NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Large Scale Net Zero Energy Commercial Buildings: NREL's Research Support Facility

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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.

What We Do

Advanced Commercial Buildings Research, through applied research and demonstration, supports DOE's speed-and-scale goals to reduce building energy use.

Focus areas:

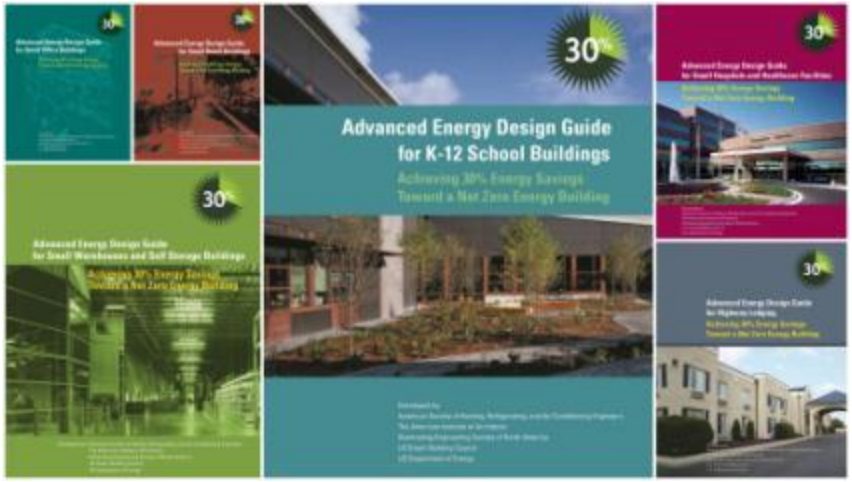
- Whole-building systems integration
- Comprehensive building energy modeling
- Cutting-edge energy efficiency technologies
- Systematic performance metrics and monitoring

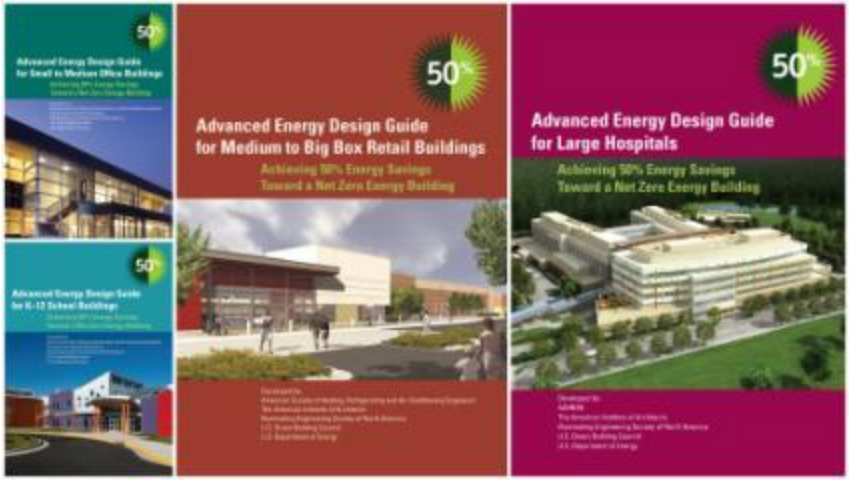
Our team's key strength lies in combining all these tools to design well-integrated new buildings and cost-effective retrofits.

Advanced Energy Design Guides

30% guides
- Small office buildings
- Small retail buildings
- K-12 school buildings
- Small warehouse and self-storage buildings
- Highway lodgings
- Small hospitals and healthcare facilities

50% guides
- Small to medium office (SMO) buildings
- K-12 school buildings
- Medium to big box retail (MBR) buildings
- Large hospitals (LH)





What Is an AEDG?

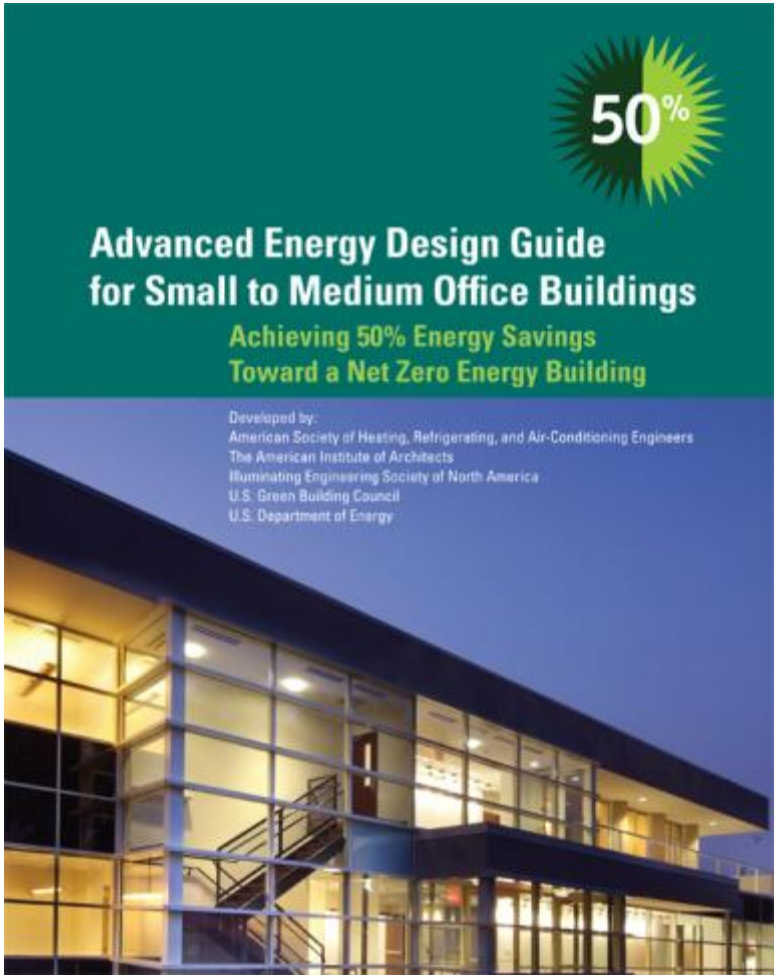
Developed in collaboration with ASHRAE, AIA, IES, USGBC, DOE

Two series:

- Original series targeted 30% savings over 90.1-1999
- Current series targets 50% savings over 90.1-2004

Educational guidance—not a code or standard

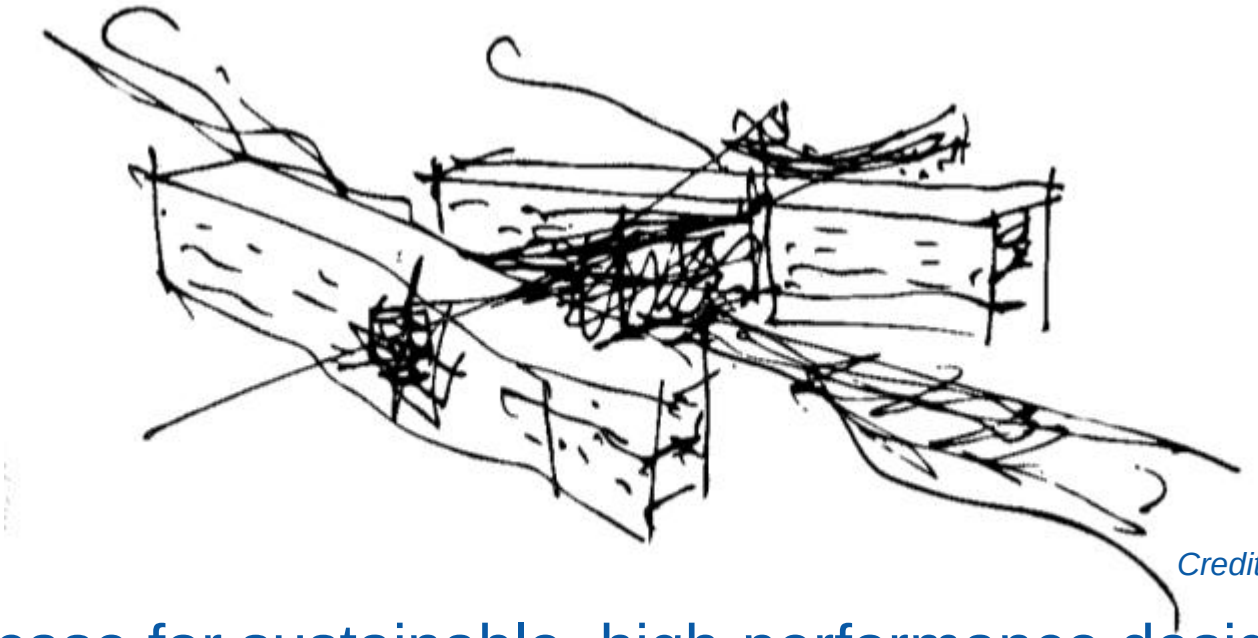
Available for free as a PDF download from www.ashrae.org/freeaedg



NREL: 2006

NREL PIX

Research Support Facility Vision



Credit: RNL

- A showcase for sustainable, high-performance design
  - Incorporates the best in energy efficiency, environmental performance, and advanced controls using a “whole-building” integrated design process
- Serves as a model for cost-competitive, high-performance commercial buildings for the nation’s design construction, operation, and financing communities

DOE/NREL Research Support Facility: Project Goals

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

- 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/ARRA)
- Open first phase June 10, 2010

Problem Definition – RFP Objectives Checklist

MISSION CRITICAL

Attain safe work performance/Safe Design Practices

LEED Platinum

Energy Star "Plus"

