Integrating Renewable Energy Systems in Buildings




British Columbia and Vancouver Island ASHRAE Chapters

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Sheila J. Hayter, PE, FASHRAE

2018-19 ASHRAE President

National Renewable Energy Laboratory

Golden, Colorado USA

Distinguished Lecturer (DL) Program

This ASHRAE Distinguished Lecturer is brought to you by the
ASHRAE Society Chapter Technology Transfer Committee (CTTC).

- Please silence your phones.
- DL Evaluation Forms are very important. Please complete at the end of the presentation and return to the CTTC Chair or Program Chair.
- Lecturer presentations and/or opinions do not necessarily reflect the policies or position of ASHRAE or the chapter.
- More information on the DL Program available at: ashrae.org/distinguishedlecturers

Who is ASHRAE?

- Founded in 1894
- >52,000 volunteer members
  - >4000 student members
- Members in > 130 countries
- 15 regions
- Nearly 200 chapters
- Partnerships
  - 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!

LEADERSHIP WANTED!

Become a future leader in ASHRAE – Write the next chapter in your career!

ASHRAE members who are active at their chapter and society becomes leaders and bring information and technology back to their job.

You are needed for:

- Society Technical Committees
- Society Standard Committees
- Young Engineers in ASHRAE
- Chapter Membership Promotion
- Chapter Research Promotion
- Chapter Student Activities
- Chapter Technology Transfer

Find your place in ASHRAE and volunteer
ashrae.org/volunteer

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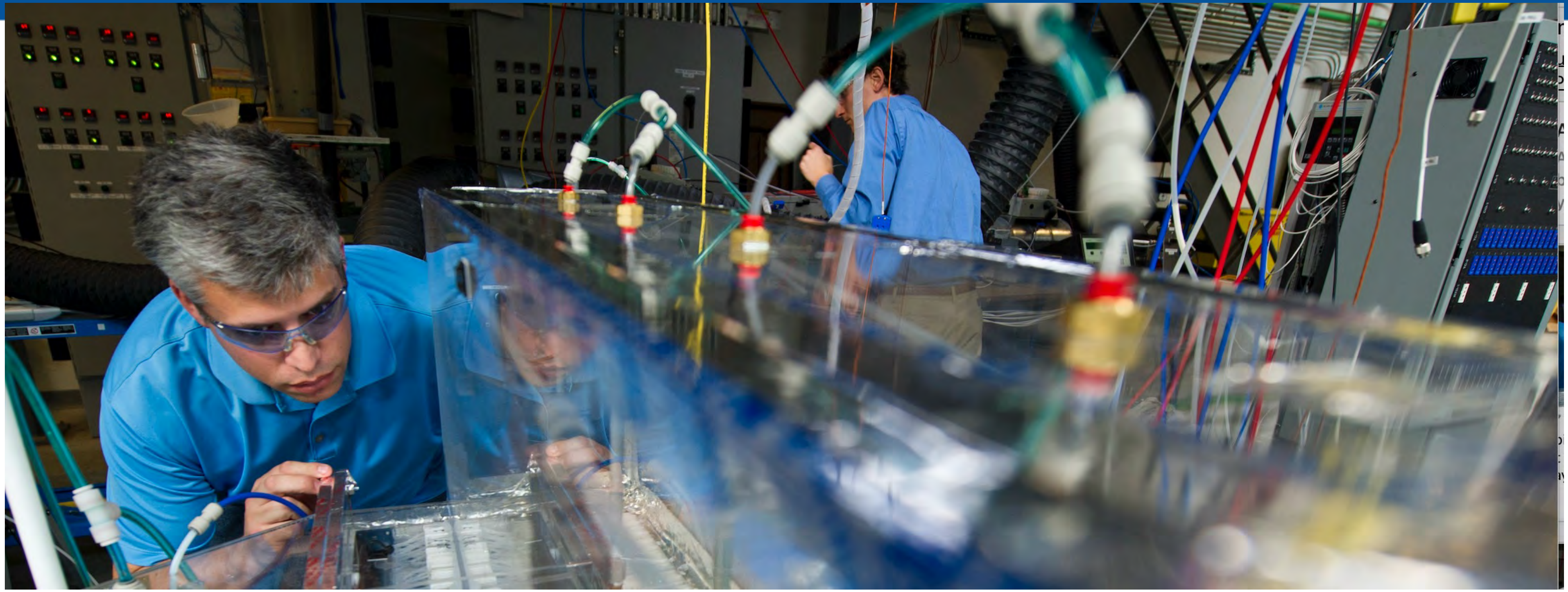
ASHRAE - Shaping Tomorrow's Built Environment Today



Mission: To serve humanity by advancing the arts and sciences of heating, ventilation, air conditioning, refrigeration and their allied fields.

Vision: A healthy and sustainable built environment for all.

Why Integrate RE Systems in Buildings?

- Buildings account for ~40% of worldwide annual energy consumption, >60% of worldwide electricity, and 33% of worldwide greenhouse gas emissions
- Most of world energy consumption is from fossil fuels (~83%)
- 65% to 80% of the buildings that will exist in 2050 already exist today
- Projected global energy consumption to increase nearly 50% from 2018 to 2050

Total global energy consumption in 2019 was >173 trillion kWh (591 quadrillion British thermal units [Btu])

Buildings consumed about 40% - 69 trillion kWh (236 quadrillion Btu).

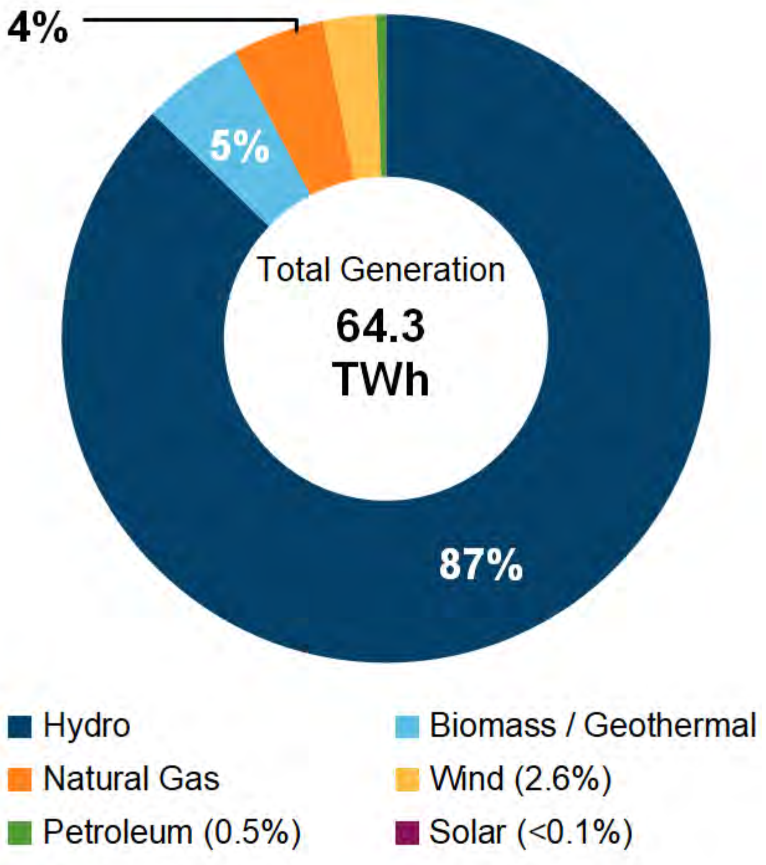
Energy use and production in British Columbia

- In 2020, B.C. accounted for 35% of the total Canadian natural gas production, averaging 5.38 billion cubic feet per day (Bcf/d).
- B.C. is the 4th largest producer of electricity in Canada (~ 10% of total Canadian generation). About 95% of B.C.'s electricity is generated from renewable resources.
  - ~ 87% is produced from hydroelectric sources, most of which is located on the Columbia River.
  - ~5% is generated from biomass, which relies mostly on waste from B.C.'s extensive forestry industry. B.C. is the larges biofuels consumer in Canada.
  - Other sources of power include wind, solar, natural gas, and refined petroleum (used in off-grid communities).
- In 2019, annual electricity consumption per capita in B.C. was 11.8 MWh, 21% less than the national average and ~13% lower than in 2016.
  - The residential and commercial building sectors combined are the largest electricity consuming sector in B.C. consuming 19 TWh and 15.1 TWh, respectively (total 34.1 TWh).
- B.C.'s per capita emissions are the lowest in Canada at 12 tonnes of $C0_2e$, 32% below the national average. B.C.'s emissions have increased 20% since 1990.
- B.C.'s electrical grid greenhouse gas intensity (GHG emitted in generating B.C.'s electrical power) was 7.6 g of CO_2e per kWh in 2020, a 70% reduction from 2005. The 2020 national average was 110 g of CO_2e per kWh.

