National Renewable Energy Laboratory
Innovation for Our Energy Future

Net-Zero Buildings & Communities Definitions and Overview of National Trends

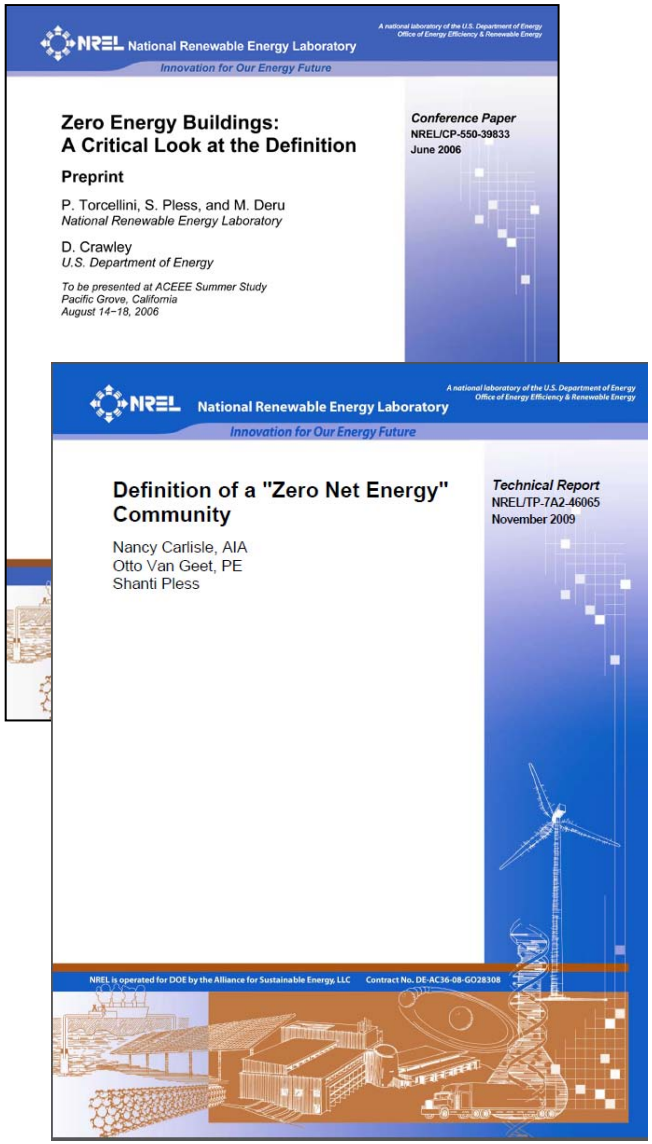
Otto Van Geet, PE

January 30, 2013

DRCOG

Promoting Energy Efficiency in Your Community: Net-Zero Buildings

Net-Zero Buildings & Communities



- Zero Energy Buildings: A Critical Look at the Definition
- Zero Energy Building: A Classification System Based on Renewable Energy Supply Options
- Definition of a "Zero Net Energy" Community http://www.nrel.gov/docs/fy10osti/46065.pdf

ZEB & ZEC Definitions

- Net Zero **Site Energy** Buildings & Communities
- Net Zero **Source Energy** Building
- Net Zero **Energy Cost** Building
- Net Zero **Energy Emissions** Building

ZEB & ZEC Hierarchy

Supply-Side

0. Reduce site energy though low-energy building technologies

On-Site Supply

1. Renewable energy within building footprint
2. Renewable energy within site

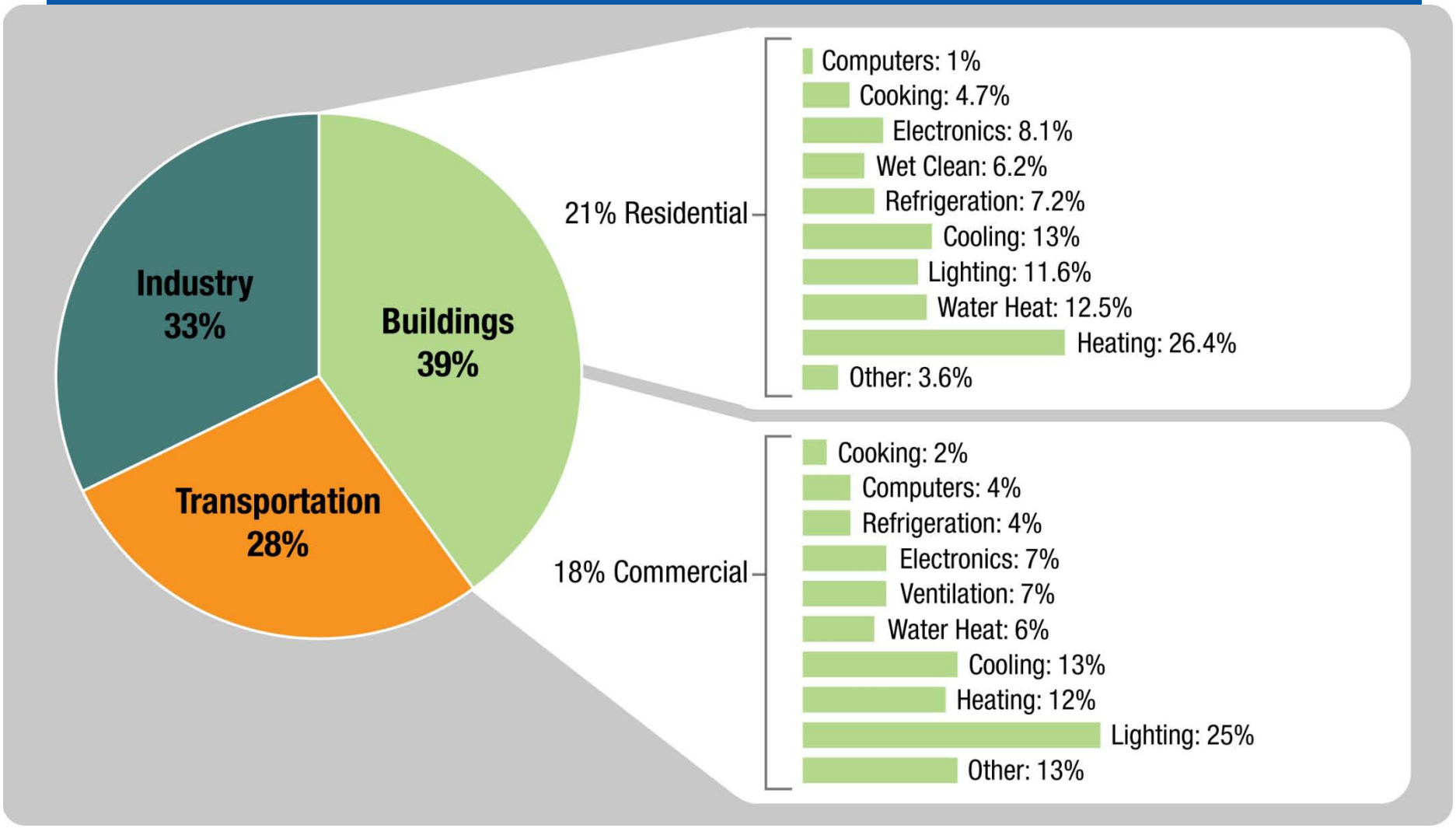
Off-Site Supply

3. Renewable energy off site to generate energy on site
4. Purchase off-site renewable energy sources

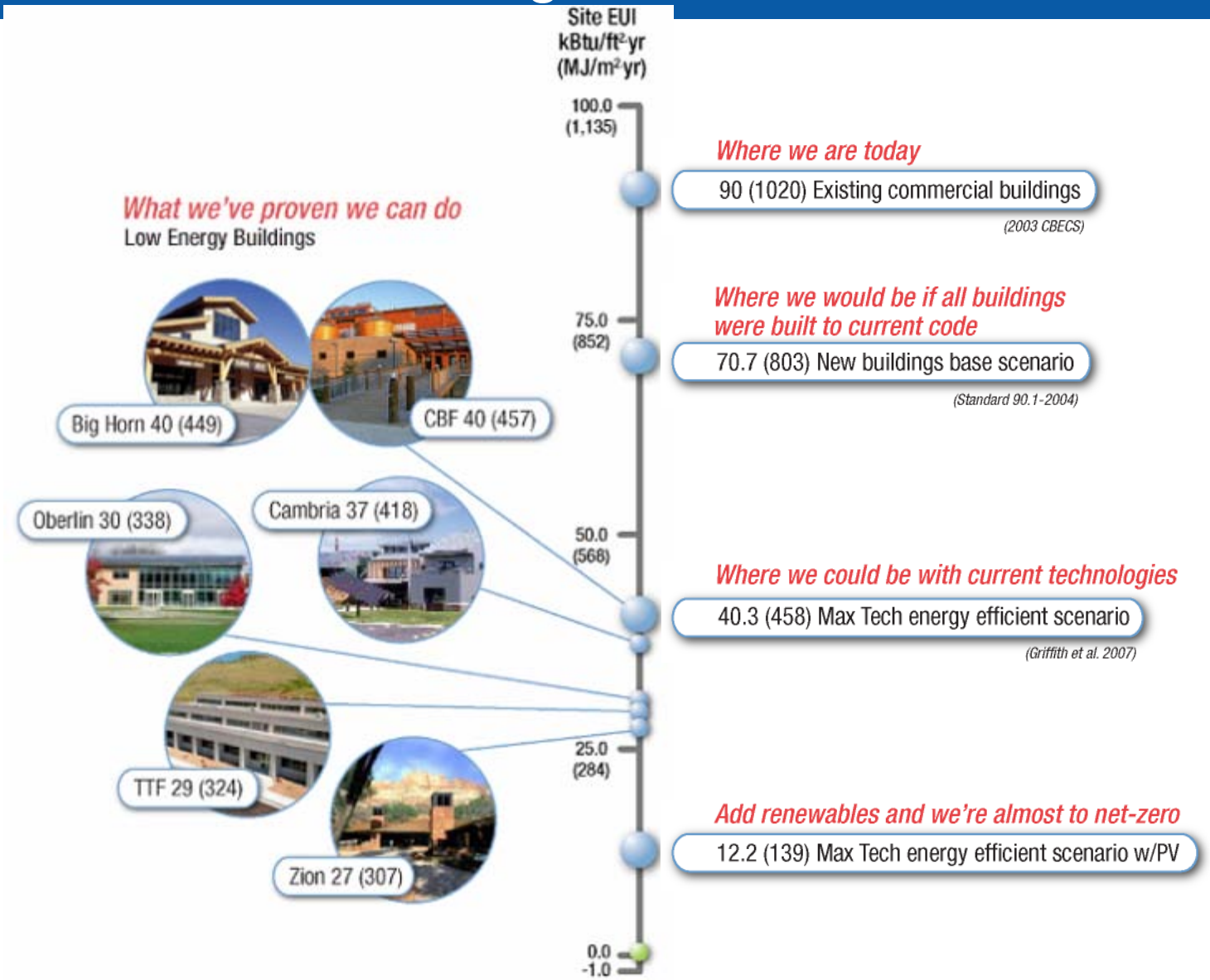
ZEB RENEWABLE HIERARCHY

0. Energy efficiency
   - Daylighting, CHP, passive solar
1. Footprint supply options
   - Building mounted PV or wind
   - RSF has 450 kW PV, RSF II 466 kW
2. Site supply options
   - Parking lot PV or wind
   - Visitor Parking 524 kW, Garage 1,098 kW
3. Imported supply options
   - Wood chips, ethanol
4. Purchase of renewable credits

