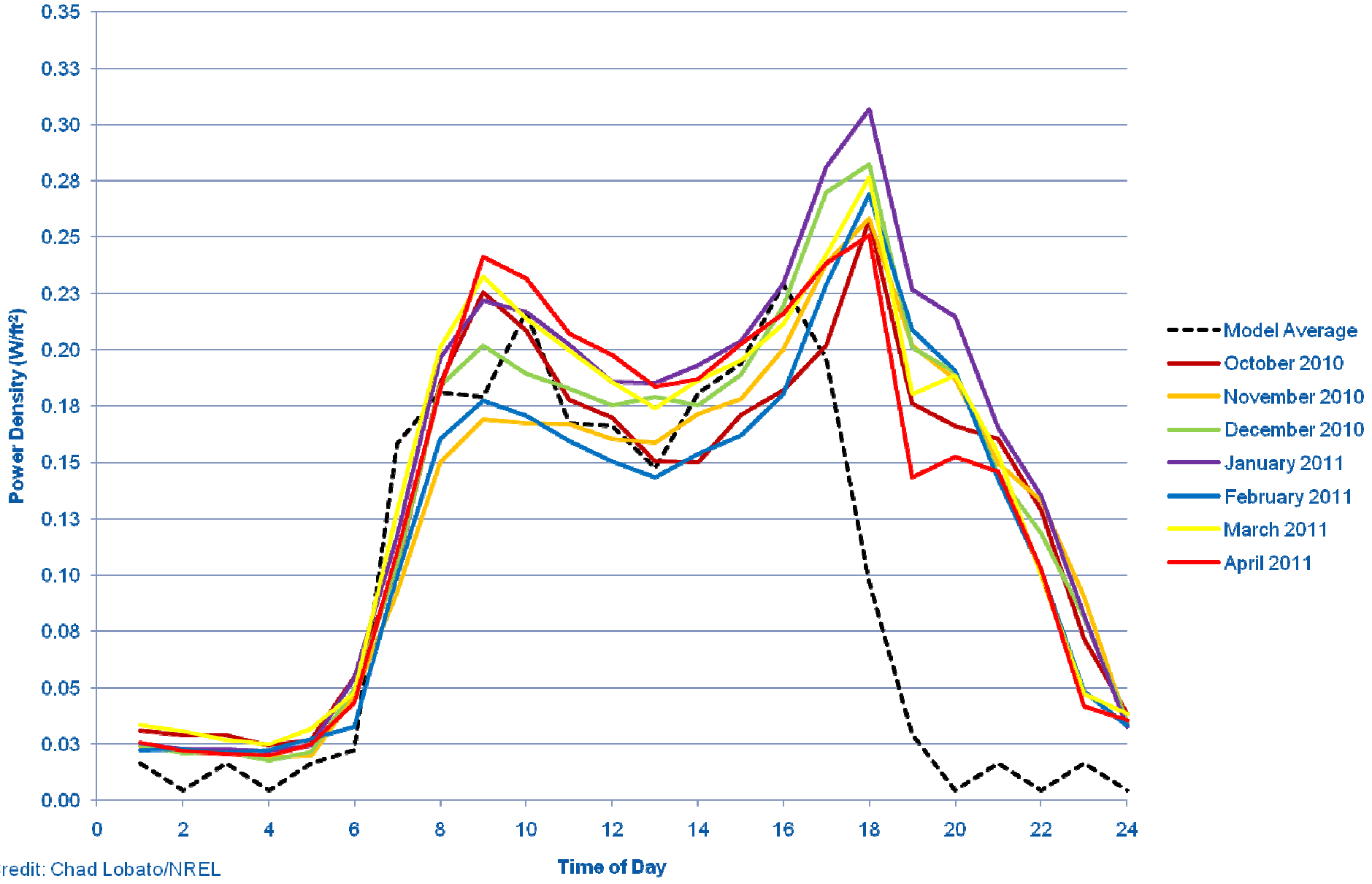


Credit: Marjorie Schott/NREL

Credit: Chad Lobato/NREL

