Integrating Renewable Energy Systems in Buildings




ASHRAE Ohio Chapter Events

April 15 - 19, 2019

Sheila J. Hayter, PE, FASHRAE

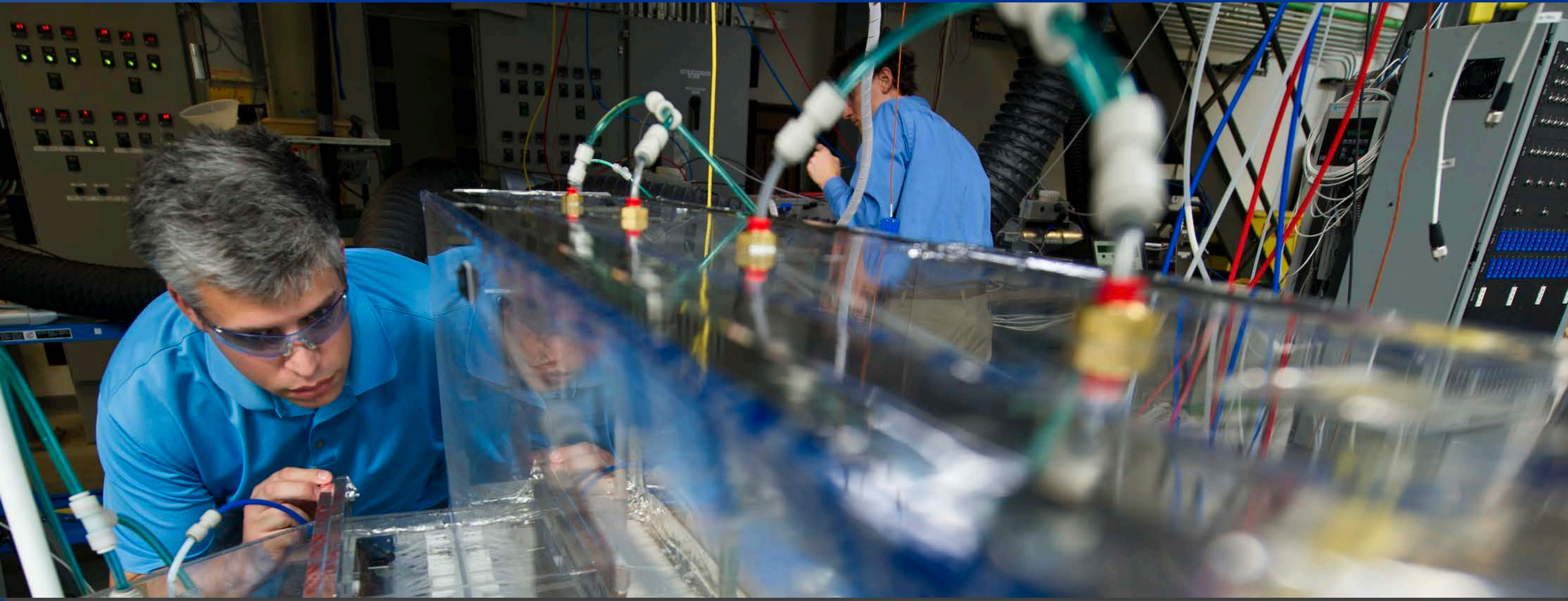
2018-19 ASHRAE President

National Renewable Energy Laboratory

Golden, Colorado USA

Shaping Tomorrow's Built Environment Today

ASHRAE



ASHRAE's mission: to advance the arts and sciences of heating, ventilation, air conditioning, and refrigeration to serve humanity and promote a sustainable world.

Who is ASHRAE?

- Founded in 1894
- ~57,500 volunteer members
  - 6000+ students members
- Members in > 130 countries
- 15 regions
- Nearly 200 chapters
- Associate Society Alliance
  - ASHRAE Associate Society Alliance - Created in 1962
  - Indoor Environmental Quality Global Alliance
  - Memoranda of Understanding (MOU) with many organizations

VOLUNTEERS are how ASHRAE Shapes Tomorrow's Built Environment

VOLUNTEERS are ASHRAE!

Why Integrate RE Systems in Buildings?

- Buildings account for ~40% of worldwide annual energy consumption & >60% of worldwide electricity
- Most of world energy consumption is from fossil fuels
- 75% to 80% of the buildings that will exist in 2030 already exist today
- National and local energy policy moving towards requiring clean energy solutions

2007 Total global energy consumption in 2007 – 145 trillion kWh (495 quadrillion British thermal units [Btu])

Buildings consumed about 40% - 58 trillion kWh (198 quadrillion Btu).

Worldwide energy consumption is expected to increase 1.4% per year through 2035, implying that buildings will consume 86 trillion kWh (296 quadrillion Btu) (EIA 2010).

Energy use and production in Ohio

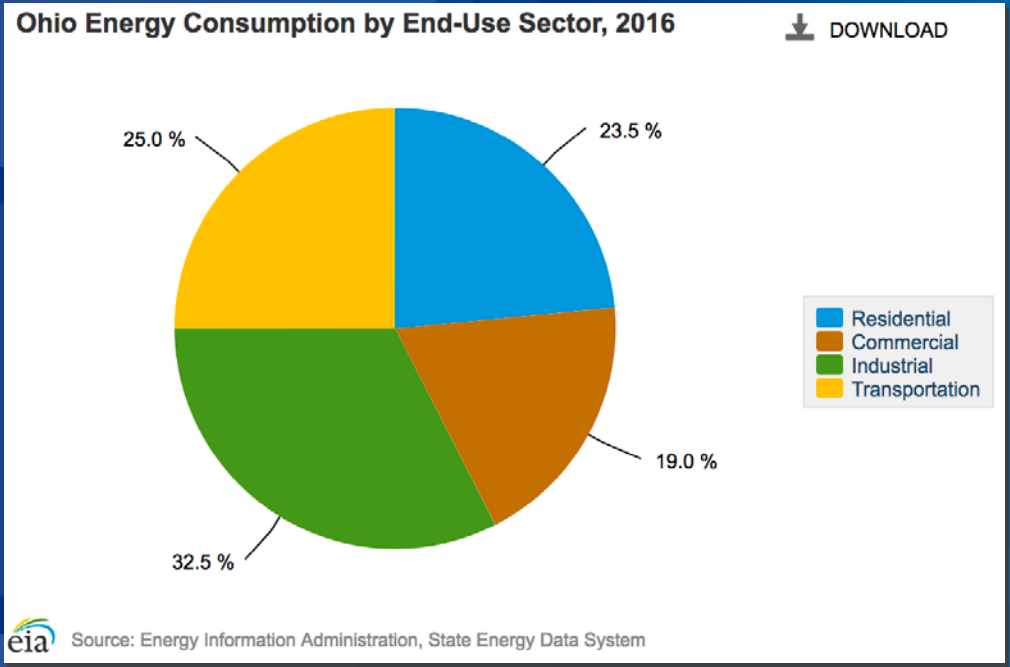
QUICK FACTS

- The Utica Shale accounts for almost all of the rapid increase in natural gas production in Ohio, which was more than 21 times greater in 2017 than in 2012.
- Ohio is the eighth-largest ethanol-producing state in the nation, supplying almost 550 million gallons of ethanol per year.
- As of January 2017, Ohio had the sixth-largest crude oil-refining capacity in the nation.
- In 2017, coal fueled 58% of Ohio's net electricity generation, natural gas fueled 24%, and nuclear energy accounted for another 15%.
- In 2017, wind provided 53% of Ohio's electricity generation from renewable resources.

Last Updated: May 17, 2018

https://www.eia.gov/state/?sid=OH

Energy use and production in Ohio



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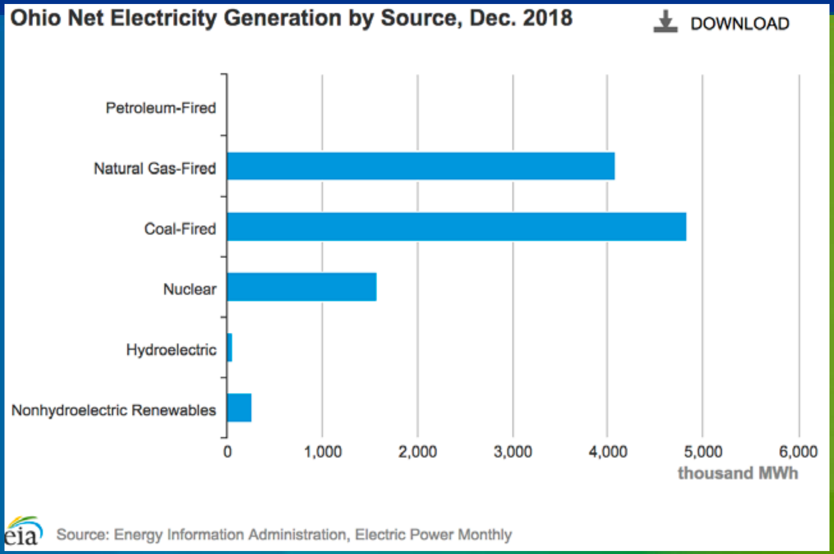
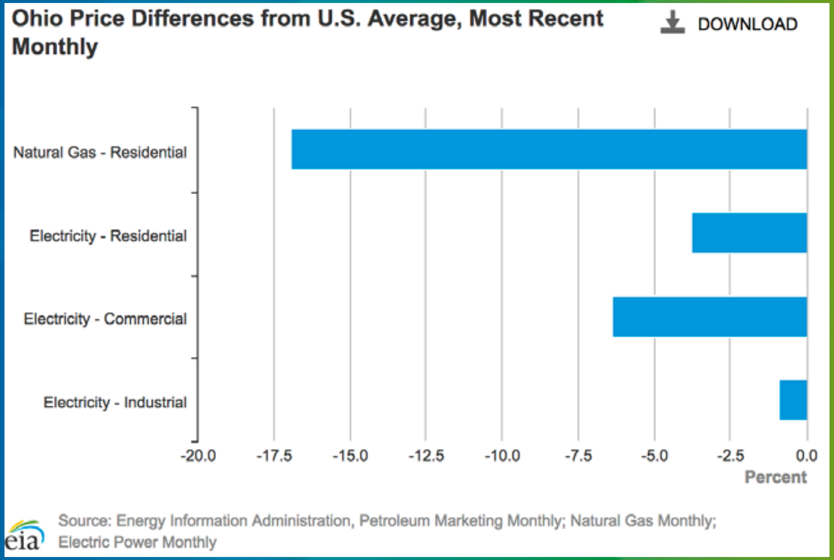







