Research Support Facility Vision

- 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
Design-Build Process
Why Performance-Based Design-Build Works

- Encourages innovation
- Reduces owner’s risk
- Faster construction and delivery
- Better cost control
- Makes optimal use of team members’ expertise
- Establishes measurable success criteria
Strategy for Superior Energy Design

What Shaped Our Strategy?
• Manic focus on energy performance
• Design and culture dictate energy performance
• Whole building approach to integrate design solutions
• Owner/Subcontractor dialogue encourages creativity and trust
• Superior project definition reduces project risk and cost to all
• Traditional design-bid-build approach would not work

Key Components of Performance-Based Strategy
• Performance-based request for proposals
• National competition for conceptual design
• Design-Build acquisition strategy
• Power Purchase Agreement
Developing a Performance-Based Request for Proposals

- $64M project cost limit
- Up-front planning drives success
  - Design charrettes
  - Design Build Institute of America
  - Owner’s representatives
- Design challenge
  - Suite of performance goals to challenge team
  - Substantiation criteria

**Tier 1: Mission Critical Goals**
- Attain Safe Work/Design
- LEED Platinum
- Energy Star “Plus”

**Tier 2: Highly Desirable Goals**
- 800 Staff Capacity
- 25k BTU/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 “How To” Manual
- Allow Secure Collaboration with Visitors
- Completion by 2010

**Tier 3: If Possible Goals**
- Net Zero Energy
- Most Energy Efficient Building in the World
- LEED Platinum Plus
- 50% Better than ASHRAE 90.1
- Visual Displays of Current Energy Efficiency
- Support Public Tours
- Achieve National and Global Recognition and Awards

Up-front planning drives success:
- Design charrettes
- Design Build Institute of America
- Owner’s representatives

Design challenge:
- Suite of performance goals to challenge team
- Substantiation criteria

$64M project cost limit

Design challenge:
- Suite of performance goals to challenge team
- Substantiation criteria
How Do You Get to Net Zero?
• 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.
Design Requirements

- 25 kBtu/ft²/yr for standard office space occupant density and data center loads
- Normalized up to 35.1 kBtu/ft²/yr for better space efficiency and to account for full data center load

CBECs – Commercial Buildings Energy Consumption Survey
HPB – High Performance Building
EPA – Environmental Protection Agency
Energy Consumption in the United States

Energy Modeling

NREL RSF Energy Use Breakdown

End Use

- Space Heating: 8.58 kBTu/ft²
- Space Cooling: 0.85 kBTu/ft²
- Pumps: 0.48 kBTu/ft²
- Ventilation Fans: 1.88 kBTu/ft²
- Domestic Hot Water: 0.90 kBTu/ft²
- Exterior Lights: 0.12 kBTu/ft²
- Lights: 2.07 kBTu/ft²
- Office Plug Loads: 7.87 kBTu/ft²
- Task Lights: 0.10 kBTu/ft²
- Data Center Equipment: 10.65 kBTu/ft²
- Data Center Cooling: 0.02 kBTu/ft²
- Data Center Fans: 0.20 kBTu/ft²
Key Design Strategies

- Optimal orientation and office space layout
- Fully daylit office wings with high-performance electrical lighting
- Continuous insulation precast wall panels with thermal mass
- Operable windows for natural ventilation
- Radiant heating and cooling
- Outdoor air preheating
  - Transpired solar collector
  - Data Center waste heat
  - Exhaust air heat recovery
  - Crawl space thermal storage
- Aggressive plug load control strategies
- Data Center outdoor air economizer with hot aisle containment
- Roof top- and parking lot-based PV
Building Efficiency Features
Back to the Future

- Daylighting
- Thermal Mass
- Natural Ventilation
Daylighting

- Two long 60-foot wide wings with east-west orientation
- Design reduces electrical lighting
Daylighting: Light Louvers

A light louver daylighting system reflects sunlight to the ceiling, creating an indirect lighting effect.

Fixed sunshades limit excess light and glare.
Daylighting

- 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.
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.
Labyrinth Thermal Storage

- Massive, staggered concrete structures in the basement crawl space stores thermal energy to provide passive heating and cooling of the building.
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.
Triple-glazed windows with individual overhangs maximize daylighting and minimize glare, as well as heat loss and gain.
Window Technologies

The west elevation windows feature NREL-developed **electrochromic technology** in which the windows tint in response to a small electric current, reducing heat gain in the afternoon hours.

**Thermochromic windows** on the eastern balcony windows react to temperature change and have glass resistant to heat transfer.
Radiant Heating/Cooling

- Office wings are hydronically heated and cooled using radiant ceiling slabs.

- Five zones in each wing of the building are controlled by the Radiant Zone Control Valves.
• **42 miles** of radiant heating tubes run through the ceilings throughout the building.
Ventilation system

- Ventilation air is distributed by an under-floor air distribution system.
- Carbon dioxide sensors respond to occupancy and control ventilation when needed.
- Evaporative coolers provide cool ventilation air when needed.
- Sensible heat recovery system captures either warm or cool air from the exhaust air system to precondition the outdoor air.
RSF I and II increase NREL’s South Table Mountain square footage by more than 50% but increase campus energy use by only 10%.
Green Data Center
What Makes the Data Center Special?