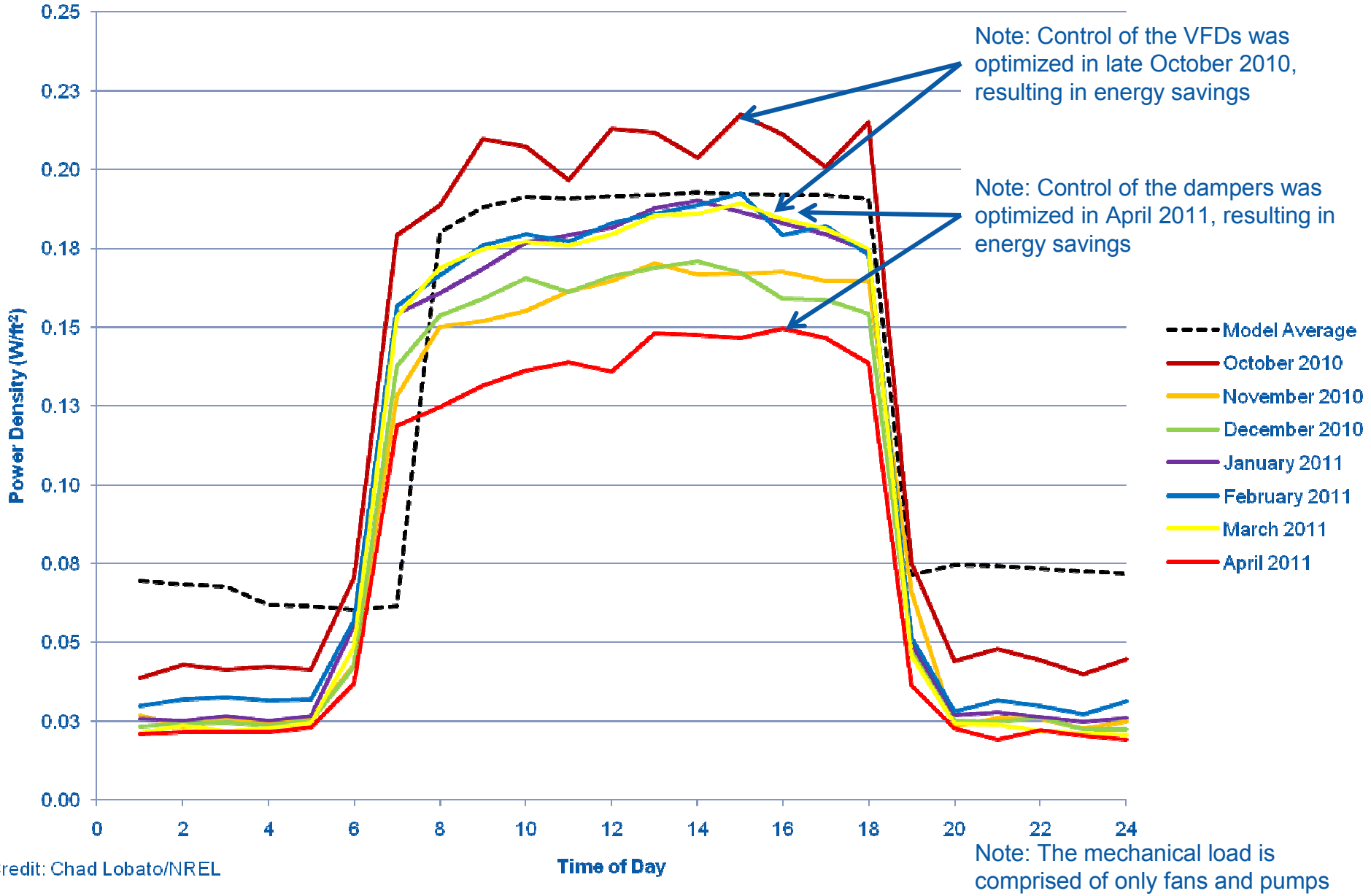
Note: The elevators are included in the plug loads