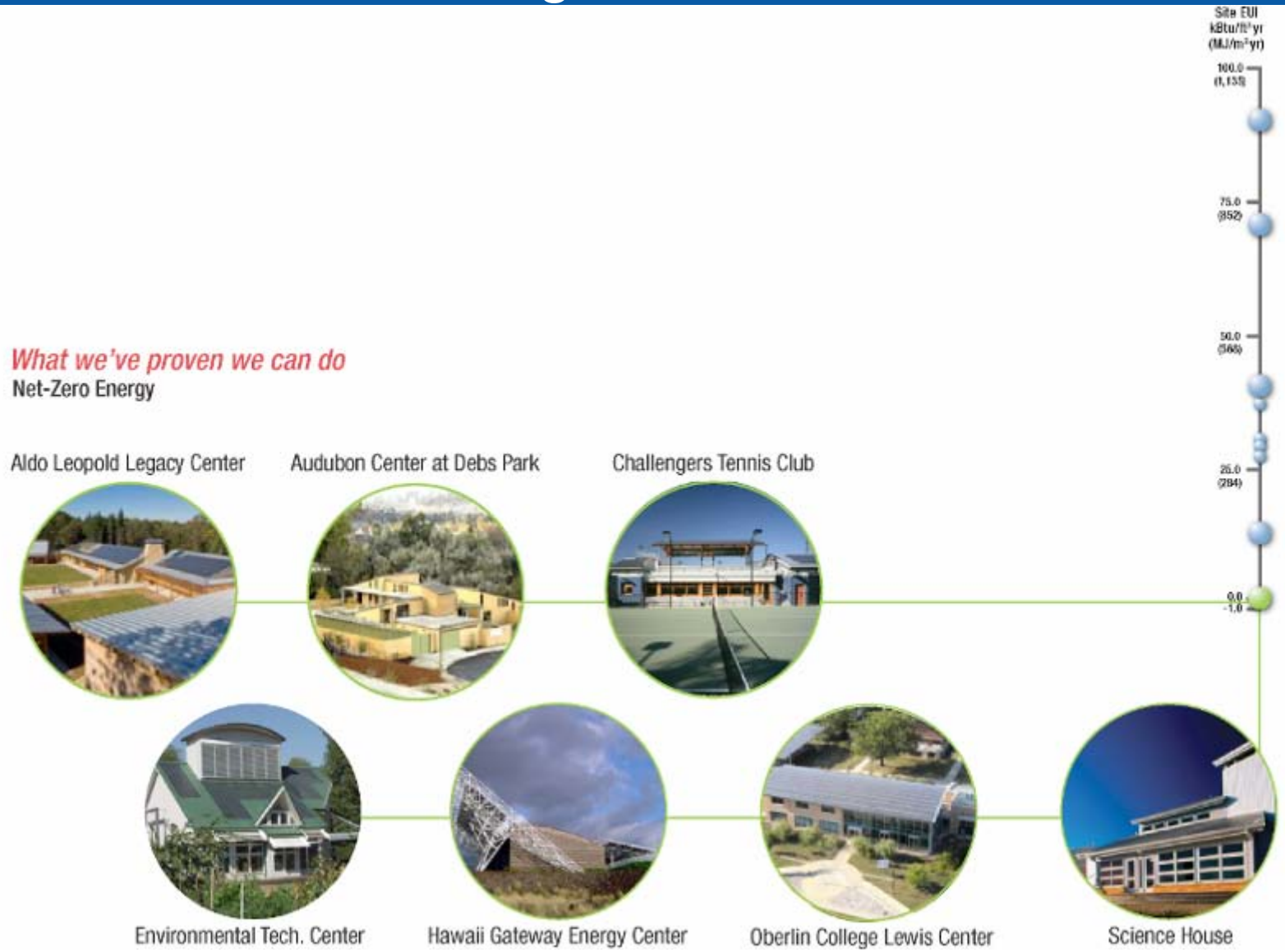
US Energy Use by Sector



Great Potential in Commercial Buildings



Great Potential in Commercial Buildings



DOE/NREL Research Support Facility: Project Goals

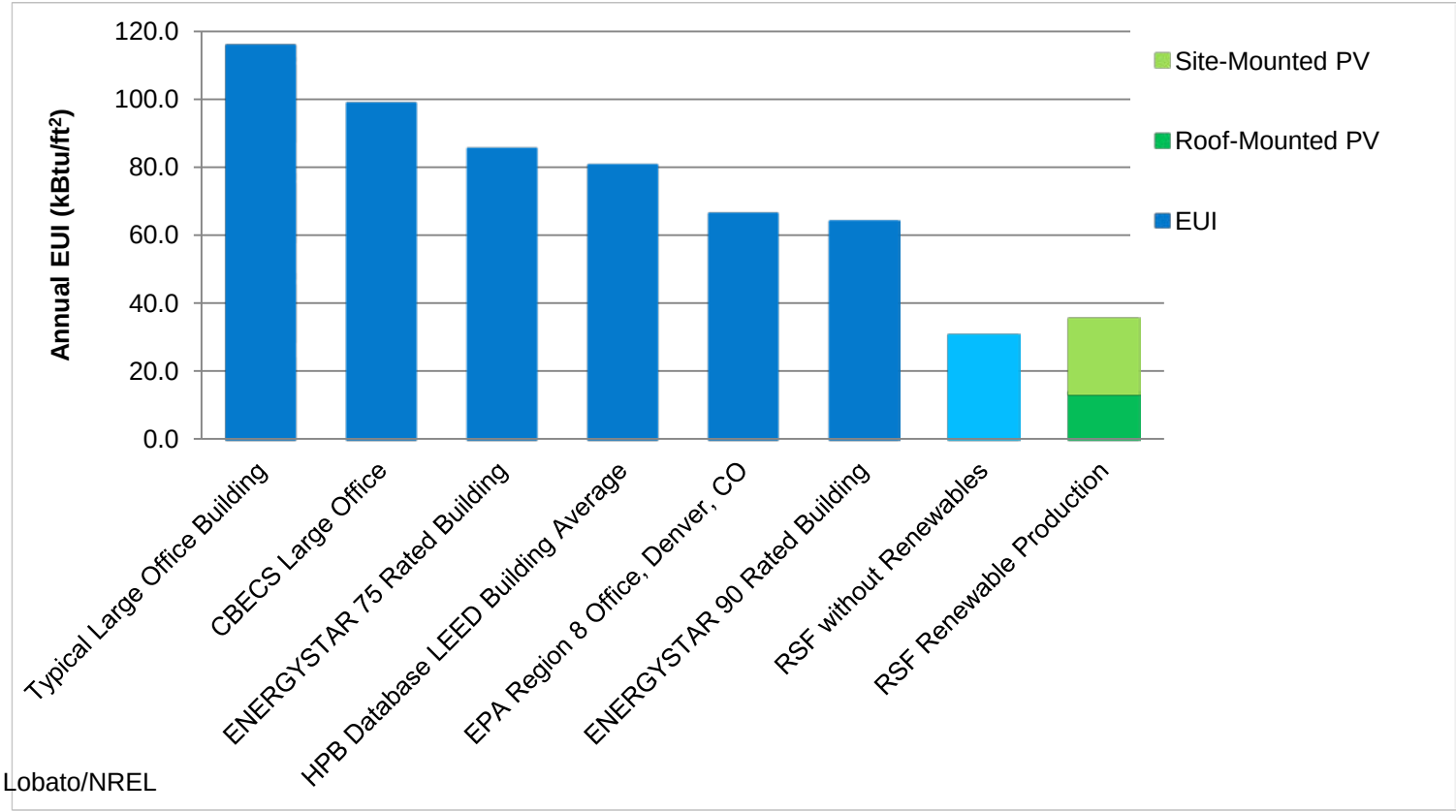
- More than 800 (now 1300)people in DOE office space on NREL's campus
- 220,000 (now 360,000) ft^2
- Design/build process with required energy goals
  - 25 $kBtu/ft^2$
  - 50% energy savings
  - LEED Platinum
- Replicable
  - Process, Technologies
  - Cost

Credit: Haselden Construction

- Site, source, carbon, cost ZEB:B
  - 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

Design Requirements

- 25 kBtu/ft^2/yr for standard office space occupant density and data center loads
- Normalized up to 35.1 kBtu/ft^2/yr for better space efficiency and to account for full data center load

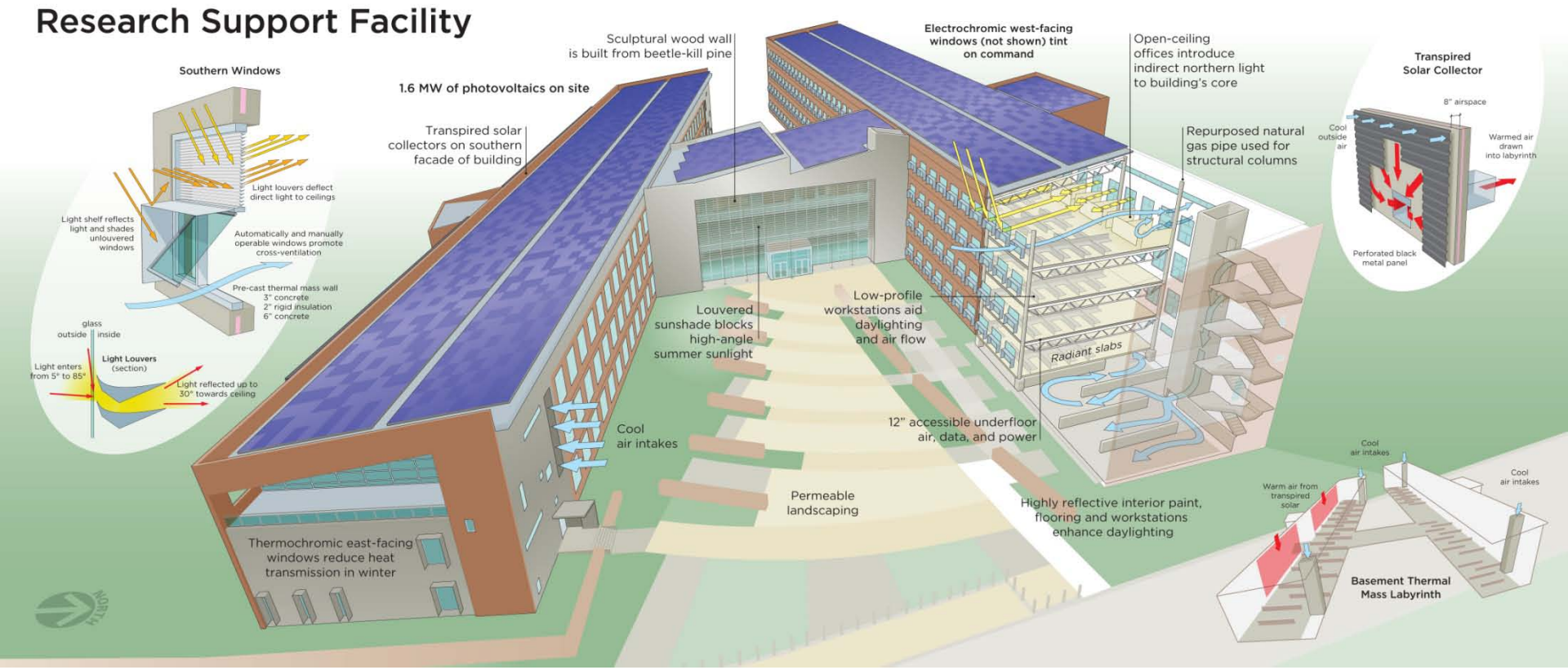


Credit: Chad Lobato/NREL

Key Design Strategies

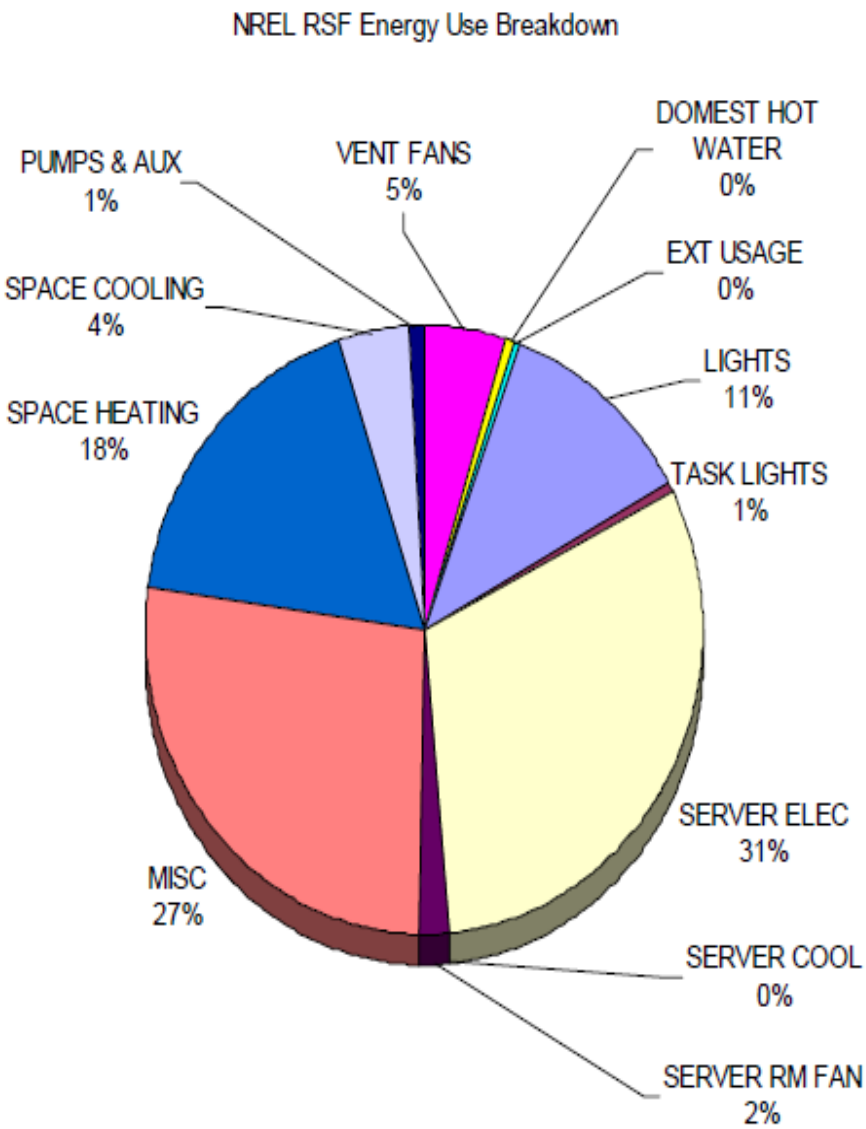
1. Optimal orientation and office space layout
2. Fully daylit office wings with high performance electrical lighting
3. Continuous insulation precast wall panels with thermal mass
4. Operable windows for natural ventilation
5. Radiant heating and cooling
6. Outdoor air preheating
    - Transpired solar 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