HIGHLY DESIRABLE

800 staff Capacity

25kBTU/sf/year

Architectural integrity

Honor future staff needs

Measurable ASHRAE 90.1

Support culture and amenities

Expandable building

Ergonomics

Flexible workspace

Support future technologies

Documentation to produce a "How to" manual

"PR" campaign implemented in real-time

Allow secure collaboration with outsiders

Building information modeling

Substantial Completion by 2010

IF POSSIBLE

Net Zero/design approach

Most energy efficient building in the world

LEED Platinum Plus

ASHRAE 90.1 + 50%

Visual displays of current energy efficiency

Support public tours

Achieve national and global recognition and awards

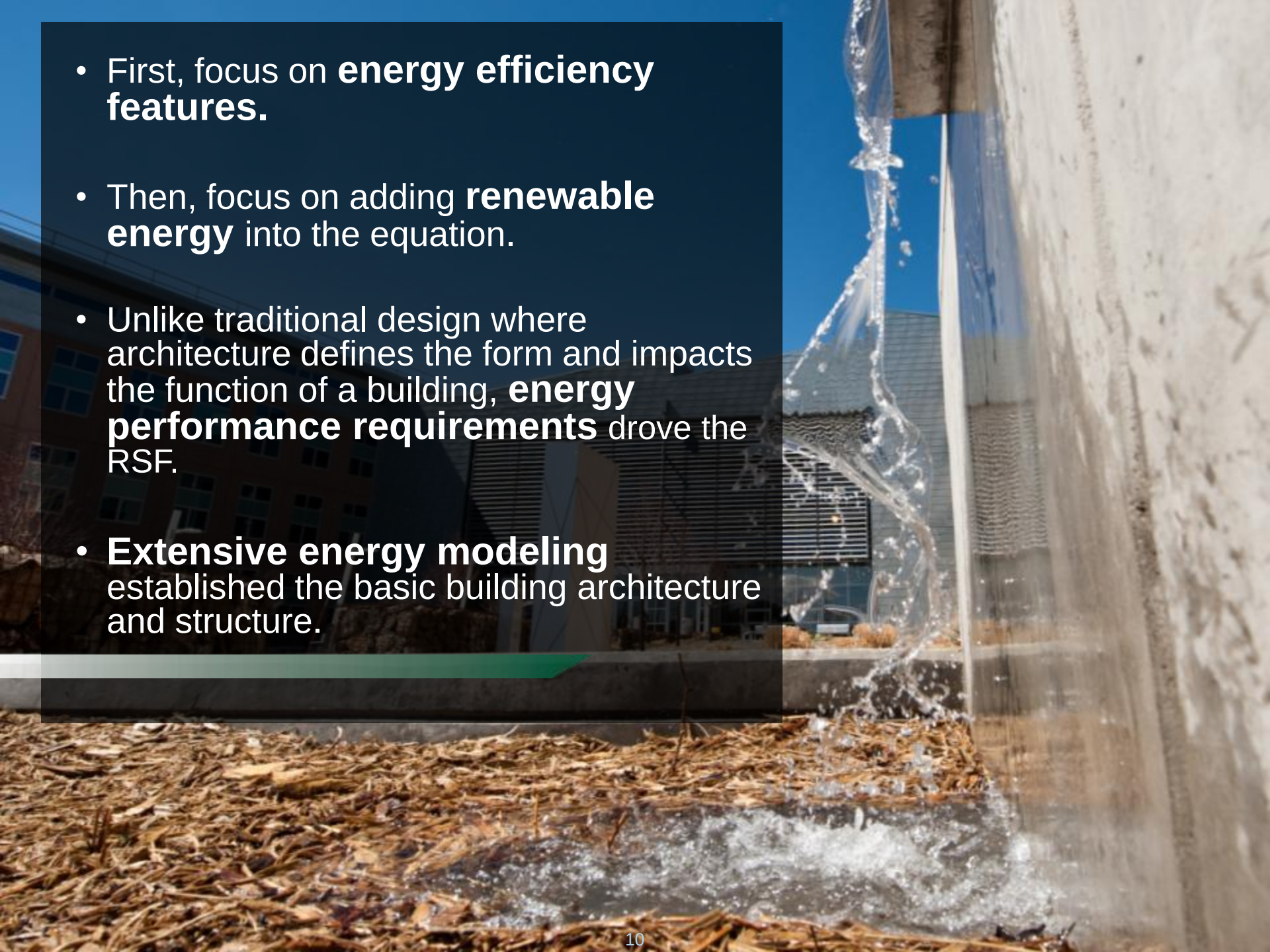
Support personnel turnover

RFP also required maximum use of natural ventilation and 90% of floor space fully daylit

Full Performance RFP ➡ No drawings in RFP = No change orders!

NREL: Today

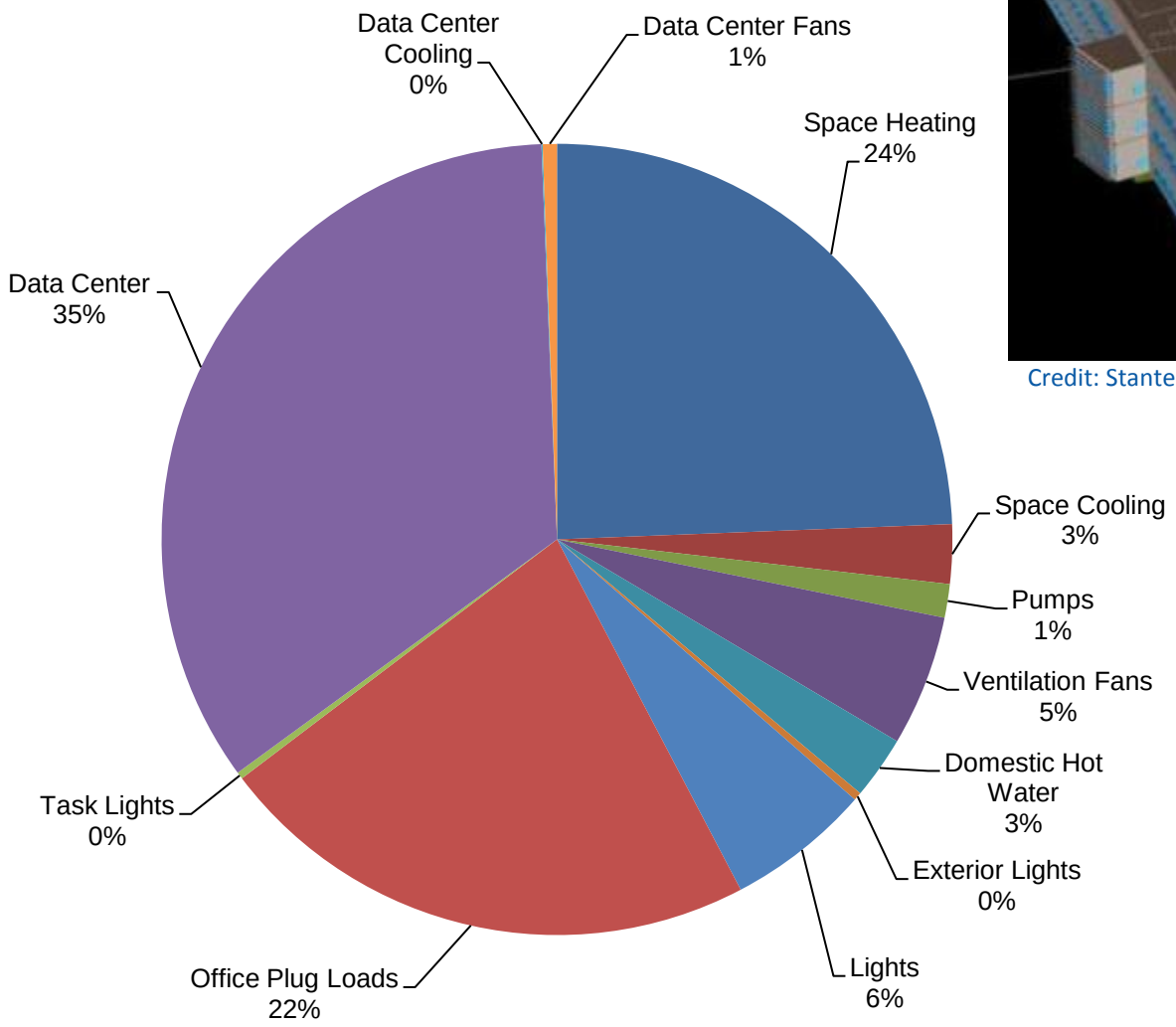
Used with Permission from Haselden



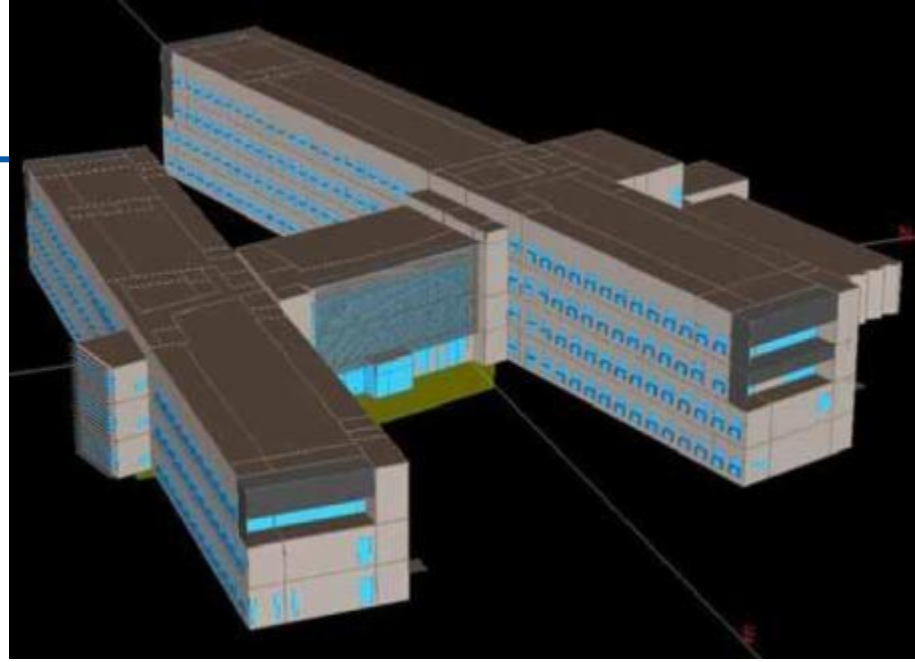
- First, focus on **energy efficiency features.**
- Then, focus on adding **renewable energy** into the equation.
- Unlike traditional design where architecture defines the form and impacts the function of a building, **energy performance requirements** drove the RSF.
- **Extensive energy modeling** established the basic building architecture and structure.

