How Buildings of All Shapes and Sizes are Achieving Zero Energy

Wednesday, July 10th, 2019
1:30 PM – 3:00 PM
Session Panel

Rachel Bannon-Godfrey
Stantec

Greg Farley
Washington College

Jason Fierko
Ewing Cole

Sarah Zaleski
DOE
Net Zero
Engineering Change
Net Zero

Innovation | Challenges | Scale
Net Zero
Playbook | Place | People
Net Zero

Playbook | Place | People

Evolving Model Uses | Regional Grids | Connection to Wellbeing
Dynamic Decision Making | Grid Citizenship | Financial Vision
NREL Research Support Facility
Net Zero Energy, Net Positive Campus
LEED Platinum, LEED Zero
360,000 sf Office, Golden, CO
NREL Research Support Facility
Site EUI 35 kBtu/sf/yr
857 kW Roof Solar + 1.15 MW Carport
Design Build with Performance Target
California Military Department HQ
Net Zero Energy, LEED Platinum
282,000 sf Site, 227,500 sf HQ Office
Sacramento, CA
California Military Department HQ
Site EUI 30.6 kBtu/sf/yr
2.5MW Solar + 10% Safety Factor
Design Build with Performance Target
Denver Water OCR Administration

Net Zero Energy, LEED Platinum

One Water Site

175,000 sf Office, Denver, CO
Denver Water OCR Administration
Site EUI 26 kBtu/sf/yr, 100% Electric
Rooftop Solar + Carport
Design Bid Build
UC Davis Student Housing West Village
Net Zero Energy, LEED Silver
3,300 Beds
175,000 sf, Student Housing, Davis, CA
UC Davis Student Housing West Village
Site EUI 21.5 - 23 kBtu/sf/yr, 100% Electric
5.5 MW Solar Carport
P3 with Performance Target
Parc Gouin
Net Zero Energy, LEED Gold
5100 sf Visitor Center
Montreal, QB
Net Positive Energy, LEED Platinum
1st CaGBC Certified Zero Carbon Building
110,000 sf Office, Waterloo, ON
evolv1
105% Energy Positive
EUI 6 kBtu/sf/yr, TEDI 2 kBtu/sf/yr
700 kW Solar (roof + carport)
- VRF System
- Condenser tied to geo-exchange field
- Back-up electric boiler
- Central heat pump plant COP > 3.1
- Heat recovery ventilation, 80% eff
- DOAS sized to fresh air
- Demand control ventilation
- Transpired solar collector for MAU
- Instantaneous electric HW heaters
- Rain water harvesting for WC, urinals
- 700kW on-site solar PV
- 28 EV charging stations
Integrated Team Approach
Life-Cycle Prioritized
Integrated Vision: Design & Performance
Permitting Issues!
Align funding for CapEx AND OpEx
A Decade of Net Zero

From NREL RSF to evolv1

Transpired Solar Collector
Daylight-Optimized Floorplate

Glazing
Thermal Labyrinth
No Cost Premium
Thermal Energy Demand Intensity TEDI

Annual heat loss from a building’s envelope and ventilation after accounting for all passive heat gains and losses

Specific TEDI targets for ZCB-Design certification
Envelope

R-30 walls (nominal)
R-40 roof
R-15 below-slab insulation at perimeter
U-0.2 windows
40% window-to-wall ratio
Foam insulation backup at spandrel panels
Transpired solar collector on southern façade
Comfort (Survival)

<table>
<thead>
<tr>
<th>House Type</th>
<th>Time to Freeze (hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive House</td>
<td>216+</td>
</tr>
<tr>
<td>SuperGreen</td>
<td>198</td>
</tr>
<tr>
<td>R2000</td>
<td>41</td>
</tr>
<tr>
<td>1980s</td>
<td>19</td>
</tr>
<tr>
<td>Outdoor DBT</td>
<td></td>
</tr>
</tbody>
</table>
Parametric Analysis
Parametric Analysis
Parametric Analysis
Three States

CMD HQ Building

EUI (kBtu/sf/yr):
- Unoccupied Unconditioned (Cold Shell)
- Unoccupied Conditioned
- Occupied Conditioned
## Four Options