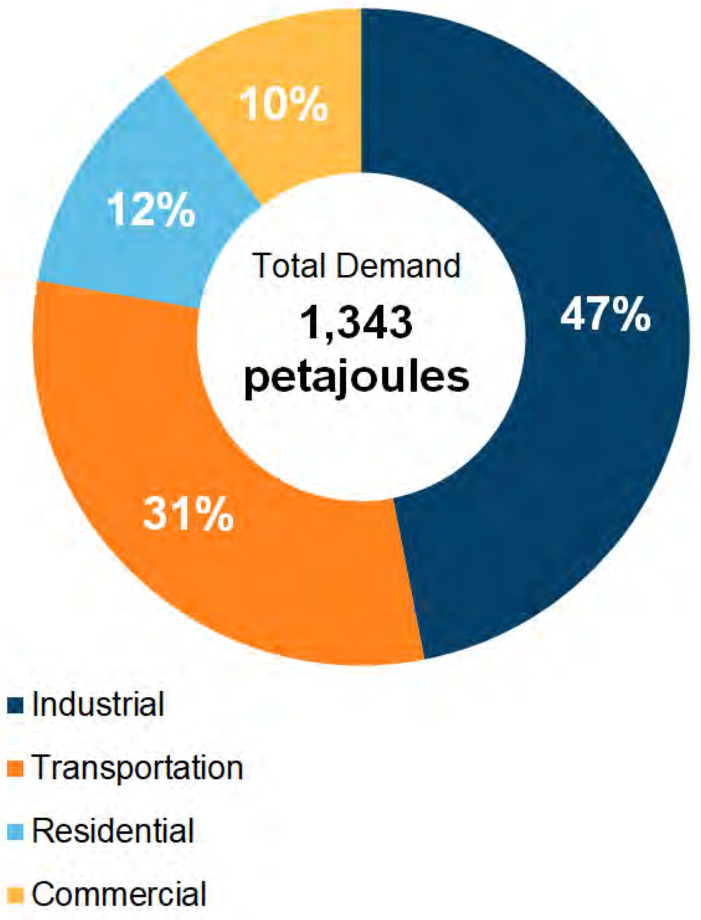
https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-british-columbia.html

Energy use and production in British Columbia

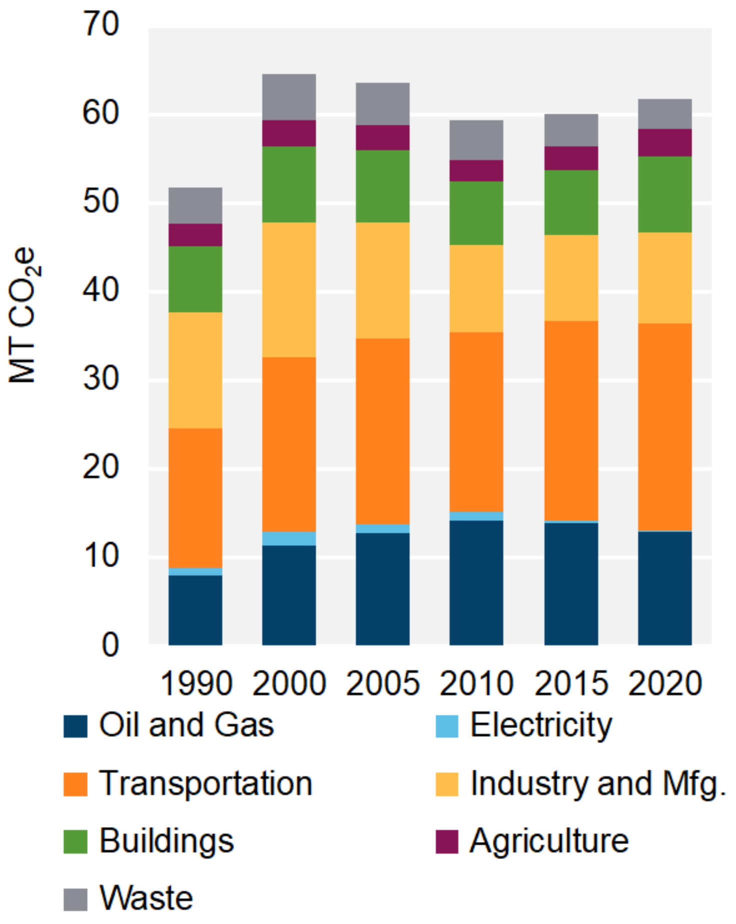
Electricity Generation by Fuel Type (2019)



End Use Demand by Sector



GHG Emissions by Sector



https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-british-columbia.html




RENEWABLE ENERGY RESOURCES AND TYPICAL APPLICATIONS

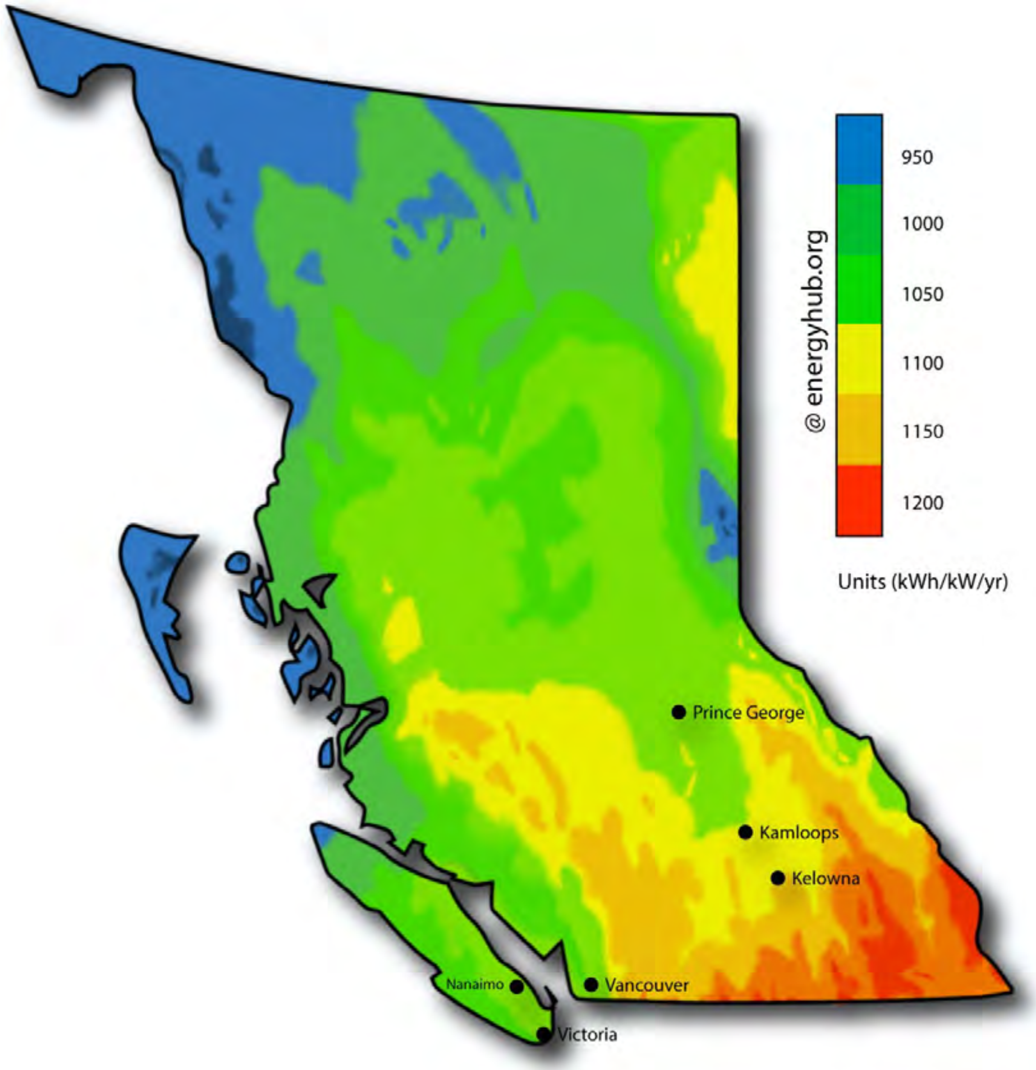
What RE Technologies are Available for Building Applications?