October 2010 – April 2011 Lighting Power Density



Credit: Chad Lobato/NREL

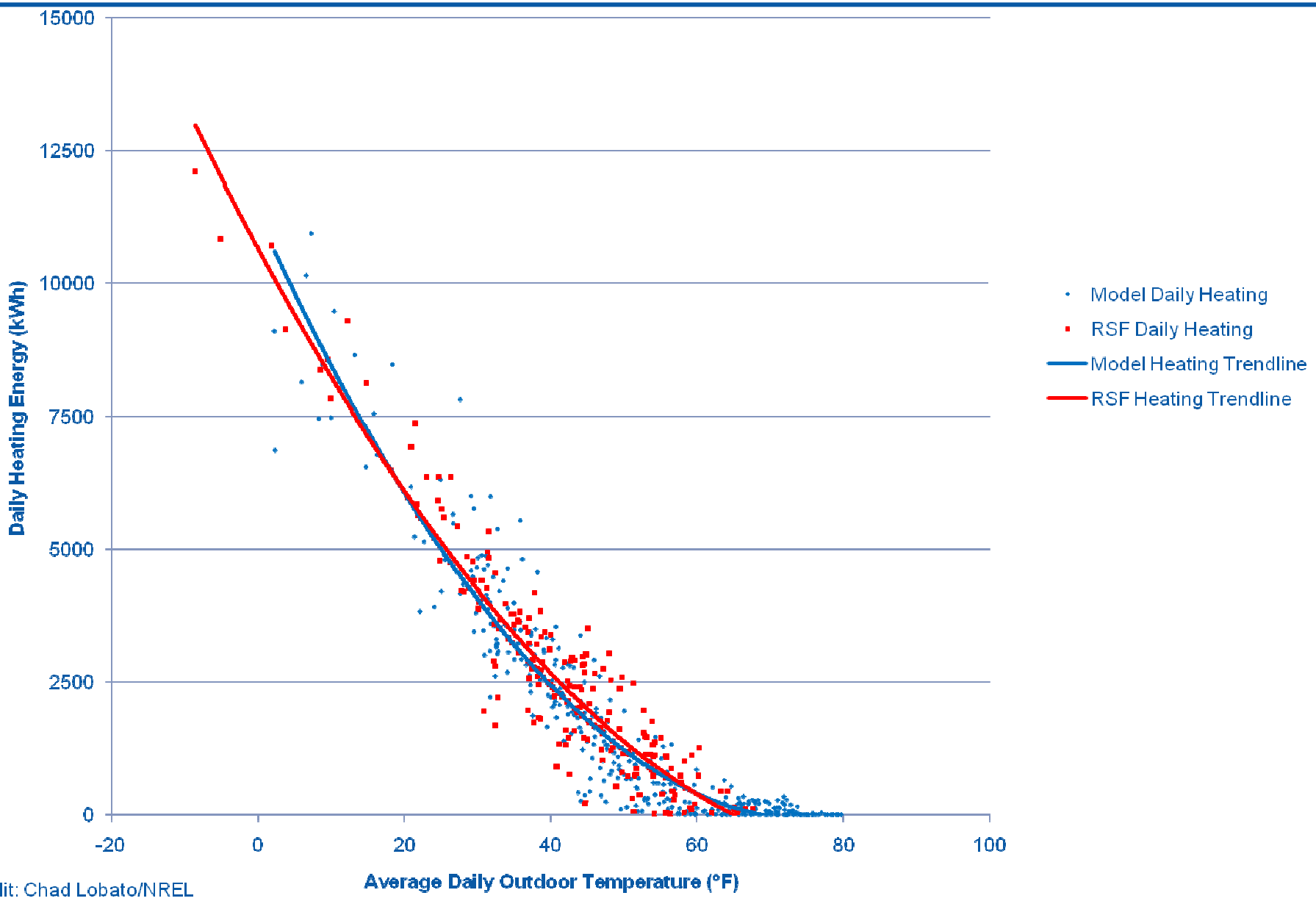
October 2010 – April 2011 Mechanical System Power Density



