RMI Innovation Center

Monitored Data for the First PHIUS+ Source Zero Certified Office Building

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Outline

• Intro & overview of the Innovation Center
• Energy and occupancy performance
• Economics
• Lessons learned
• Conclusion
• What’s Next / Other related RMI work: REALIZE project
Building Overview

Type: Commercial office building

Use: Headquarters of Rocky Mountain Institute, accommodating 50 staff and 80 in convening center

Location: Basalt, Colorado

Size: 15,610 ft²

Completed: Dec 2015

Design Team:
ZGF – Architect
PAE – MEP
Architectural Applications – High Performance Design
RMI – Owner
J.E. Dunn - Builder
Innovation Center Highlights

Achieves **net-positive energy** (only 200 buildings are NZE as of 2015)

**PHIUS 2015+ Certification, and PHIUS+ Source Net Zero**

The **highest performing** office in the **coldest climate zone** in the US even before PV

**74% more efficient** than the average office building in its climate

**LEED Platinum (NC 2009)**

Meets the architecture 2030 goal of a **70% energy reduction**, even before the solar-electric system is accounted for

**No cooling system and a small, distributed heating** system with equivalent capacity of 1 mid sized home
Integrative and Passive Design

**Process**
- IPD process with performance pool, specifying energy goals in contract
- Deep efficiency to eliminate / reduce mechanical systems
- Focus on comfort not temperature
- Smart controls to optimize performance, while providing occupant control / overrides

**Design Features**
- Super insulation: R67 Roof, R50 Walls, R20 Slab
- R6 glazing average w/ frame
- Very tight envelope: 0.04 CFM50/ft² (0.36 ACH50)
- Passive Solar design
  - High mass + some phase change
  - Glazing tuned by orientation
- Exterior automated blinds
- Daylighting: Light shelves, dimmable LEDs
- Natural ventilation and night flush
- Targeted direct occupant conditioning
Integration and Automation

Simple concepts, complex system interplays

**INPUTS FOR SYSTEM DECISIONS**
- Temperature
- People
- Weather
- Sunlight
- Ventilation

**AUTOMATIC**
- FLOOR HEATING
- PRE-COOLING THE SPACE
- VENTILATION

**USER CAN OVERRIDE**
- AUTOMATED WINDOWS/
  NATURAL VENTILATION
- AUTOMATED EXTERIOR
  BLINDS
- WALL FANS

**USER CONTROLLED**
- MANUAL WINDOWS
- CEILING FANS
- PERSONAL COOLING/HEATING
  CHAIRS
- INTERIOR GLARE
  SHADES

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Integration and Automation

Scenario: Cooling the building before a hot day

**NIGHT BEFORE**

- System looks at predicted temp. for next day, determining how much to cool the space overnight to maintain a comfortable temp. throughout the day

- System confirms building is unoccupied, and it is not raining or windy

- If all above conditions are satisfied, all automated windows are opened and wall fans in office/conference spaces turn on

- Windows remain open until slab temp. Meets target, air temp. gets too low, morning occupancy approaches

**MORNING**

- System ensures heat does not turn on as a result of the space being cold and monitors internal temperature

- Occupants encouraged to use personal comfort technologies if cold

**AFTERNOON**

- As the space warms (measured in slab and interior), system lowers external sunshades

- Automated windows open or close based on external temperature

- Light indicates whether it is too hot/cold outside to open manual windows
This building serves as a model

The Innovation Center is right in the ‘sweet spot’ to move the market

90% of commercial buildings are under 25,000 SF

Offices are the biggest use of commercial buildings under 25,000 SF

Half of commercial buildings under 25,000 SF are owner occupied

By 2035, about three-fourths of U.S. floor space will be new or renovated.

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Monitoring and Transparency

- Real-time performance data available on energy dashboard
- More than 120 sensors and data monitors
- We collect and monitor data from plug loads, renewable solar production, energy flows (PV to battery to grid), and EVs

Total Electricity Production vs. Consumption

Kilowatt-hours of electricity consumed today

Production

29 Kilowatt-hours

Consumption

169 Kilowatt-hours

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Overall Energy Performance

- EUI Lower than expected trending towards 15.9 kBtu/ft²/yr
- Modeled EUI 17.2 kBtu/ft²/yr
- Original goal in RFP was 19 kBtu/ft²/yr
End Use Breakdown

Plug loads are becoming the dominate end use in Net Zero / Passive House buildings

June Load Breakdown

- Heating office kwh: 15.9%
- Heating Impact kwh: ~1.6 kBtu/ft²/yr
- Lighting kwh: 57.4%
- EV kwh: ~1.7 kBtu/ft²/yr
- Ventilation kwh: ~5.8 kBtu/ft²/yr
- Plug Loads kwh

June Total 3,857 kWh
Plug Load Breakdown

- Video conferencing is a large load -> opportunities for additional controls
- Monitors are significant despite specifying efficient models

July Plug loads: 2,390 kWh
Plug Loads
Seeing what’s going on
Solar Performance

- We estimate we will produce 75% more energy than the building needs by the end of the year.
- Capacity for charging 6 Electric vehicles & ensuring net positive energy balance.