- 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 <u>all</u> renewable energy projects:

Determine resource availability of the renewable energy technologies under consideration

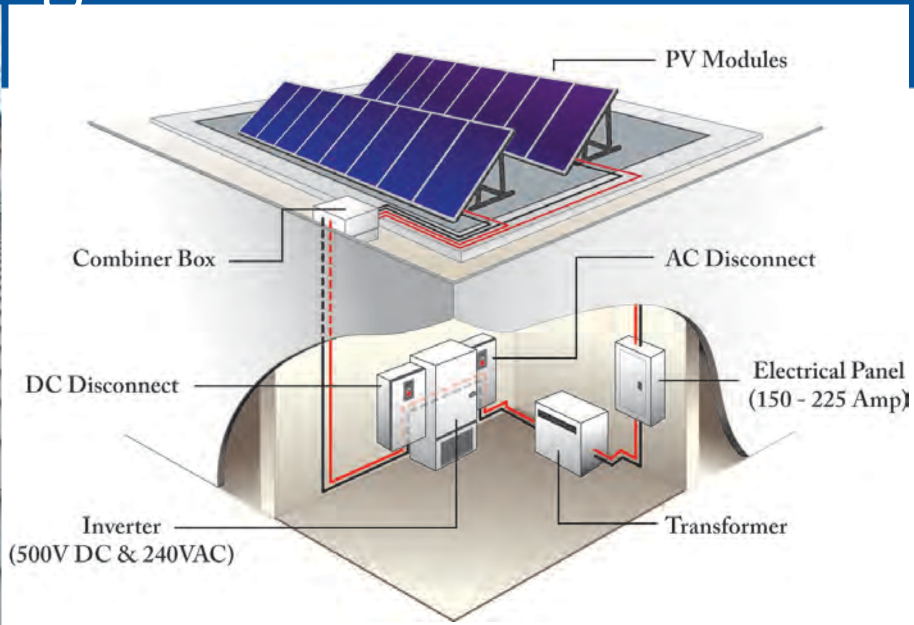


https://energyhub.org/solar-energy-maps-canada/

Typical Solar Applications for Buildings

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

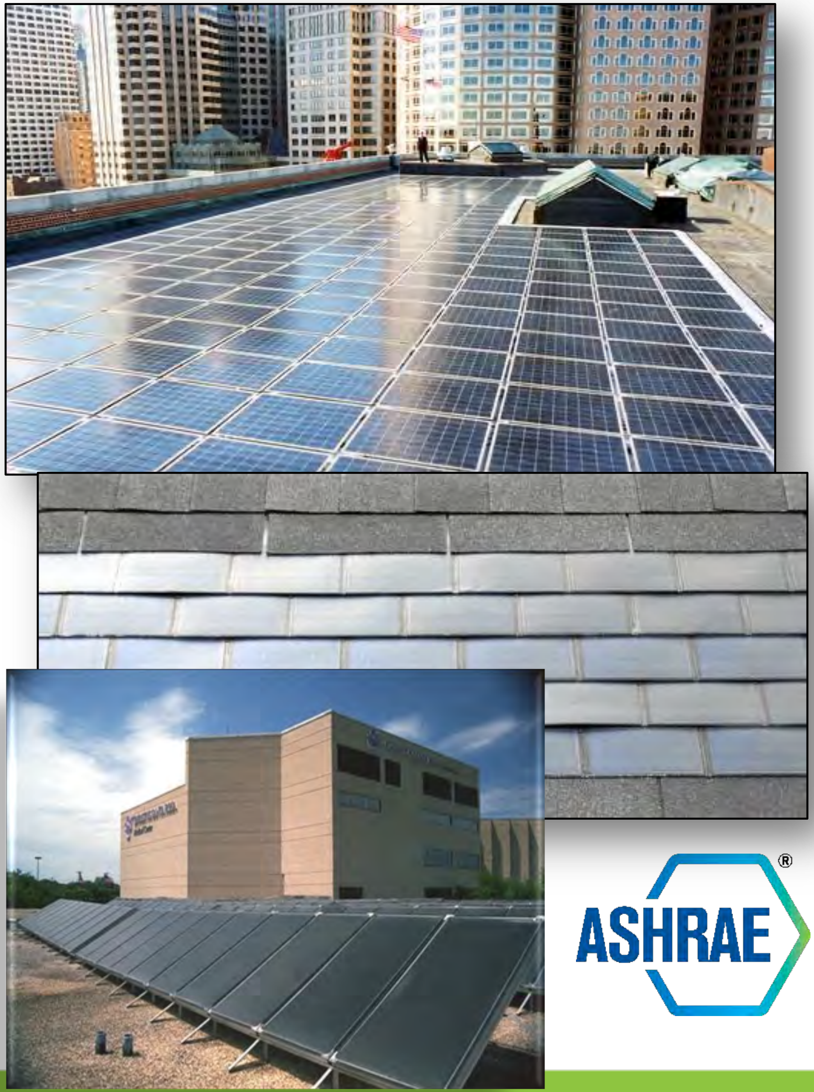
- Solar thermal systems for hot water



Source: Jim Leyshon, NREL

Solar System Considerations – PV and Solar Water Heating

- Install array in an un-shaded 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, but not required
- 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



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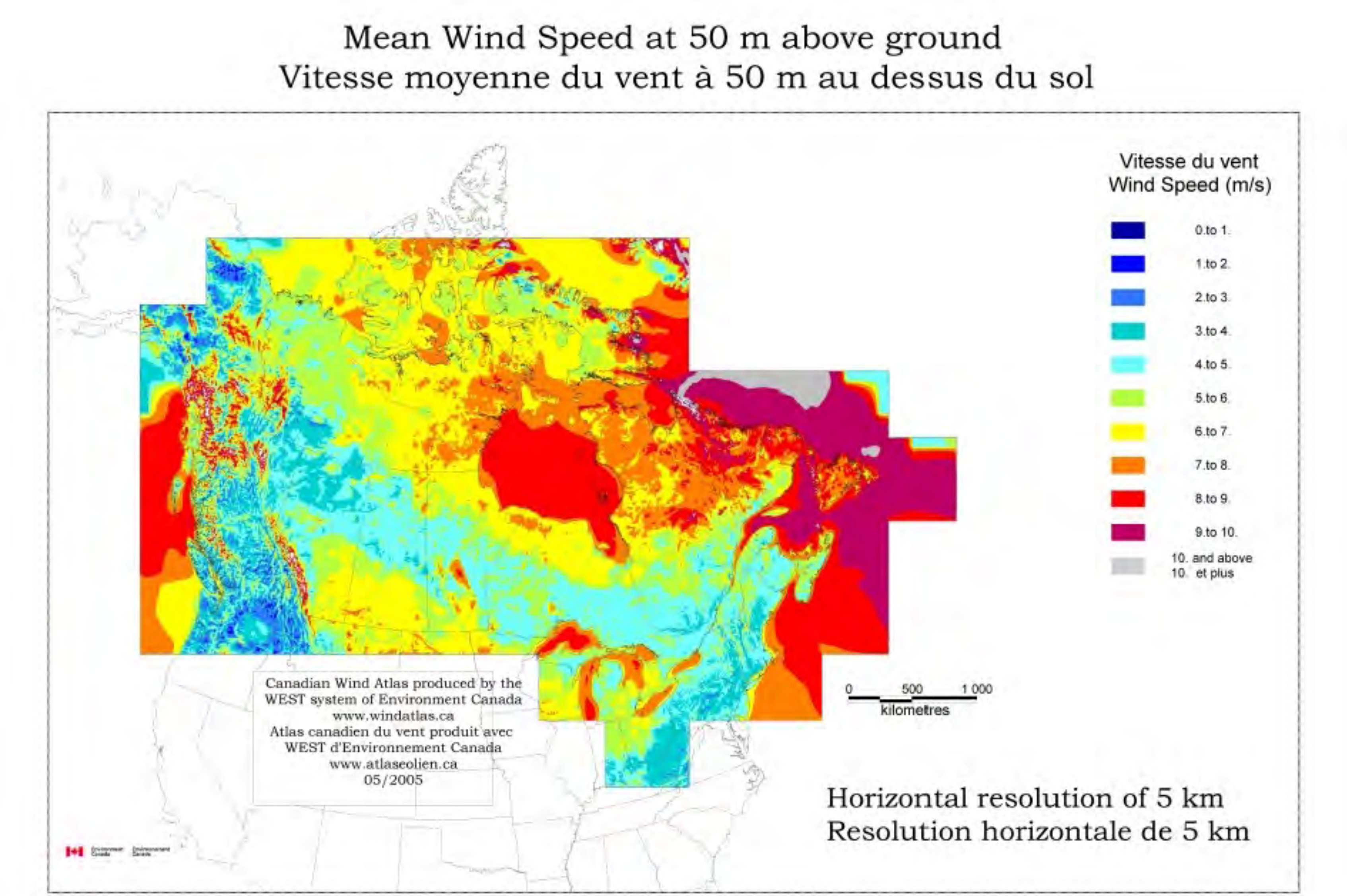
Wind Applications