RENEWABLE ENERGY RESOURCES AND TYPICAL APPLICATIONS

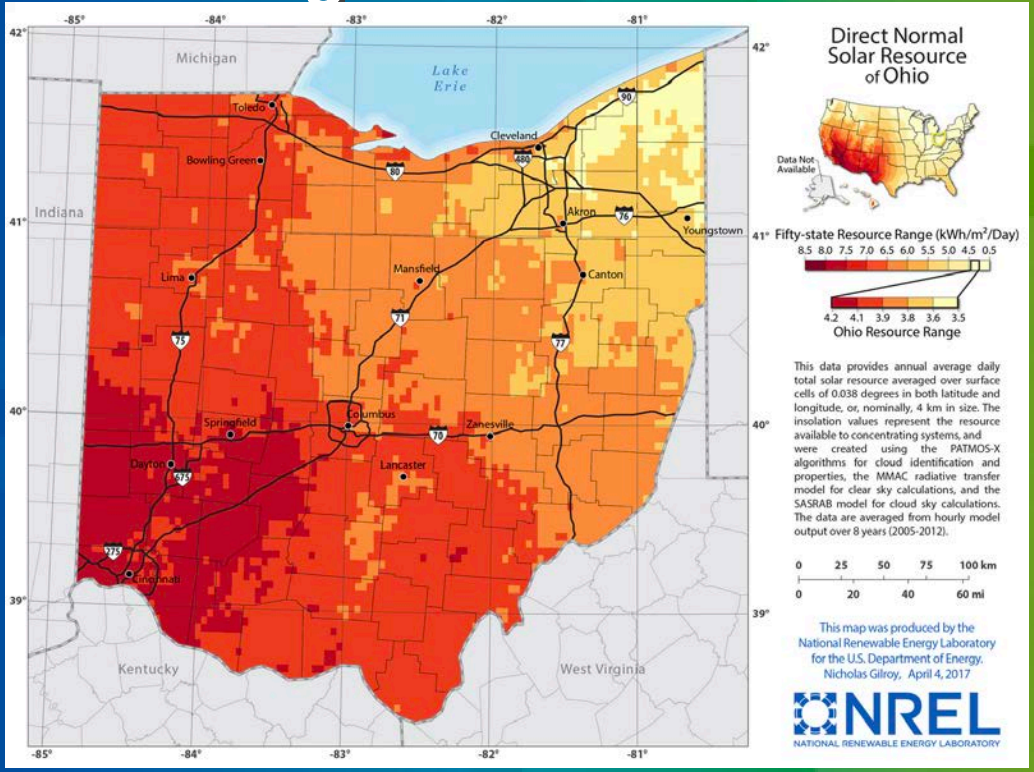
What RE Technologies are Available for Building Applications?

- Any available RE resource can be used to meet building energy loads, including:
  - Solar
  - Wind
  - Geothermal
  - Biomass
  - And others (including Hydroelectricity, Ocean Power, etc.)

Understand Available RE Resources

FIRST STEP for all renewable energy projects:

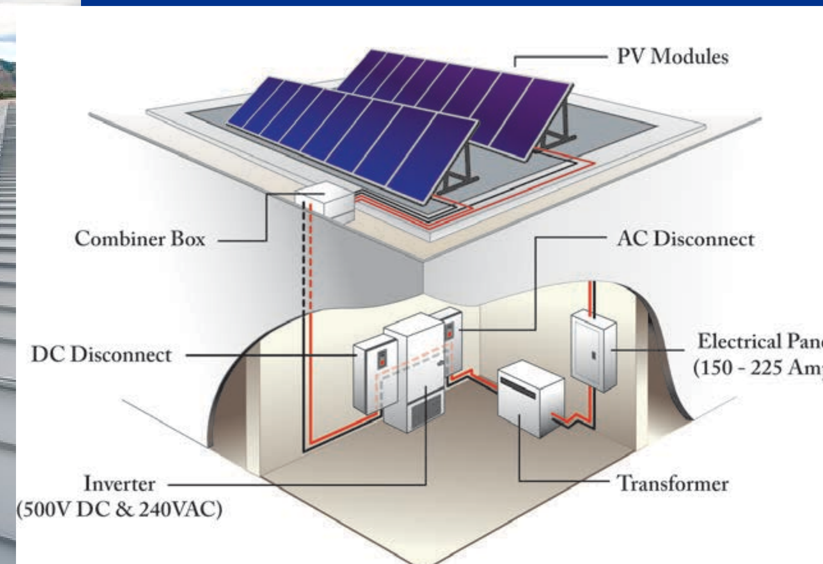
Determine resource availability of the renewable energy technologies under consideration



Source: www.nrel.gov

Typical Solar Applications for Buildings

- Grid-connected solar electric (photovoltaic or PV) systems



Source: Jim Leyshon, NREL

- Solar thermal systems for hot water

Solar System Considerations – PV and Solar Water Heating

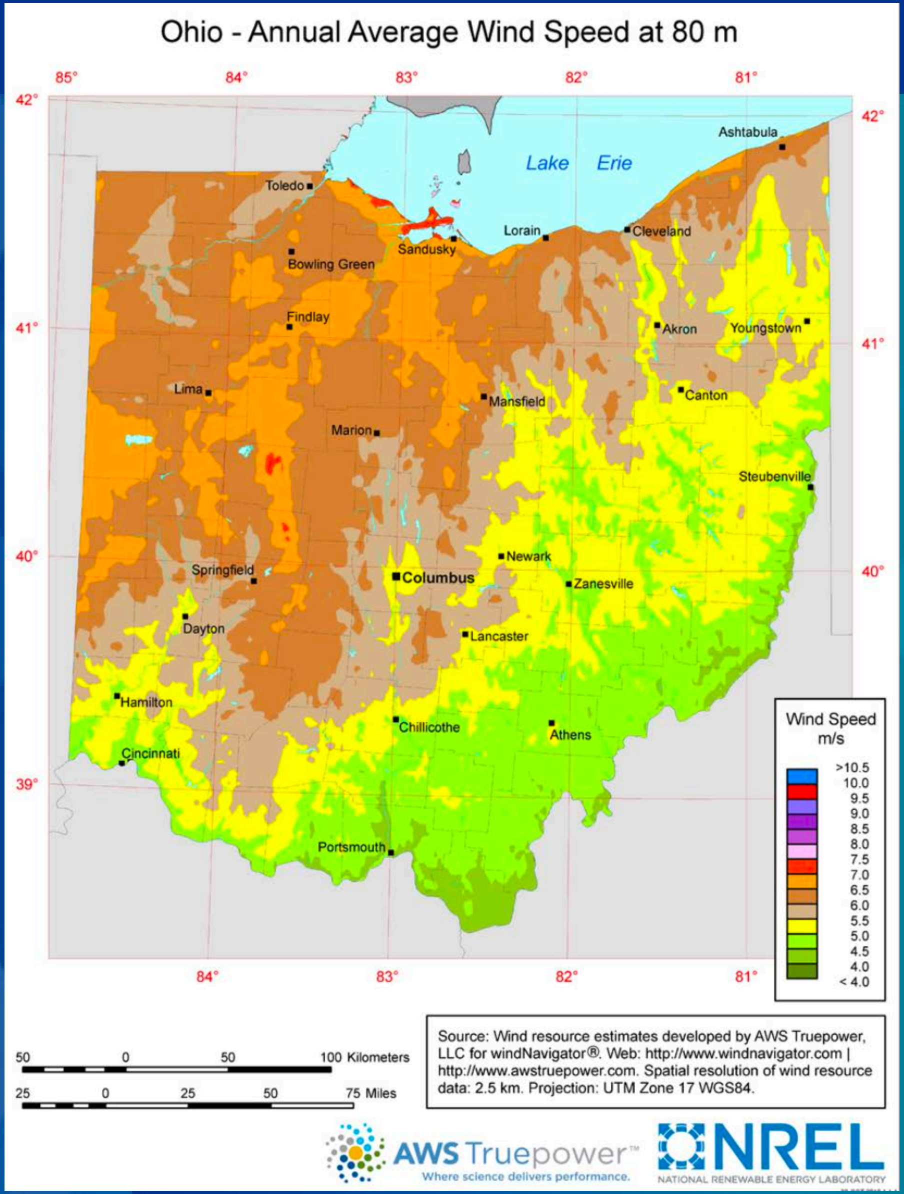
- Install in an unshaded location
  - Building roof in good condition (> 15 years expected roof life and can accept the load)
  - Ground (pole-mounted)
  - Integrated into building materials
  - Parking areas, pedestrian paths, etc.
  - On compromised land (e.g., land fills)

- Orientate array due south preferred
- Tilt array to maximize energy production

- Analyze building electrical and thermal load profiles
- Address grid-connection issues (PV systems)

- ALL new buildings should be "solar ready" http://www.nrel.gov/docs/fy10osti/46078.pdf

Wind Applications



Source: www.nrel.gov

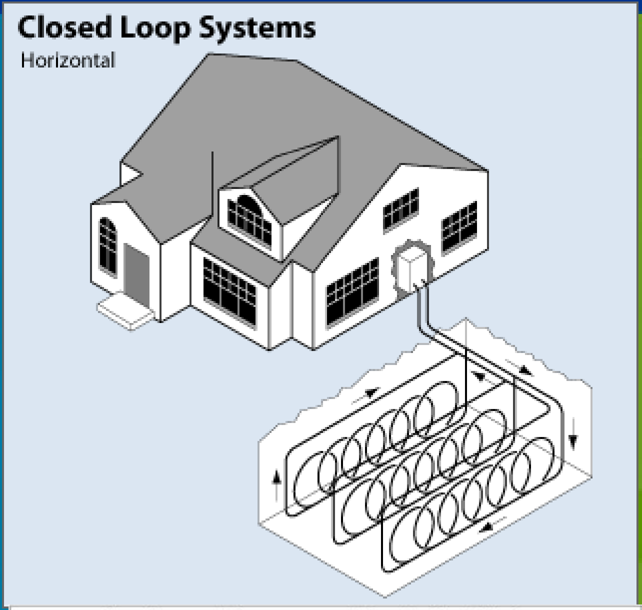
Wind System Considerations

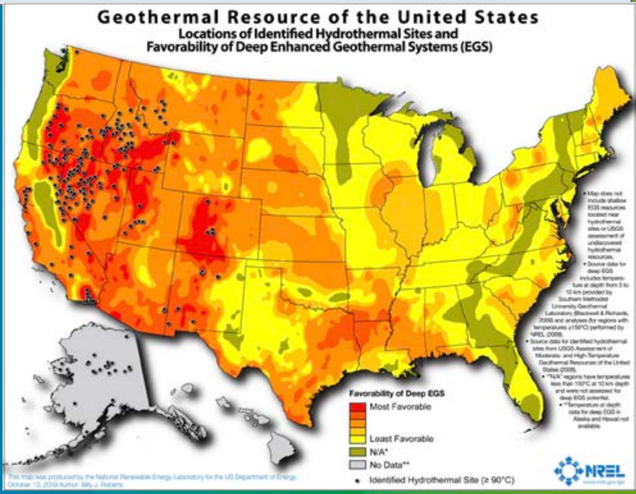
- Needs specific resource
  - Site must have an appropriate wind resource and few obstructions
  - MEASURE! MEASURE! MEASURE!
    - “It’s really windy here” isn’t bankable
- Site near facility to provide power directly to building
  - Land area required to install turbines
  - Best if can be sited 500-650ft (150-200m) from any occupied facility
- 20-year operating life for most turbines, little maintenance required