Energy Modeling

NREL RSF Energy Use Breakdown



Credit: Chad Lobato/NREL



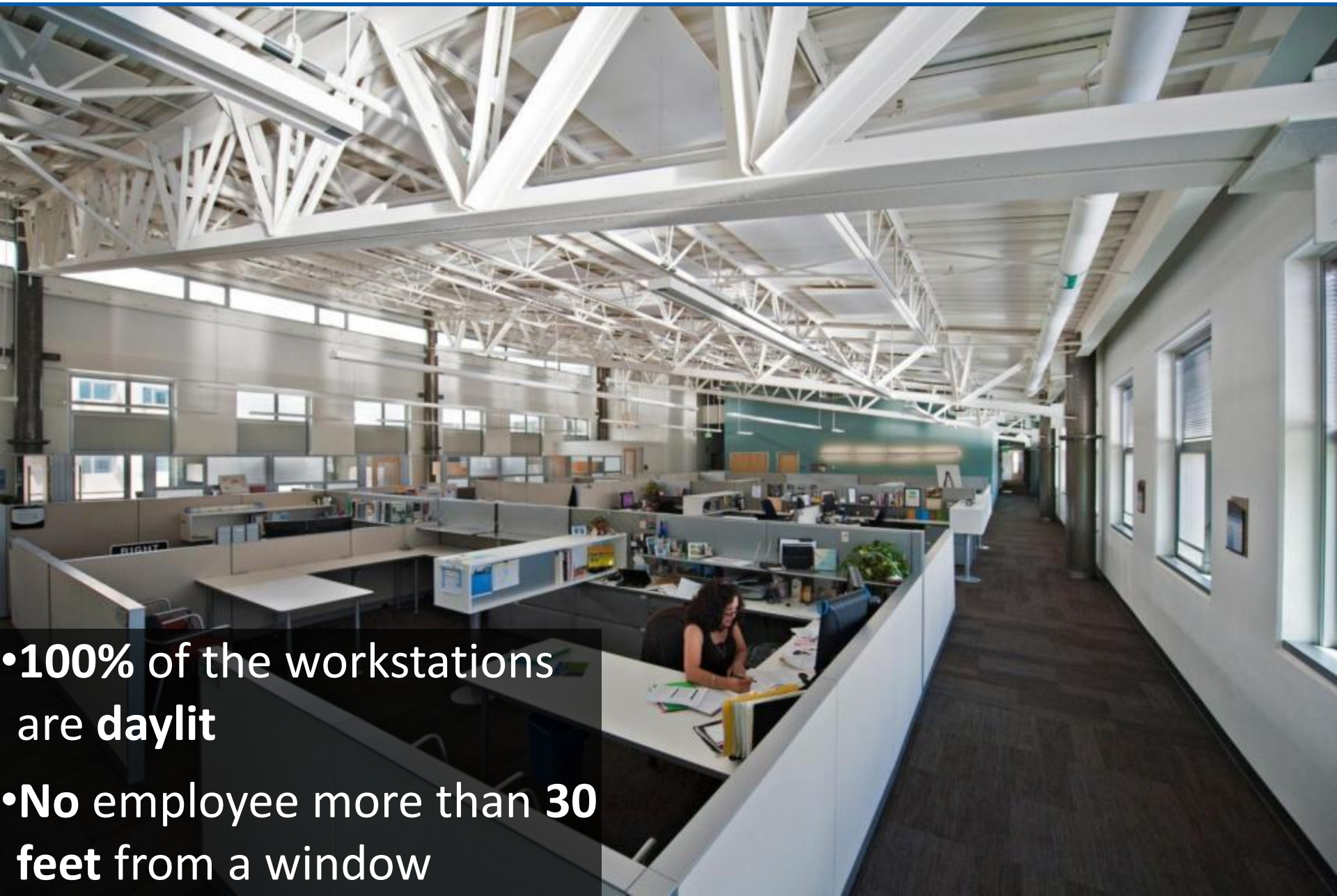
Credit: Stantec

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

Level 2
Level 3
Level 4
Level 1
OPEN OFFICE AREA
BUILDING SUPPORT
ENCLOSED OFFICE AREA
CONFERENCE
PUBLIC SPACE
n

Floor Plans

Daylighting

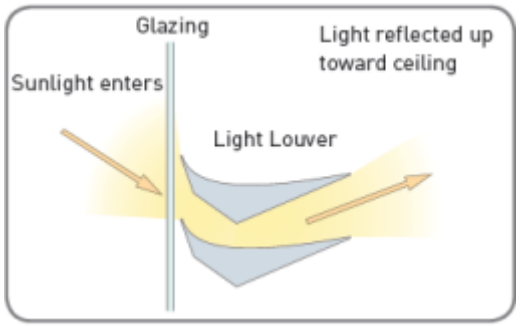


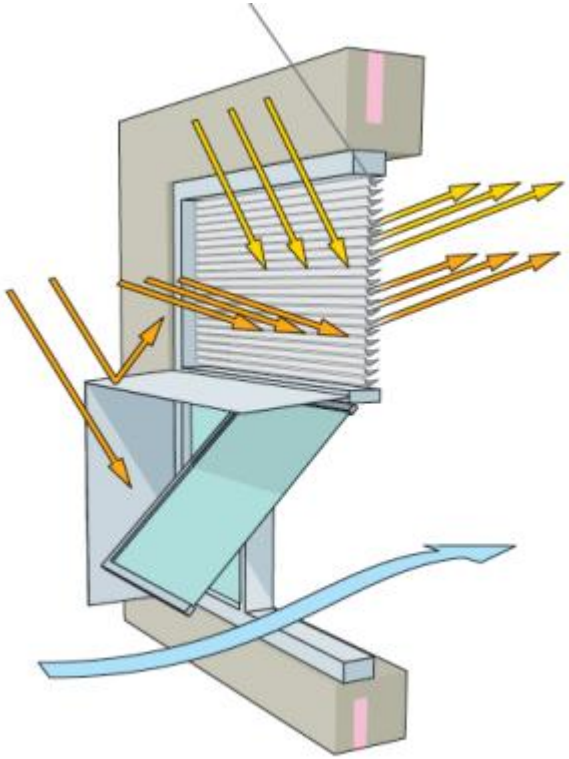
- **100%** of the workstations are **daylit**
- **No** employee more than **30 feet** from a window

Daylighting: Glare Control

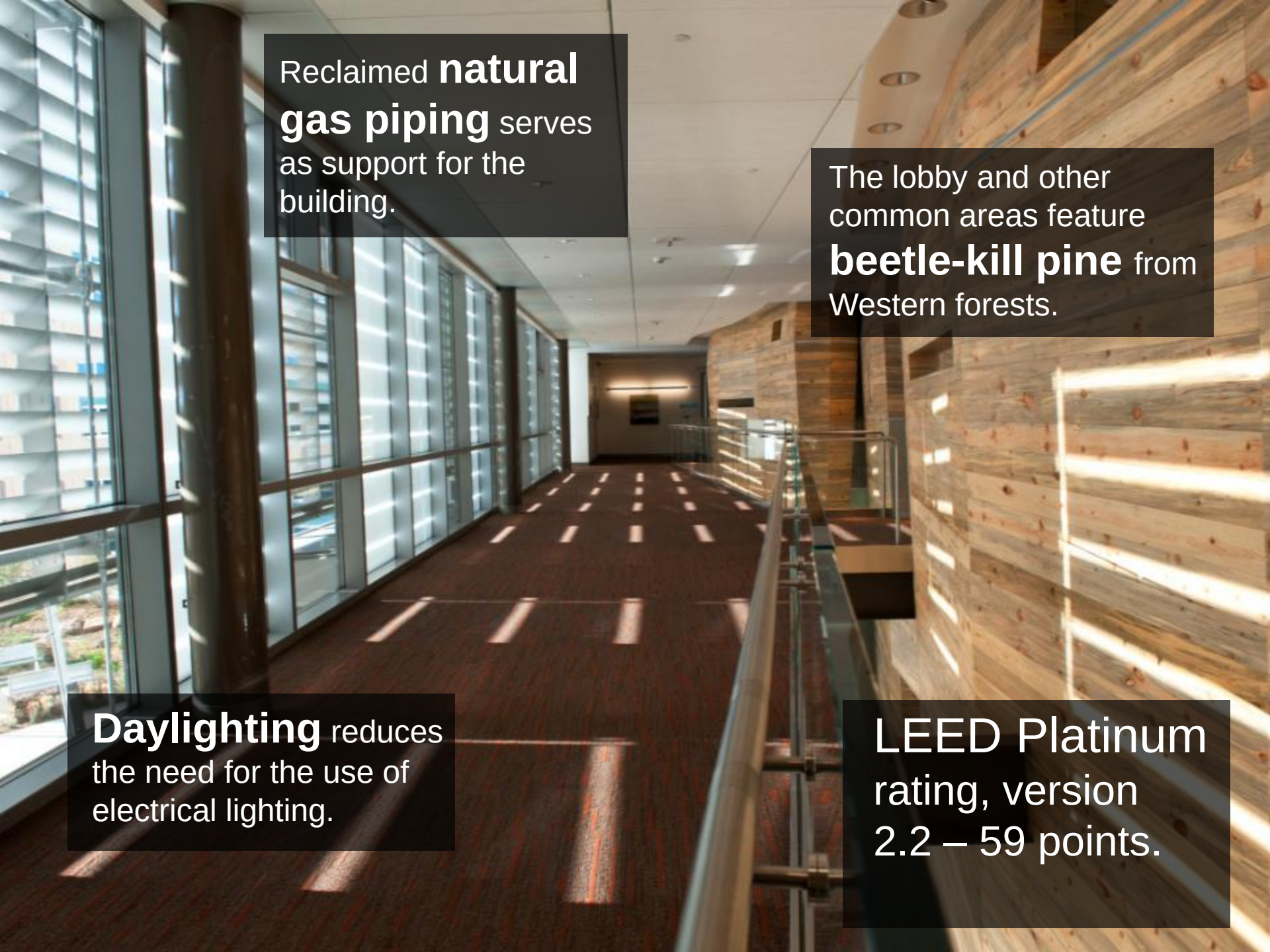
A light redirecting device reflects sunlight to the ceiling, creating an indirect lighting effect.

Fixed sunshades limit excess light and glare.