<table>
<thead>
<tr>
<th>Performance Targets</th>
<th>Focus</th>
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<tbody>
<tr>
<td>Option 1: Minimal Departmental Standard</td>
<td>Energy Efficiency</td>
</tr>
<tr>
<td>Option 2: Cost Neutral and Low Carbon</td>
<td>Cost Neutrality</td>
</tr>
<tr>
<td>Option 3: Maximum Site Potential</td>
<td>Carbon Reduction</td>
</tr>
<tr>
<td>Option 4: Hybrid Option</td>
<td>Best Hybrid Design</td>
</tr>
</tbody>
</table>
Place

Castle Rock Ridge
Pincher Creek, Alberta
Carbon

30 Buildings
2.8M sf
Carbon Intensity

GHG Intensity of Electricity Generation in Canada
Dirty Grid?
Alternative energy sources:
- Solar PV
- Local Biomass
- Wind
- CHP

Clean Grid?
Fuel switch to electricity:
- No combustion
- Electric boilers
- Geoexchange
- Heat pumps
People
Plug Loads

Site Energy End Uses Breakdown

- Interior Equipment: 6,675, 54%
- Space Heating: 1,186, 10%
- Space Cooling: 1,004, 8%
- Fan: 948, 8%
- Heat Rejection: 22, 0%
- Humidification: 44, 0%
- Pump: 407, 3%
- DHW: 708, 6%
- Exterior Lighting: 259, 2%
- Elevator: 102, 1%
- Interior Lighting: 981, 8%
Plug Loads

NREL RSF 23%

CMD 54%

evolv1 46%
Food

Electricity vs Gas

CMD 16% deviation (elec + gas) Equivalent to +0.4 Site EUI

Brick Pizza Ovens...
How to Scale (rapidly)

Behavioural Messaging
Engineering Wellbeing

Grid Citizenship
GridOptimal Rating System
Redefine the Project Team (utilities)

Finance Success Stories
evolv1
Boulder Commons ZNE Lease
Developer-Driven Activity
Building Net-Positive at a Small Liberal-Arts College

Gregory S. Farley
Director of Sustainability
Washington College
Chestertown, MD

July 10, 2019
About Washington College

• Chartered in 1782
• Founding gift and naming rights from General Washington
• Liberal Arts; 1400 undergraduates
• Centers of Excellence:
  – Writing & Literature
  – the American Experience
  – Environment & Society
• Strong Environmental Value Proposition
Chestertown, MD
Semans-Griswold Environmental Hall
Semans-Griswold Environmental Hall
Semans-Griswold Environmental Hall
Building Statistics

• 9947 GSF (interior); 11,400 GSF (including decks)
• Classroom, teaching and research labs, office space
• Flow-through river water system
• $11.7M, all donor-funded
• Former brownfield site
• New home for WC’s Center for the Environment And Society
Interior Layout
Living Building Challenge

- Buildings MUST pursue Energy, Water or Materials
- **Energy**: building must be 105% net positive, and back up 10% of lighting for 1 week

http://humanaturearchitecture.com/nature/living-building-challenge/
Energy Features of SGEH

• Solar PV: 82.2 kW, 208V: 274 panels, roof-mounted
• Ground-source HVAC
• Heat recovery wheel
• Ample natural light
• LED lighting
• Battery: 46 kWh Li-ion
  – Johnson Controls
• EUI:
How did we get here?

• Decision to honor Msrs. Semans and Griswold
• Donors stipulated a “green” building
• LEED Platinum not a good fit
• Living Buildings perceived as more cutting-edge
• Expensive building on square-foot basis!
• Planning for resilience
Planning for Climate Resilience

For Colleges, Climate Change Means Making Tough Choices
PROJECT OVERVIEW

Location: Silver Spring, MD

Size: 120,000 SF (office/lab)
- 75,000 SF (parking)
- 10,000 SF (retail)
- 5,000 SF (atrium)

**Total: 210,000 sf**

Program:
- Office, Virtual Labs
- Retail, Public Space
- Parking
- Swimming Pool

Goals:
- Net Zero Energy
- All Renewables On Site
- 70-75% Reduction in Energy
- Landmark Building on East Coast
I'm a person who likes to hear why something can't be done and I'll whittle down every one of the can't's one at a time.