Geothemal

- Geothermal Heat Pumps
  - Most common geothermal applications for buildings
    - Shallow ground (upper 10ft (3m) of earth's surface) maintains ~constant temperature of 50°-60°F (10°-16°C).
- Affective in mixed climates – can heat/cool buildings and supply buildings with hot water
- System components – heat pump, air delivery system, heat exchanger (buried pipes)
- Four types – horizontal, vertical, pond/lake, and open loop
- Challenges
  - For retrofit projects, tying the system to existing building HVAC system

- Geothermal Direct Heat
  - Needs specific resource
  - Available resource is less common
  - Best for buildings with heating loads due to climate or process needs
  - Can be a cost-effective and consistent energy source





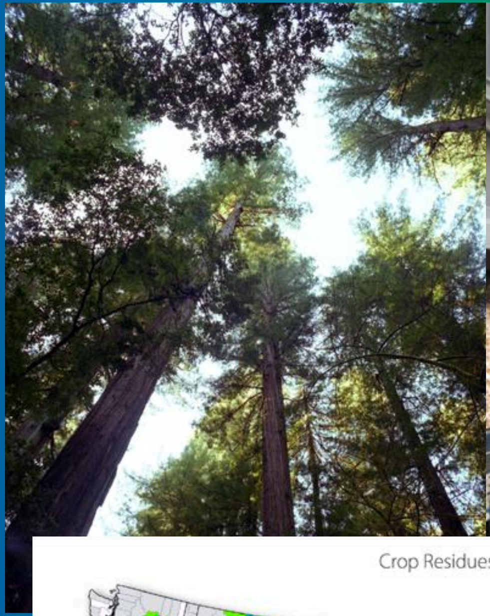
Biomass Technology Applications

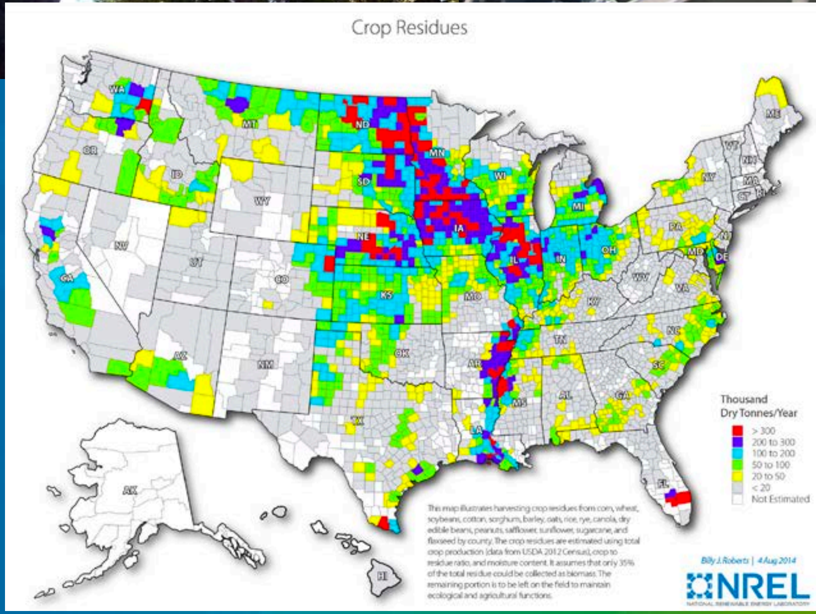
- Types of biomass
  - Organic matter (plants, residues from agriculture, forestry, livestock)
  - Organic components of municipal and industrial wastes

- Biomass technology breaks down organic matter to release stored energy

- Biomass can heat buildings and produce electricity.

- Consider this resource if there is a permanent, steady stream of biomass resource within a 50-mile (80-km) radius





RE in Building Project Considerations

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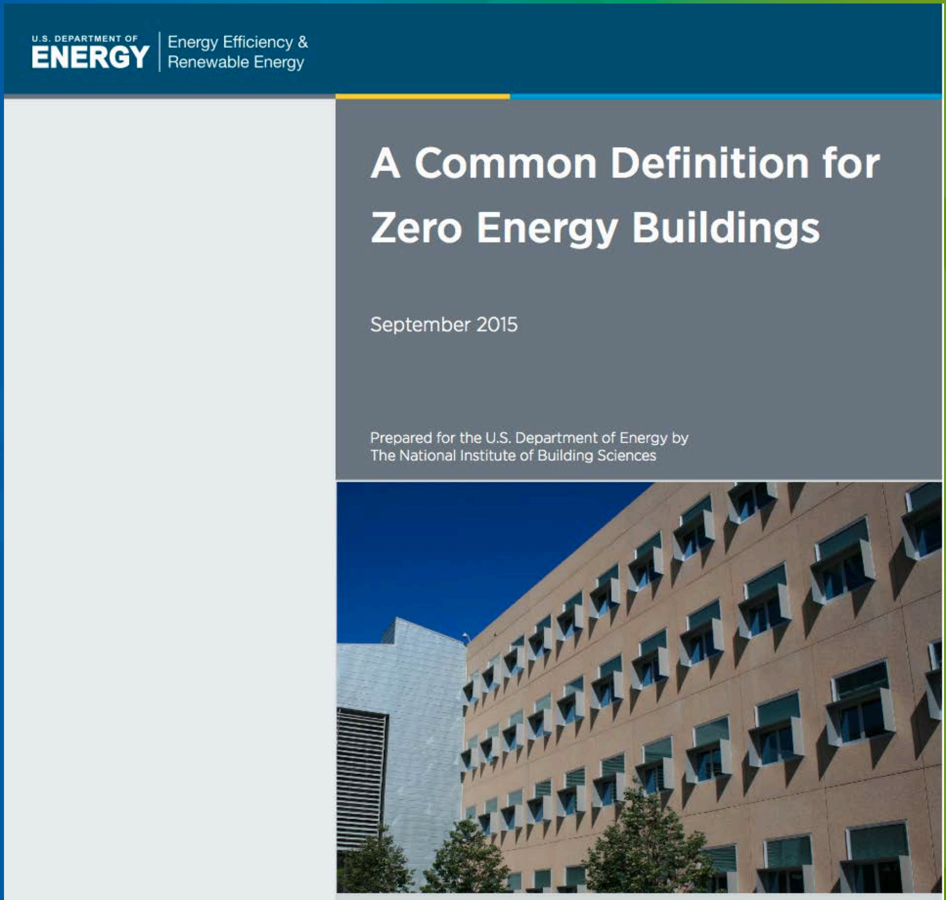
- Renewable energy resources at or near the building site
  - Area to install the renewable energy system
  - Building roofs, parking shade structures, open land
- Characteristics of building's energy profile
  - Simulate building energy consumption and RE system contributions
- Ability to connect to the electrical grid
  - National and local interconnection policies
- Incentives to offset renewable energy system cost
  - National and local RE incentive information
- Cost of purchased electrical and thermal energy
  - Utility bill information
- Government mandates & regulations affecting renewable energy systems
- Desire to preserve/not alter existing building architecture

Research Support Facility (RSF) – A NET Zero Energy Facility

Zero Energy Building Definition

- An energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy.
  - This definition applies to campuses, portfolios, and communities.



Source: http://energy.gov/sites/prod/files/2015/09/f26/bto_common_definition_zero_energy_buildings_093015.pdf

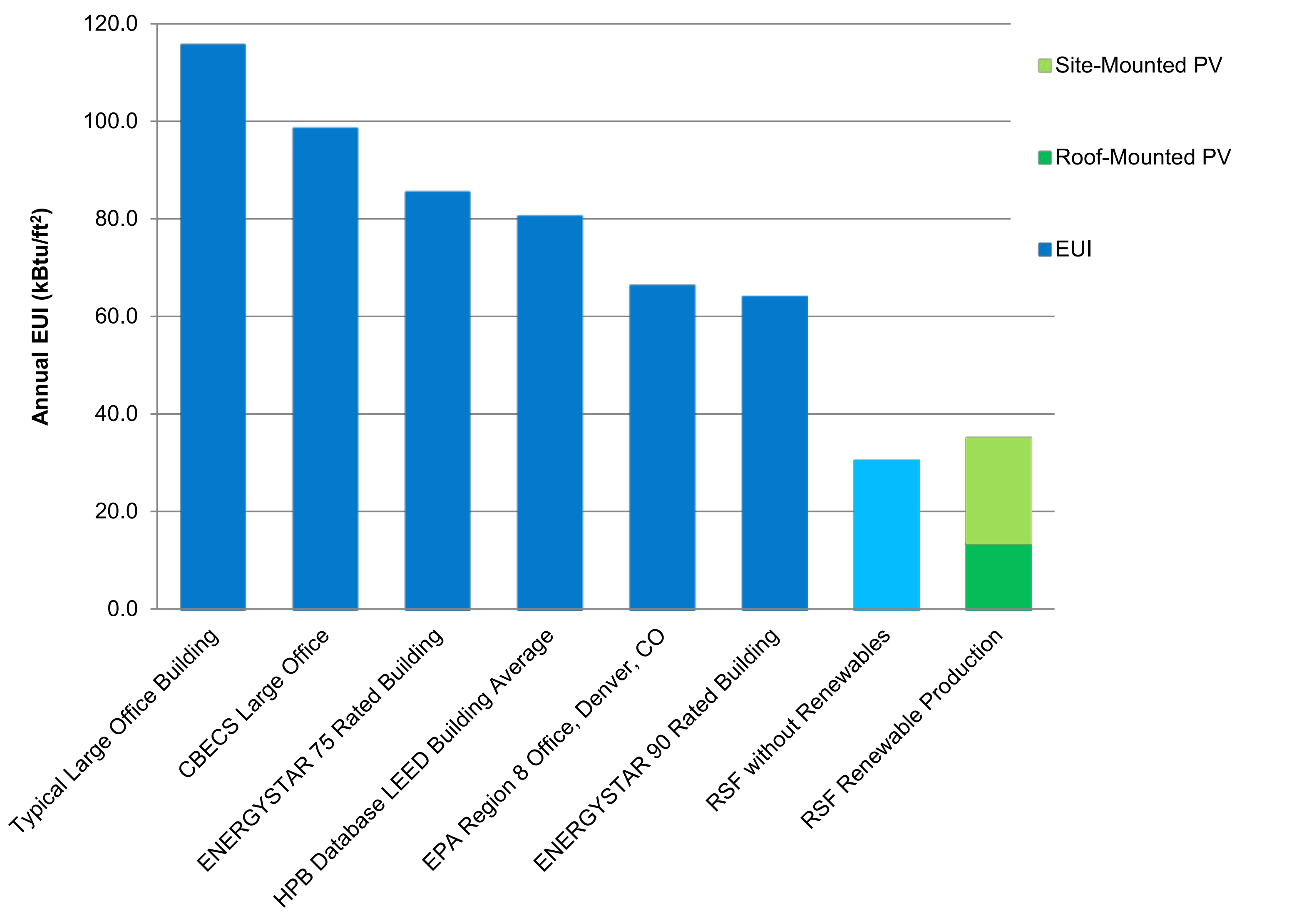
Research Support Facility: Project Goals