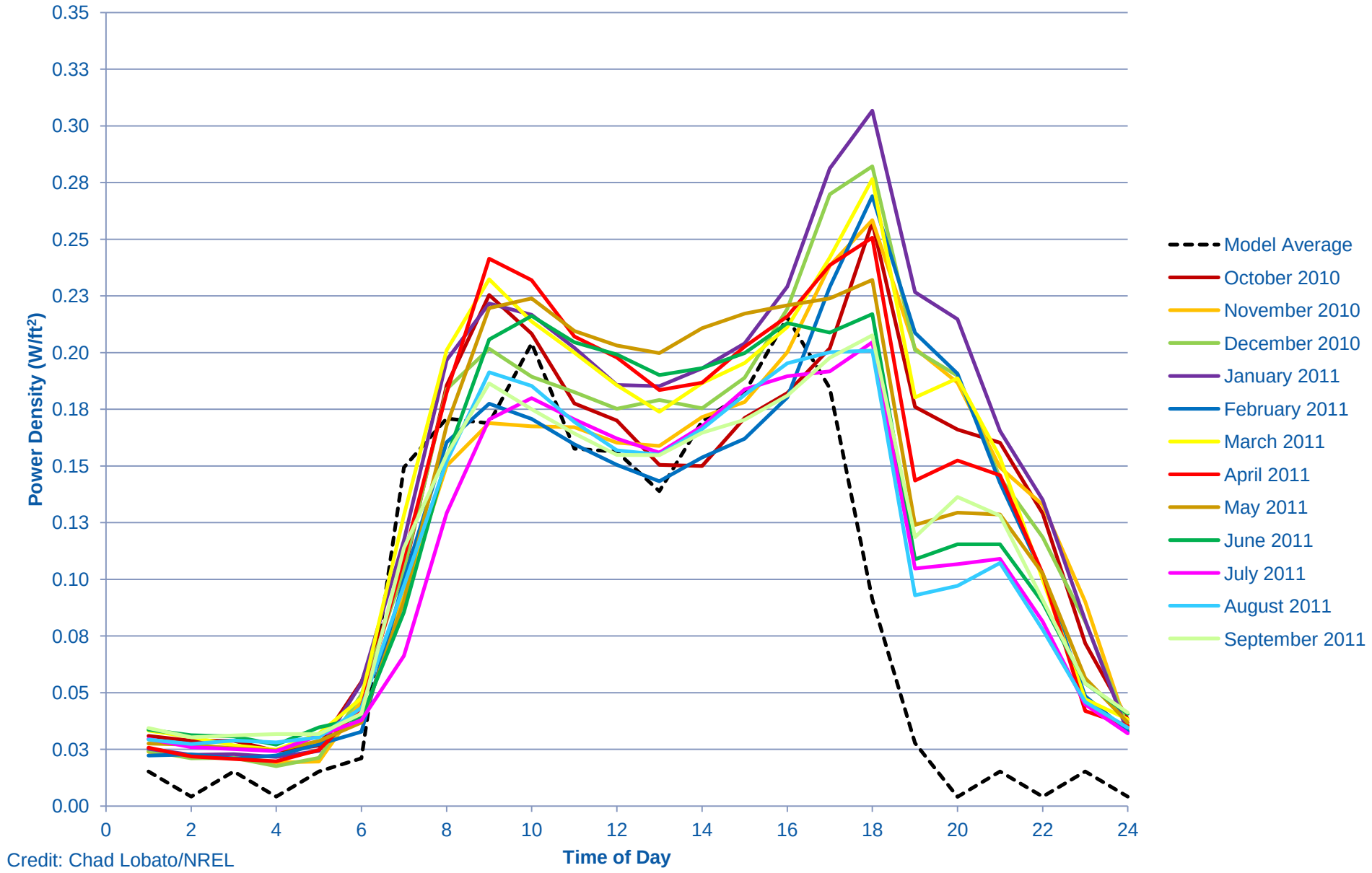




Credit: RNL

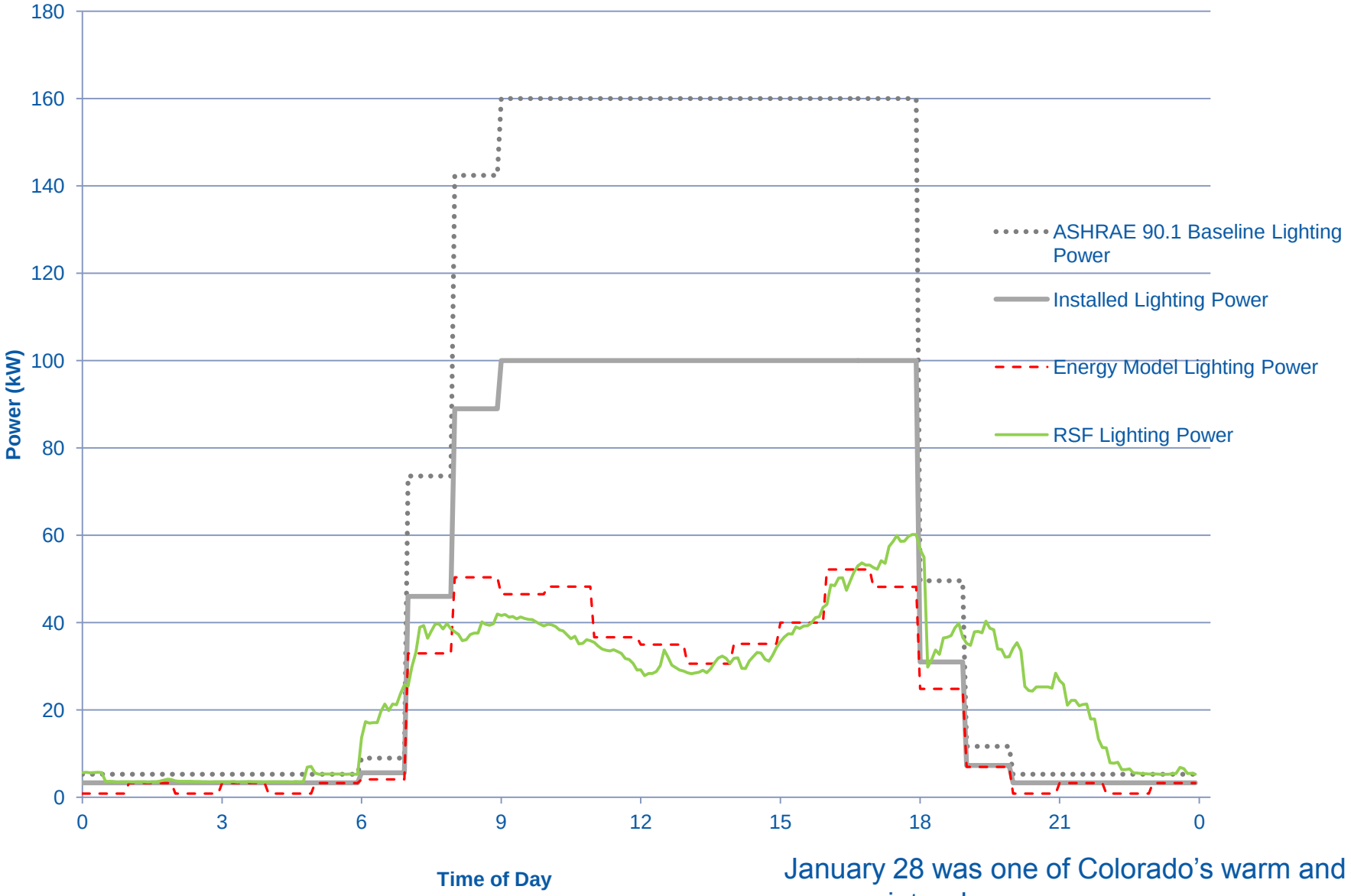

Reclaimed **natural gas piping** serves as support for the building.
The lobby and other common areas feature **beetle-kill pine** from Western forests.
Daylighting reduces the need for the use of electrical lighting.
LEED Platinum rating, version 2.2 – 59 points.

Weekday Lighting Power Density



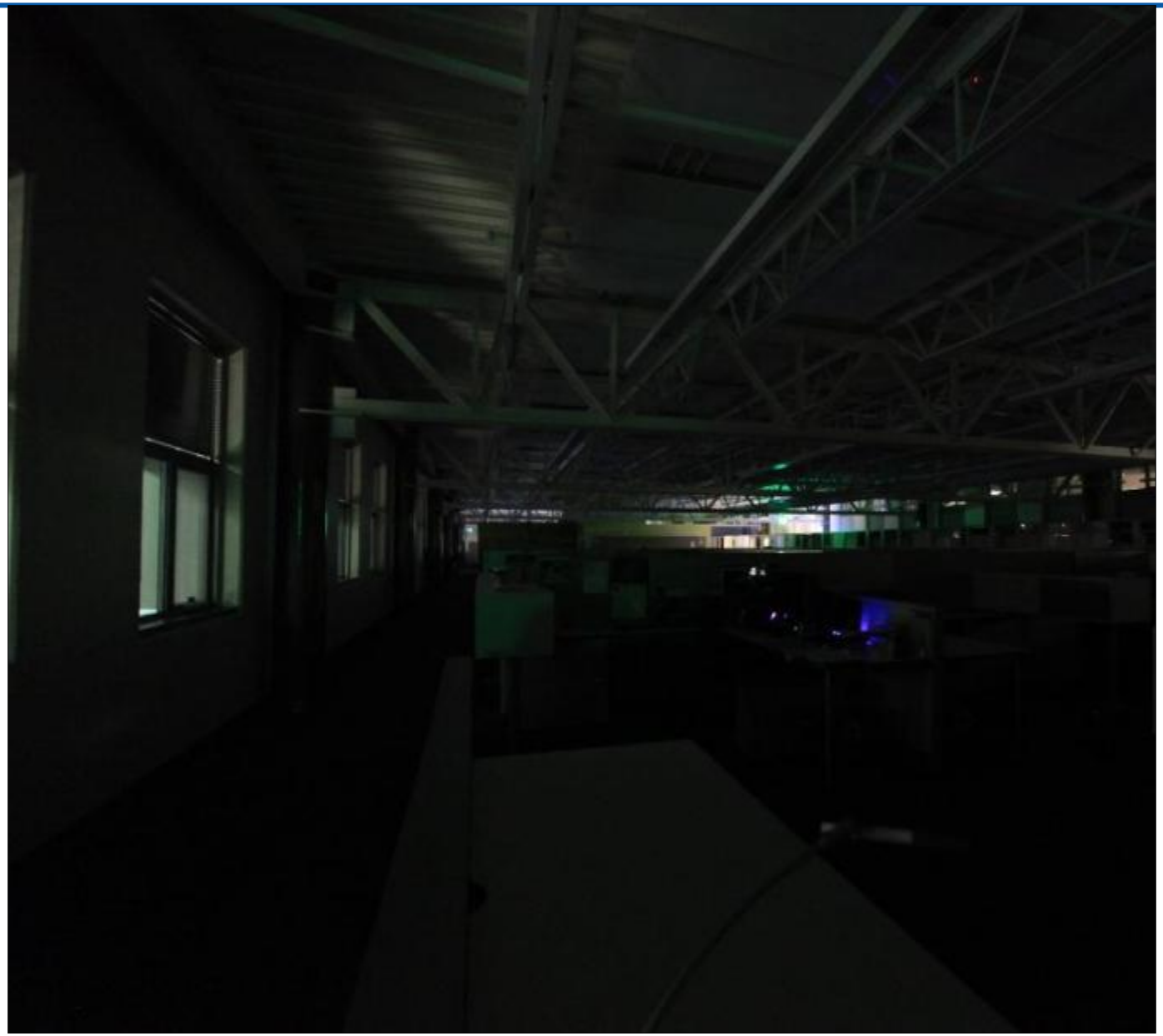
Credit: Chad Lobato/NREL

January 28, 2011 Lighting and Daylighting



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

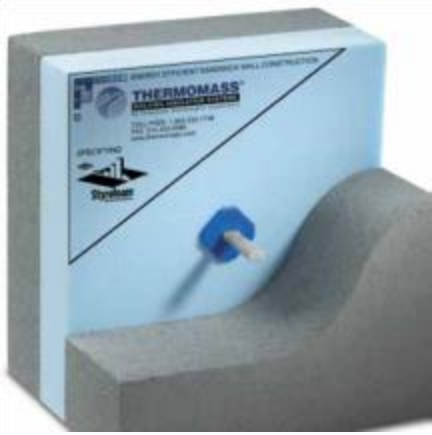
All Dark at Night?