- Hot aisle containment
- Reuse of Data Center waste heat
- Hybrid cooling system
- State-of-the-Art power systems
- Energy efficient equipment
• The Air Intake System brings in outside air for the majority of the Data Center’s cooling needs.
Comparison of NREL Data Centers

Cooling + Power + Equipment

PUE = \frac{\text{Cooling + Power + Equipment}}{\text{Equipment}}

Power Usage Effectiveness

Watts Per User

<table>
<thead>
<tr>
<th>PUE</th>
<th>Watts/User</th>
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</thead>
<tbody>
<tr>
<td><strong>1.1</strong> RSF</td>
<td><strong>42</strong> Watts/User</td>
</tr>
<tr>
<td><strong>3.3</strong> 17/1</td>
<td><strong>217</strong> Watts/User</td>
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## Results: 81% Reduction in Power Requirements

<table>
<thead>
<tr>
<th>Data Center</th>
<th>Watts/User</th>
<th>kW/User/Yr</th>
<th># Users</th>
<th>Data Center kW/Yr</th>
<th>CO₂ Emissions (in pounds)</th>
<th>Electricity $$</th>
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<td>2,100</td>
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<tr>
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<td>(1,533)</td>
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<td>(3,219,300)</td>
<td>(4,828,950)</td>
<td>$ (321,930)</td>
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</tbody>
</table>
RSF Power Generation
RSF Net Zero Energy PV Arrays

1146 kW - RSF Staff Parking Garage
418 kW - RSF II
450 kW - RSF I
524 kW - RSF Visitor Parking Lot
450-kW Roof-Mounted PV Installed and Operational December 2010

Hitting Zero!
Even with high-performance, innovative building features, we have found that 30% of building performance is related to occupant behavior.
Energy efficient workspace….requires new occupant behavior

- LED task lights: 6 Watts
- Fluorescent task lights: 35 Watts
- 24” LCD Energy Efficient Monitors: 18 Watts
- Typical 19”-24” Monitors: 30-50 Watts
- Desktop Computer (Energy Star): 300 Watts
- 24” LCD Energy Efficient Monitors: 18 Watts
- Typical 19”-24” Monitors: 30-50 Watts
- Laptop: 30 Watts
- Desktop Computer (Energy Star): 300 Watts
- Workstation load: 70W; 300W continuous power draw per person (entire building)
- iGo Power Smart Towers: Reduces “vampire” energy use
- VOIP phones: 2 Watts
- Removing personal space heater: saves 1500 Watts
- Multi-function Devices: 100 Watts (continuous)
- Removing desktop printers saves ~460 Watts/Printer
The RSF is a living laboratory – energy usage is continuously studied and adjusted as needed.
Energy Usage and Data

What are we monitoring?

• Everything!
  o Lighting
  o Heating
  o Cooling
  o Plug Loads
  o Data Center
  o Daylighting
  o Mechanical System Power Density
  o Outdoor Air Temperature
  o Monthly End Use Energy Consumption
  o Elevator Lighting
  o PV Output
RSF Weekday Plug Load Power Density

Power Density (W/ft²)

Time of Day

Model Average
- October 2010
- November 2010
- December 2010
- January 2011
- February 2011
- March 2011
- April 2011
RSF II

- 138,000 sq. ft.
- 525 occupants
- $39 million expansion
- Building 17% more efficient than the RSF
- Cost savings of 5%
- Completion scheduled for end of 2011
Small Improvements, Big Difference

• More efficient solar panels were purchased at a lower cost
• Less window area, while still fully daylighting office spaces
• Larger transpired collector, creating more "free" warmed air
• Better thermal breaks in the window frames, leveraging the latest in commercial windows and aluminum frames, driving down energy consumption and increasing comfort
• Displacement ventilation in conference rooms, improving thermal comfort
• Natural passive cooling in stair wells vs. mechanical ventilation in the RSF
• Daylighting controls in day-lit stairwells, allowing enhanced energy savings during the day
Sustainability and Recognition
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.

Anticipated LEED Platinum rating, version 2.2 – 59 points.
Aggregate in the foundations and slabs came from the demolition of Denver’s previous airport.

Crushed recycled glass used in the stormwater management basins outside the building.
National Media and Recognition

• Major national news stories about the RSF
  o Popular Science Online (7/6/11)
  o New York Times Online (2/14/11), New York Times Online (2/15/11)
  o Associated Press Wire Story (2/23/11)
  o Wall Street Journal (2/28/11)
• Total award count – 20
  o Engineering News Record (ENR)
    – 2011 Award of Excellence
    – 2010 Newsmaker Award
  o McGraw-Hill Construction, Outstanding Green Building, 2010
  o American Institute of Architects (AIA), Top Ten Green Project
How Did We Do?
How Did We Do?

What We Wanted

• 800 employees
• LEED Platinum
• 50% better than ASHRAE 90.1-2004
• Net zero energy goal
• Replicable whole building design process
• Competitive cost for Class A space
• As many Mission, Desirable, and If Possible goals as achievable

What We Got

• 825 employees
• LEED Platinum (59 Points)
• 50% better than ASHRAE 90.1-2007
• Net zero site energy using photovoltaics
• Documented design process
• 220K gsf @ $259/gsf of Class A space
• Every Mission Critical, Highly Desirable, and If Possible performance goal achieved

Building completed 130 days early
Construction Costs

COMMERCIAL CONSTRUCTION BUILDING COSTS - By Cost Per Square Foot

Per Square Foot Costs

PROJECTS AND LEED CERTIFICATION

NATIONAL RENEWABLE ENERGY LABORATORY