- Building can accommodate more than 1300 people in office spaces
- 358,000 ft^2 (33,260 m^2) (RSF I and RSF II combined)
- Design/build process with required energy goals
  - 25 kBtu/ft^2 (78.7 kWh/m^2)
  - 50% energy savings
  - LEED Platinum
- Replicable
  - Process
  - Technologies
  - Cost

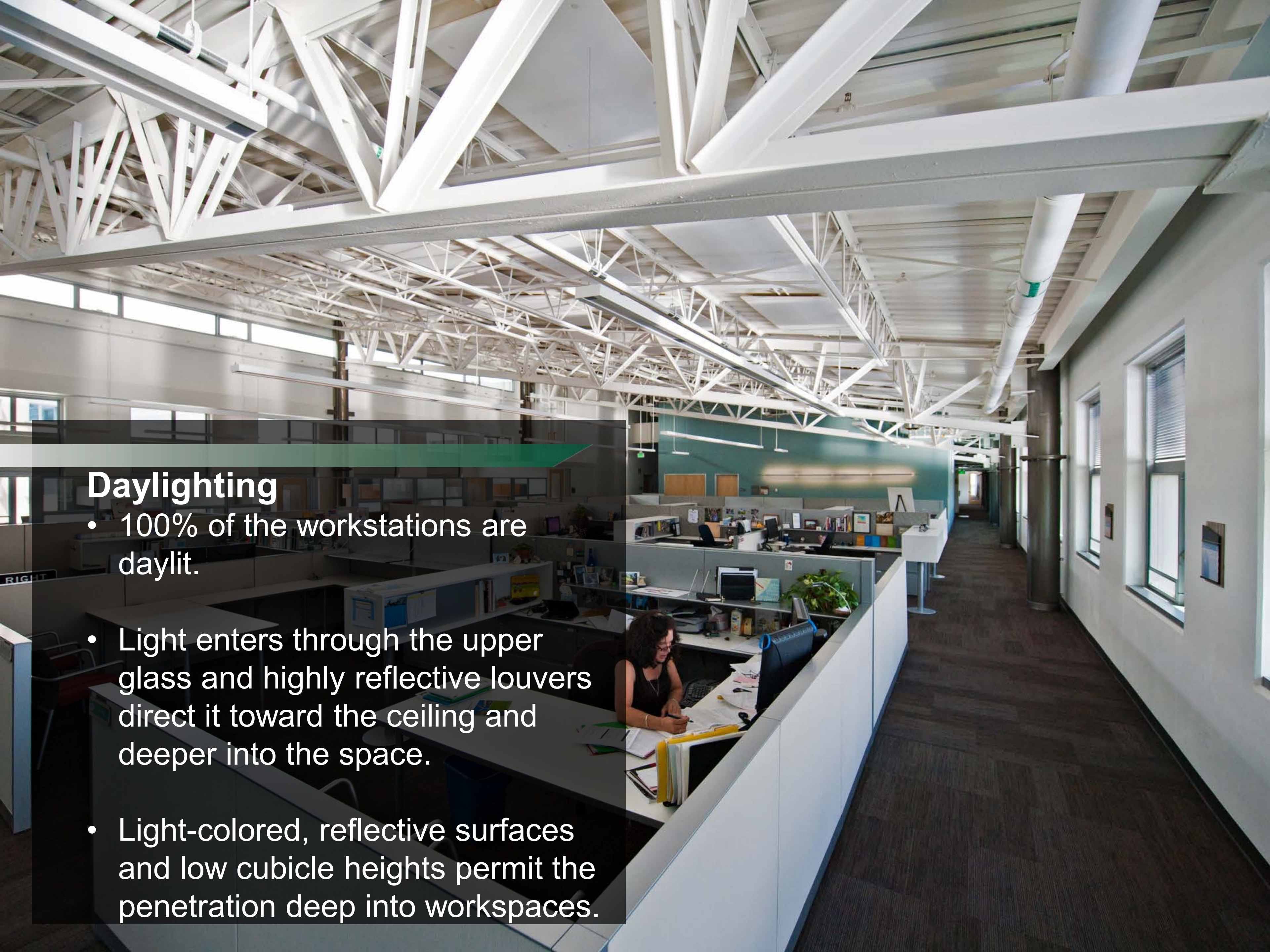
Credit: Haselden Construction

- Site, source, carbon, cost ZEB:B
  - Includes plugs loads and data center
- RSF I – Firm fixed price of ~$64 million
  - $259/ft^2 ($2,789/m^2) construction cost (not including $29/ft^2 ($312/m^2) for PV from PPA)
- Opened RSF I June 2010, RSF II November 2011

RSF Design Requirements Comparison



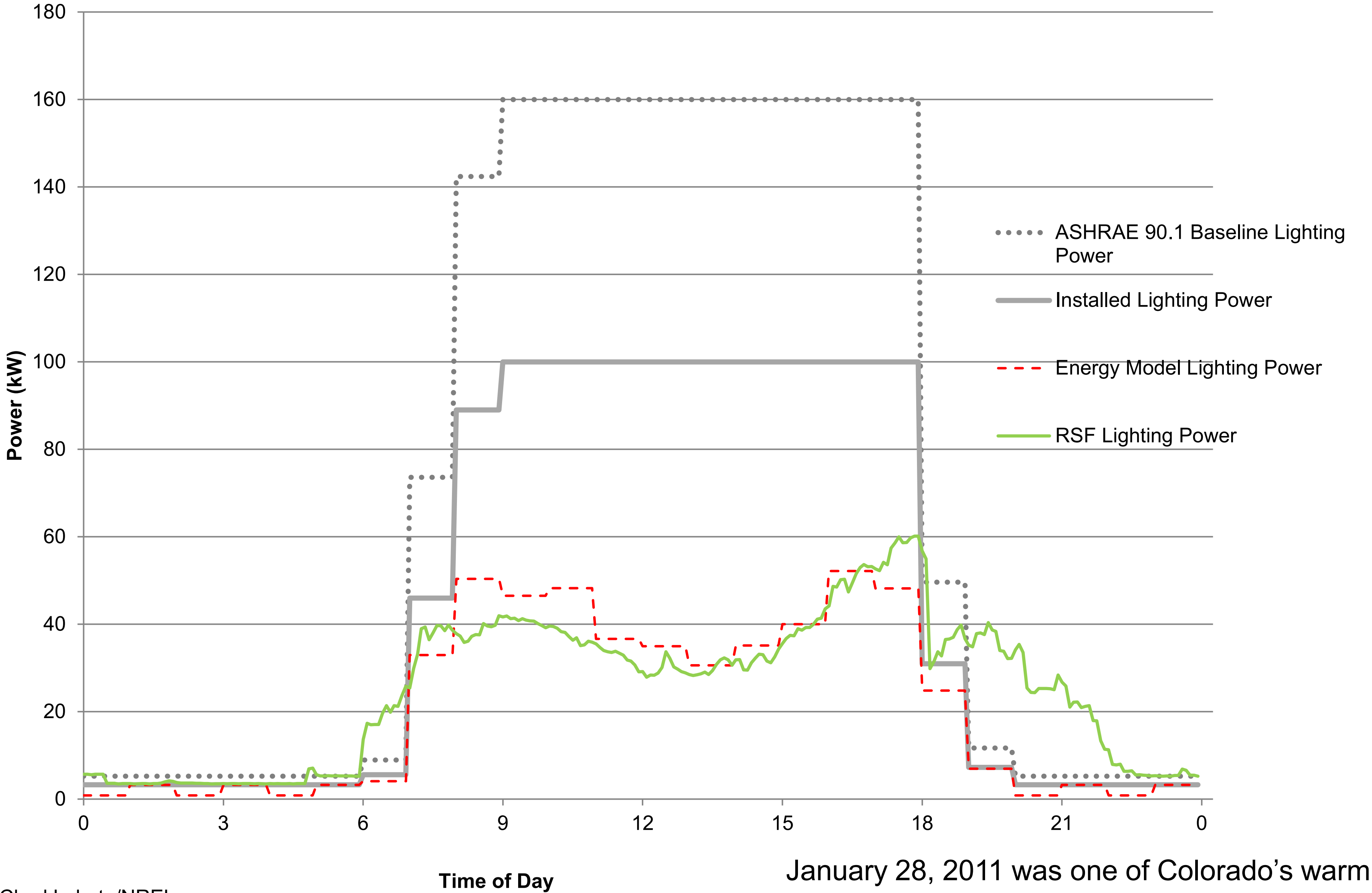
Credit: Chad Lobato/NREL



Daylighting

- 100% of the workstations are daylit.
- Light enters through the upper glass and highly reflective louvers direct it toward the ceiling and deeper into the space.
- Light-colored, reflective surfaces and low cubicle heights permit the penetration deep into workspaces.