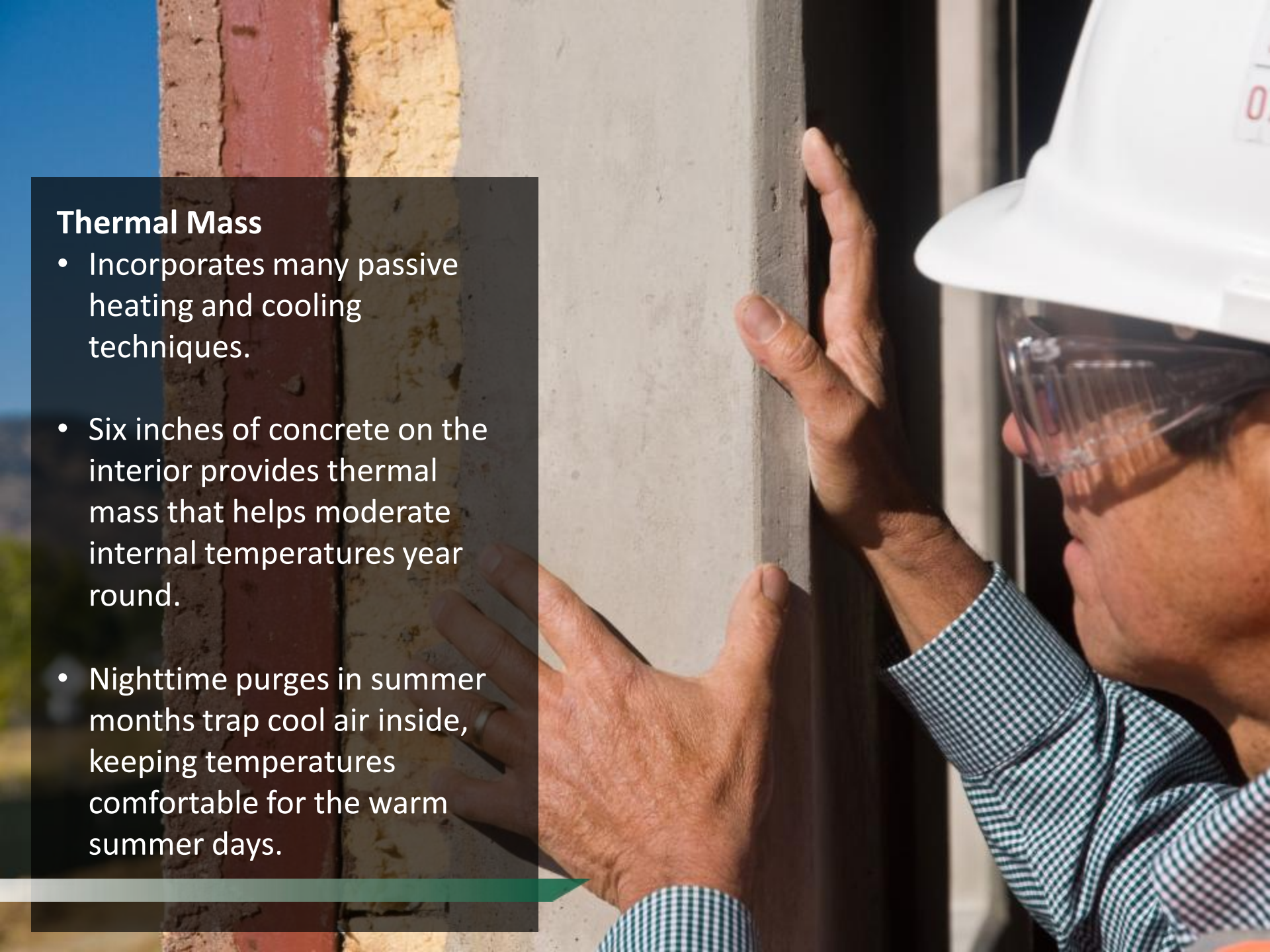


WEST

High Performance Envelope

- R-15 continuous insulation precast panels
  - 6” interior exposed concrete panel
- R-35 roof deck insulation
- Triple pane windows
  - Window frames a weak point…
- Reduced thermal bridging





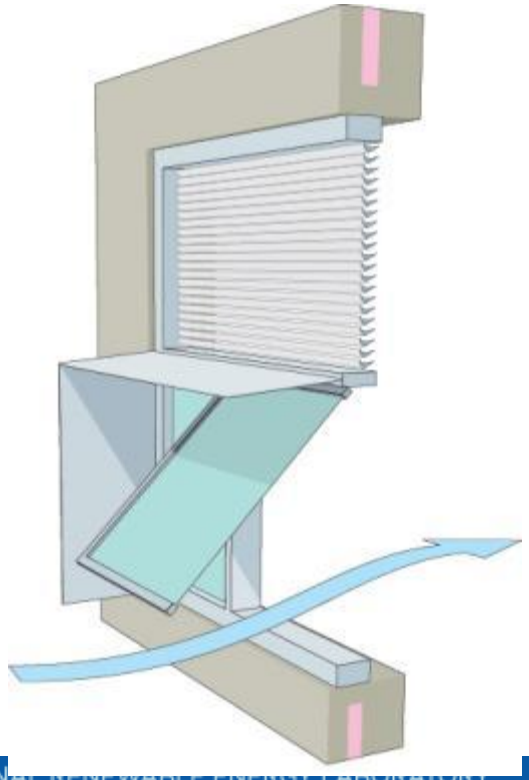
Thermal Mass

- Incorporates many passive heating and cooling techniques.
- Six inches 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.

HVAC Systems

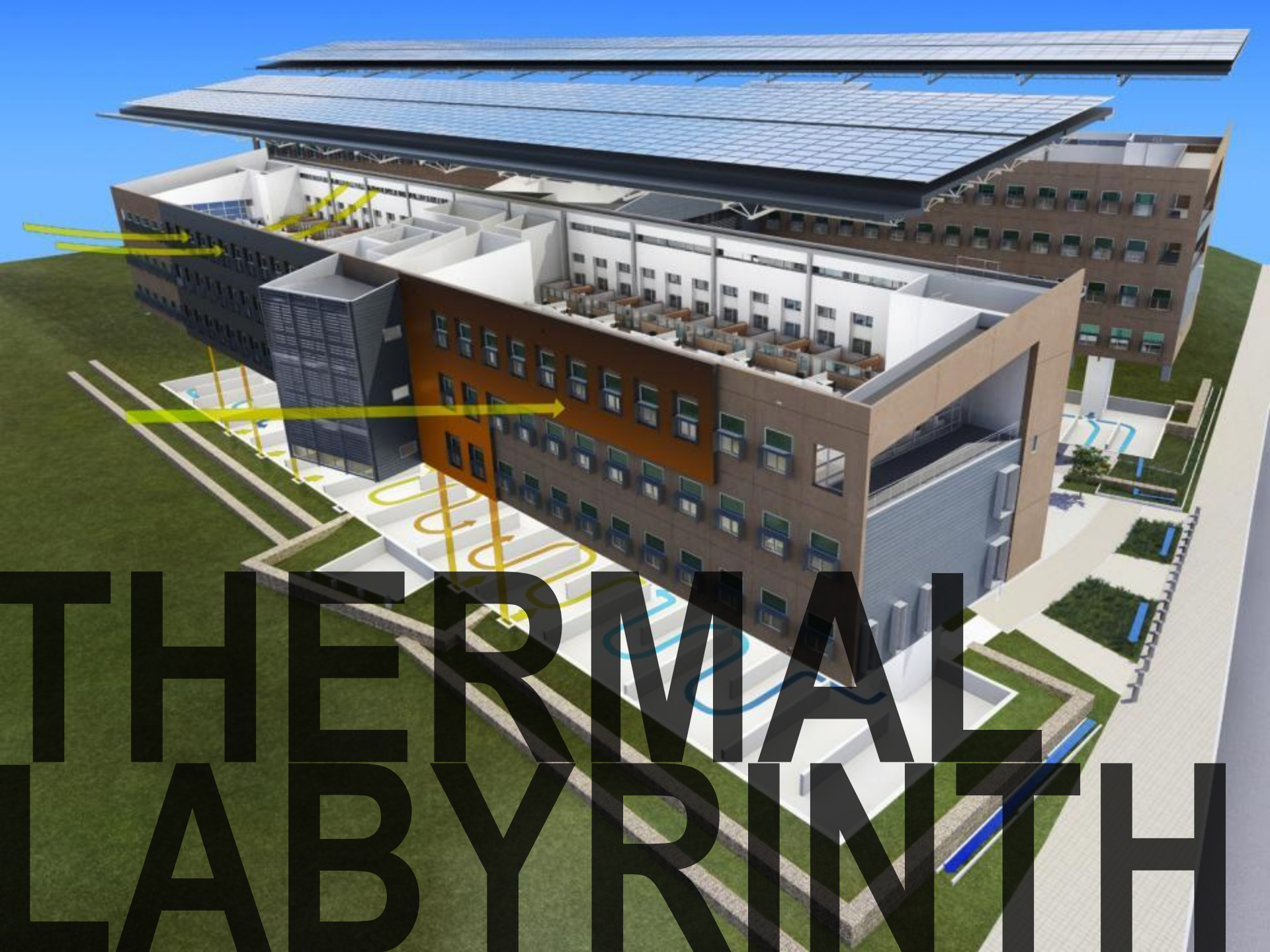
- Radiant space heating and cooling
- Dedicated outdoor air with underfloor delivery
- Natural ventilation
  - Automatic and manual windows
  - Security waiver

NATURAL VENTILATION

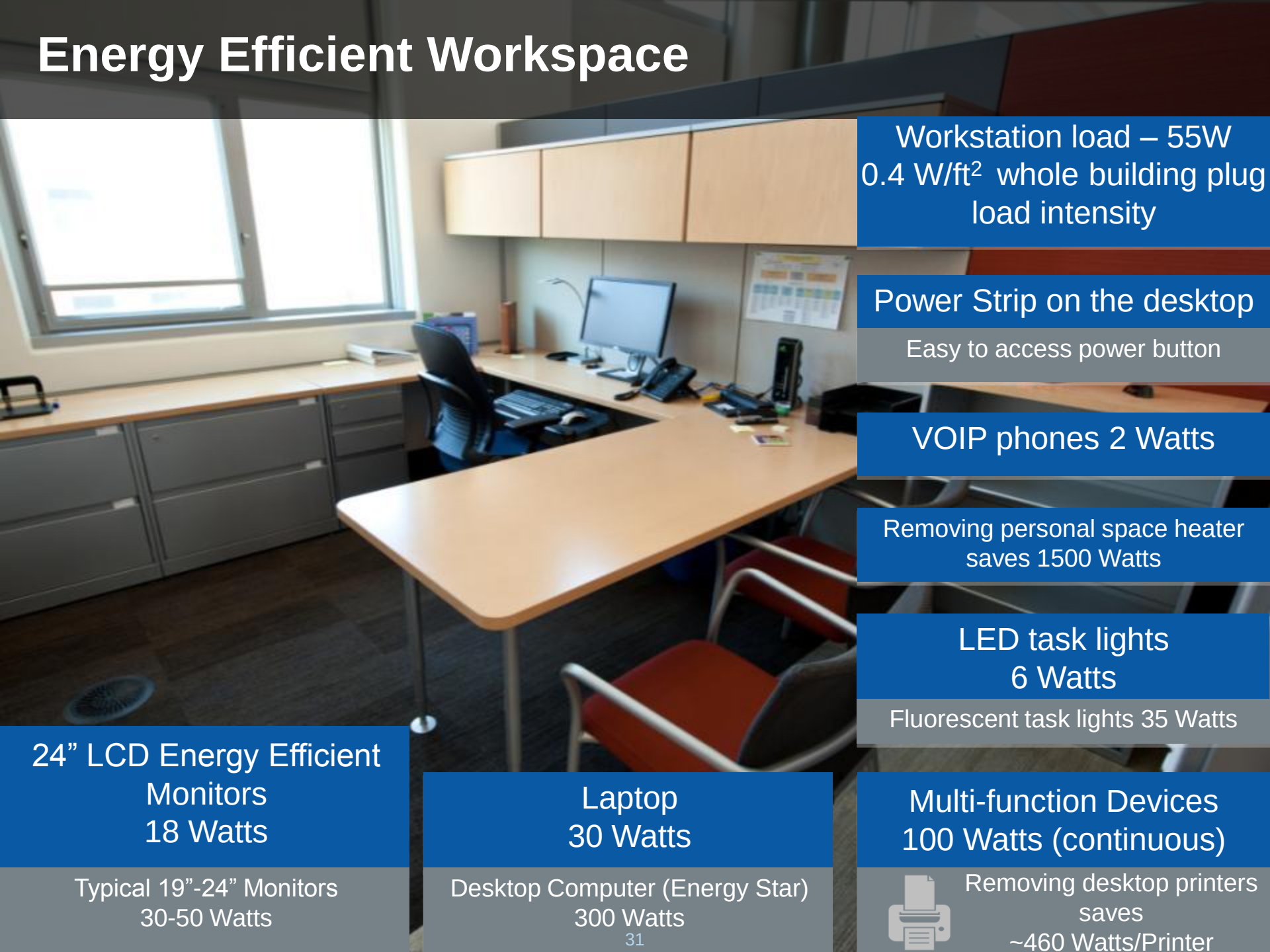


Natural Ventilation

- 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.