Source: Canadian Wind Energy Atlas (Environment Canada) www.windatlas.ca

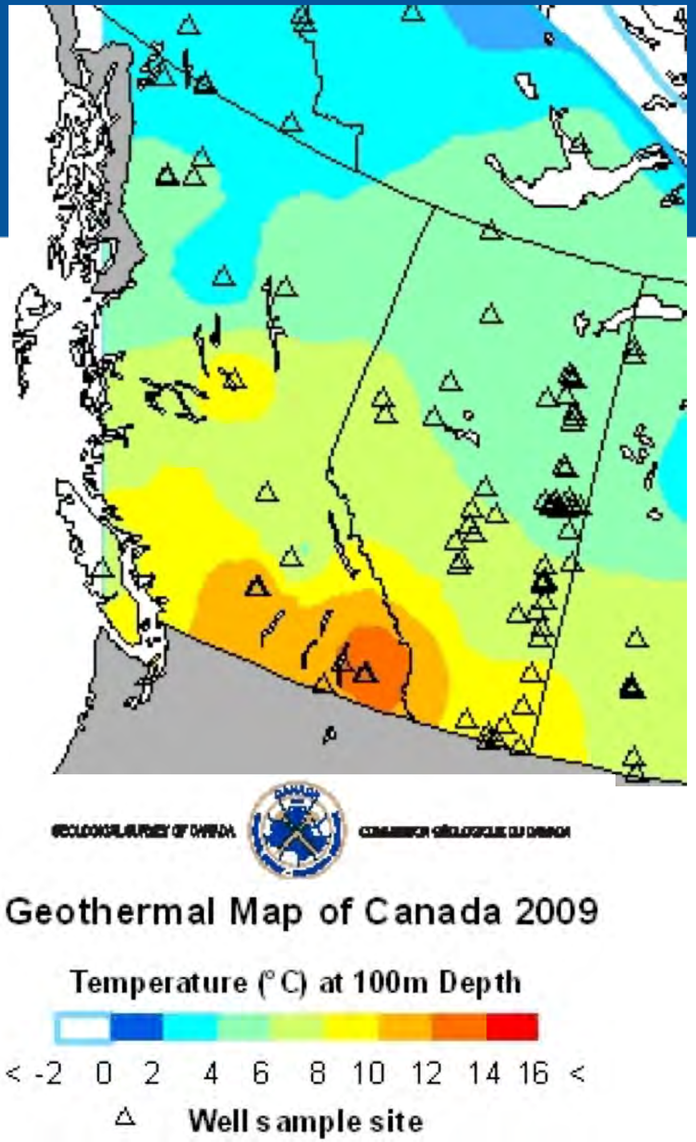
Wind System Considerations

- 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

Geothermal

- 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



Source: Geological Survey of Canada Open File 6167, 2009, *ftp://ftp.geogratis.gc.ca/pub/nrcan_rncan/publications/ess_sst/247/247765/of_6167.pdf*

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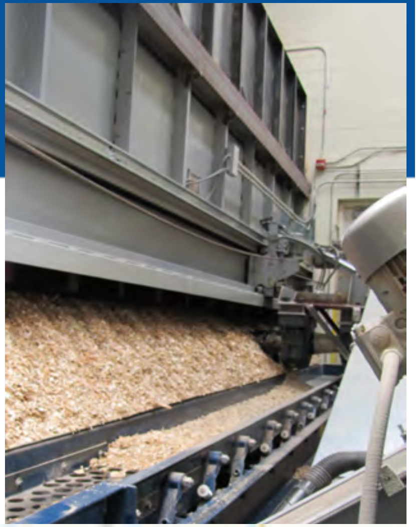
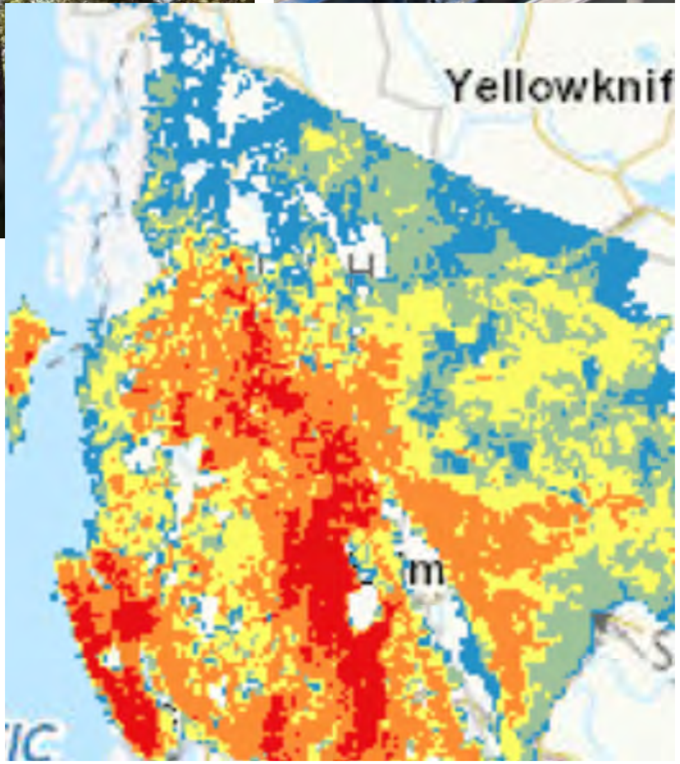
Biomass Technology Applications

- 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





Logging Residues
www.open.Canada.ca

RE in Building Project Considerations

- 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 (https://www.dsireusa.org/)
- 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

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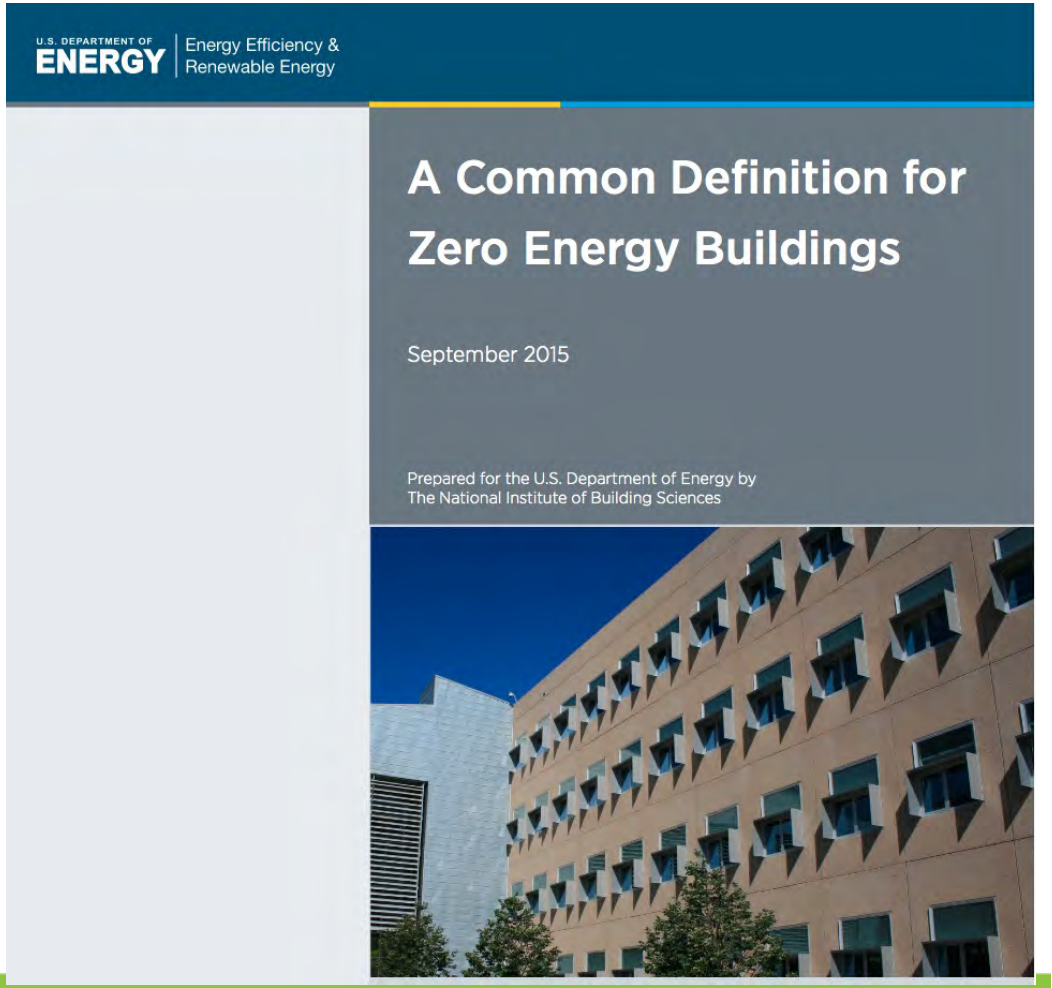
Research Support Facility (RSF) –
A NET Zero Energy Facility

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
- Site, source, carbon, cost ZEB
  - 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