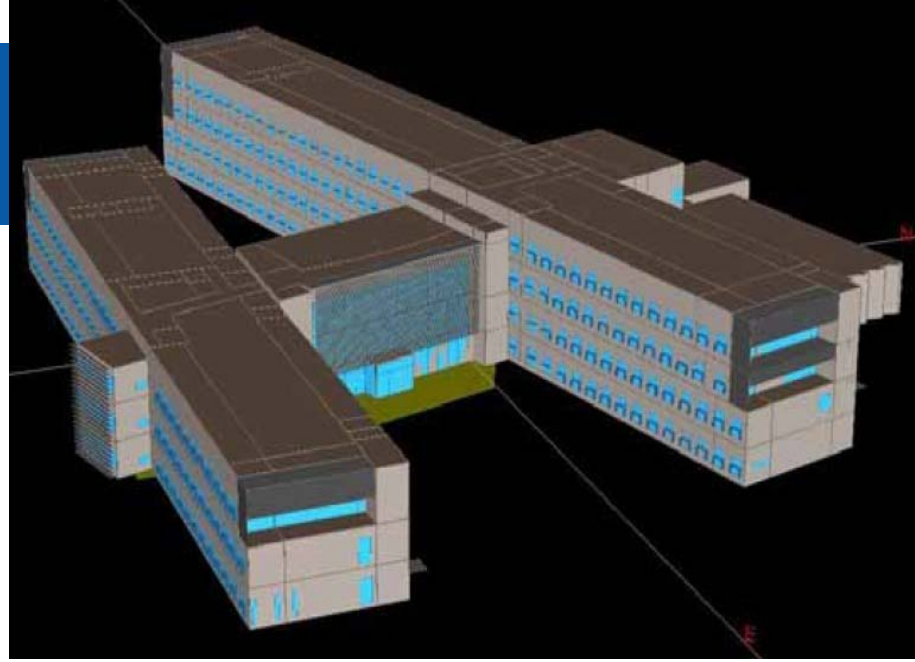
Research Support Facility



Credit: NREL

Energy Modeling
NREL RSF Energy Use Breakdown

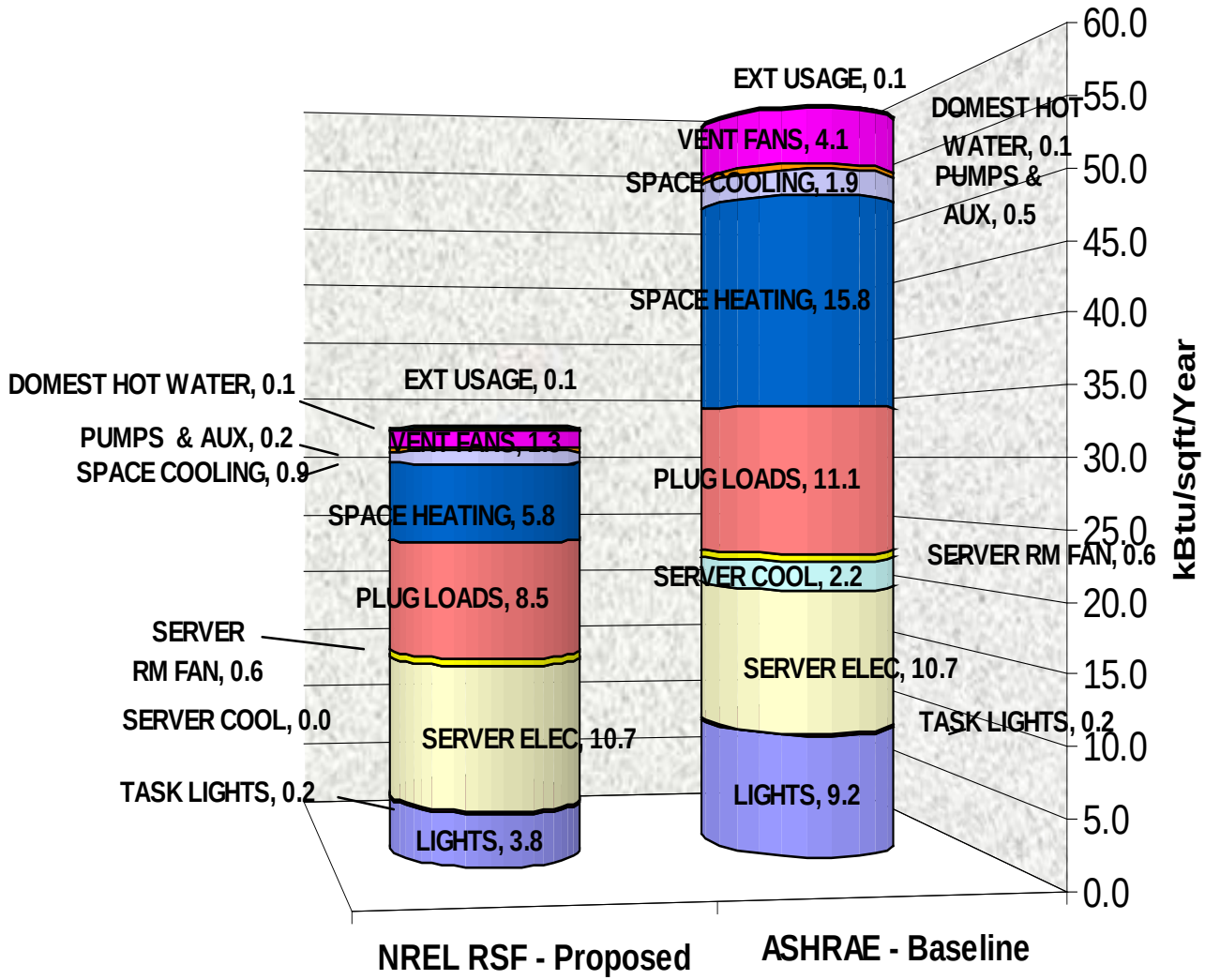




Credit: Stantec

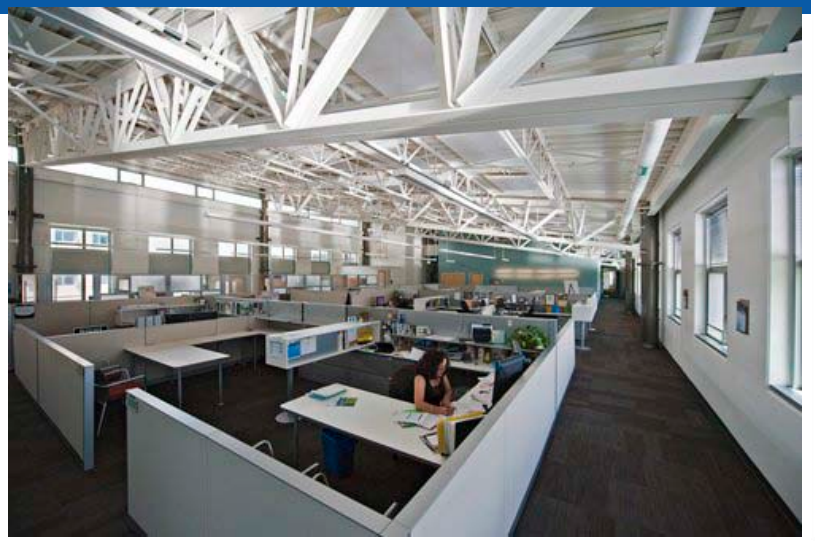
End Use	kBtu/ft2
Lights	3.85
Task Lights	0.19
Data Center	10.60
Data Center Cooling	0.01
Data Center Fans	0.55
Office Plug Loads	9.16
Space Heating	6.11
Space Cooling	1.42
Pumps	0.27
Ventilation Fans	1.61
Domestic Hot Water	0.13
Exterior Lights	0.12

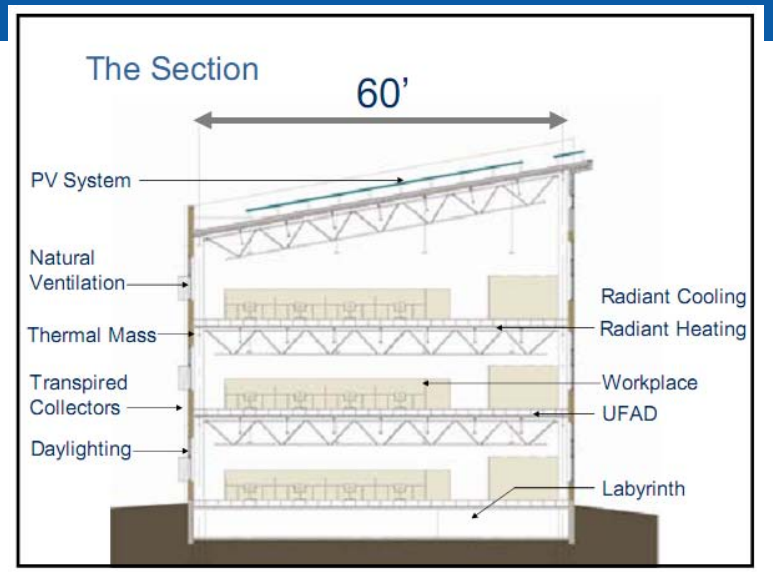
NREL RSF Annual Energy Consumption Comparison

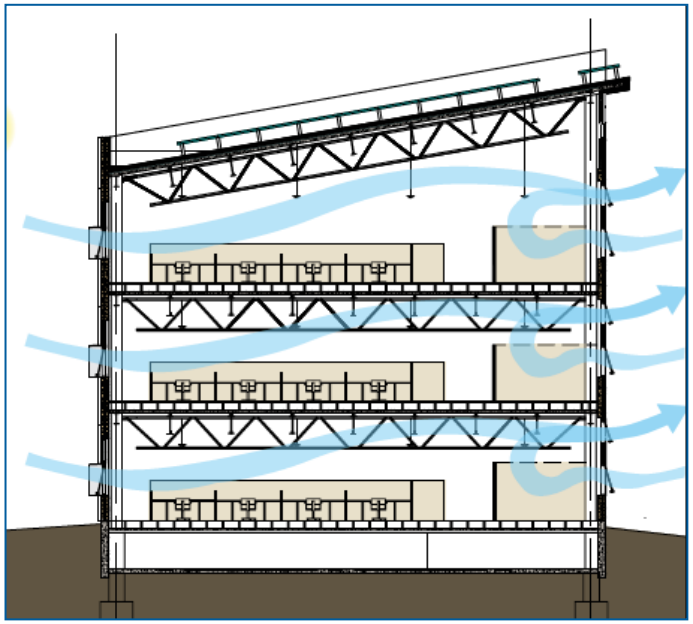


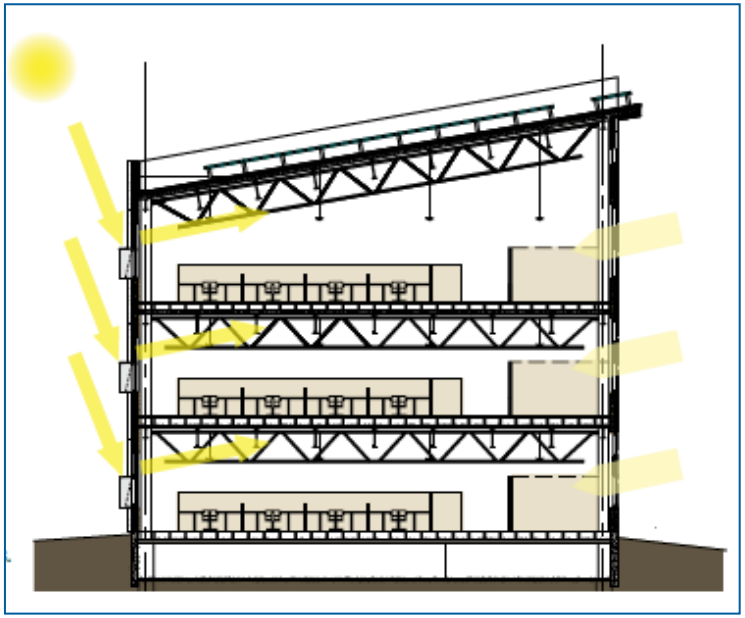
LIGHTS
TASK LIGHTS
SERVER ELEC
SERVER COOL
SERVER RM FAN
PLUG LOADS
SPACE HEATING
SPACE COOLING
PUMPS & AUX
VENT FANS
DOMEST HOT WATER
EXT USAGE