**KEYS TO SUCCESS**

- Net Zero Goal from Inception
- High Level Support
- Buy-In at All Levels
- Creating a Culture of “Yes”
- Technical Capability
- Collaborative Approach
- Persistence
DESIGN APPROACH

“Form and function must inform one another”
Space Temperature
Space Humidity
Higher Level of Individual Control
Individual Accountability
Training & Education
Mobile Working Environment
Open vs. Closed Office
Shared Resources

CULTURAL IMPLICATIONS
STRATEGIES

Passive
- Building Orientation
- External Shading
- Day Lighting
- Natural Ventilation
- Earth Labyrinth
- Evaporative Cooling

Active
- Geo Exchange
- Energy Recovery
- Demand Control
- Electrochromic Glazing
- Building Automation
- Plug Load Mgmt
- Renewable Energy
### METRIC

<table>
<thead>
<tr>
<th>METRIC</th>
<th>AVERAGE (90.1-2010)</th>
<th>TARGET</th>
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</thead>
<tbody>
<tr>
<td>Wall Construction U-Value</td>
<td>R-13 + R-7.5 continuous U = 0.064</td>
<td>R-16.8 continuous U = 0.060</td>
</tr>
<tr>
<td>Glazing Conduction U-Value</td>
<td>U = 0.45 (Glazing + Frame)</td>
<td>U = 0.24 (Triple Paned)</td>
</tr>
<tr>
<td>Glazing Transmission SHGC</td>
<td>SHGC = 0.40</td>
<td>SHGC = 0.23 (Clear State)</td>
</tr>
<tr>
<td>Roof Construction R-Value</td>
<td>R-20 continuous</td>
<td>R-30 continuous</td>
</tr>
<tr>
<td>Lighting Density W/SF</td>
<td>0.90 W/SF</td>
<td>0.60 W/SF</td>
</tr>
<tr>
<td>Equipment Density W/SF</td>
<td>2 -3 W/SF</td>
<td>0.75 – 1 W/SF</td>
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<tr>
<td>EUI (kbtu/sf-yr)</td>
<td>85</td>
<td>20 - 25</td>
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<tr>
<td>Solar Array (kW)</td>
<td></td>
<td>1,000 kW</td>
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**GOAL SETTING**
Restrictive Urban Site

Urban vs. Rural Site

Energy Generation Becomes Limiting Factor

Adjust Program to Meet Net Zero Goal:

- Size
- Number of Occupants
- Activity
INSPIRATION

SITE ORIENTATION
SOLAR AVAILABILITY ANALYSIS

Modeled Entire Site in Ecotect
Incorporated Shading from Adjacent Buildings
Measured Total Radiation Available on Surfaces
Determined Optimal Solar PV Placement

Two Prime Locations
- Rooftop Solar Tray
- South Façade

Prioritized Placement of PV
CLIMATE MITIGATION

Minimize Effects of Climate

Minimize Effects of Extreme Seasons

Envelope Upgrades
- Triple Paned Glazing
- Dual Low-e Coatings
- Dynamic Tinting for Glare Control
- Super-Insulated Day Light Panels (Okalux®)
- Increased Insulating Values

Energy Recovery
- Total Energy (Sensible + Latent)
- Dual Wheels
Central Atrium

Shallow Floor Plate – Maximize Day Light Penetration

Create a Hierarchy of Spaces - Mobile Environment

Shared Common Spaces – Pantries

Encourage Stair Travel

PLAN LAYOUT
Concept Development

Initial Concept

Refined Concept

Completed Office

Modeled Solution
Outdoor vs. Indoor Space

Passive Heating/Cooling
- Earth Labyrinth
- Solar Baffles
- Water Feature

Thermal Chimney
- Stack Effect
- “Engine” for Natural Ventilation

Thermal Pool
- Lap Pool
- Evaporative Cooling
- Heat Rejection Source
ATRIUM & EARTH Labyrinth
GEO-EXCHANGE LAYOUT
ACTIVE CHILLED BEAM SYSTEM
PLUG LOAD ANALYSIS

1 Laptop + Dual Monitors
OR
1 Cloud PC + Dual Monitors

Occupancy Sensors
Plug Load Management
Printer Sharing

Cloud
DAYLIGHT MODELING

DAYSIM Model

Dim Artificial Lighting System in Response to Day Light

Fully Addressable System

Glare Analysis

Incorporate into Energy Model

Day Light 100% of Office Spaces

Day Light is Adequate 70 – 80% of Occupied Hours
SOLAR TRAY:
1206X360W
SUNPOWER X22 MODULES
434 KW DC ARRAY
578 MWH/YR