THERMAL
LABYRINTH

Energy Efficient Workspace



Workstation load – 55W
0.4 W/ft^2 whole building plug load intensity

Power Strip on the desktop

Easy to access power button

VOIP phones 2 Watts

Removing personal space heater saves 1500 Watts

LED task lights
6 Watts

Fluorescent task lights 35 Watts

24” LCD Energy Efficient Monitors
18 Watts

Typical 19”-24” Monitors
30-50 Watts

Laptop
30 Watts

Desktop Computer (Energy Star)
300 Watts

Multi-function Devices
100 Watts (continuous)

Removing desktop printers saves
~460 Watts/Printer

RSF Plug Load Reduction Strategies

Elevators
- Use energy efficient traction elevators
- Change elevator lighting to energy efficient fluorescent lighting
- Turn off elevator lighting when the elevator is unoccupied

Break Rooms
- Increase the number of people that use each break room from approximately 40 to 60
- Eliminate the cooler on the drinking fountain

Task Lights
- Move from 35W fluorescent task lights to 6W LED task lights

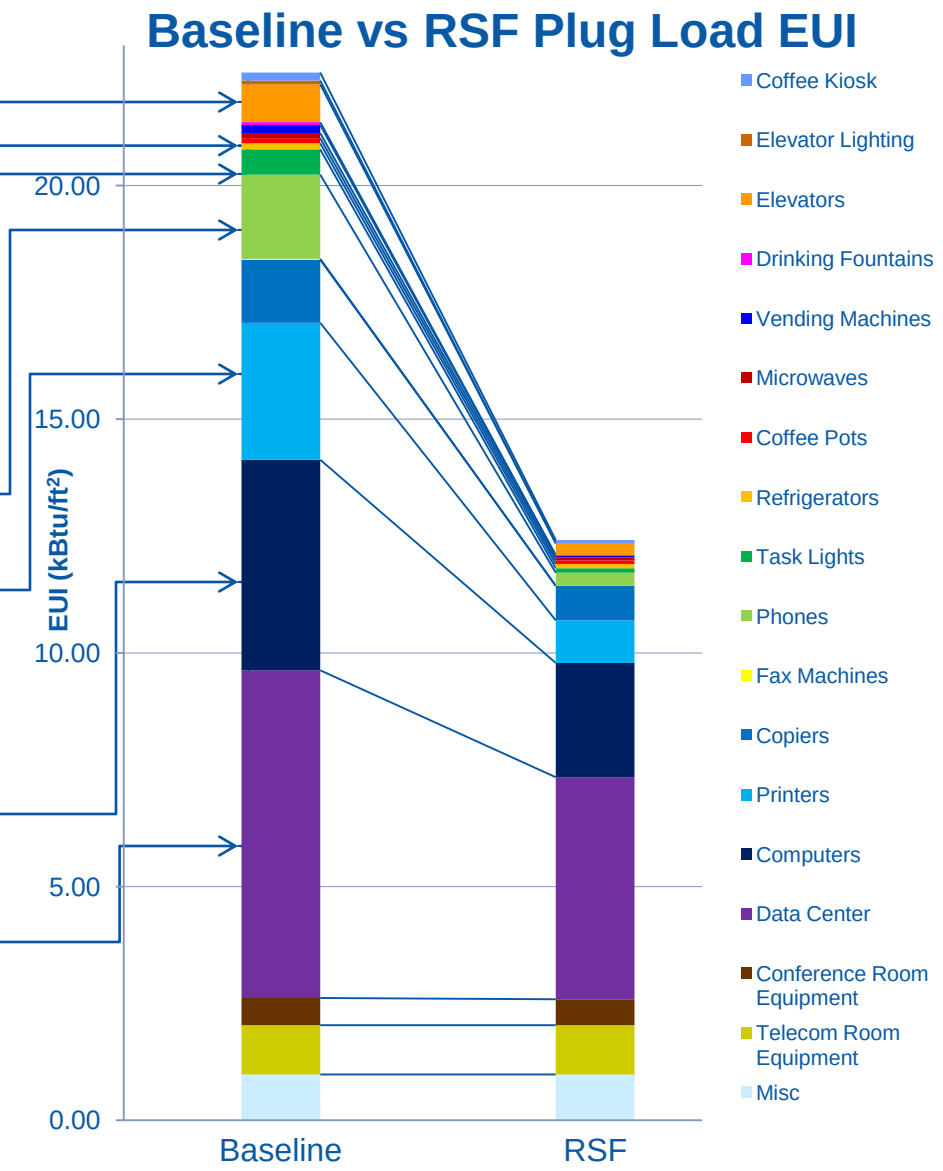
Phones
- Go from 1000 standard phones to 1000 VOIP phone that consumes 2W each

Copiers, Printers, Fax Machines
- Decrease the number people that use individual copiers, printers and fax machines
- Increase the number of people that use common, or group, copiers, printers and fax machines from 15 to 20
- Increase the use of all-in-one machines

Computers
- Go from approximately 260 laptops, 33% of staff, to 720, 90% of staff, ensure standby mode works for all workstations

Data Center
- Blade Servers with Virtualization
- High efficiency UPS
- 65W/employee current to 48W/employee in RSF

The result of these strategies is a 47% reduction in plug loads



October 2010 – August 2011 Plug Load Power Density

Credit: Marjorie Schott/NREL

Power Density (W/ft²)

Time of Day

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

Credit: Chad Lobato/NREL

Note: The elevators are included in the plug loads

Annual Occupied Hours for GSA Offices

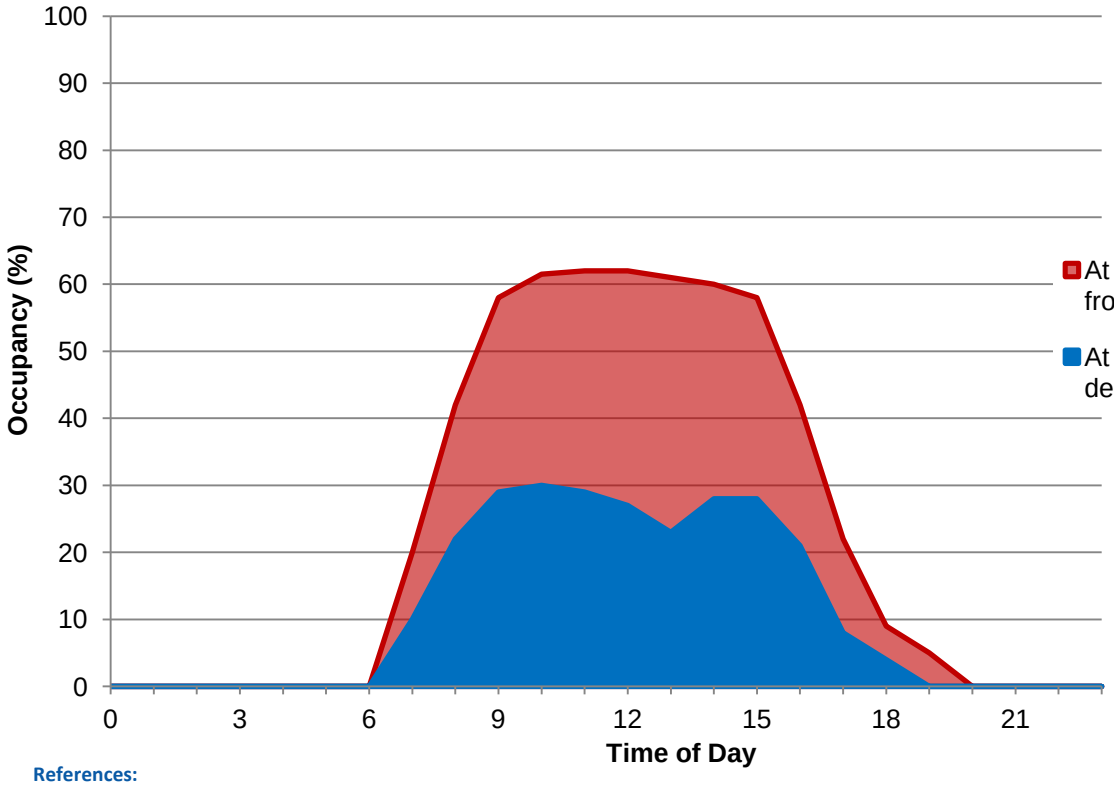
Nights, weekends, and holidays account for 66% of the year

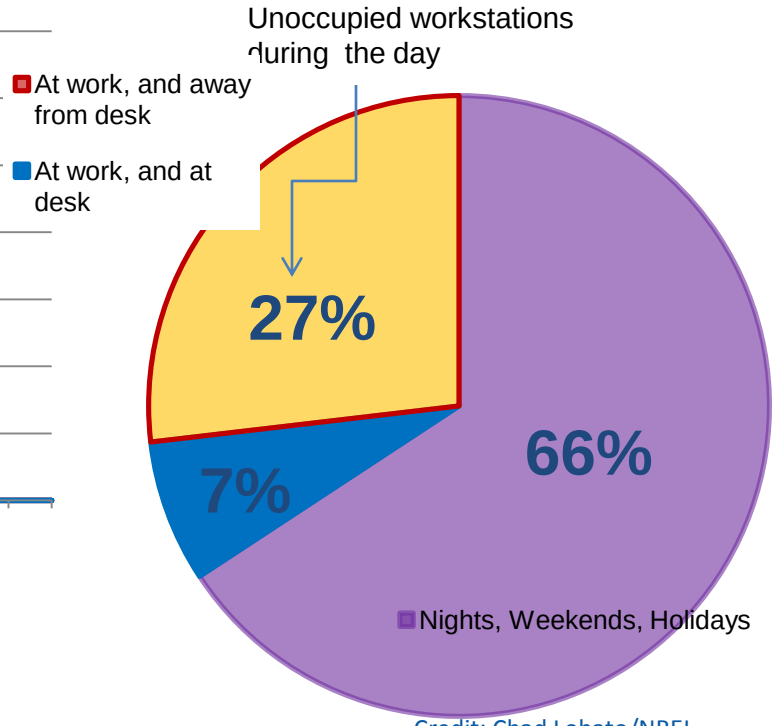
- A typical office building is unoccupied during this time

During a typical work day, building occupants are only at their desk less than 30% of the time

- Workstations are vacant and should be powered down during more than 70% of business hours

Workstations should only be powered 7% of the year!