Open plan, narrow floor plate for natural lighting and ventilation









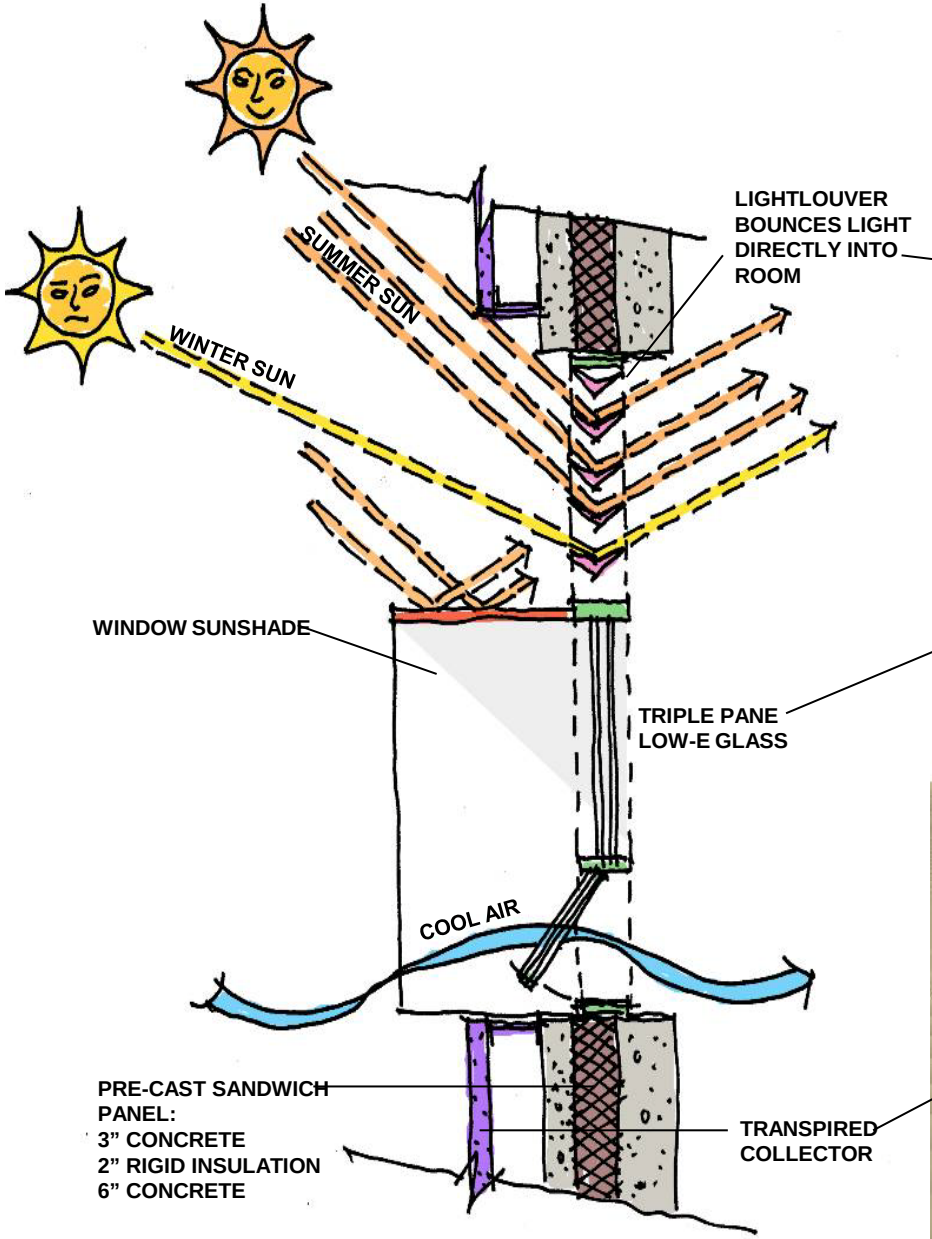


FIGURE #1
NREL

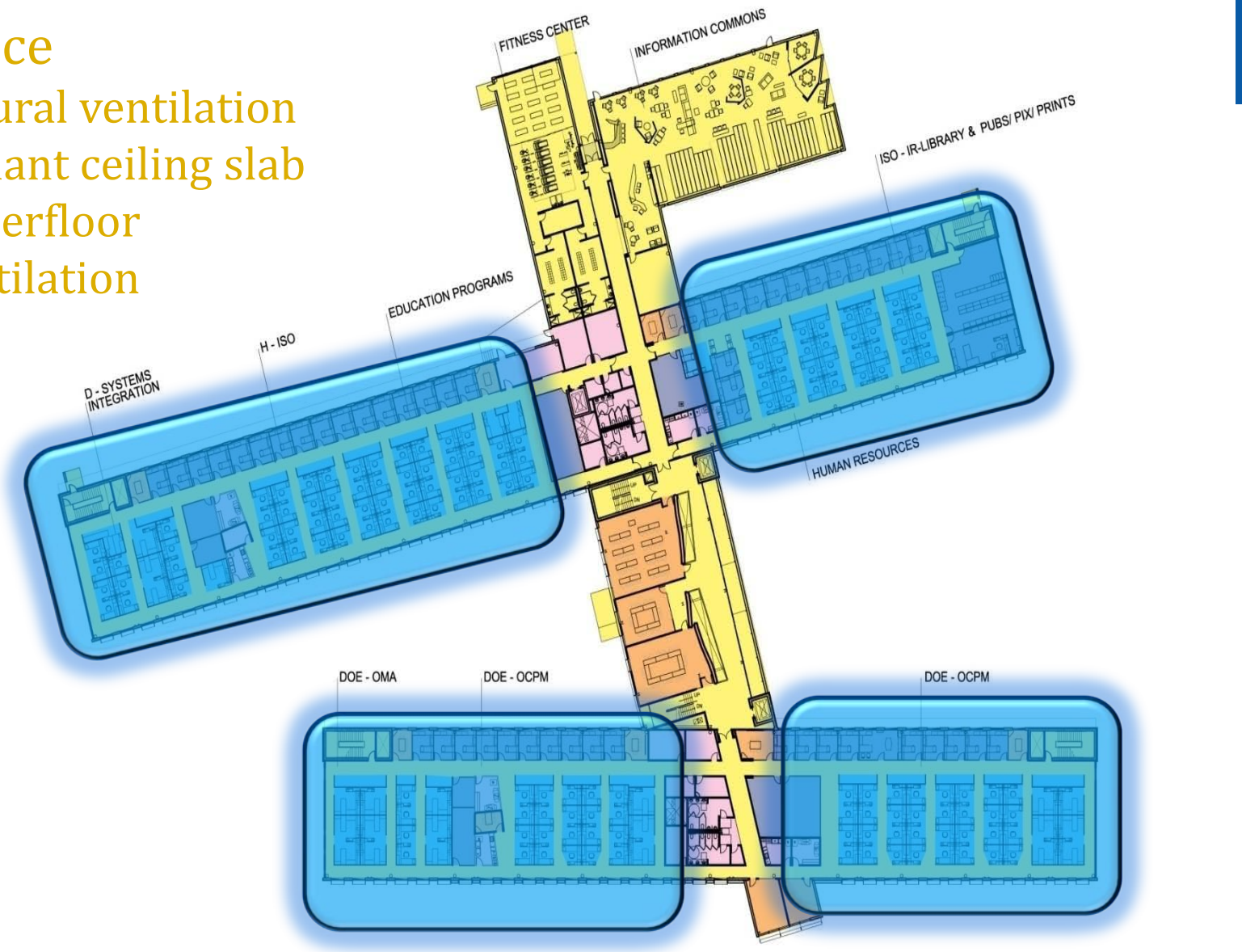
HVAC System

- DOAS underfloor in office areas, CO2 controls per zone
- Natural Ventilation in office, corridors, and conference rooms
- Radiant Heating and Cooling in offices with core and N/S zones
- VAV for conference rooms
- Campus Hot water and chilled water
    - Wood chip boiler 80% of hot water
    - High efficiency water cooled chillers
- Increased campus square footage by 60%, energy use by 6%
- 1,000 ft^2 per Ton of central plant cooling
    - typical 300-400 ft^2 /Ton

RSF HVAC Strategies

office

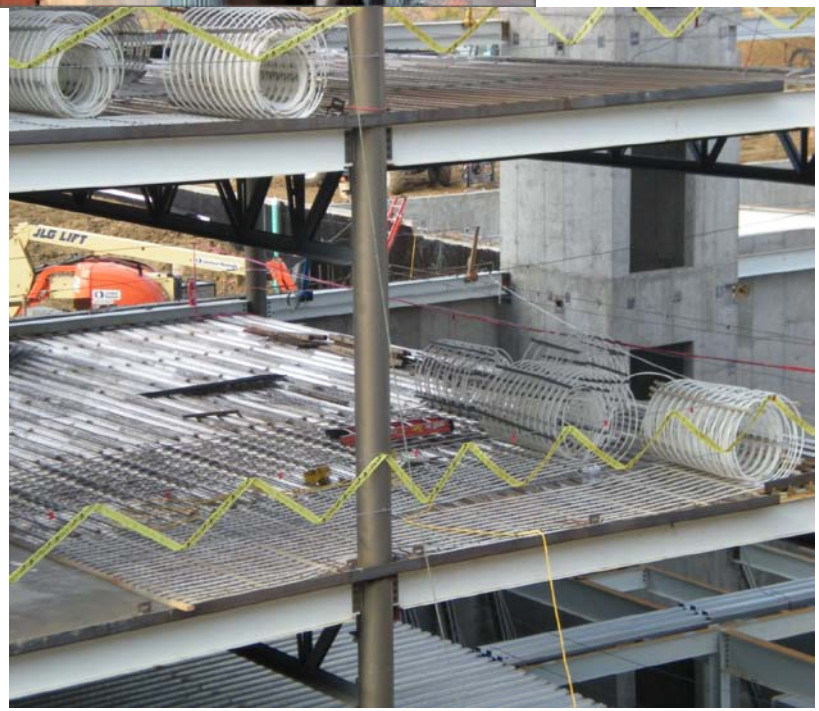
natural ventilation
radiant ceiling slab
underfloor
ventilation



SECOND FLOOR SPACE PLAN

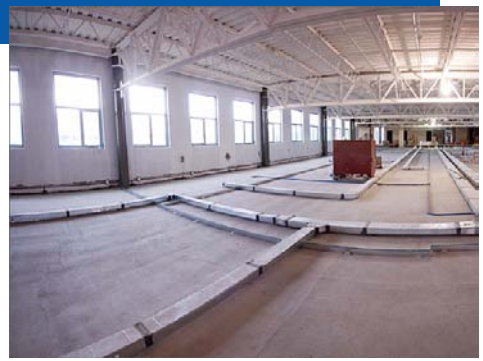
NREL RESEARCH SUPPORT FACILITY

Radiant Heating and Cooling in Ceiling Slab

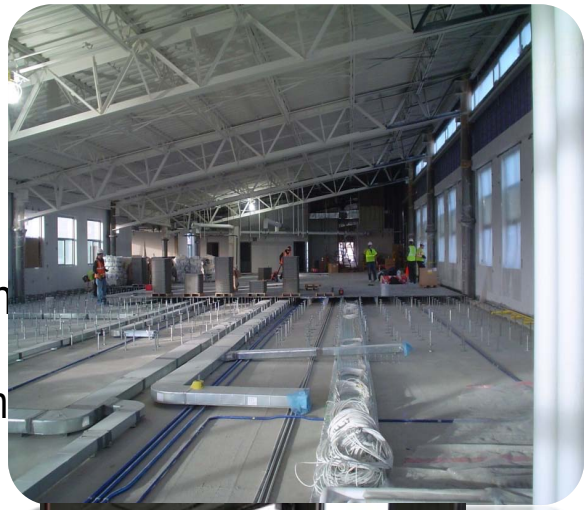


Radiant Ceiling Slabs

Outdoor Air System



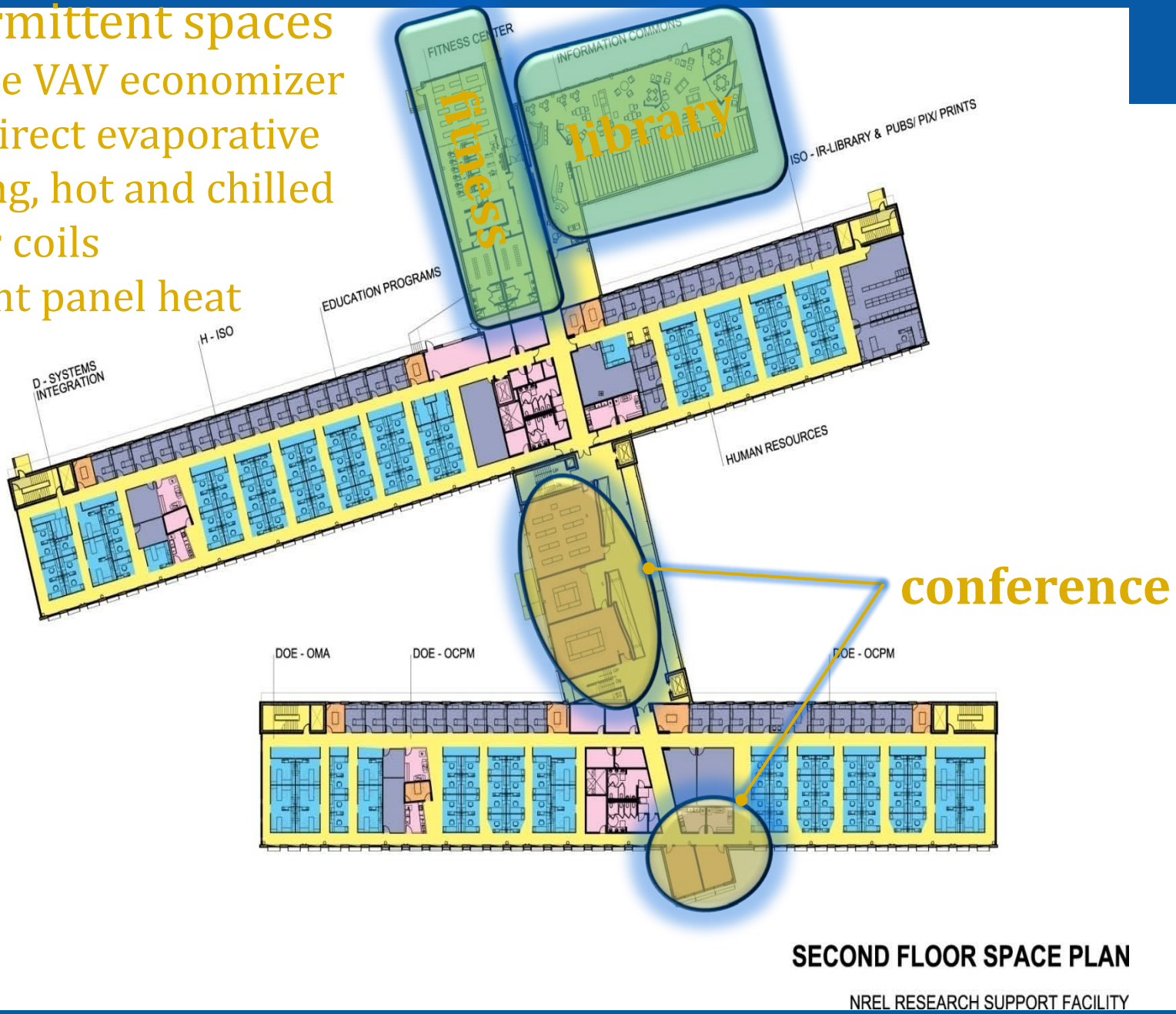
- Dedicated OA system with radiant ceiling space heating/cooling
- Underfloor air distribution
  - Ducted underfloor OA supply to local underfloor distribution zone with manual swirl diffusers
  - High returns
- Natural ventilation
  - OA perimeter and core zones
  - Nighttime space cooling with automated windows
  - 2/3 windows automatic on south and north
- Demand controlled CO2 VAV dampers in underfloor zones with displacement ventilation providing space neutral temp air
  - R-5 insulation between heated slab and underfloor air distribution
  - 30% additional ventilation flow for LEED
- Energy recovery runaround loop from bathroom/copier room/general exhaust
- Direct evaporative cooling and cooling coil
- Transpired solar collector/data center exhaust into OA hot deck



