Whole Building Energy Performance: Driving Towards Net Zero

October 12, 2016

Presented by: Clark Denson, PE, CEM, BEMP, LEED AP BD+C
Outline / Learning Objectives

• What are the drivers for high performance and net-zero energy buildings?

• What are the tools and approaches needed to achieving low-energy or zero-energy buildings?

• What is a net-zero energy building, anyway, and how feasible are they?

• How do you keep a building operating at peak efficiency for the long-term?
High Performance Design Drivers

- Government
  - U.S. DOE
  - 10 CFR 433
  - Executive Order 13514
  - Better Buildings Initiative

- Codes & Standards
  - ASHRAE 90.1
  - ASHRAE 189.1
  - IECC
  - IgCC

- Incentives/Rating Systems
  - LEED
  - Energy Star
  - IRS Code Section 179(d)
  - Utility Rebates

- Other
  - Architecture 2030 Challenge
  - ASHRAE bEQ
Architecture 2030 Challenge Goals

- 2005: 50%
- 2010: 60%
- 2015: 70%
- 2020: 80%
- 2025: 90%
- 2030: 100% carbon neutral
Energy Code Stringency

Improvement in ASHRAE Standard 90.1 (1975 - 2013)

Normalized EUI (1975 Use = 100)

Year


Energy Codes – Changing the face of architecture?

Too much skylight area?  Not enough skylight area?
What’s the effect of all this change?

- More use of the performance (modeled) compliance path

- Energy modeling used early in design, just to show compliance!

- Changes to ASHRAE 90.1
  - Performance Rating Method can be used for compliance
  - PRM Baseline consistent with 90.1-2004

- Specialized code-compliance energy modeling software
  - California – CBECC-Com
  - Florida – FLACom

“The only constant is change.” - Heraclitus
Tools and design approach needed for high performance buildings
Taking the right steps in the right order

- Define Needs and Goals
- Identify Appropriate Strategies
- Reduce Building Loads
- Select Appropriate & Efficient Systems
- Optimize Controls & Operations for Part-load Conditions
- Seek Synergies and Explore Alternative Power
Qualities of Analysis Tools for High Performance Building Design

- gbXML import from Sketchup or Revit
- Climate, Shading, HVAC Loads, Energy, Daylighting, Natural Ventilation, CFD all integrated into same 3D model
- Optimization functions
- Financial (LCCA) analysis
- Appropriate level of detail during each phases of design and operations ("Wizards")
- Robust and detailed HVAC system modeling
Site Conditions – Virginia Hospital
Building Orientation: Office Massing study
Building Orientation: Office Massing Study Results

- 2% is not insignificant
- Every little bit helps!
- Some building types more sensitive to exterior loads than others
- Colder climates more sensitive than warmer

<table>
<thead>
<tr>
<th>Option</th>
<th>Energy Use Intensity (kBtu/sf/yr)</th>
<th>Cooling EUI (kBtu/sf/yr)</th>
<th>Heating EUI (kBtu/sf/yr)</th>
<th>Energy Cost Intensity ($/sf/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - North-South Option</td>
<td>54.0</td>
<td>10.1</td>
<td>16.1</td>
<td>$1.29</td>
</tr>
<tr>
<td>2 - East-West Option</td>
<td>52.7</td>
<td>9.9</td>
<td>15.1</td>
<td>$1.27</td>
</tr>
<tr>
<td>% Savings</td>
<td>2.3%</td>
<td>1.8%</td>
<td>6.3%</td>
<td>1.3%</td>
</tr>
</tbody>
</table>
Load Reduction Modeling Case Study

- 11-story office building in San Francisco
- Schematic Design
- Goals
  - 2009 LEED Core & Shell
  - 24% energy cost savings over ASHRAE 90.1-2007, App. G
  - Compliance with 2013 California Title 24
- Baseline(s)
  - Design Team Concepts
  - ASHRAE 90.1-2007, App. G
Load Reduction Measures

- **Walls**
  - R-13 + R-5 c.i.
  - R-13 + R-7.5 c.i.
  - R-13 + R-10 c.i.