FACADE:
630X300W
SOLARWORLD MODULES
189 KW DC ARRAY
200 MWH/YR

GARAGE ROOF:
1088X360W
SUNPOWER X22 MODULES
392 KW DC ARRAY
389 MWH/YR

SOLAR WALL:
35X360W
SUNPOWER X22 MODULES
13 KW DC ARRAY
10 MWH/YR

TOTALS:
2,959 MODULES
1,028 KW
1,177 MWH

SOLAR GENERATION
Integrate systems to **REDUCE** energy use

Create a system that **RESPONDS** to changes in state:

- Temperature
- Humidity
- Carbon Dioxide
- Occupancy
- Daylight
- Energy Use

Integrate the **APPROPRIATE** level of systems

Ensure integrated systems can communicate **PRIOR** to final system installation

Include provisions for the system to **LEARN** over time to improve energy efficiency
COMPREHENSIVE BUILDING ENERGY METERING
BUILDING FEEDBACK SYSTEMS
BUILDING FEEDBACK SYSTEMS
<table>
<thead>
<tr>
<th>Area</th>
<th>Energy kWh</th>
<th>Energy therms</th>
<th>kBTU</th>
<th>Associated Area (SF)</th>
<th>EUI kbtu/sf/yr</th>
<th>CO2 Factor* lb/MWH or lb/MMBTU</th>
<th>lb CO2 Emission or (Offset)</th>
<th>Metric tons CO2</th>
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<tbody>
<tr>
<td>Phase 3 Building Electric</td>
<td>(896,021)</td>
<td>-</td>
<td>(3,057,224)</td>
<td>121,711</td>
<td>25.1</td>
<td>758</td>
<td>679,184</td>
<td>308</td>
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<tr>
<td>Phase 3 Building Gas</td>
<td>-</td>
<td>(714)</td>
<td>(71,400)</td>
<td>121,711</td>
<td>0.6</td>
<td>117</td>
<td>8,354</td>
<td>4</td>
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<td>Retail</td>
<td>(87,925)</td>
<td>-</td>
<td>(300,000)</td>
<td>10,000</td>
<td>30.0</td>
<td>758</td>
<td>66,647</td>
<td>30</td>
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<td>Parking Garage</td>
<td>(17,150)</td>
<td>-</td>
<td>(58,516)</td>
<td>76,029</td>
<td>0.8</td>
<td>758</td>
<td>13,000</td>
<td>6</td>
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<tr>
<td><strong>Total</strong></td>
<td>(1,001,096)</td>
<td>(714)</td>
<td>(3,487,139)</td>
<td>207,740</td>
<td><strong>16.8</strong></td>
<td></td>
<td>767,185</td>
<td><strong>348</strong></td>
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<tr>
<td>Solar Generation</td>
<td>1,177,000</td>
<td></td>
<td>4,015,924</td>
<td></td>
<td></td>
<td>758</td>
<td>(892,166)</td>
<td>(406)</td>
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<tr>
<td><strong>Net Energy/Emissions</strong></td>
<td></td>
<td></td>
<td>528,785</td>
<td></td>
<td></td>
<td></td>
<td>(124,981)</td>
<td>(58)</td>
</tr>
<tr>
<td><strong>EPA EUI Calculation</strong></td>
<td></td>
<td></td>
<td>(3,428,624)</td>
<td>131,711</td>
<td>26.0</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

* CO2 factors for electric are from 2016 eGRID data for sub region RFCE and 2018 EIA data for natural gas

**ENERGY SUMMARY**
Solar Decathlon Design Partners Pilot

Who: YOU! Organizations ready to explore zero energy design for their next new building or major retrofit!

What: Partner with a Solar Decathlon Design Challenge student team to receive a conceptual design and basic cost estimate for a zero energy version of your building.

When: Apply by August, 2019

For more info: Attend the Solar Decathlon Networking Lunch Wednesday @ 12:30 in Regency Ballroom OR contact Holly Carr at holly.carr@ee.doe.gov
Thank You

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