Underfloor Ventilation

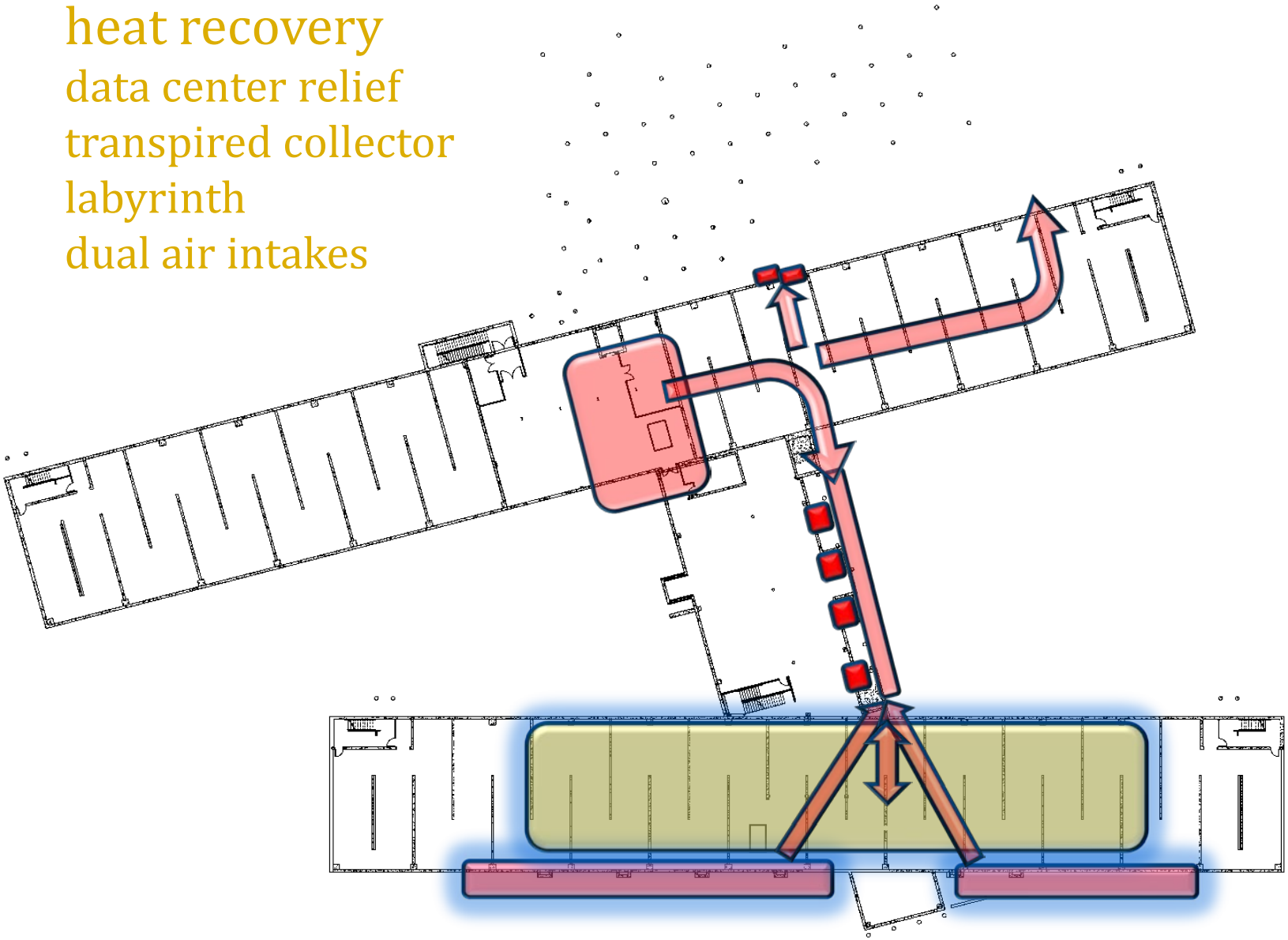
Intermittent spaces

airside VAV economizer and direct evaporative cooling, hot and chilled water coils
radiant panel heat



heat recovery

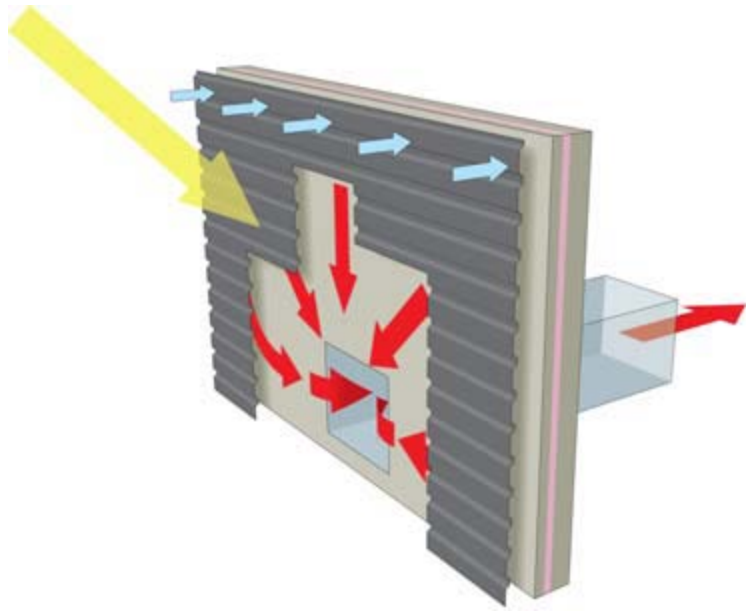
data center relief
transpired collector
labyrinth
dual air intakes