- **Roof**
  - R-25
  - R-30
  - R-35

- **Roof Reflectance**
  - 0.45

- **Windows**
  - U-0.29 (COG)
  - U-0.24 (COG)
  - U-0.18 (COG)

- **Windows**
  - SHGC-0.25
  - SHGC-0.21
  - SHGC-0.17
Energy and HVAC Load Results

- **Cooling Load Reduction (tons)**
  - R-13 + R-5 Walls
  - R-13 + R-7.5 Walls
  - R-13 + R-10 Walls
  - R-25 Roof
  - U-0.79 Windows
  - U-0.18 Windows
  - SHGC-0.25 Windows
  - SHGC-0.17 Windows
  - White Roof

- **Heating Load Reduction (kW)**
  - R-13 + R-5 Walls
  - R-13 + R-7.5 Walls
  - R-13 + R-10 Walls
  - R-25 Roof
  - U-0.79 Windows
  - U-0.18 Windows
  - SHGC-0.25 Windows
  - SHGC-0.17 Windows
  - White Roof

- **Energy Cost Savings ($/yr)**
  - R-13 + R-5 Walls
  - R-13 + R-7.5 Walls
  - R-13 + R-10 Walls
  - R-25 Roof
  - U-0.79 Windows
  - U-0.18 Windows
  - SHGC-0.25 Windows
  - SHGC-0.17 Windows
  - White Roof

The graphs illustrate the energy and HVAC load results for various configurations, showing the impact on cooling load reduction, heating load reduction, and energy cost savings.
### Financial Analysis

<table>
<thead>
<tr>
<th>LR</th>
<th>Description</th>
<th>Envelope Cost Change ($)</th>
<th>Energy Cost Savings ($/yr)</th>
<th>Simple Payback Period (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1</td>
<td>R-13 + R-5 Walls</td>
<td>$13,071</td>
<td>$2,041</td>
<td>6.4</td>
</tr>
<tr>
<td>1-2</td>
<td>R-13 + R-7.5 Walls</td>
<td>$36,930</td>
<td>$4,688</td>
<td>7.9</td>
</tr>
<tr>
<td>1-3</td>
<td>R-13 + R-10 Walls</td>
<td>$57,743</td>
<td>$6,770</td>
<td>8.5</td>
</tr>
<tr>
<td>2-1</td>
<td>R-25 Roof</td>
<td>$39,387</td>
<td>$7,705</td>
<td>5.1</td>
</tr>
<tr>
<td>2-2</td>
<td>R-30 Roof</td>
<td>$80,620</td>
<td>$9,047</td>
<td>8.9</td>
</tr>
<tr>
<td>2-3</td>
<td>R-35 Roof</td>
<td>$123,697</td>
<td>$9,956</td>
<td>12.4</td>
</tr>
<tr>
<td>5-1</td>
<td>White Roof</td>
<td>$0</td>
<td>$1,009</td>
<td>Immediate</td>
</tr>
</tbody>
</table>

- RS Means provides envelope first cost estimates
- Relatively poor payback (6 – 12 years)
- What about HVAC equipment cost?
- Contractor provides HVAC cost estimates...

### Detailed Analysis

#### Bundle quick payback items with High Performance Glass, and keep going...

- RS Means provides envelope first cost estimates
- Relatively poor payback (6 – 12 years)
- What about HVAC equipment cost?
- Contractor provides HVAC cost estimates...
HVAC Selection - Case Study

- Methodist Olive Branch Hospital – Olive Branch, MS
- 206,000 sq. ft., 100 bed, greenfield hospital
- Analysis started during concept phase
- IPD contract, Contractor on-board from start
- Goals: On-time, under budget, LEED-HC Gold, Energy Star
Typical Energy Use in Hospitals

- Space Heating: 30%
- Space Cooling: 13%
- Ventilation: 8%
- Water Heating: 14%
- Cooking: 9%
- Lighting: 7%
- Refrigeration: 2%
- Office Equipment: 2%
- Computers: 4%
- Other: 11%

University of Washington Integrated Design Lab

- Electric: 42.3%
- Reheat: 3.5%
- Service Hot Water: 1.7%
- Process Steam: 6.2%
- Preheat: 0.3%
- Kitchen, Labs, etc.: 1.2%
- Interior Lighting: 8.2%
- Misc. Equipment: 13.0%
- Plant Med. Equip.: 0.8%
- Imaging: 0.8%
- Kitchen: 0.9%
- Cooling: 4.2%
- HVAC Fans: 10.6%
- Pumps: 5.7%
- Heat Rejection: 0.2%