Credit: Haselden Construction

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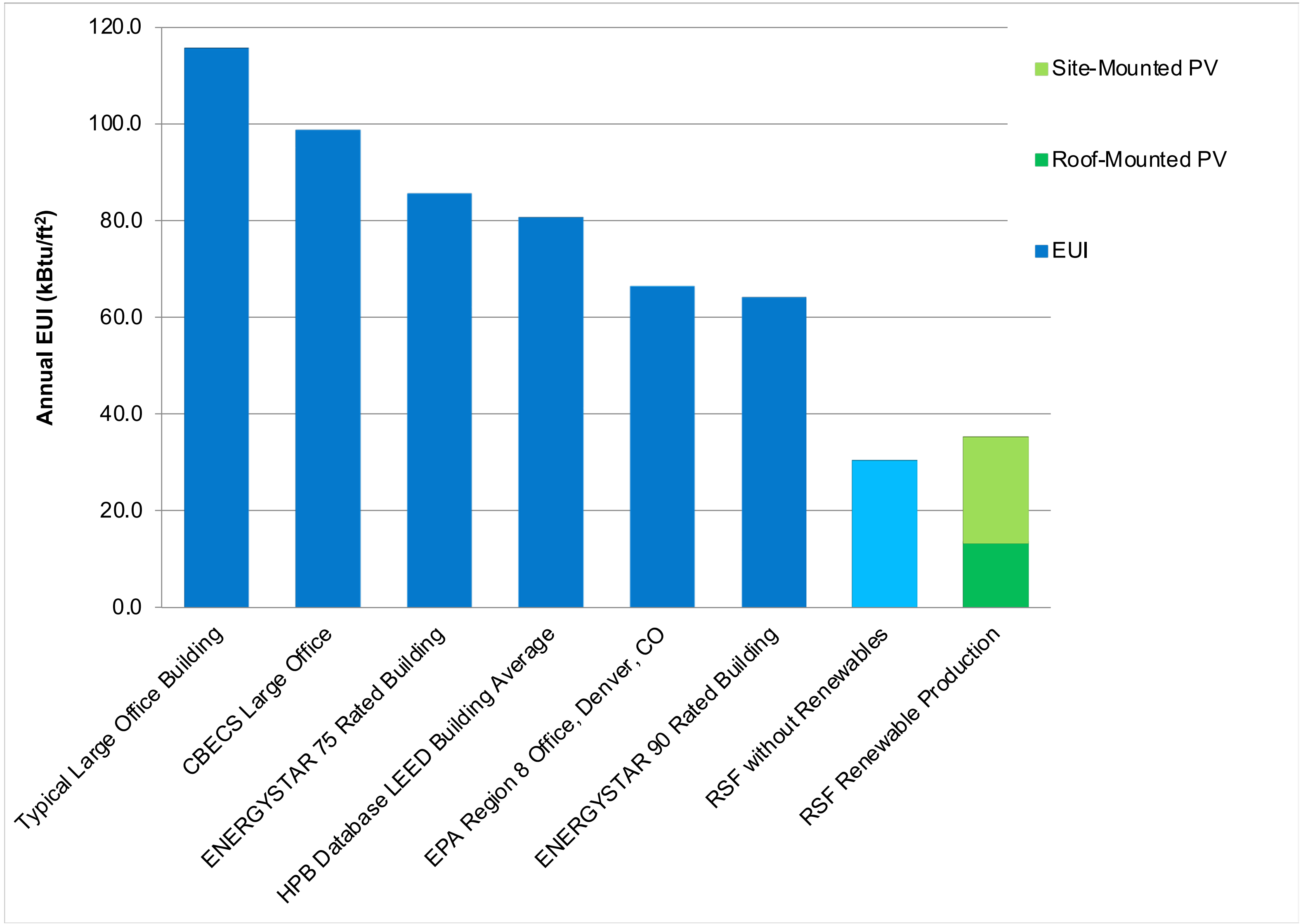
RSF Design Requirements Comparison