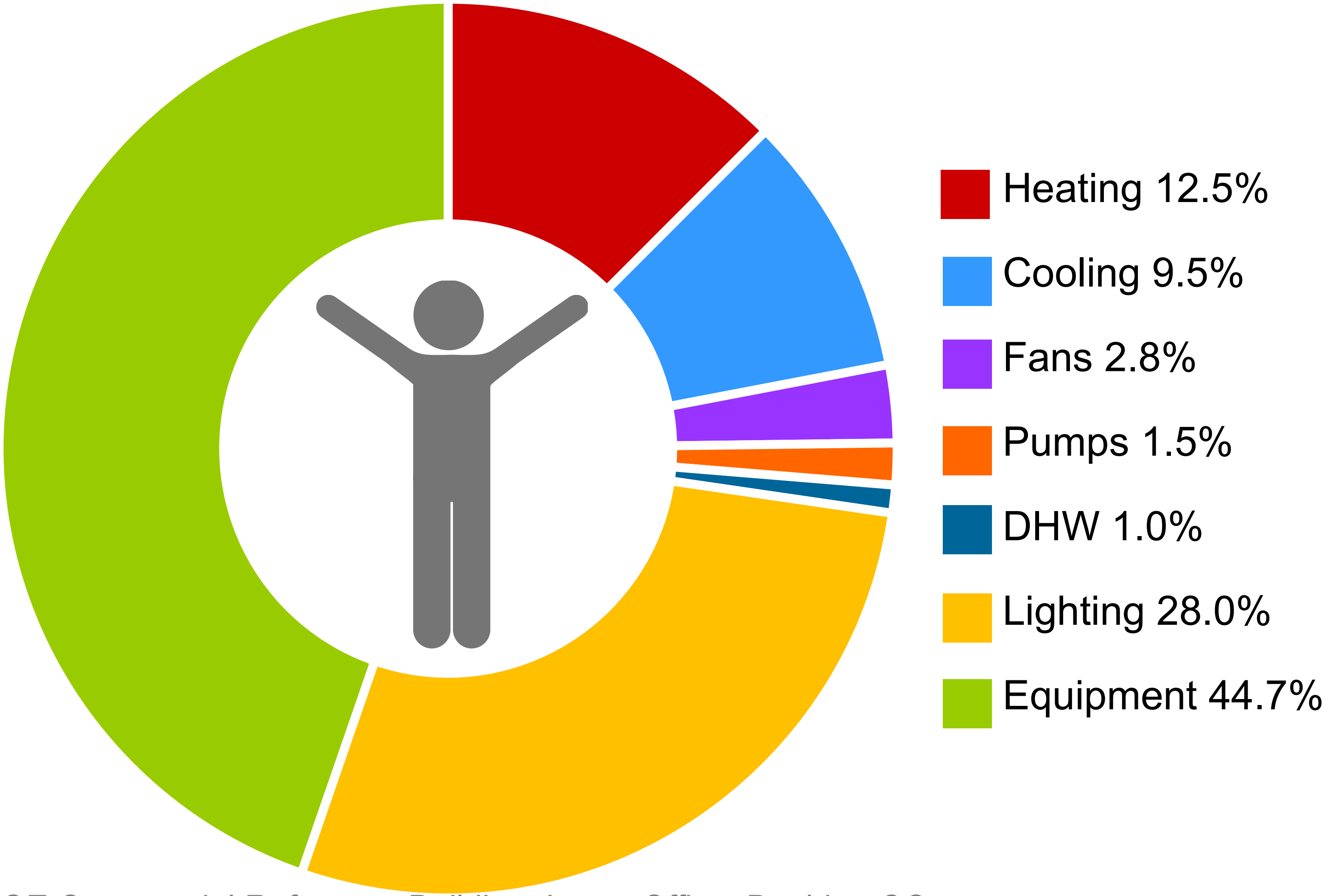
January 28, 2011 Lighting and Daylighting



Credit: Chad Lobato/NREL

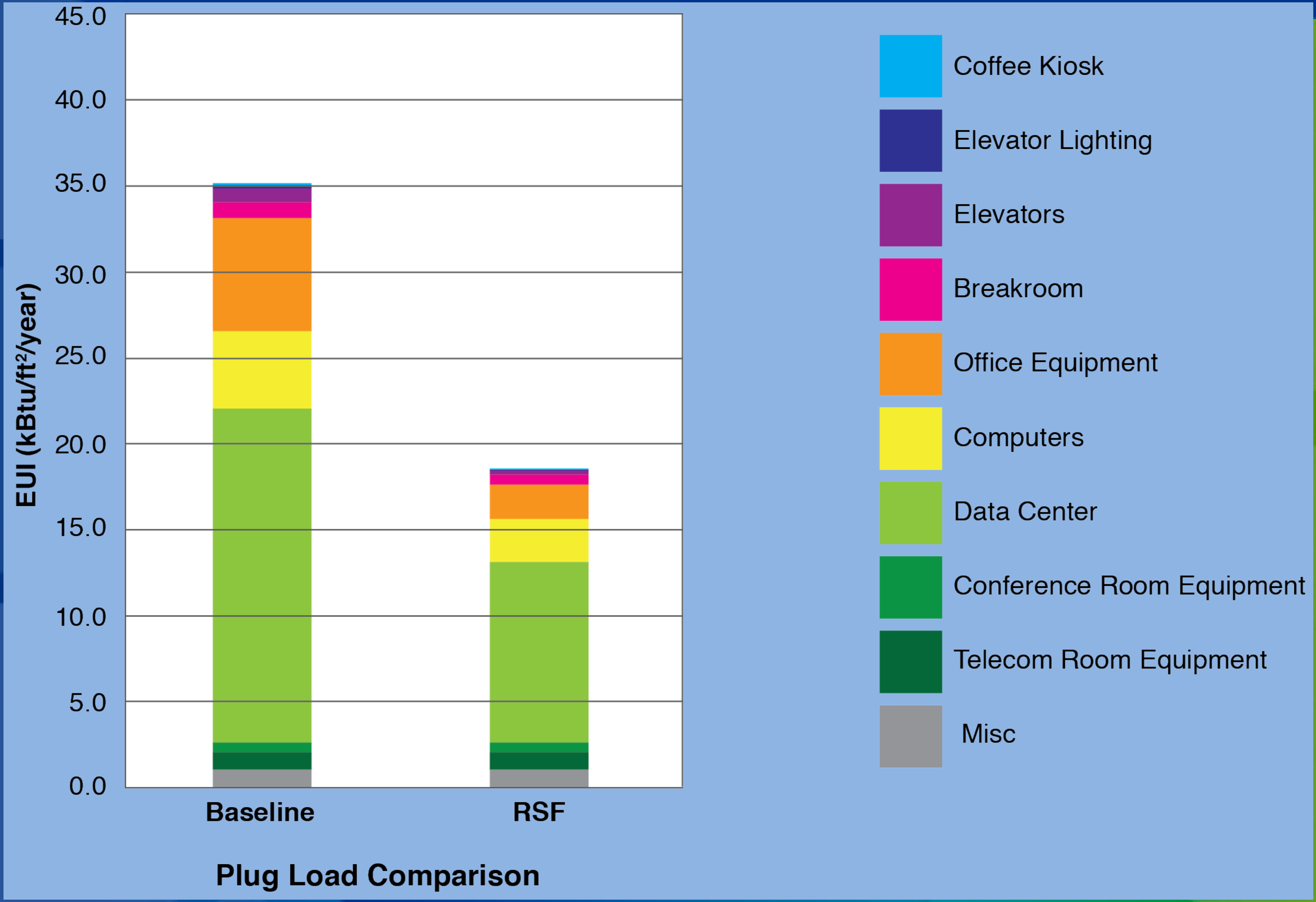
January 28, 2011 was one of Colorado's warm and sunny winter days.

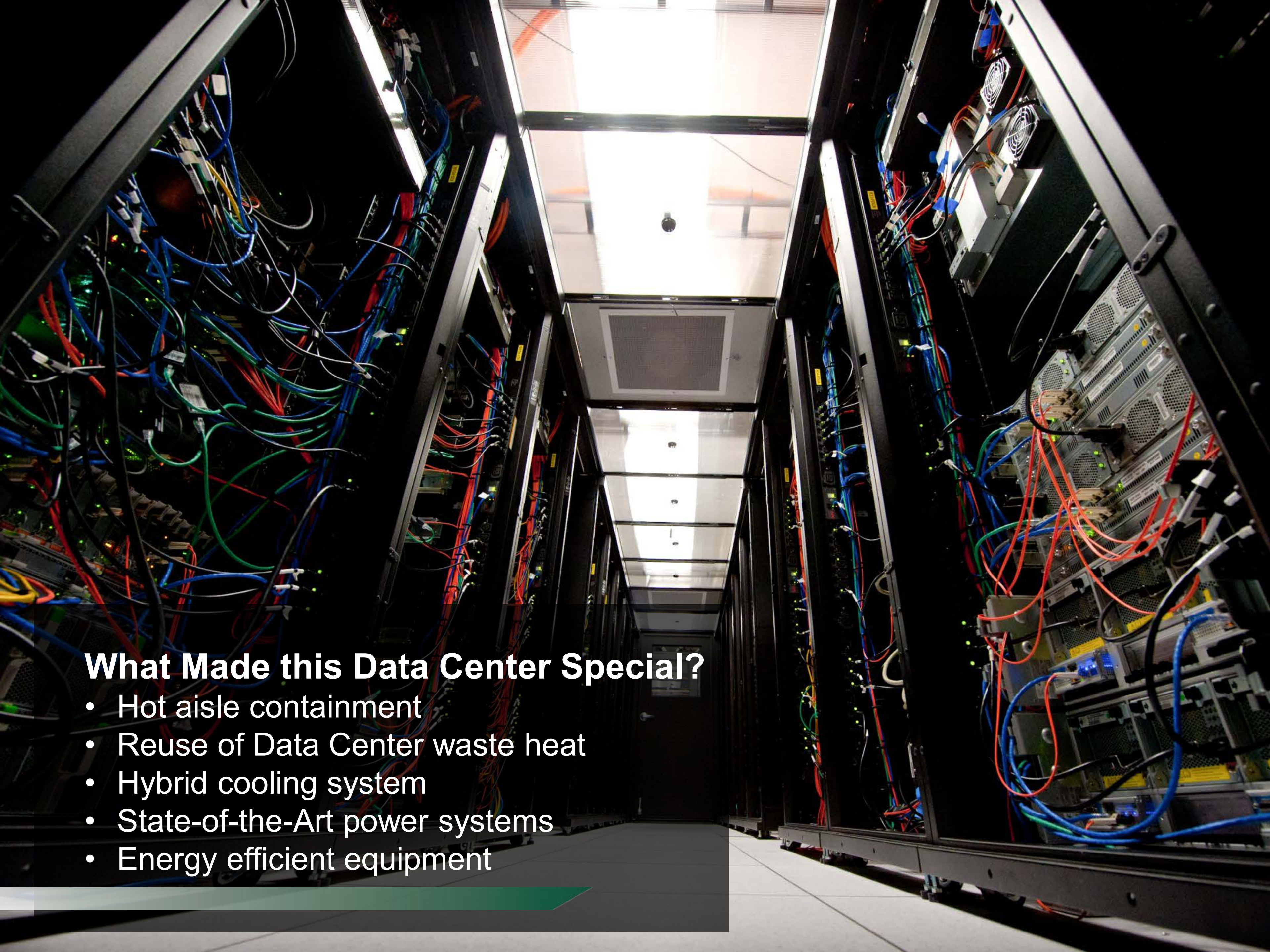
What Energy does an Occupants Influence?