<table>
<thead>
<tr>
<th></th>
<th>Consumption</th>
<th>Production</th>
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<tbody>
<tr>
<td><strong>KWh</strong></td>
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<td><strong>Feb</strong></td>
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<td><strong>Sep</strong></td>
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<td><strong>Oct</strong></td>
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**Net Energy Balance to Date (kWh):**

<table>
<thead>
<tr>
<th>Category</th>
<th>kWh</th>
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<tbody>
<tr>
<td>Building</td>
<td>-34,452</td>
</tr>
<tr>
<td>Electric Vehicles</td>
<td>-1,007</td>
</tr>
<tr>
<td>PV</td>
<td>87,541</td>
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<tr>
<td>Net Production</td>
<td>52,082</td>
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</table>
Battery System

- 30 kW 45 kWh Lithium Ion battery storage system, with customizable control system
- Reduces the building’s peak energy demand, which will help us stay below a peak demand of 50 kW, which keeps us in the small-commercial rate class.
Occupant Performance

- Daylight and spatial qualities are not to be undervalued – highlight for our staff
- Overall very positive feedback on thermal comfort
# Economics: Cost Breakdown

The most recent industry studies show a 3-16% premium for net zero energy buildings. RMI’s building incurred an 10.8% premium.

<table>
<thead>
<tr>
<th>Category</th>
<th>Description of high performance elements</th>
<th>Cost premium above baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall and Roof Assembly</td>
<td>SIPS, liquid applied air barrier, custom products-learning curve, blower door testing</td>
<td>$27/SF</td>
</tr>
<tr>
<td>Electrical specialties</td>
<td>Conduit and rough-in, BMS and advanced submetering, automated operable windows, floor heat, ceiling fans</td>
<td>$18/SF</td>
</tr>
<tr>
<td>Windows</td>
<td>High performance windows (R-12), curtain wall system from Germany, single sourced suppliers, window controls</td>
<td>$14/SF</td>
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<tr>
<td>Lighting</td>
<td>LED/OLED vs. standard linear fluorescent</td>
<td>$11/SF</td>
</tr>
<tr>
<td>HVAC</td>
<td>Less ducts and equipment, no cooling vs. 60 ton split DX system with reheat boxes and AHU’s</td>
<td>Reduction of $9/SF</td>
</tr>
<tr>
<td>Space utilization</td>
<td>Avoided HVAC equipment saved 258 SF in mechanical space</td>
<td>Reduction of $7/SF</td>
</tr>
</tbody>
</table>
| Design and Soft Costs        | 1. Highly integrated design process including construction trade partners and additional specialty consultants  
                                      2. Integrated Project Delivery (IPD) learning curve  
                                      3. Additional energy modeling fees (IESVE)                                                                                                                                 | $32/SF                      |

**Total Premium for Net Zero** $86/SF
## Economics: Savings and Benefits

<table>
<thead>
<tr>
<th>Annual operating costs</th>
<th>Annual Savings</th>
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<tbody>
<tr>
<td><strong>Energy</strong> <em>(Compared against a LEED baseline building, includes annual PPA expenses for building related PV, not for PV dedicated to EV charging)</em></td>
<td>$8,100</td>
</tr>
<tr>
<td><strong>Maintenance</strong> <em>(reduced exterior repainting, lower HVAC equipment maintenance, reduced lighting bulb replacement)</em></td>
<td>$3,000</td>
</tr>
<tr>
<td><strong>Productivity and Satisfaction</strong> <em>(3% gain in revenue per employee due to productivity increase from individualized temperature controls, natural ventilation and increased daylight availability. This is a conservative estimate based on findings from over 34 studies.)</em></td>
<td>$334,100</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$345,200/year or $22/SF</td>
</tr>
<tr>
<td><strong>Premium for net zero energy</strong> <em>(including construction and design and soft costs)</em></td>
<td>$86/SF</td>
</tr>
<tr>
<td><strong>Simple payback</strong></td>
<td>3.9 years</td>
</tr>
</tbody>
</table>

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3% Productivity Increase

34 studies compiled and analyzed by Carnegie Mellon’s Center for Building Performance and Diagnostics show...

- **3.6% average productivity gain** for individualized temperature control
- **5.5% average productivity gain** for maximized daylighting
- **9% average productivity gain** for mixed-mode or all-natural ventilation.

The Innovation Center could yield up to an 18% increase. Acknowledging that this is not a linear increase, RMI has conservatively estimated a 3% increase, which will provide a value of over $2.5 Million over 10 years.
Lessons Learned
Setting up the project for success

- Formalize goals in contract - eg. we set passive house air tightness target as a requirement in the contract
- Carry out blower door testing during construction to identify any minor leaks before they become difficult to fix
- IPD Performance pool approach has been successful
Lessons Learned

Pushing the boundaries of passive design

- ‘Oversize’ insulation instead of HVAC
- Have a plan b: allow for easy addition of cooling or heat
Lessons Learned

Controls

- Install sub metering with enough granularity to find problems and ensure building is operating as designed, but requires active management.

- Involve a commissioning agent or controls expert earlier on in the design process to check specifications, provide input, tackle **system interoperability issues**, and overcome **scope gaps**, expand scope to cover these issues.
What’s next?
Innovation Center Future Plans

• Examining options for predictive control for building, heating, cooling ventilation
• Exploring how to optimize battery use with different rate structures
• Will be sharing OPR, IPD contract, operating performance pool
• Post occupancy CBE surveys
REALIZE

Goal: design and operationalize a national business model that offers single family and multifamily residents the lowest carbon home retrofit solution, financeable through the energy savings of the home.

EnergieSprong Net Zero Retrofits, Netherlands

Criteria:
• Net Zero including plug loads
• Financed through energy savings (30 years)
• 1 week construction time
• Aesthetically pleasing

Approach:
• Aggregating demand through social housing
• Address policy barriers where they exist
• Create standardize financing mechanism
• Push industry to develop solutions, competitive but open source solutions
Thank You

Contact: Hayes Zirnhelt hzirnhelt@rmi.org

Further resources available at:
http://www.rmi.org/innovationcenter