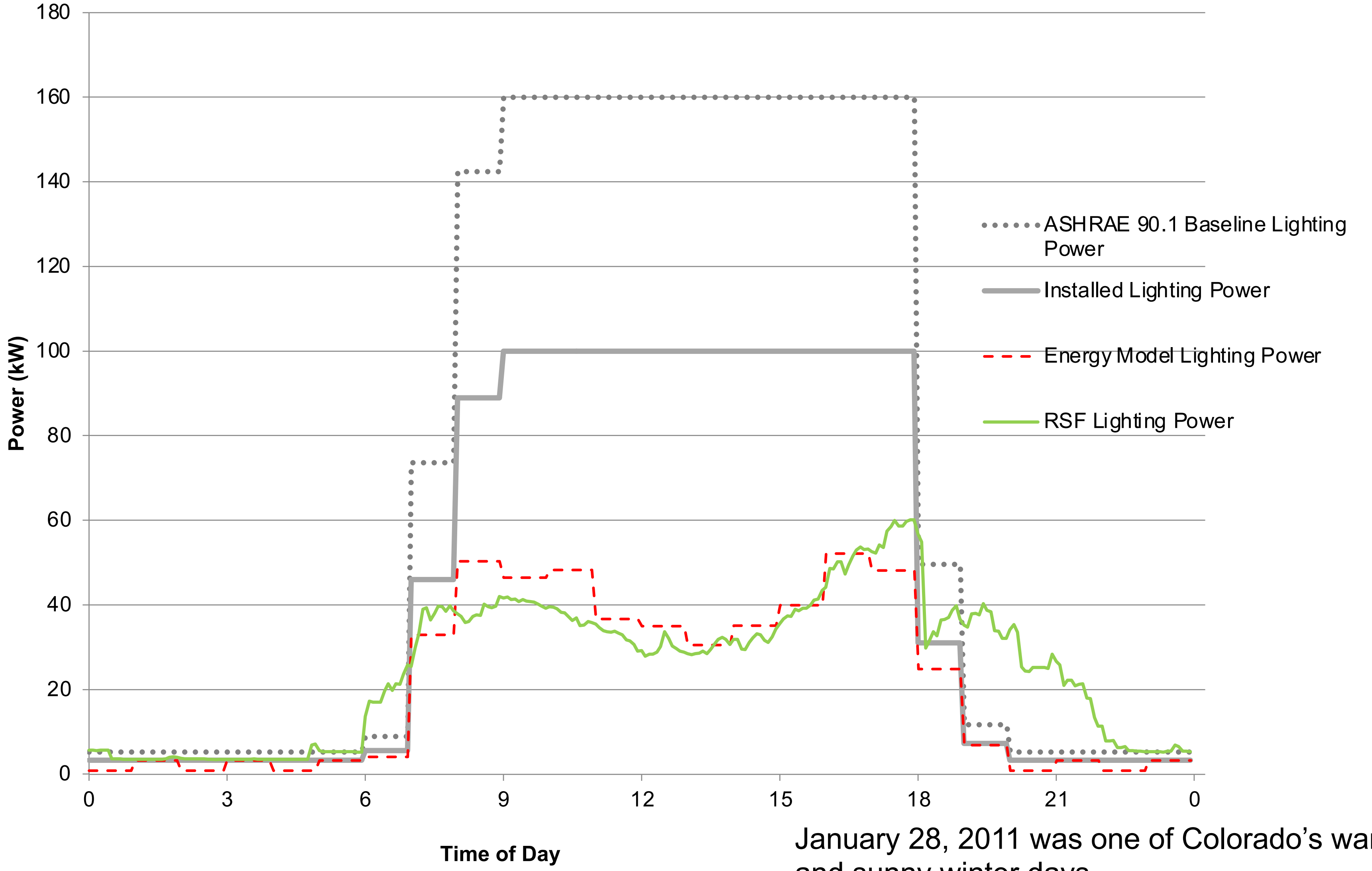


Credit: Chad Lobato/NREL

Daylighting

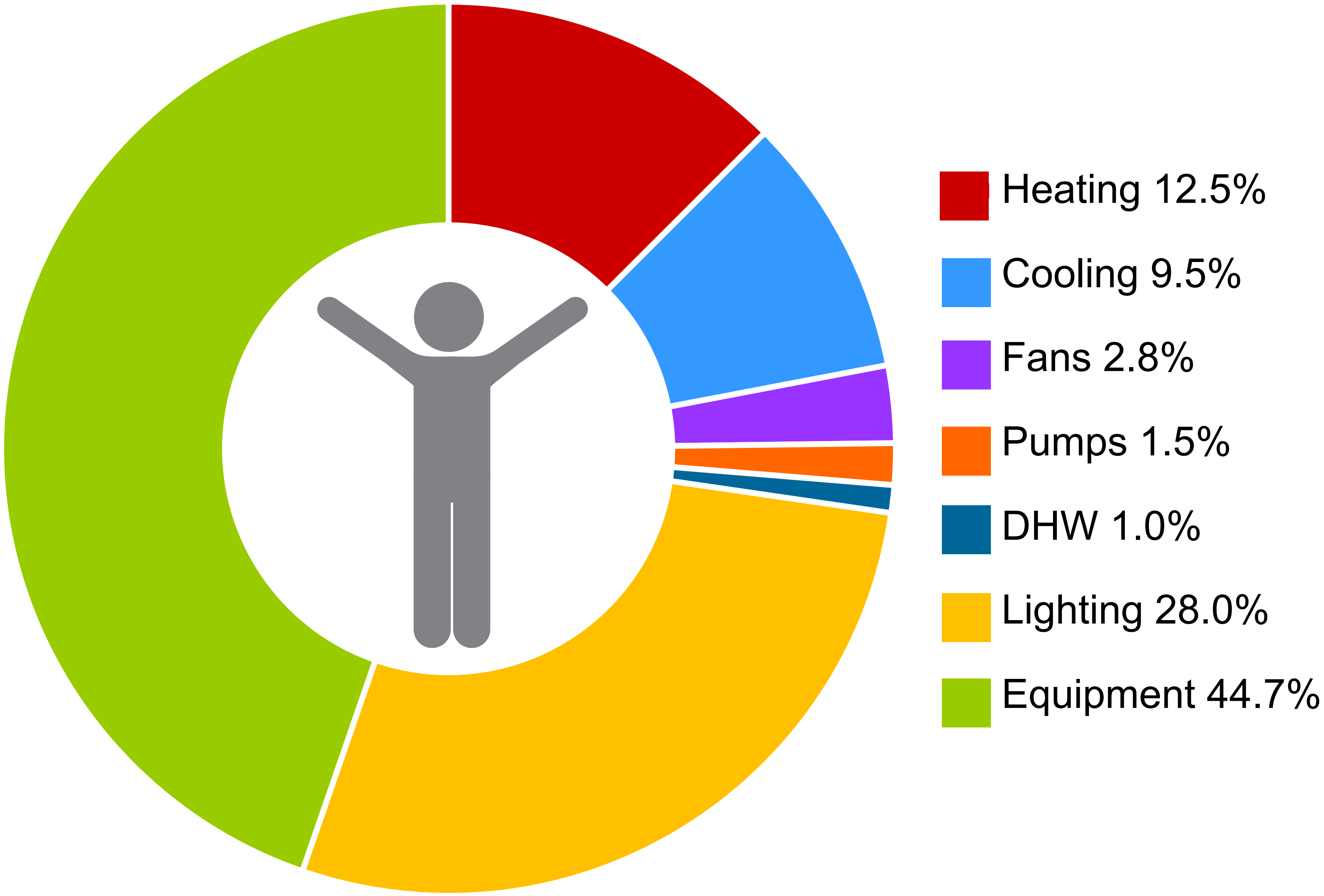
- 100% of the workstations are daylit
- Light enters through the upper glass and highly reflective louvers direct it toward the ceiling and deeper into the space
- Light-colored, reflective surfaces and low cubicle heights permit the penetration deep into workplaces

January 28, 2011 Lighting and Daylighting



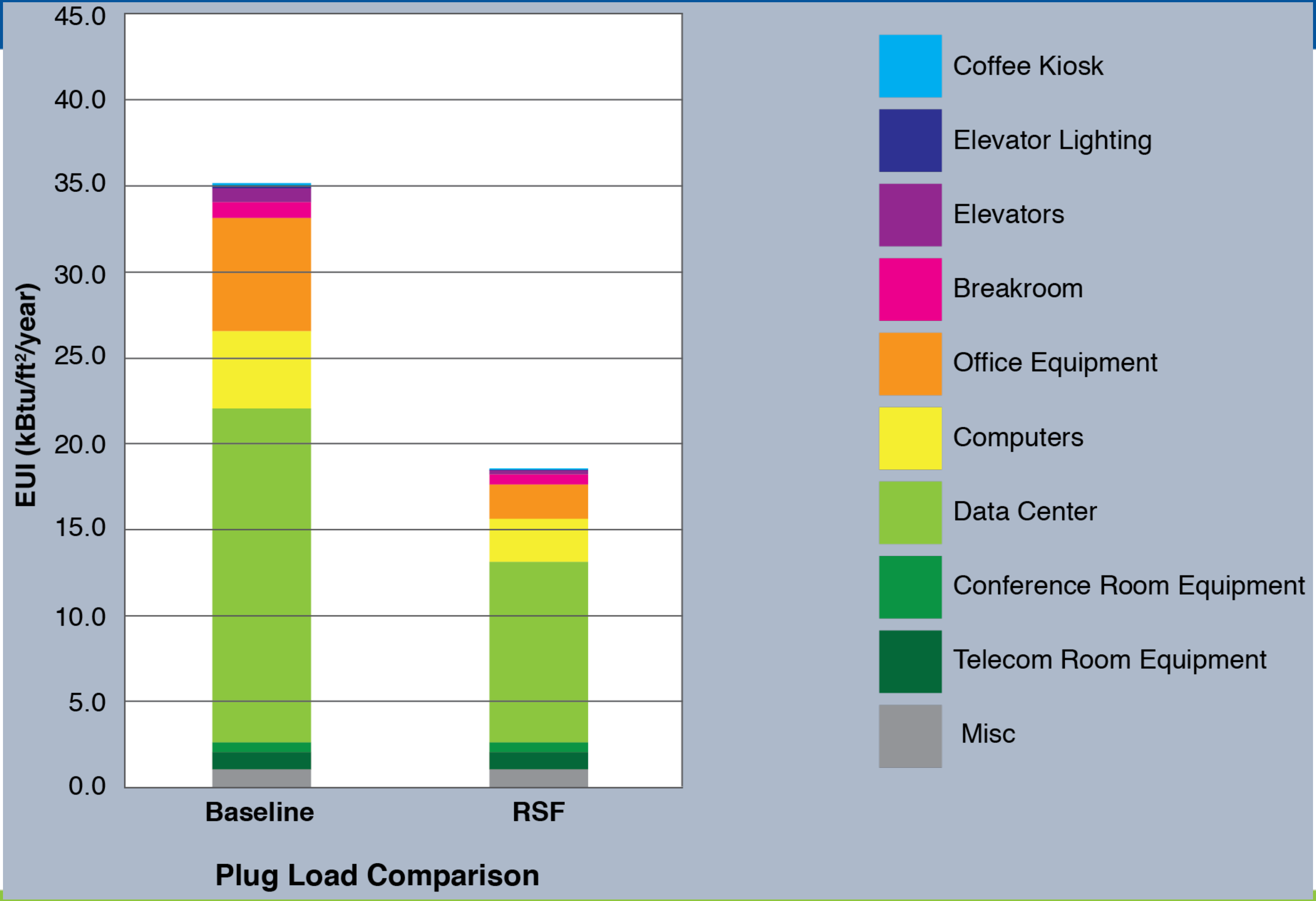
January 28, 2011 was one of Colorado's warm and sunny winter days.

What Energy does an Occupants Influence?



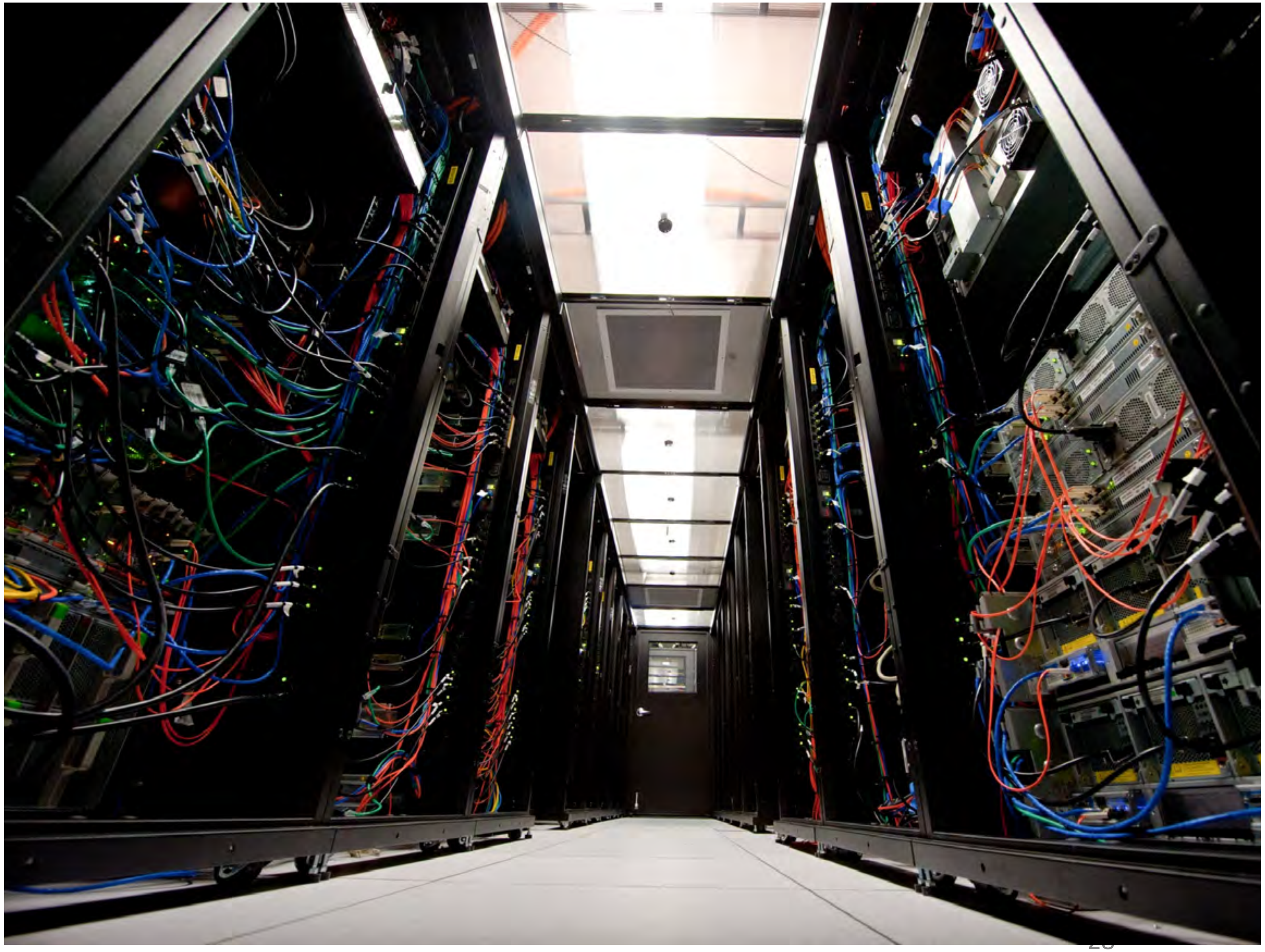
DOE Commercial Reference Building: Large Office, Boulder, CO