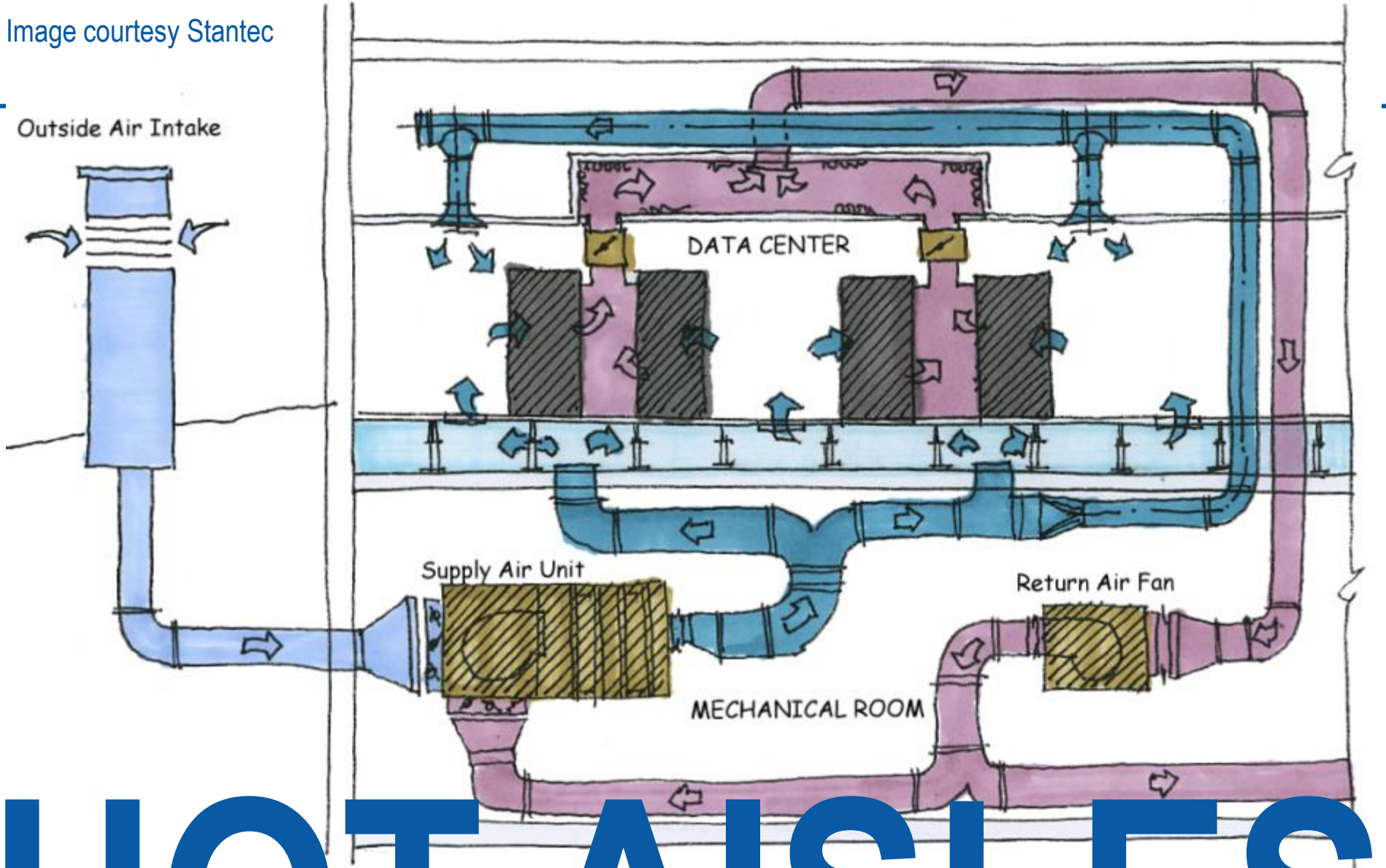
Credit: Chad Lobato/NREL

References:

http://www.gsa.gov/graphics/pbs/WorkPlace_Matters_FINAL508_lowres.pdf

FREE HEAT

Image courtesy Stantec

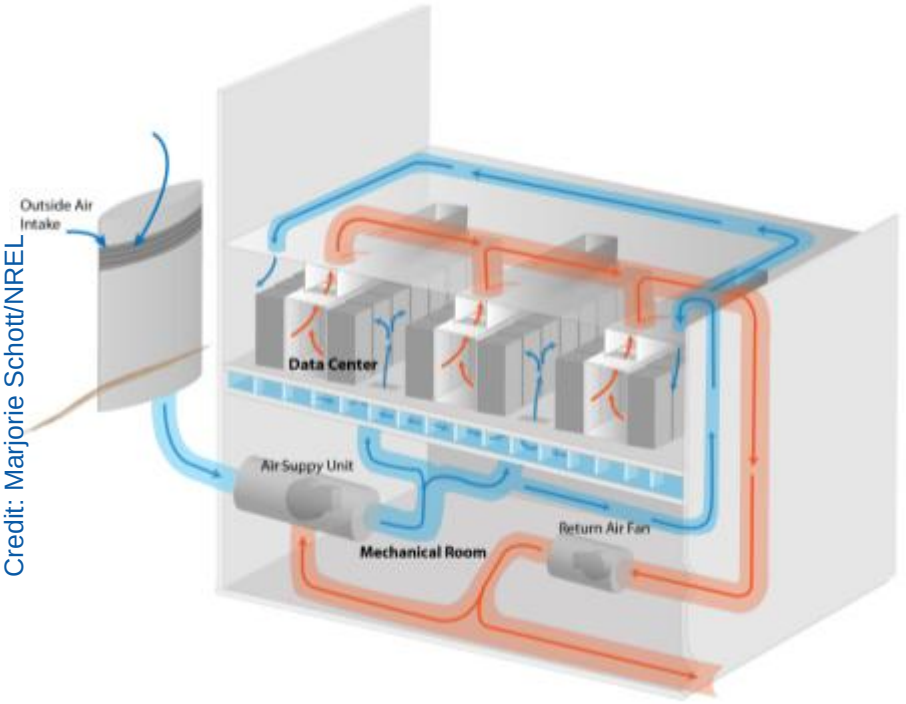


HOT AISLES

Operational Lessons- Datacenter

- Fully containing hot aisle difficult
  - Custom aisle floor and door seals
  - Ensure equipment designed for cold aisle containment
    - And installed to pull cold air
      - Not hot air…
- Have run ~1.1-1.35 PUE
  - A few hot spots were driving up PUE
  - Summer time PUE of 1.35 because of increased cooling