BASEMENT FLOOR PLAN

NREL RESEARCH SUPPORT FACILITY

Transpired Solar Collector



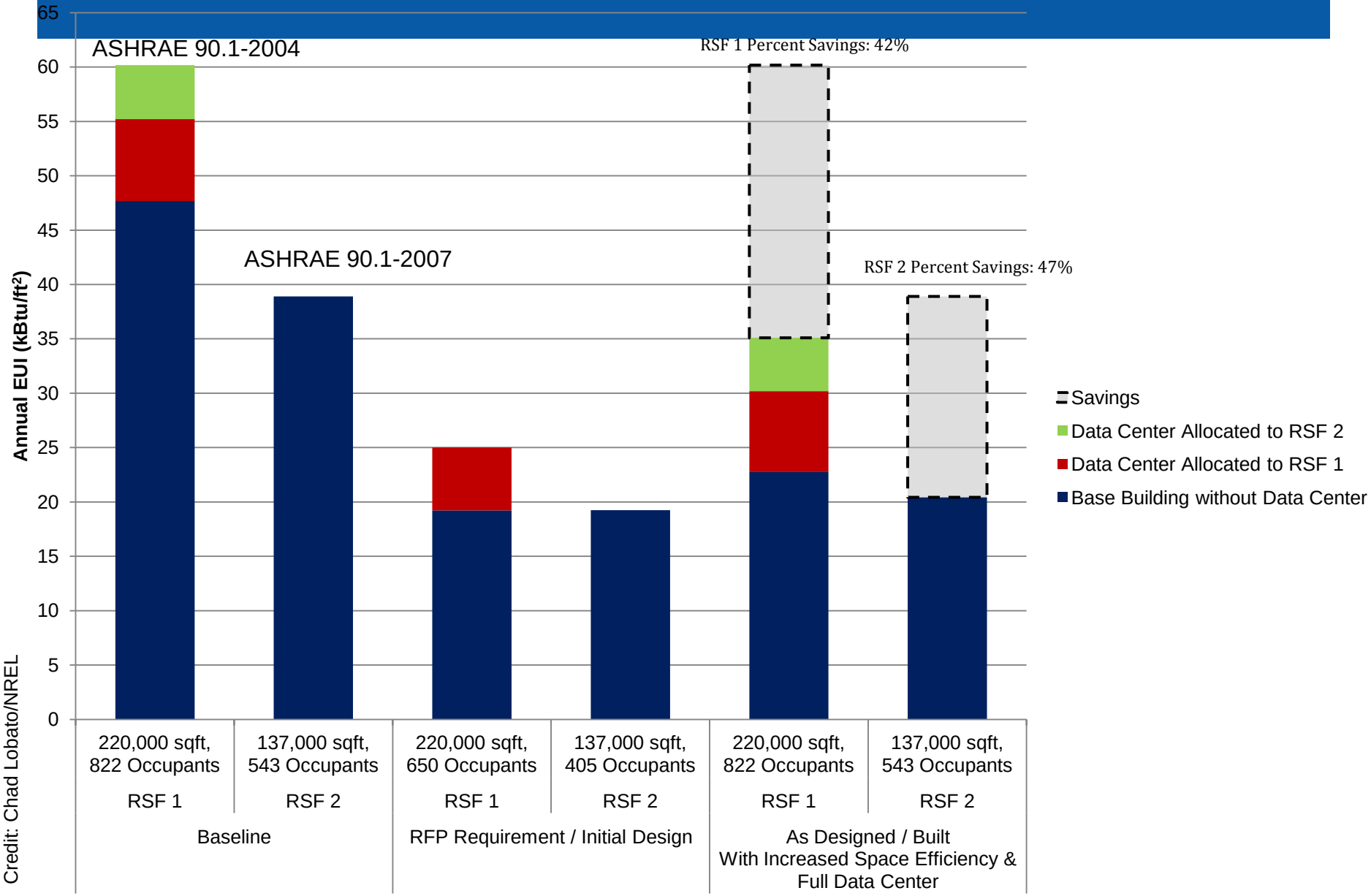
RSF Net-Zero Boundary

RSF Staff Parking Garage

Parking Garage Renderings Courtesy RNL

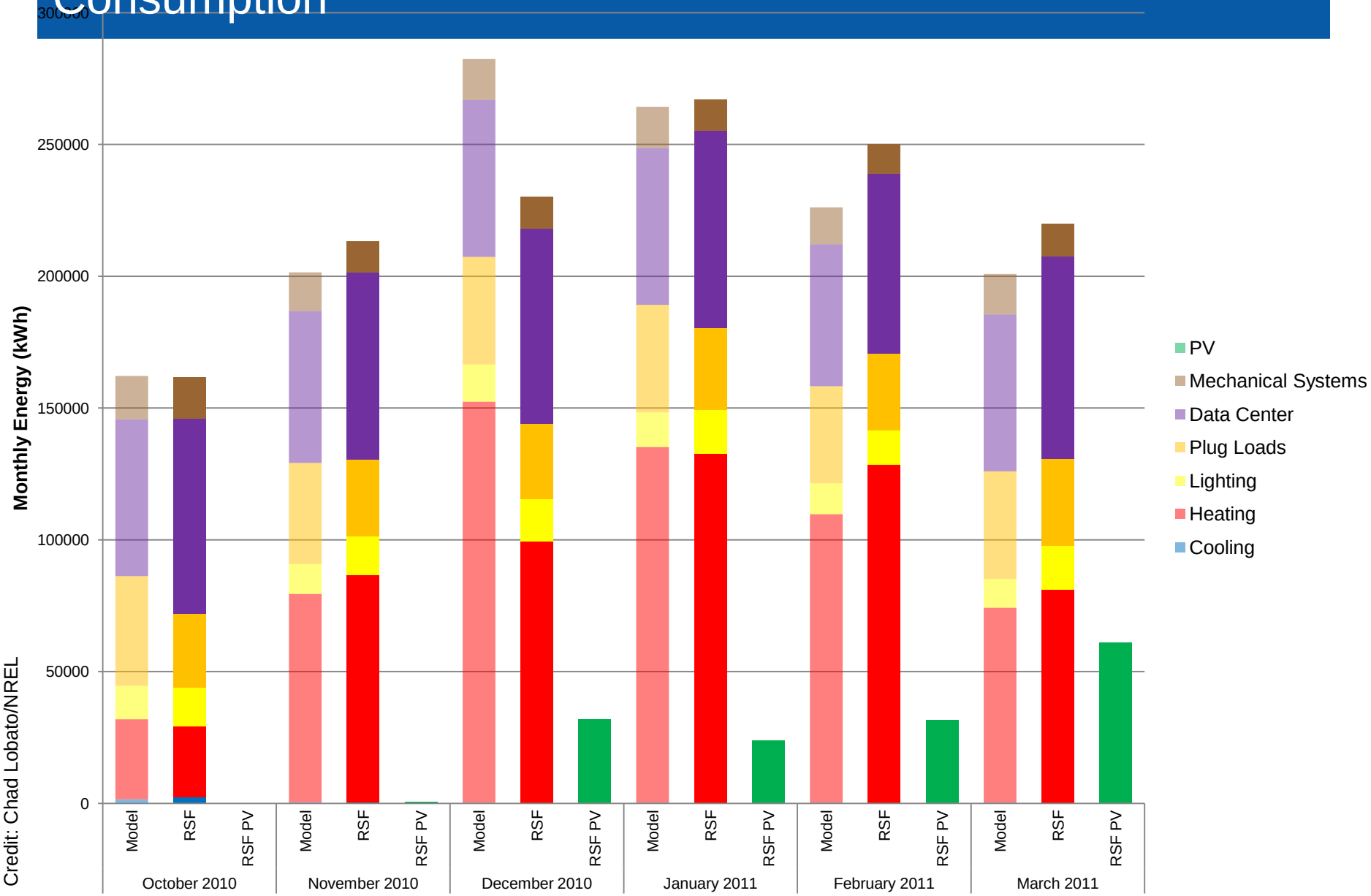
RSF Complex	Building Area (ft^2)	Contractual Building Energy Use Requirements			PV System Size (kW)	PV Power Factor	PV Energy Generation (kWh)
		kBtu/ft^2/yr	kWh/ft^2/yr	kWh/yr			
RSFI	220,000	35.1	10.3	2,263,095	450	1,350	606,150
RSFII	139,767	25.5	7.3	1,021,340	466	1,350	629,100
RSF Staff Parking Garage	500,000	0.65	0.19	95,000	1,098	1,350	1,482,300
RSF Visitor's Parking				5,000	524	1,350	707,400
Totals				**3,407,633**	**2,538**		**3,424,950**

RSF 1 and RSF 2 Energy Model Comparison



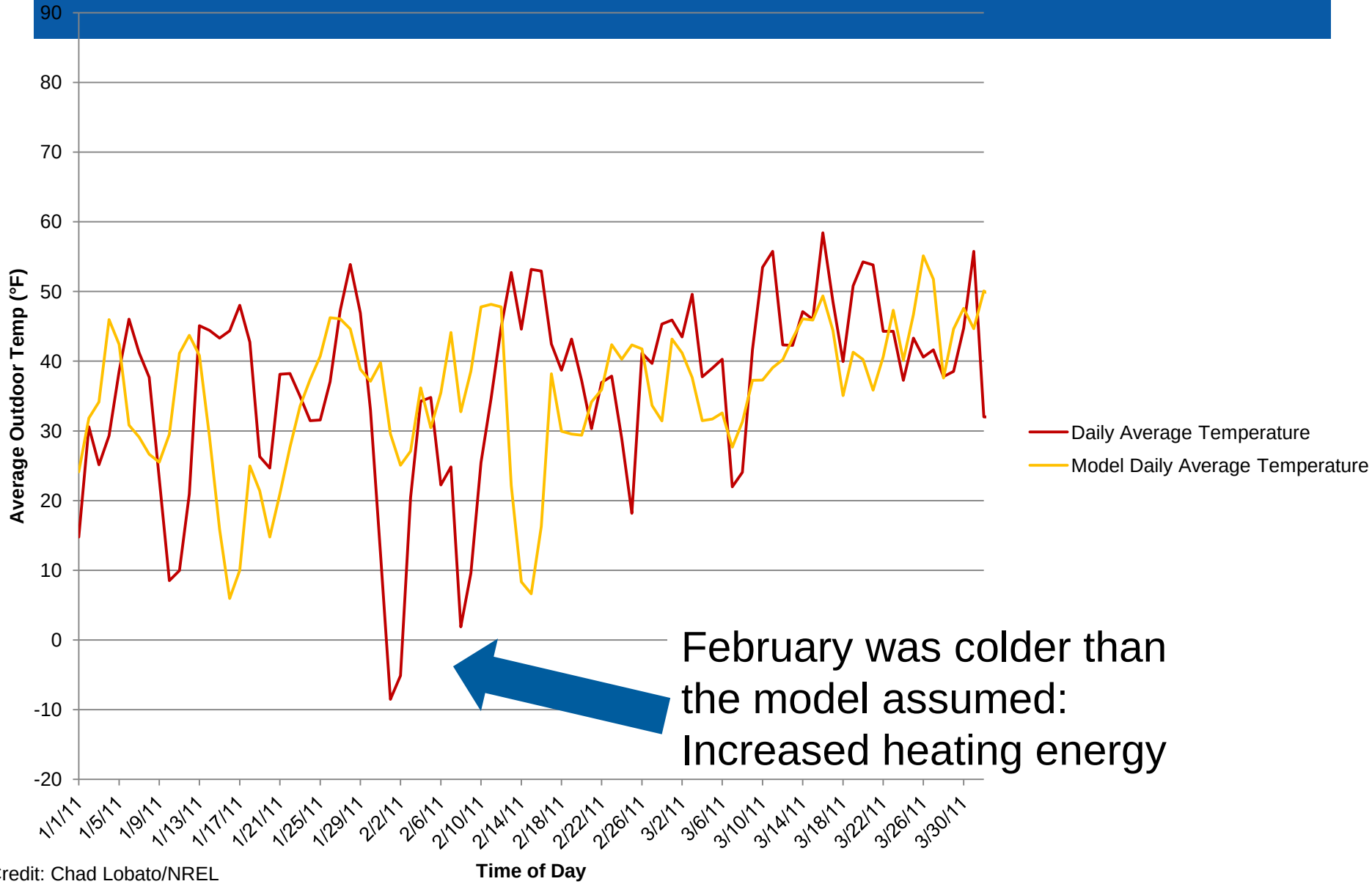
Credit: Chad Lobato/NREL

Measured Versus Modeled Monthly End Use Energy Consumption



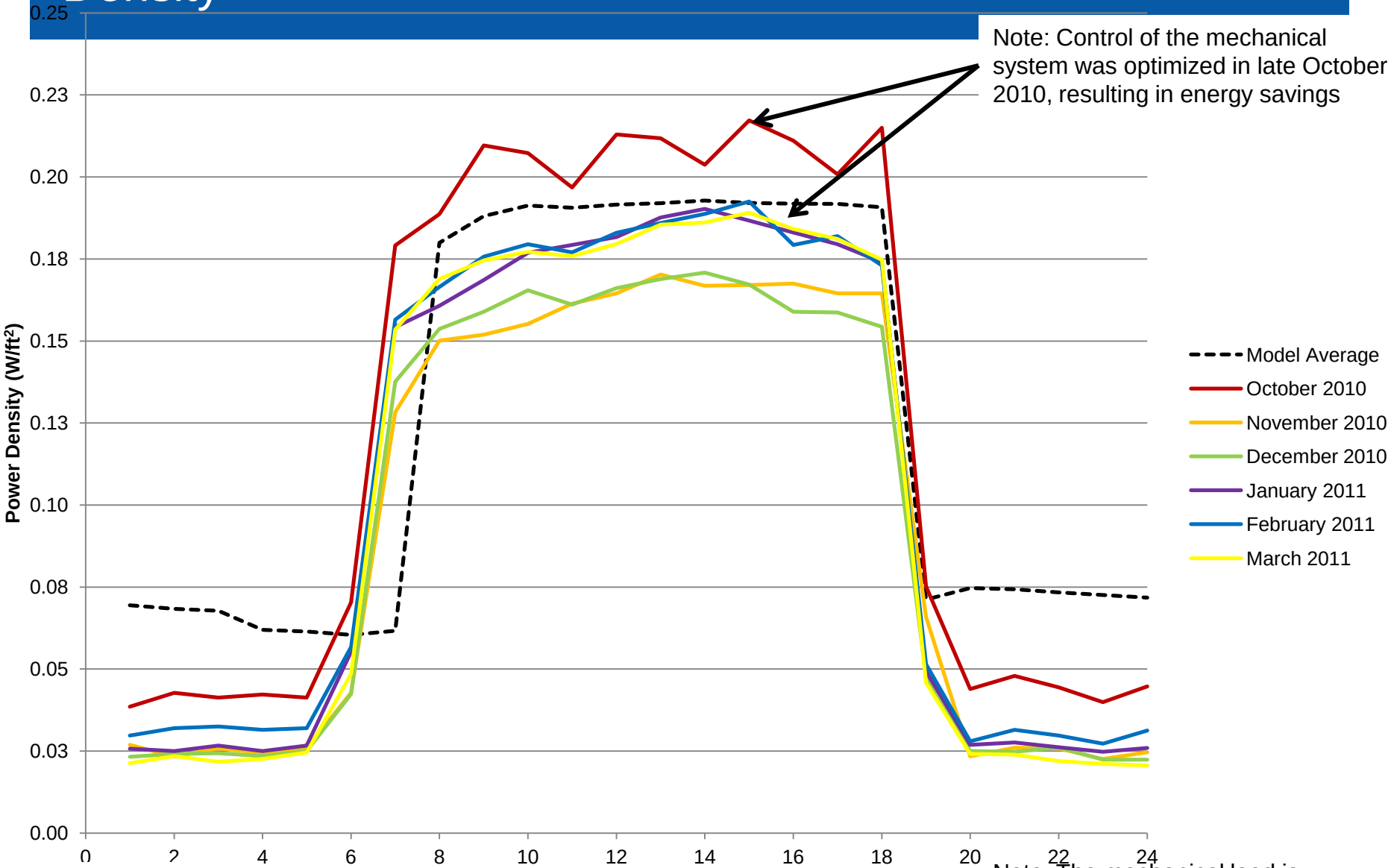
Credit: Chad Lobato/NREL

Outdoor Air Temperatures



Credit: Chad Lobato/NREL

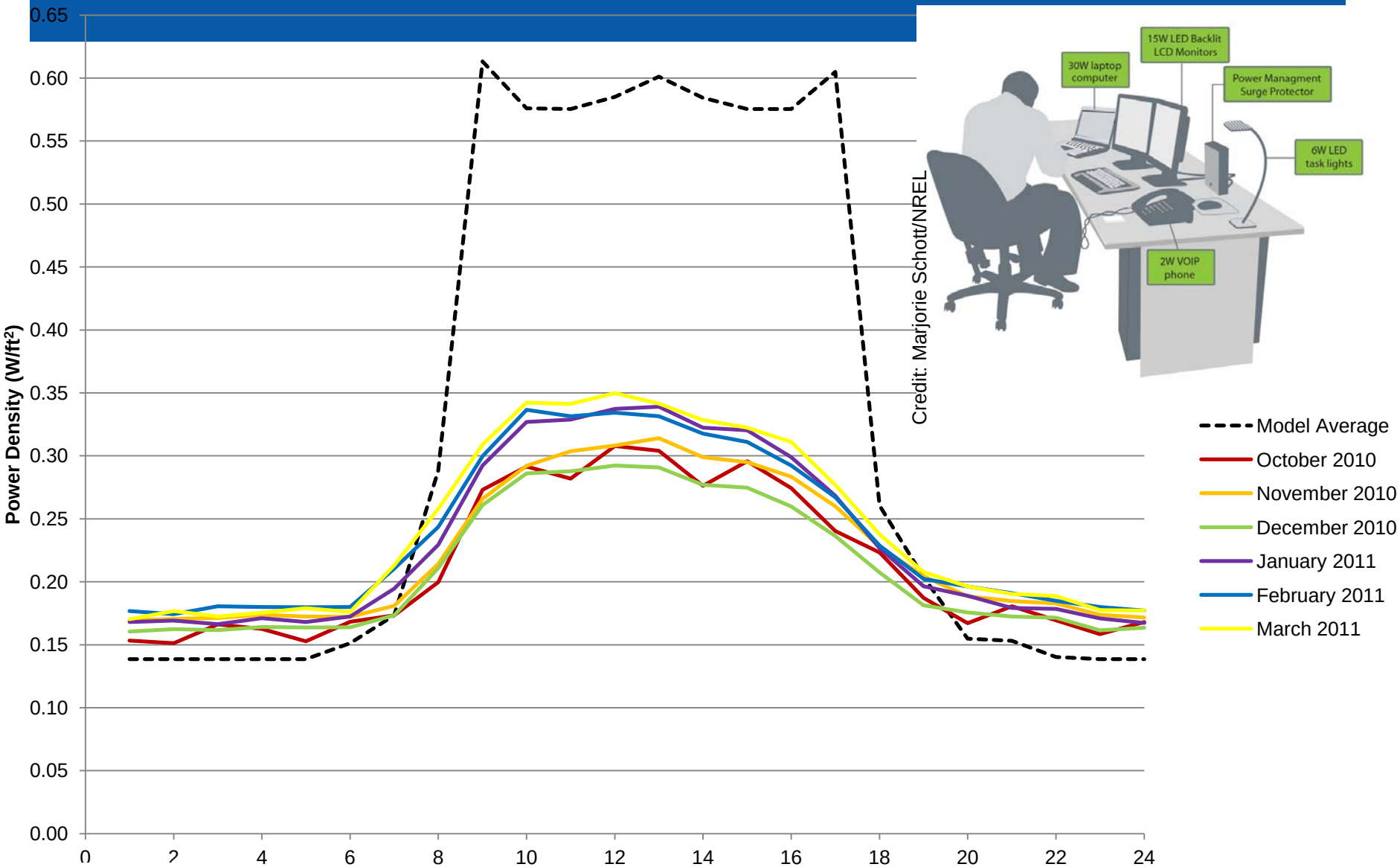
October 2010 – March 2011 Mechanical System Power Density