RSF Plug Loads Reduced

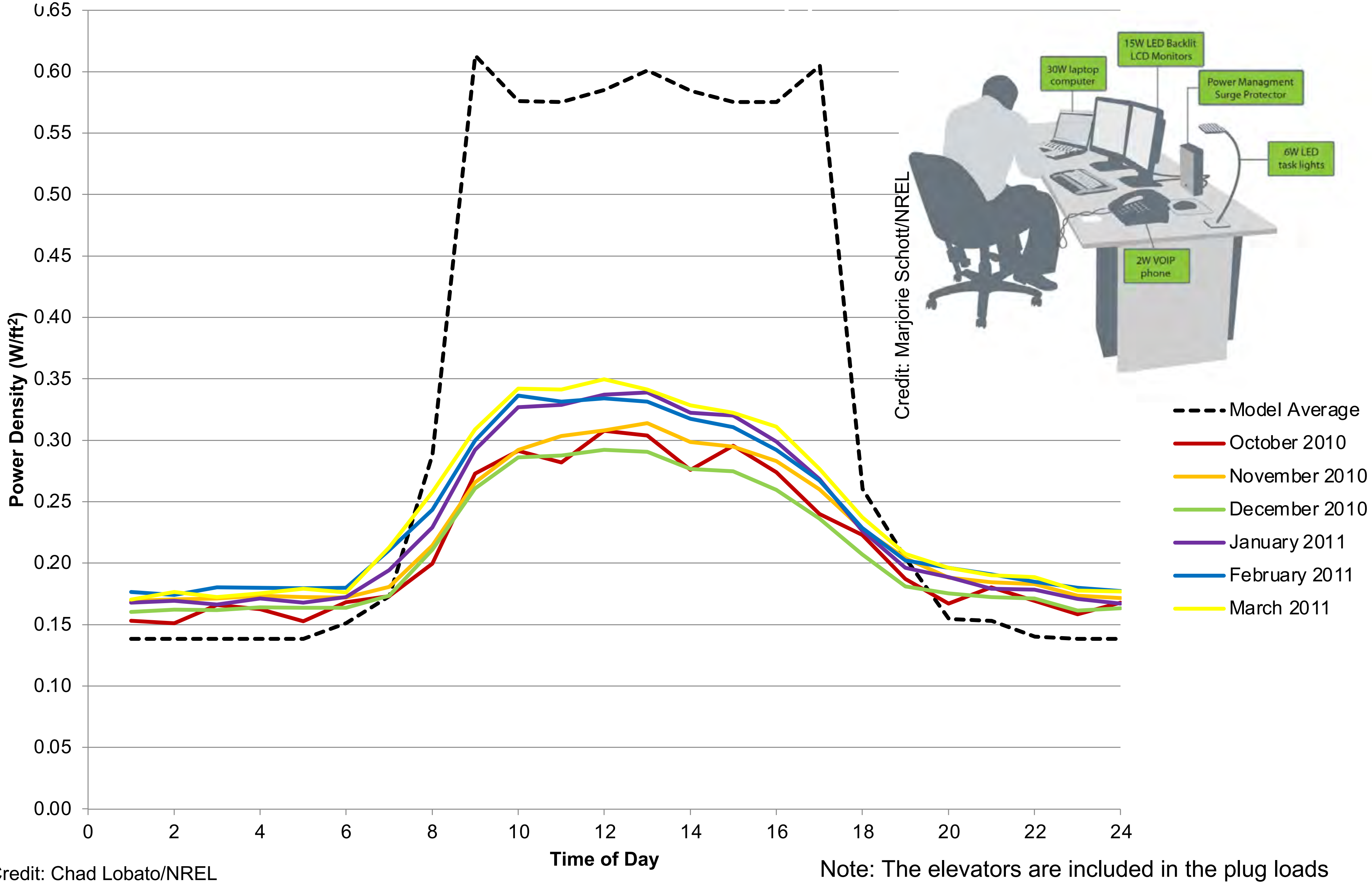


RSF Data Center – What Made It Special

- Highly efficient Data Center design in 2010 included:
  - Hot aisle containment
  - Reuse of Data Center waste heat
  - Hybrid cooling system that used free cooling first
  - State-of-the-Art power systems
  - Energy efficient equipment



October 2010 – March 2011 Plug Load Power Density



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, CO_2 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)

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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.

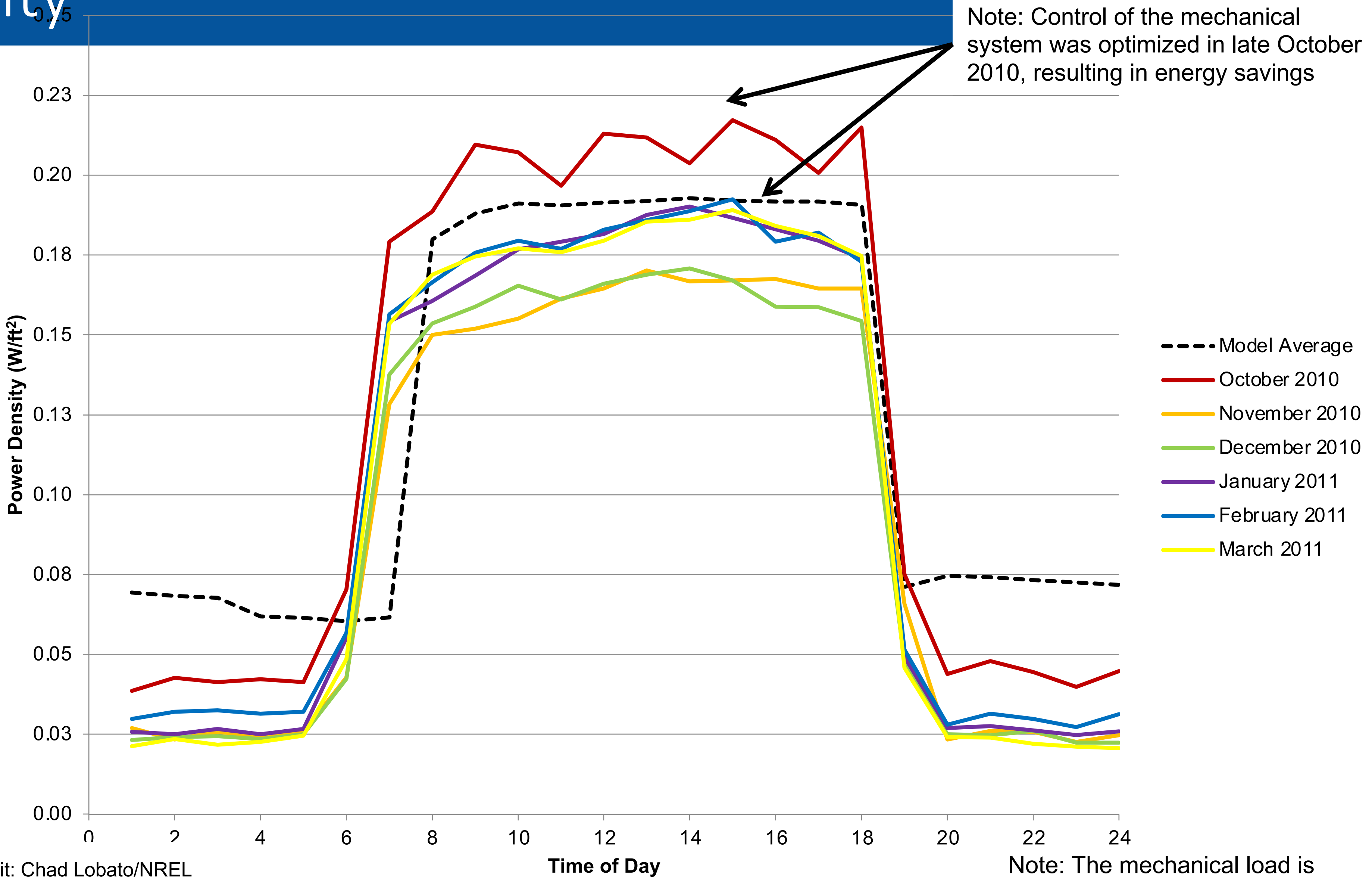
Radiant Heating/Cooling

- 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
- Heat stored in thermal mass in building’s crawl space