Control hot aisle based on return temperature of ~90F



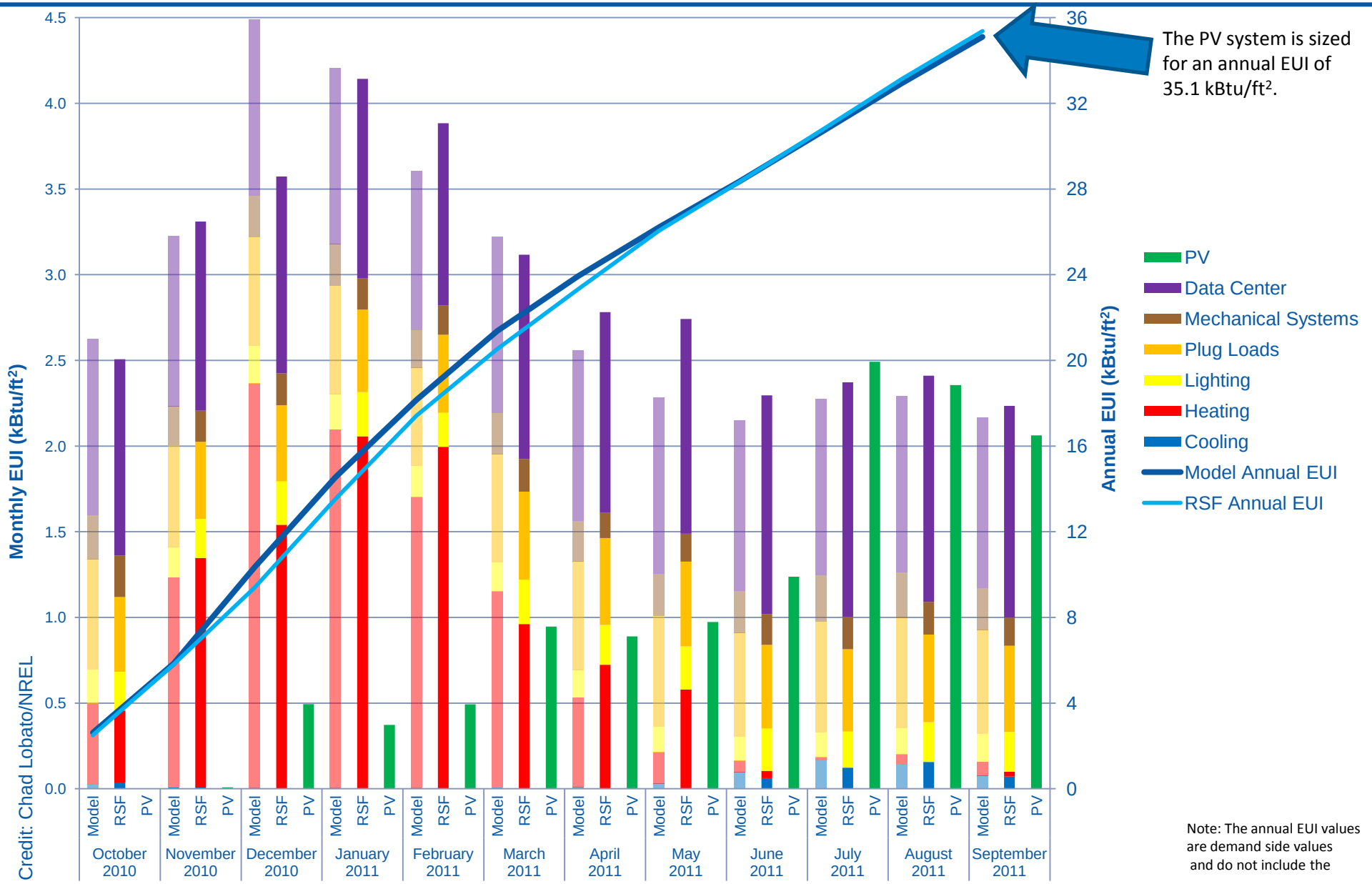
Credit: Marjorie Schott/NREL

NREL/PIX 17897

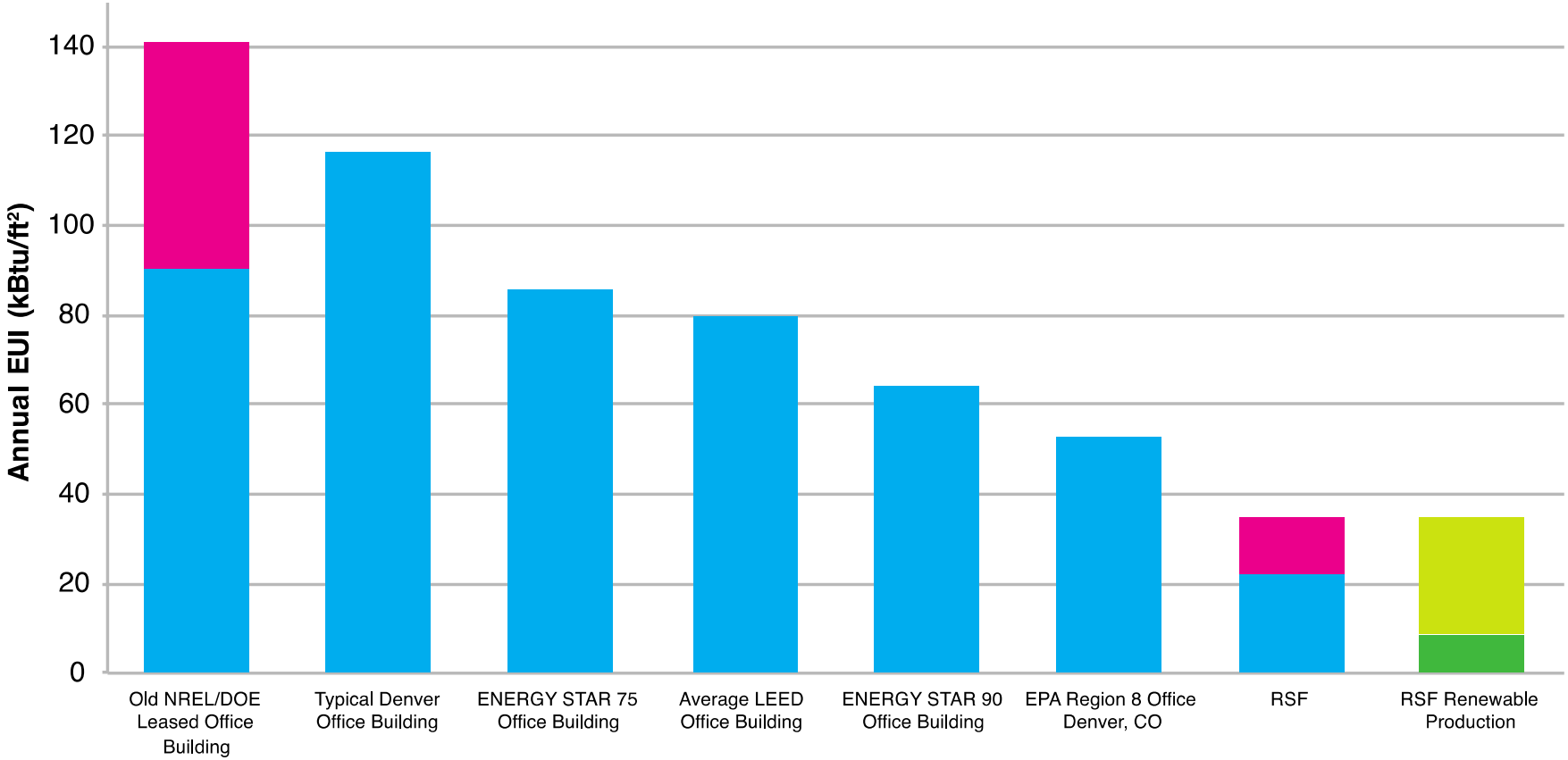
Photovoltaic System

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

Measured Versus Modeled Monthly and Cumulative EUI



BENCHMARK



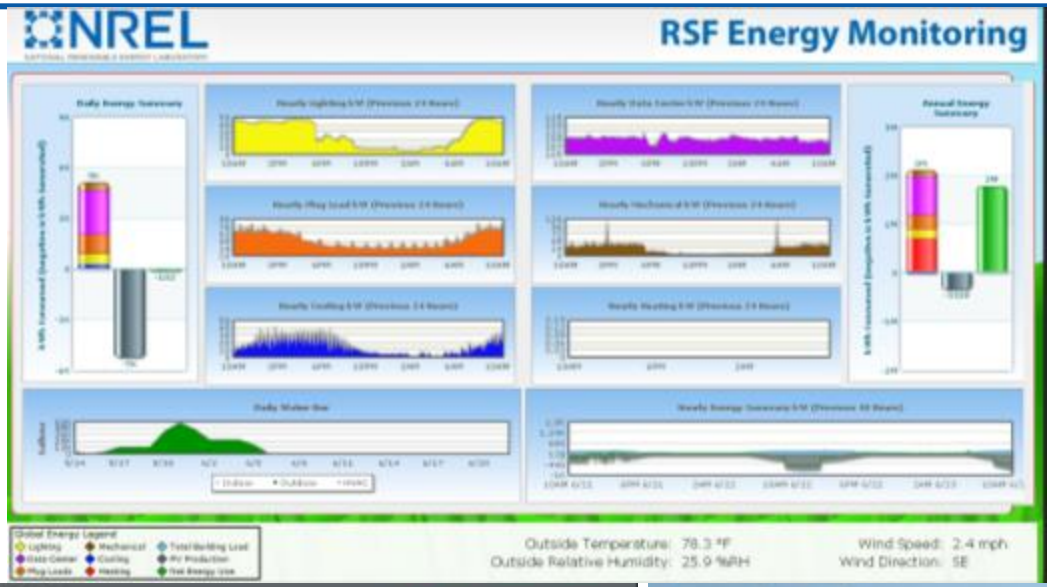
Annual Energy Use Intensity Comparison

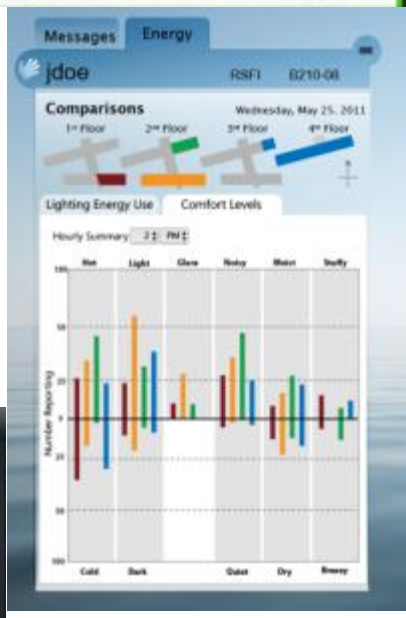
Credit: Chad Lobato/NREL

LEARNING/FEEDBACK

Reaching Goals: Big Points

- Use M+V to ensure measurable design goals are met
- Use energy model end use predictions as operational budgets
  - Need to track continuously
- Understand multiple audiences and how to influence decisions with M+V info
  - Executives
  - Occupants
  - Operators
  - IT Managers
  - Data Center Managers
- Use incentives during warranty period
  - Fix controls
  - Fix meters





Living in a ZEB: Every Watt Counts

- Whole building energy use = 283 Watts continuous per occupant
  - 4-5 incandescent light bulbs per occupant continuous
  - $8500 of PV per occupant
- For every 1 watt continuous we save, we avoid $33 of PV needed to offset this 1 watt
- Every watt counts!

- Occupant education user's manual
  - Windows, lights, standby modes

$375,000

RSF Addition Daylighting Enhancements

User Friendly Windows

Photovoltaics

- PV contractor involved with installation
- Installation technique improvements
- Standing Seam Roof

What Worked

- Performance based design build with energy performance requirements on a firm fixed price
- Vacancy sensors in daylit spaces
- Plug load efficiency
- Insulation and thermal mass
  - Attention to details
  - Ask for a continuous insulation system
  - Focus on envelope component junctions

What works (cont.)

- 0.6 W/ft^2 lighting power density with high efficiency T8s
  - Daylighting controls with north windows
  - Passive glare control with overhangs and NO shades/blinds
- Systems to turn equipment off
  - Lights
  - Fans
  - Pumps
  - Plug loads
- Decoupled outdoor air with water hydronic heating and cooling
- Power purchase agreements for PV

- Passive and SIMPLE!
- BUT need to align operations with design intent…

Thanks and Questions

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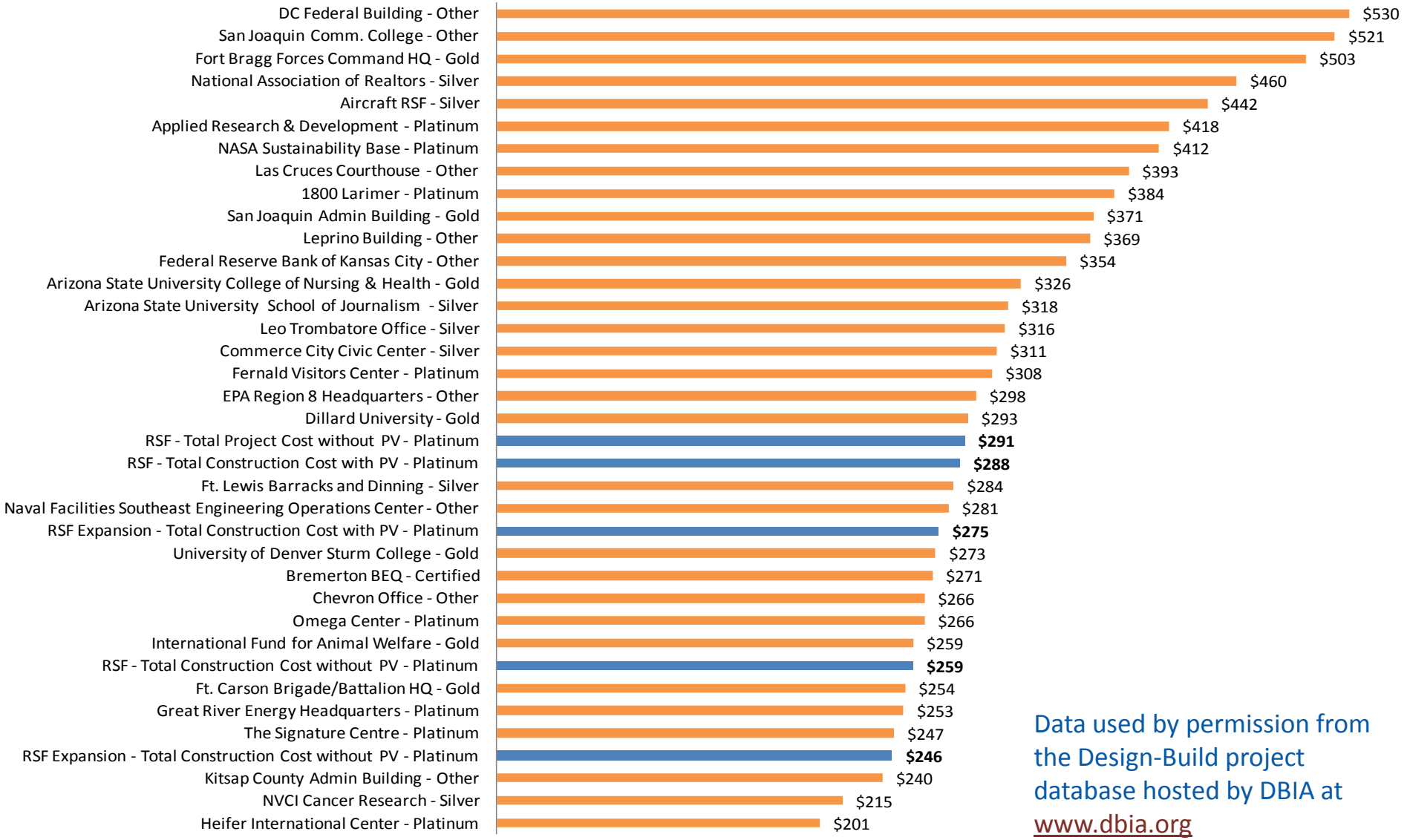
www.nrel.gov/rsf

How Much Did It Cost?

- $259/ft^2 construction costs for site work, infrastructure, and building
  - Includes interiors, furniture, and cabling
  - Does not include PV, land, or design costs
- Third-party-owned power purchase agreement for PV
  - $29/ft^2 or 11% additional cost if NREL had purchased all PV without tax breaks or subsidies (at $5/Watt)

Compare



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