DOE Commercial Reference Building: Large Office, Boulder, CO

RSF Plug Loads Reduced

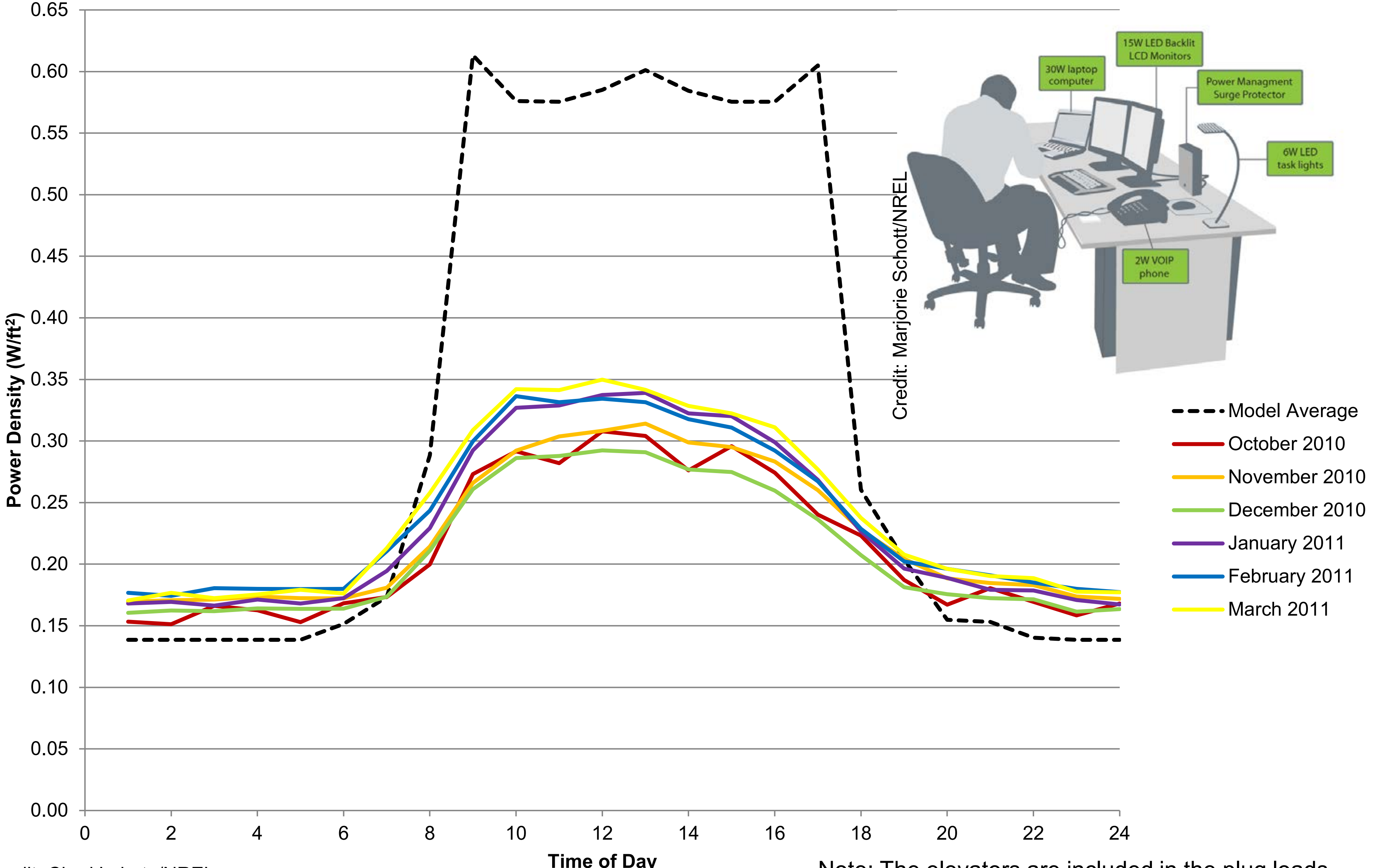




What Made this Data Center Special?

- Hot aisle containment
- Reuse of Data Center waste heat
- Hybrid cooling system
- State-of-the-Art power systems
- Energy efficient equipment

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

Thermal Mass

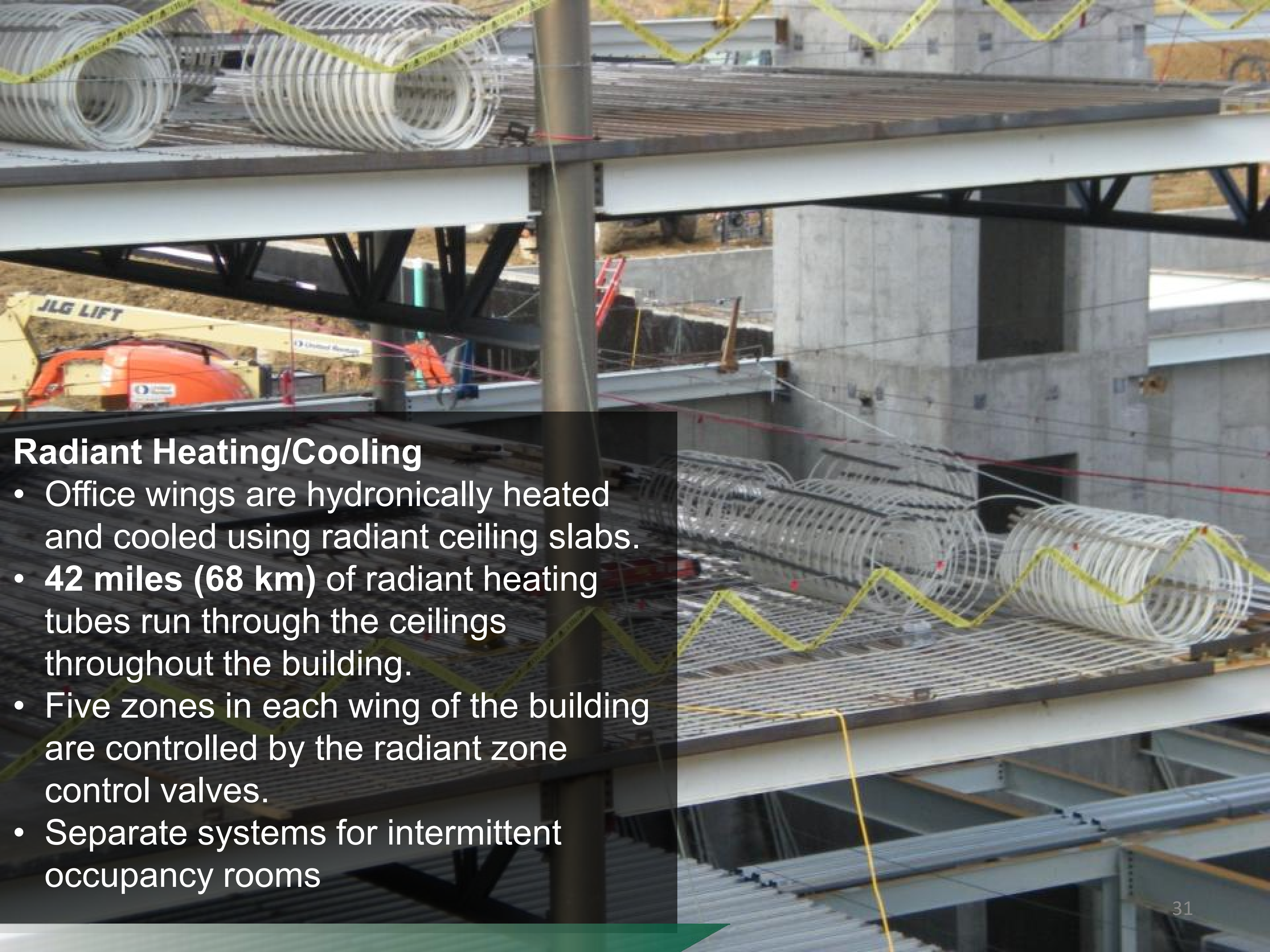
- Incorporates many passive heating and cooling techniques.
- 6 in (15 cm) of concrete on the interior provides thermal mass that helps moderate internal temperatures year round.
- Nighttime purges in summer months trap cool air inside, keeping temperatures comfortable for the warm summer days.

RSF 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 and Displacement Ventilation for conference rooms
- Campus hot water and chilled water
    - Wood chip boiler supplies 50% of hot water (only need 100F (37C))
    - High efficiency water cooled chillers (only need 62F (17C))
- 1,000 ft^2 per Ton of central plant cooling
    - Typical 300-400 ft^2 /Ton

Natural Ventilation

- During mild weather, operable windows allow for natural ventilation.
- Automatic windows are controlled and operated primarily to support nighttime precooling.
- Occupants are notified when conditions allow for manual windows to be opened.