Credit: Chad Lobato/NREL

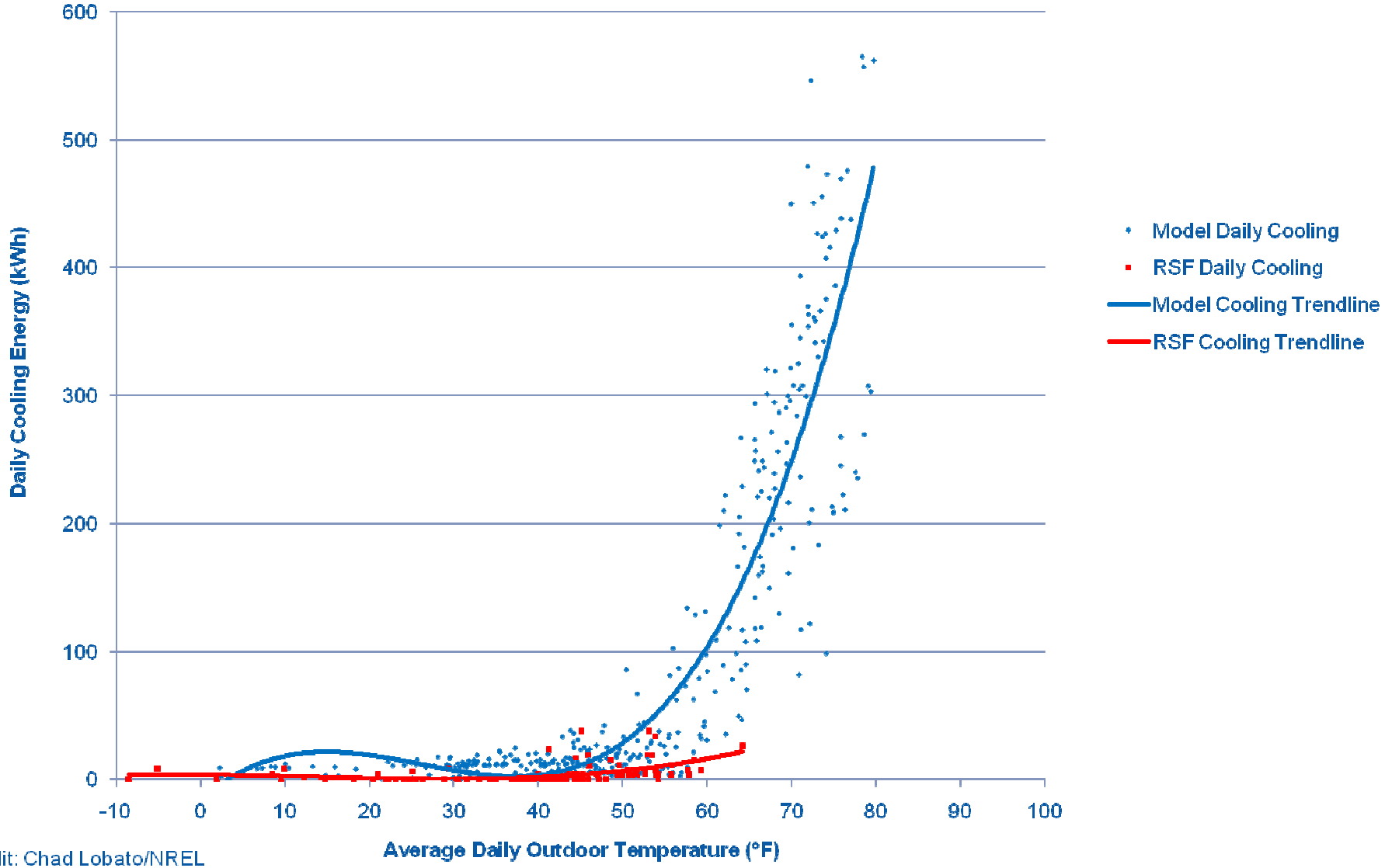
Note: The mechanical load is comprised of only fans and pumps