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

Credit: Chad Lobato/NREL

October 2010 – March 2011 Plug Load Power Density

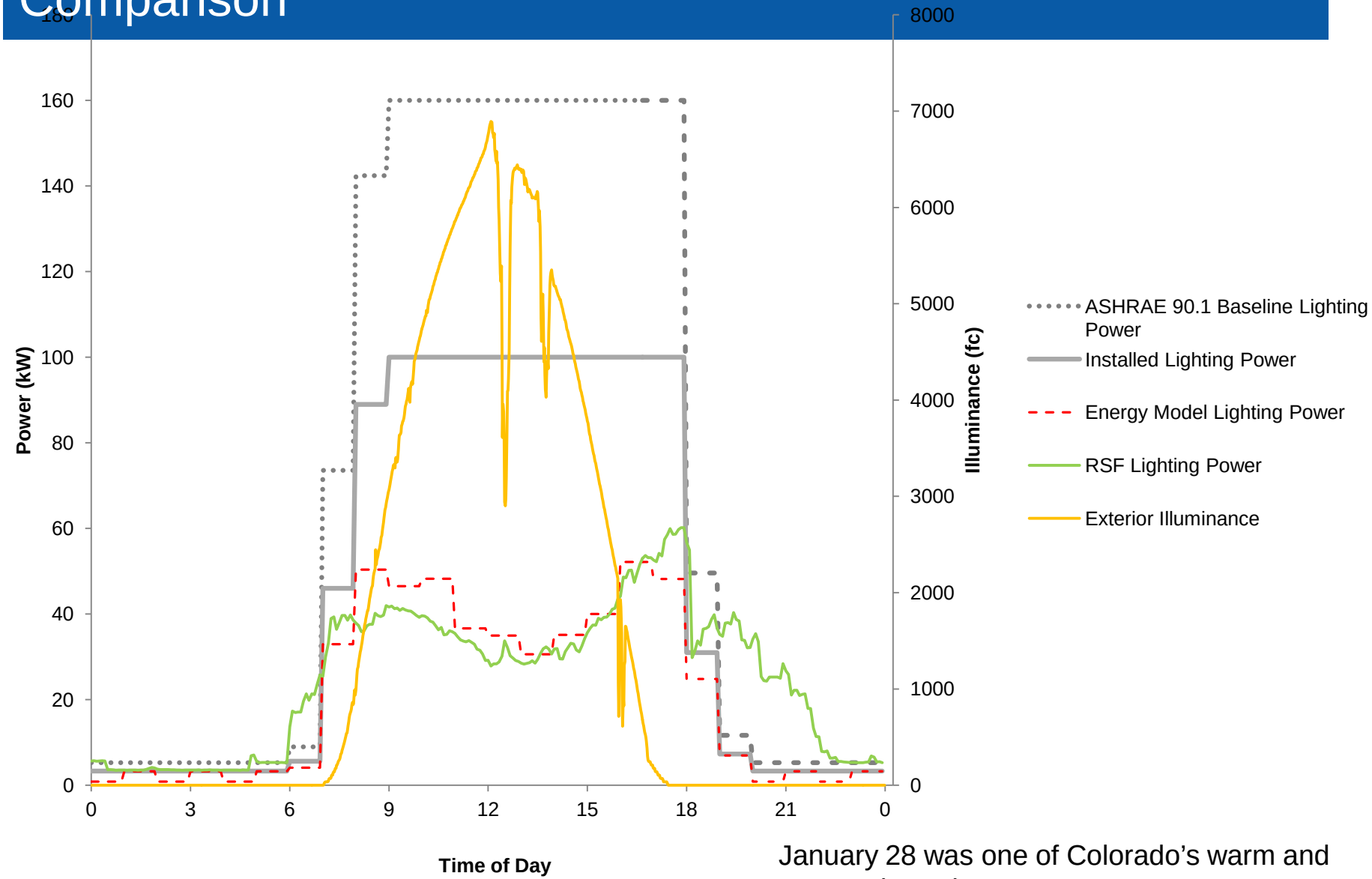


Credit: Marjorie Schott/NREL

Credit: Chad Lobato/NREL

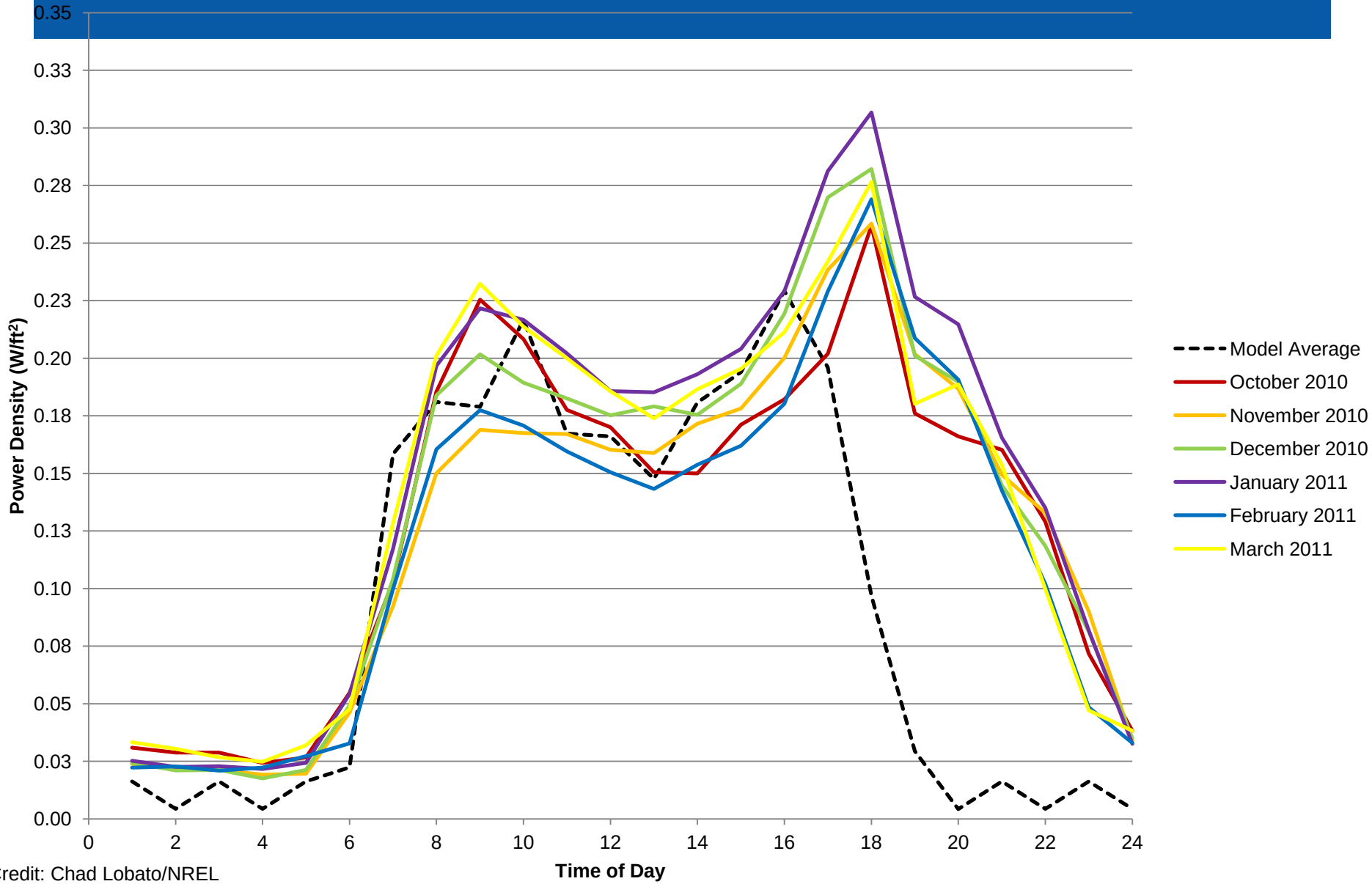
Note: The elevators are included in the plug loads

January 28, 2011 RSF Lighting Power Profile Comparison



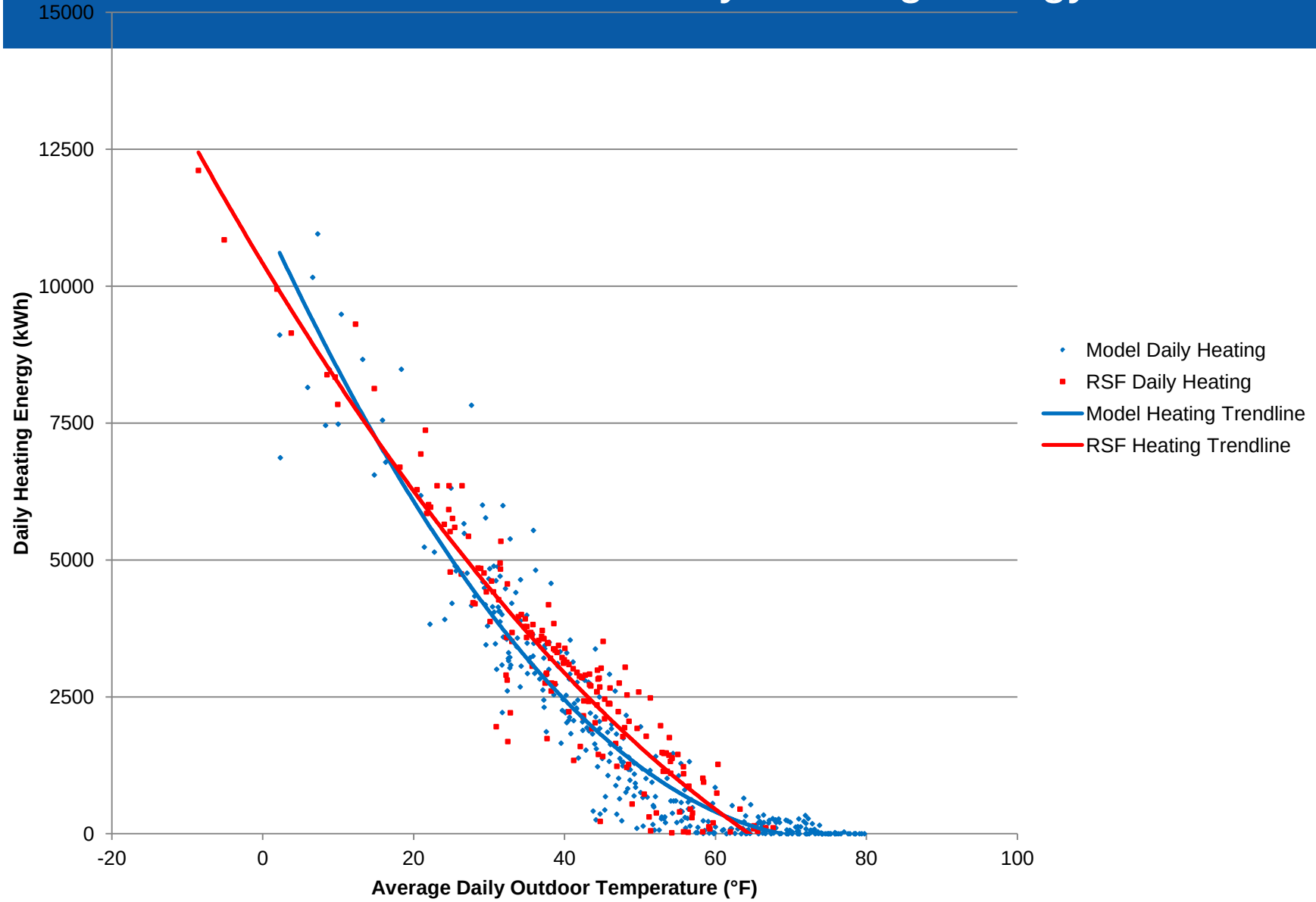
January 28 was one of Colorado's warm and sunny winter days.