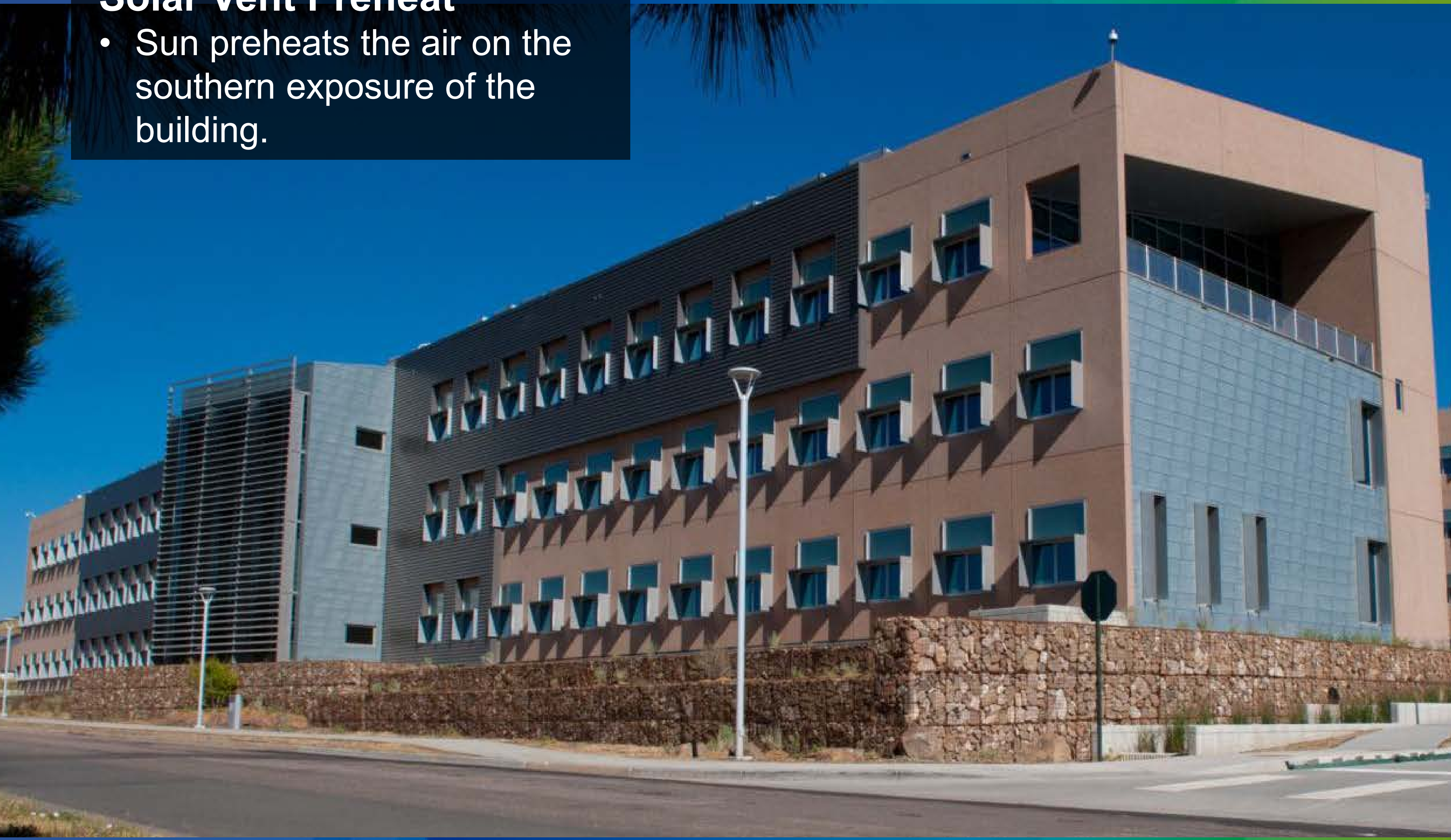


Radiant Heating/Cooling

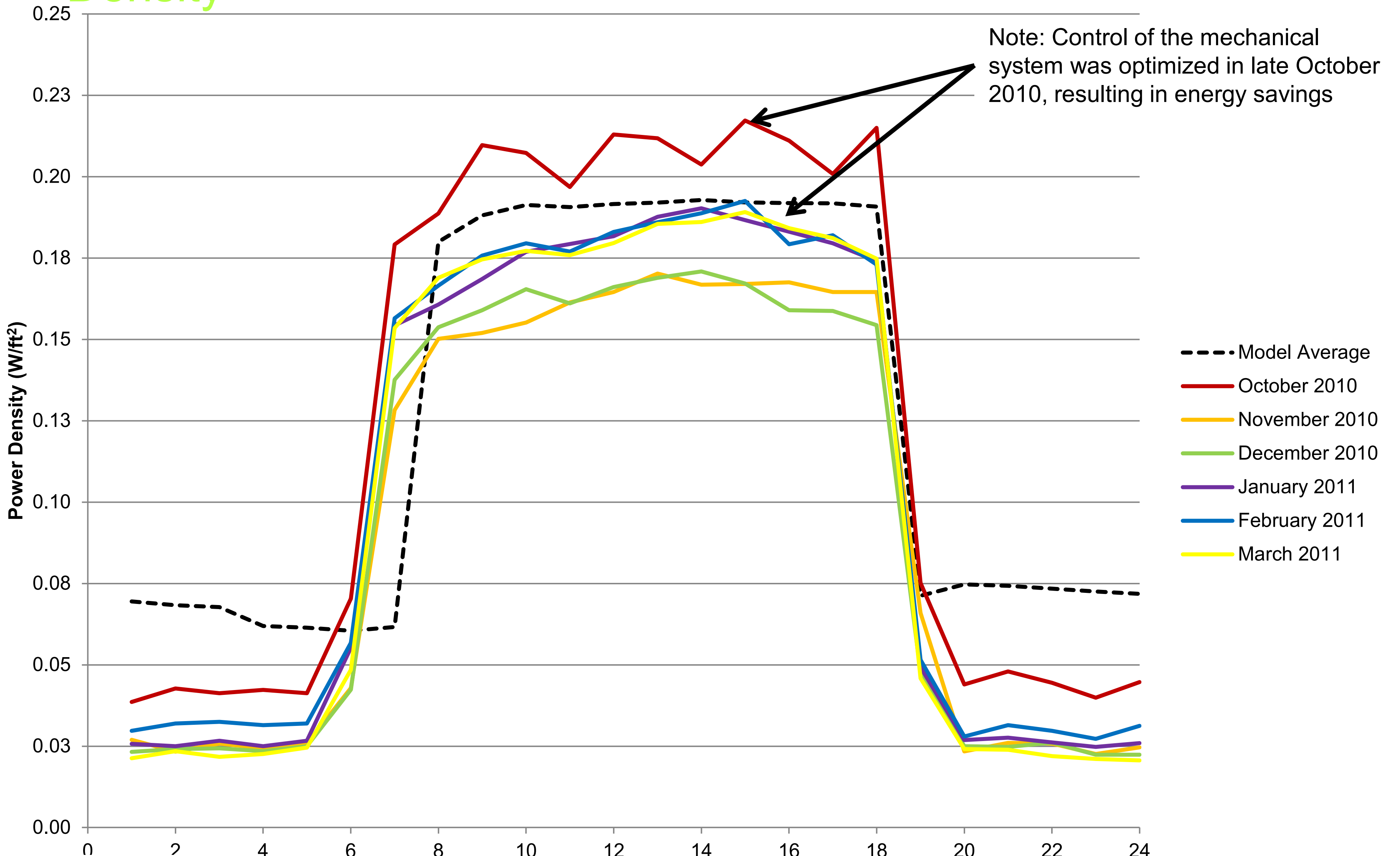
- Office wings are hydronically heated and cooled using radiant ceiling slabs.
- **42 miles (68 km)** of radiant heating tubes run through the ceilings throughout the building.
- Five zones in each wing of the building are controlled by the radiant zone control valves.
- Separate systems for intermittent occupancy rooms

Solar Vent Preheat

- Sun preheats the air on the southern exposure of the building.



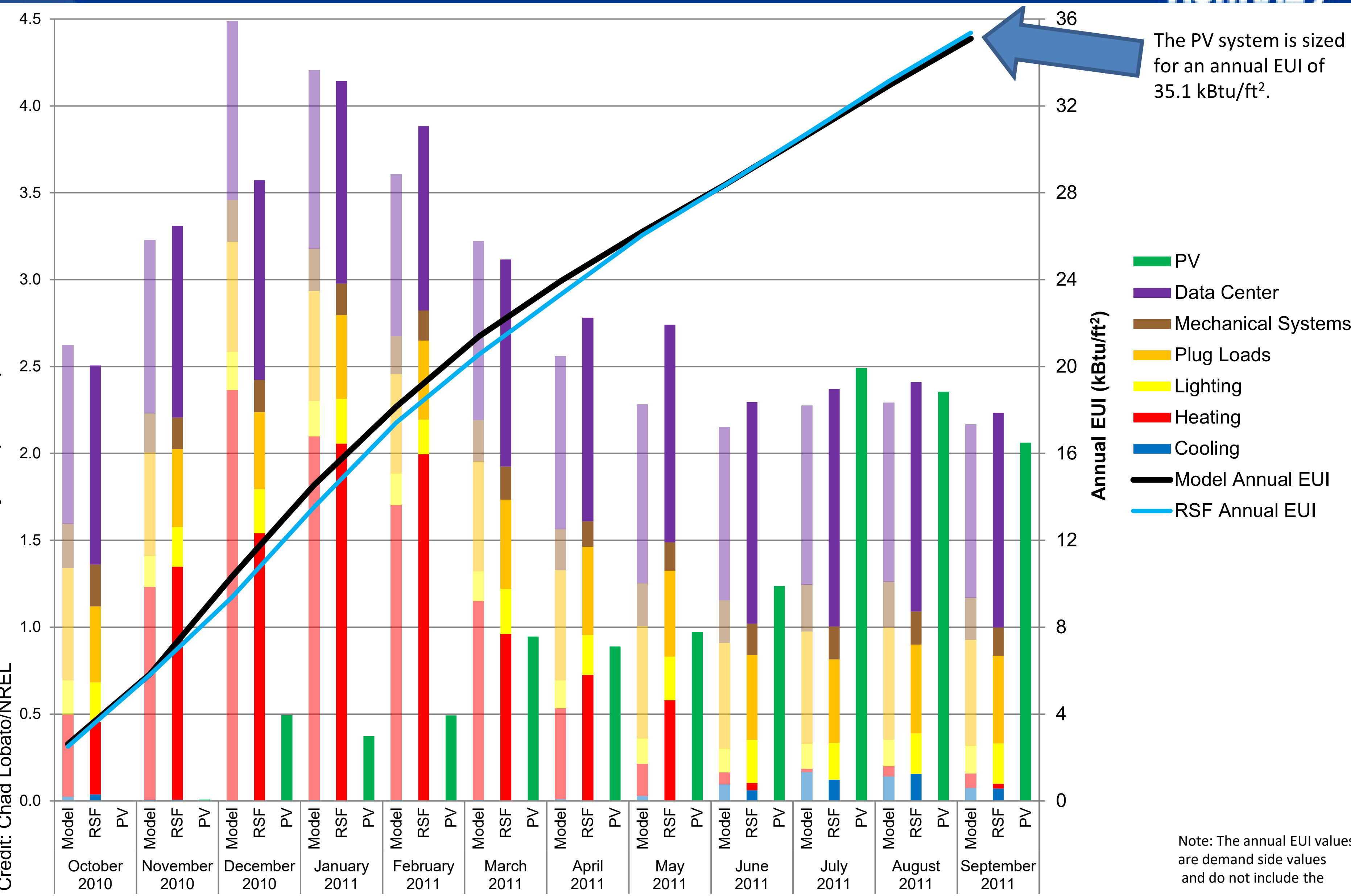
October 2010 – March 2011 Mechanical System Power Density