October 2010 – April 2011 Daily Heating Energy



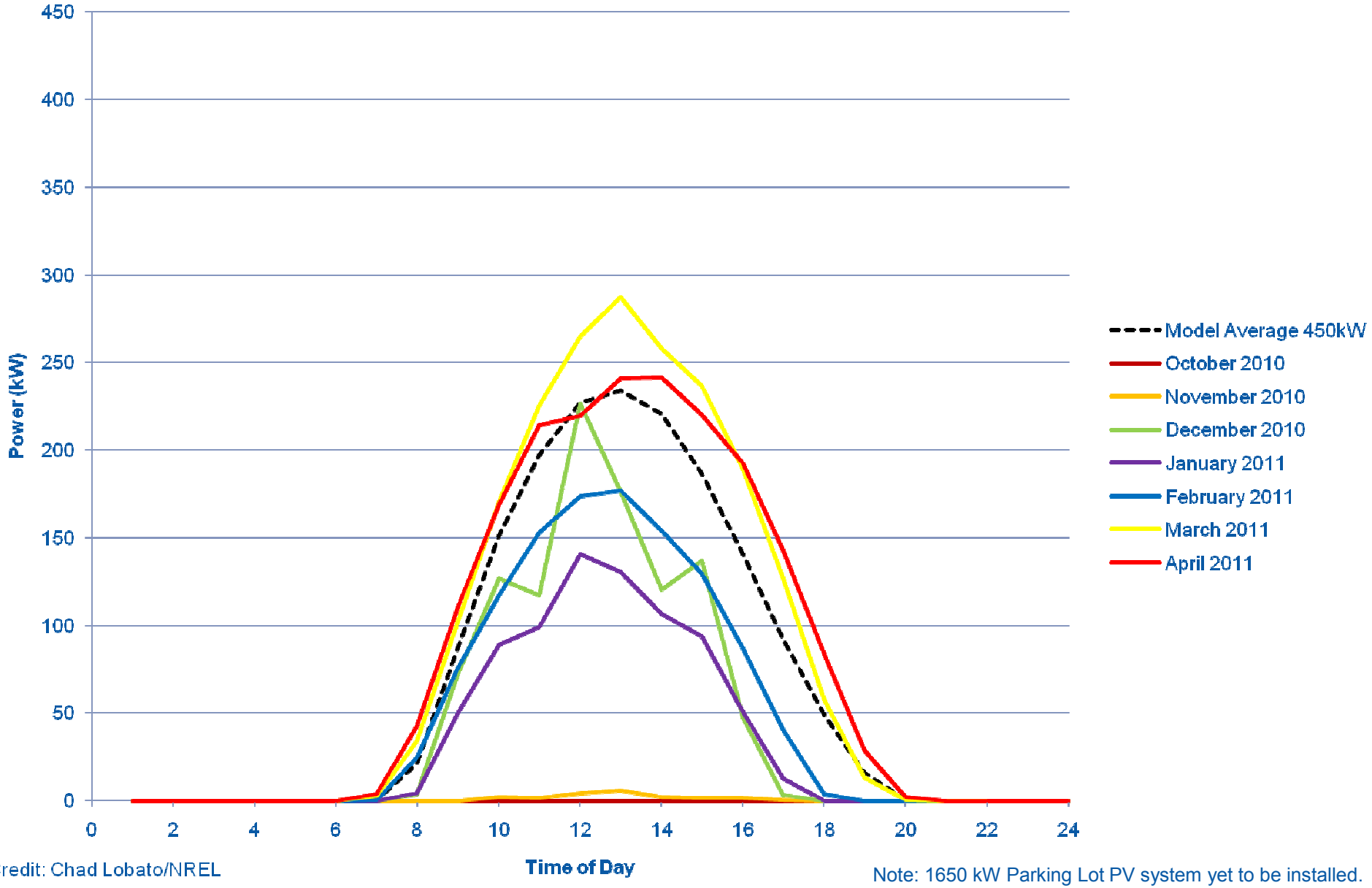
Credit: Chad Lobato/NREL

2011 YTD Daily Cooling Energy



Credit: Chad Lobato/NREL

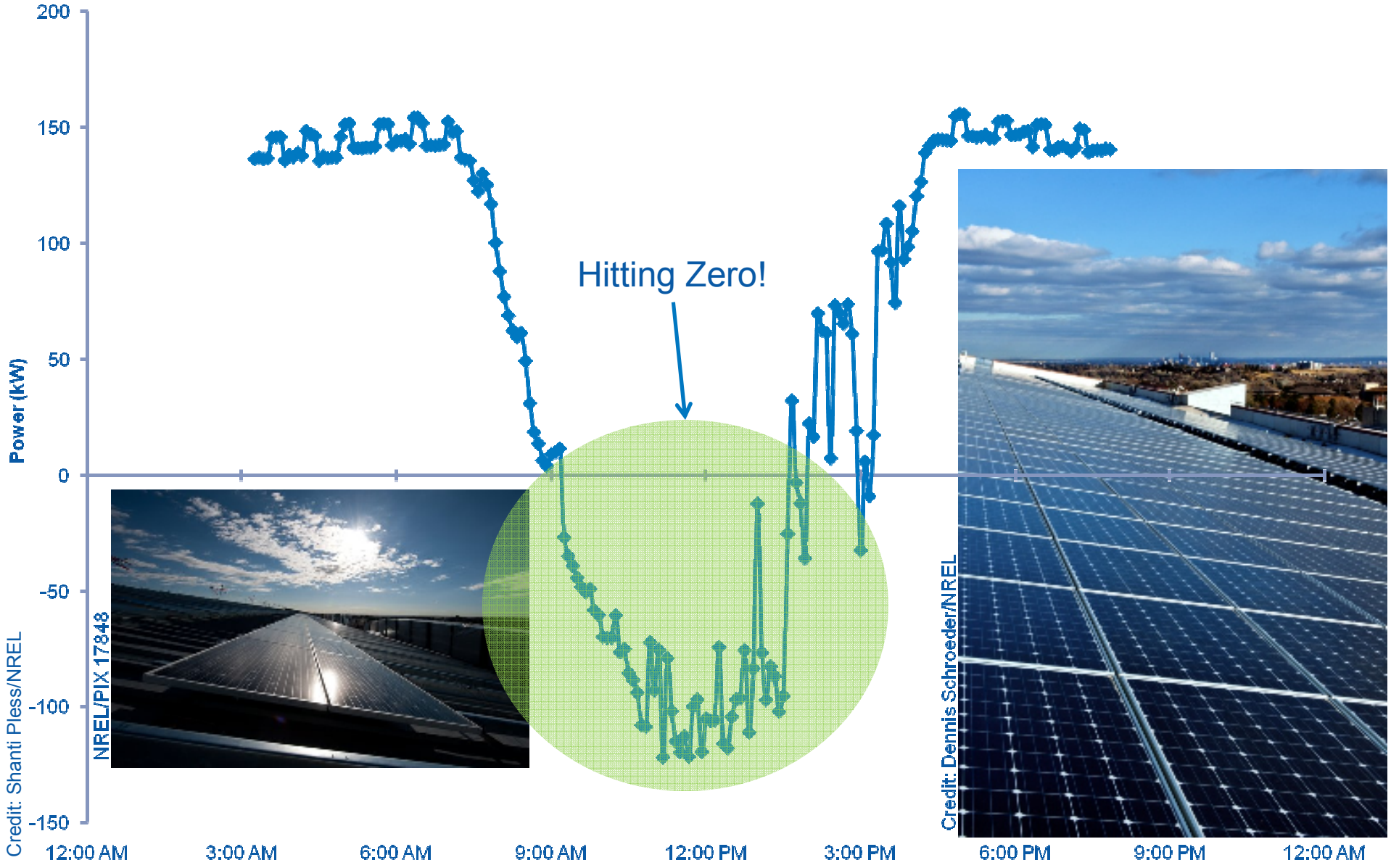
October 2010 – April 2011 450-kW PV Performance



Credit: Chad Lobato/NREL

Note: 1650 kW Parking Lot PV system yet to be installed.

450-kW Roof-Mounted PV Performance (12/2010)



Thank You…

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