October 2010 – March 2011 Lighting Power Density



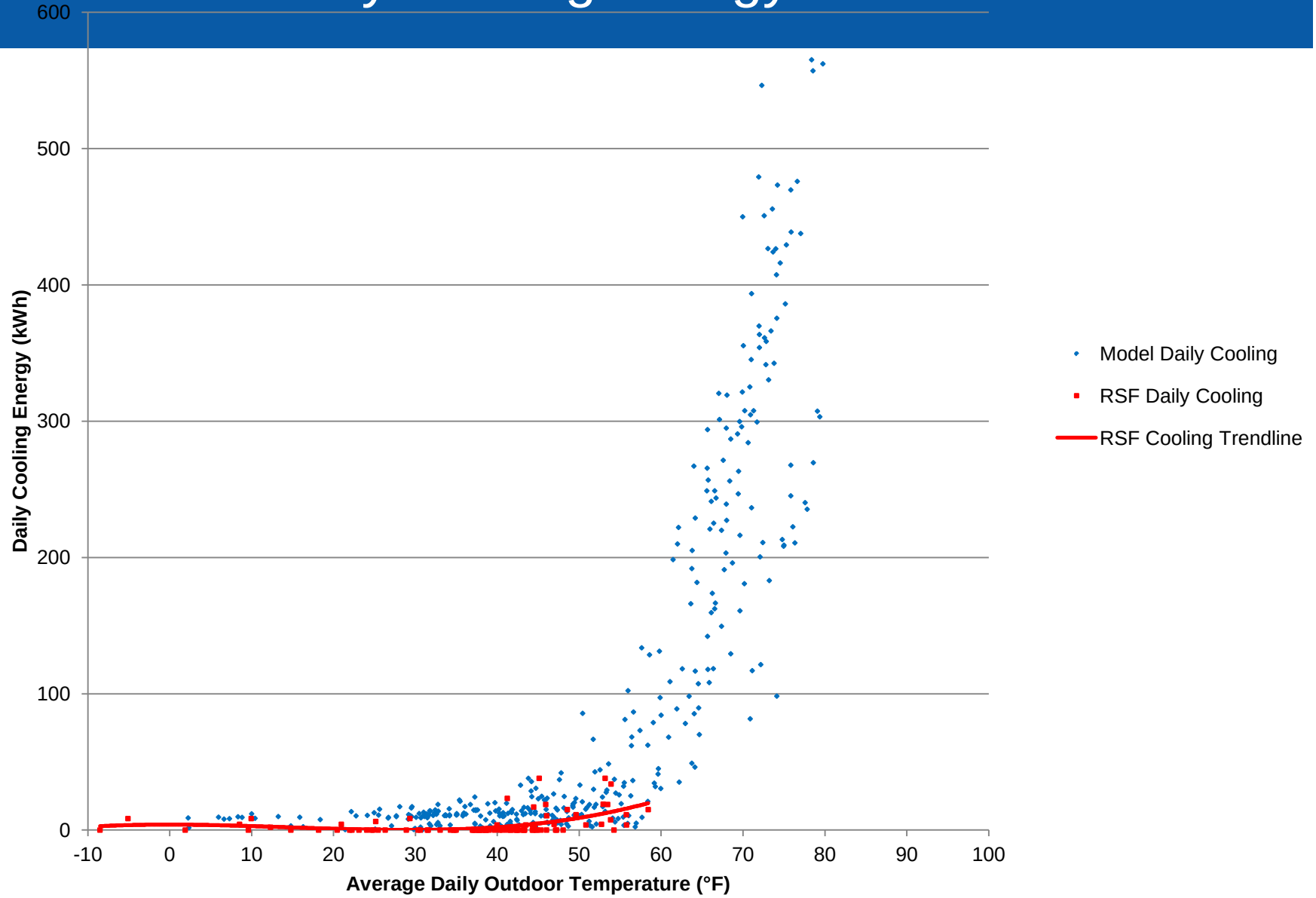
Credit: Chad Lobato/NREL

October 2010 – March 2011 Daily Heating Energy



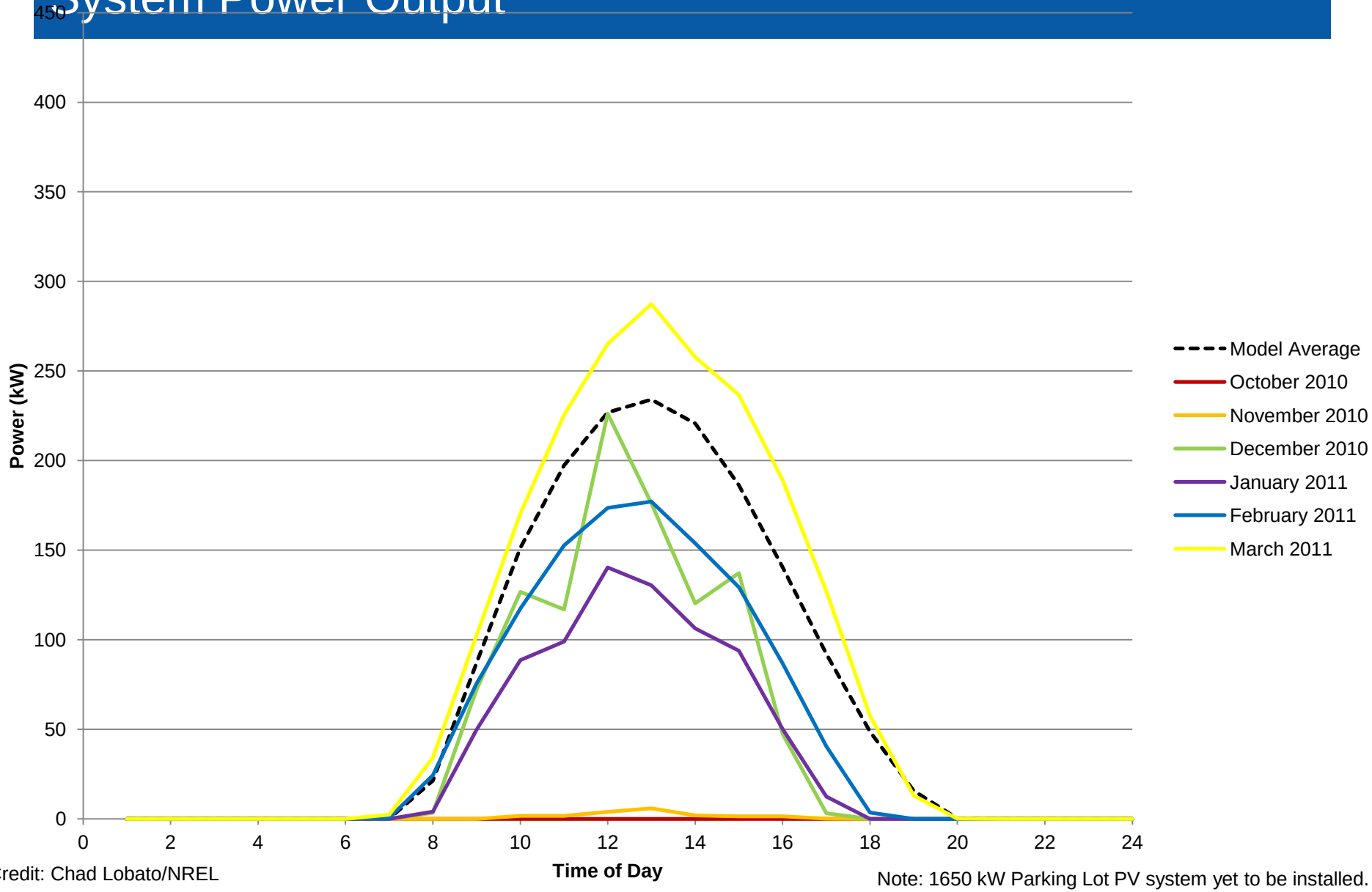
Credit: Chad Lobato/NREL

2011 YTD Daily Cooling Energy



Credit: Chad Lobato/NREL

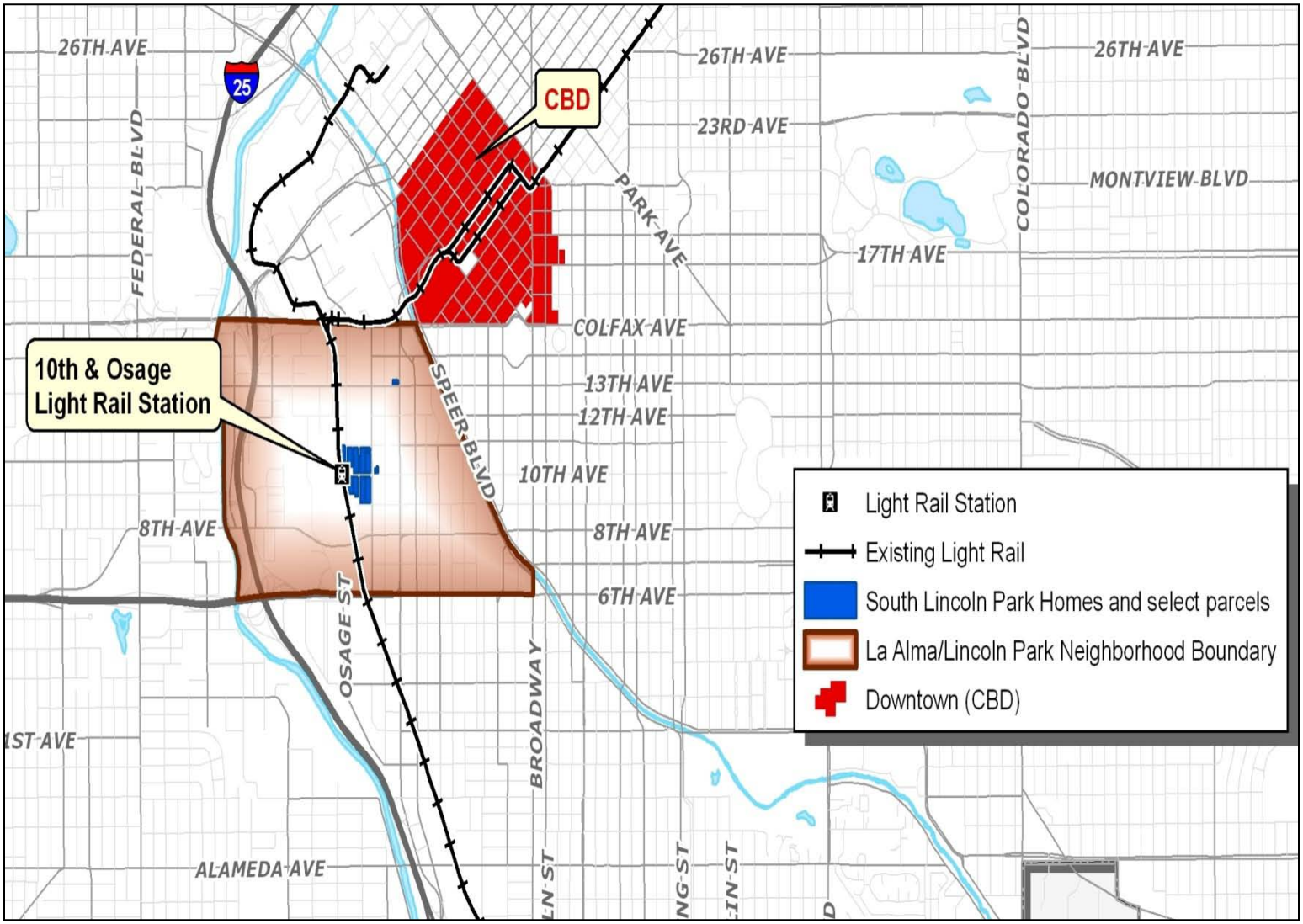
October 2010 – March 2011 450-kW Roof-Mounted PV System Power Output



Credit: Chad Lobato/NREL

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

South Lincoln (Mariposa District) Redevelopment La Alma/Lincoln Park Neighborhood, Denver, CO



Mariposa Redevelopment Master Plan

Mariposa District

Mariposa District

- 50% less energy use than code
- DHA Design Goals: 8 lbs of CO_2 per Square Foot per Year (40% less)
- Walkable/bike able community with good public transit (light rail)
- Building orientation part of Master Plan
- District energy analysis http://www.nrel.gov/docs/fy11osti/52243.pdf and
- http://www.nrel.gov/docs/fy11osti/51449.pdf (full report)

Josephine Commons -Boulder

Design and Evaluation of a Net Zero Energy Low-Income Residential Housing Development in

Lafayette, Colorado

Jesse Dean and Otto VanGeet
National Renewable Energy Laboratory

- Super insulated
- GSHP
- 50% energy reduction
- Large PV for near net zero community
- http://www.nrel.gov/docs/fy12osti/53756.pdf

Existing Buildings - EERE

- Many Energy saving opportunities in existing building
- Get low cost Xcel energy audit:
- Home Rebate = About $100 -40% of cost (http://www.xcelenergy.com/Save_Money_&_Energy/For_Your_Home/Energy_Audits/Home_Energy_Audit_-_CO
- Commercial $300 or less:
- http://www.xcelenergy.com/Save_Money_&_Energy/For_Your_Business/Energy_Audits_&_Studies/Energy_Analysis_-_CO
- Lighting, HVAC, and Controls upgrades cost effective
- Envelope measures (Insulation, Window) may be cost effective
- Add PV on roof – Xcel + federal incentives

RSF 2 - Third Wing

21 kBtu/ft2
$246/ft2 construction cost

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