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

Credit: Chad Lobato/NREL

Measured Versus Modeled Monthly and Cumulative EUI



Credit: Chad Lobato/NREL

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

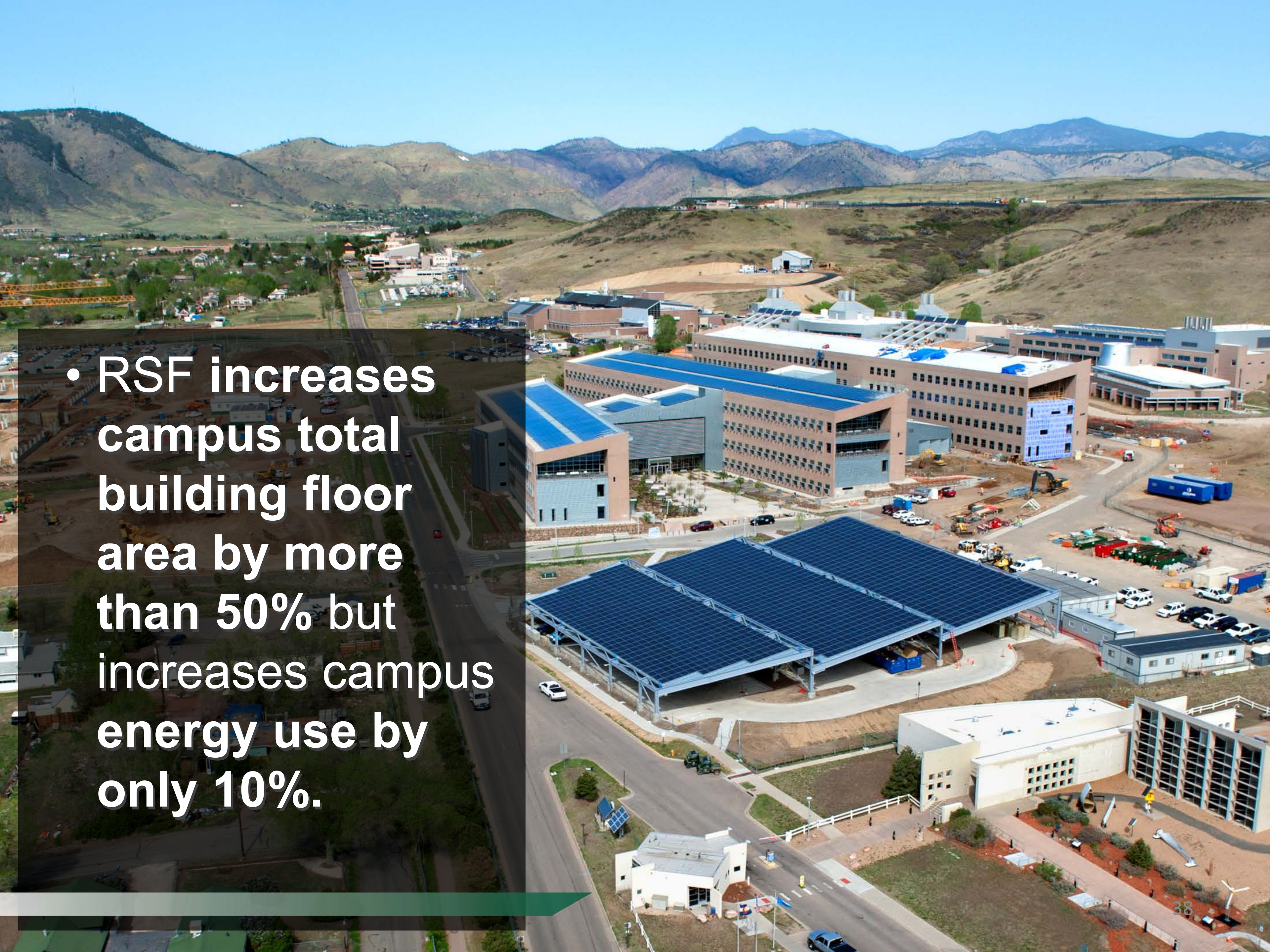
RSF II

- 138,000 sq. ft. (12,820 sq. m)
- 525 occupants
- RSF II is 17% more efficient than RSF 1
- Cost savings of 5%

Small Improvements, Big Difference

- More efficient solar panels were purchased at a lower cost
  - 13% efficient PV to 19% efficient PV
- Pre-fab wall panels with windows
- Less window area, while still fully daylighting office spaces
- Better thermal breaks in the window frames
- Displacement ventilation in conference rooms
- Daylighting controls in daylit stairwells
- More/better daylighting in the break rooms
- Increased user friendliness of operable windows
- More cost effective labyrinth, quicker to build & easier to insulate
- Indirect evaporative cooling coupled with exhaust air energy recovery
- Wall panels at foundation designed to minimize thermal bridges
- Toplit skylights for daylighting in conference rooms in the core
- Natural passive cooling in stairwells rather than fan coils
- Triple pane east/west curtain walls with 4 level electrochromics
- More flexible lighting controls
- IT and electrical rooms cooling with heat pumps
  - Removed heat used for domestic hot water heating

Energy Management is Essential

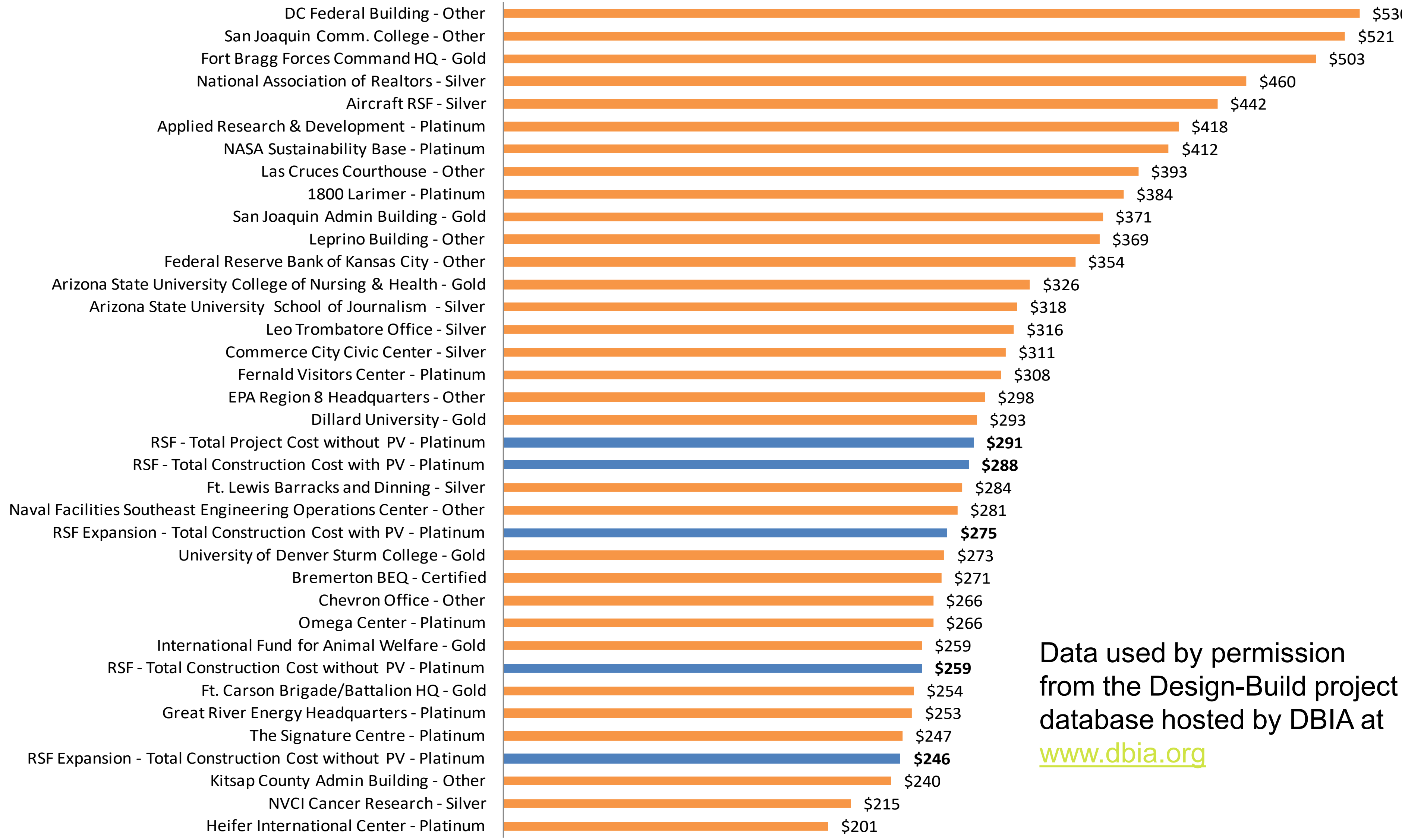


- RSF **increases campus total building floor area by more than 50%** but increases campus **energy use by only 10%.**

Photovoltaic System

- Power Purchase Agreement (PPA) provides full rooftop array on RSF and parking garage
- Zero energy = building, parking lot and parking garage arrays (>2.5MW)

Compare



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Thank You!

E-mail: **Sheila.Hayter@nrel.gov**