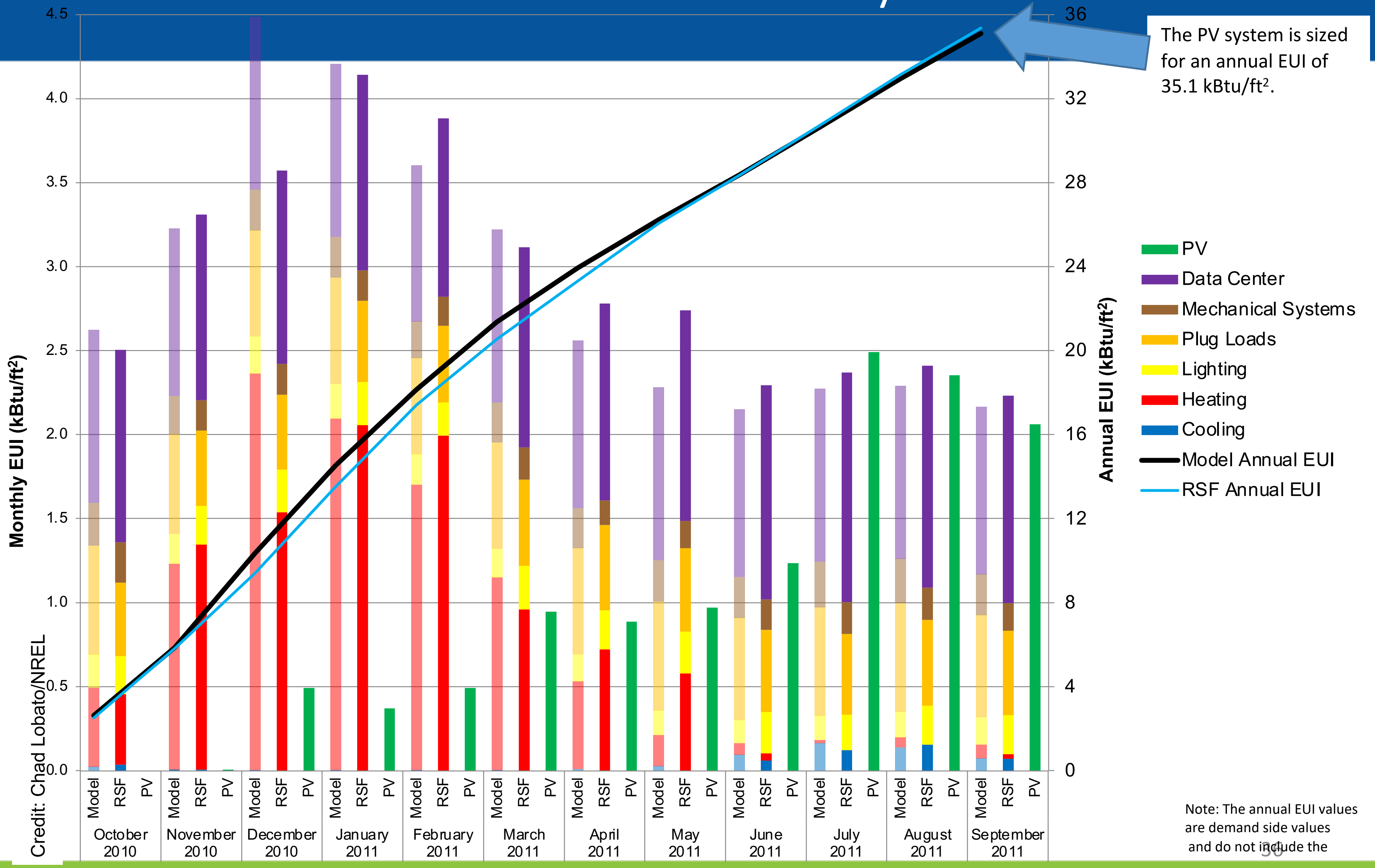
October 2010 – March 2011 Mechanical System Power Density



Credit: Chad Lobato/NREL

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

Measured Versus Modeled Monthly and Cumulative EUI



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

RSF II

- Occupied in December 2011
- 138,000 sq. ft (12,820 sq. m)
- 525 occupants
- RSF II is 17% more efficient than RSF I
- 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

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Energy Management is Essential

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

Photovoltaic Systems for the RSF

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

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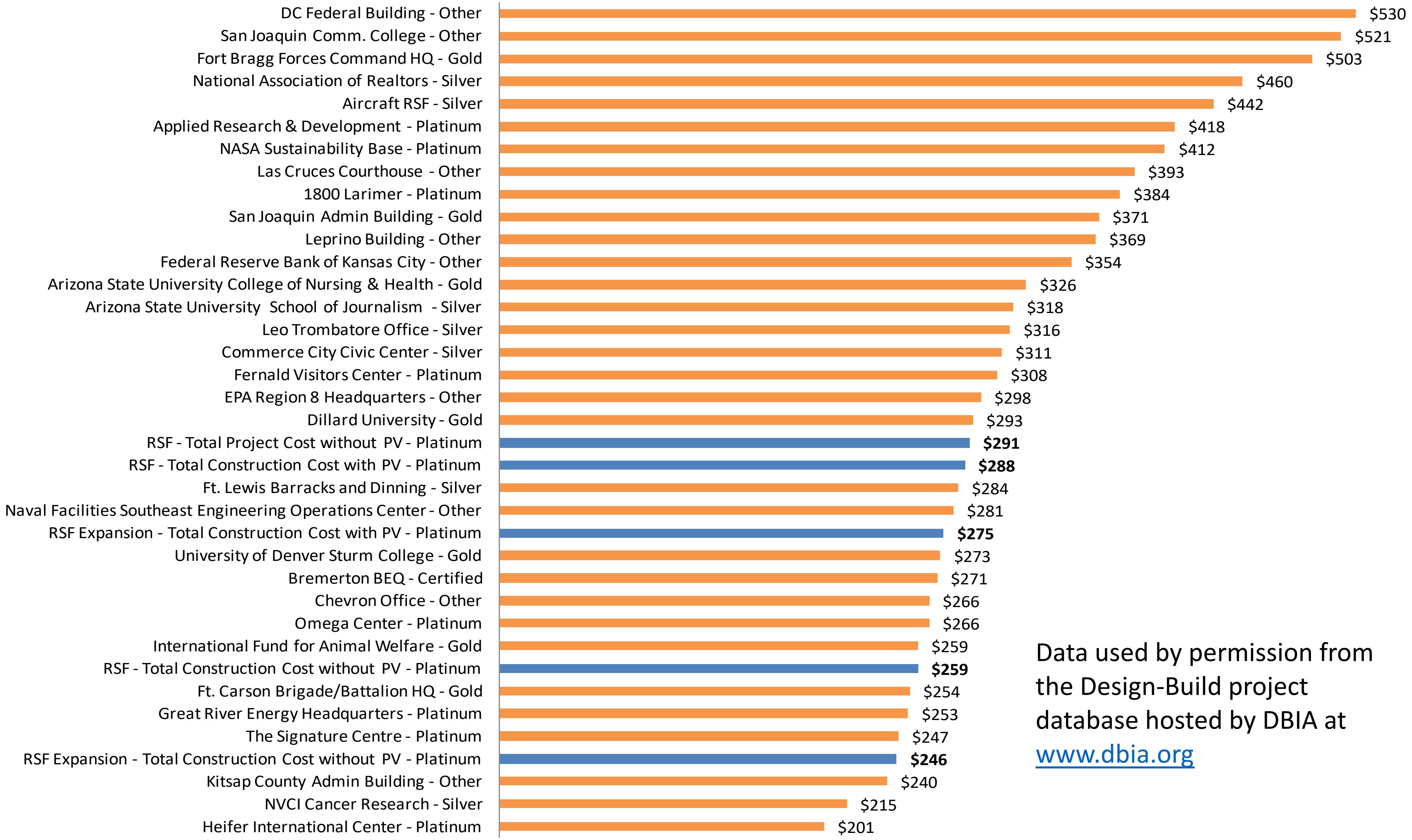
Compare



Data used by permission from the Design-Build project database hosted by DBIA at www.dbia.org

Thank You!

E-mail:

Sheila.Hayter@mail.ashrae.org