2012 Commercial Building Energy Consumption Survey (CBECS)
Alternate HVAC Systems Investigated

- Business-as-Usual = Chiller, Boiler, VAV Air Handlers
  - Air is a poor choice for a heat transfer medium
  - Choose water or refrigerant as predominant heat transfer medium, instead.
- Water Source Heat Pumps
- Variable Refrigerant Flow
- Active Chilled Beams
- Ground Source Heat Pumps
  - Decouple dehumidification from space cooling
  - Reduce simultaneous cooling and reheating
HVAC System Selection Analysis

- First Cost Evaluation
  - Mechanical
  - Electrical
  - Floor space – Equipment rooms, Central Plant
  - Floor-to-floor heights

- Energy
  - Multiple modeling scenarios
  - Comparative results

- Water

- Operations/Maintenance
  - Database comparisons
  - Staffing
  - Preventative maintenance
  - Recovery maintenance
## HVAC System Selection - Results

<table>
<thead>
<tr>
<th>HVAC System</th>
<th>EUI*</th>
<th>Annual Energy $ / ft²</th>
<th>MEP First Cost</th>
<th>Energy</th>
<th>O&amp;M</th>
<th>Total</th>
<th>Total 7 Year Investment</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSHP</td>
<td>158.3</td>
<td>$3.59</td>
<td>$27,206,429</td>
<td>$5,059,705</td>
<td>$4,532,776</td>
<td>$9,592,481</td>
<td>$36,798,909</td>
</tr>
<tr>
<td>WSHP</td>
<td>173.9</td>
<td>$4.09</td>
<td>$26,805,383</td>
<td>$5,757,045</td>
<td>$4,688,433</td>
<td>$10,445,478</td>
<td>$37,250,861</td>
</tr>
<tr>
<td>VRF</td>
<td>169.6</td>
<td>$3.88</td>
<td>$28,272,794</td>
<td>$5,467,189</td>
<td>$4,571,920</td>
<td>$10,039,109</td>
<td>$38,311,903</td>
</tr>
<tr>
<td>Chiller - VAV</td>
<td>182.7</td>
<td>$4.09</td>
<td>$28,387,134</td>
<td>$5,764,808</td>
<td>$5,017,941</td>
<td>$10,782,749</td>
<td>$39,169,883</td>
</tr>
<tr>
<td>Chilled Beam</td>
<td>176.2</td>
<td>$3.98</td>
<td>$28,023,893</td>
<td>$5,606,685</td>
<td>$4,781,578</td>
<td>$10,388,263</td>
<td>$38,412,156</td>
</tr>
</tbody>
</table>

### First Cost
1. WSHP
2. GSHP
3. ACB
4. VRF
5. VAV AHU

### Energy & Water
1. GSHP
2. VRF
3. ACB
4. WSHP
5. VAV AHU

### O&M
1. GSHP
2. VRF
3. WSHP
4. ACB
5. VAV AHU

### Total
1. GSHP
2. WSHP
3. VRF
4. ACB
5. VAV AHU

Energy cost savings alone probably wouldn’t have been enough to justify GSHP! Thus, the importance of “Budget Sharing...”
HVAC Selection Results

- Distributed Ground Source Heat Pumps (GSHPs)
- Rooftop DOAS units
- W-W GSHP for domestic HW
- No central steam
- 196 vertical bores, 300 ft. deep
- 80 ton fluid cooler
- Adaptive control & pumping system to manage borefield

- The first LEED for Healthcare Gold certified inpatient facility in the United States.
- One of six LEED for Healthcare certified facilities in the world.
- One of three LEED for Healthcare certified inpatient facilities in the United States
- Energy Star certified
Going from high performance to Net-Zero Energy
What is a Net-Zero Energy Building?

• aka “Zero Energy Building”

• 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.
For electricity, a national average site-to-source ratio of 3.15 is often used.
Site Boundary of Energy Transfer for Zero Energy Accounting

Source: A Common Definition of Zero Energy Buildings
Net Zero Energy Building Certification

• Administered by the International Living Future Institute

• The system may be grid-tied or off-the-grid.

• No combustion is not allowed

• Neither ‘green tags’ nor ‘green power’ purchases are recognized compliance paths.

• Certification is based on actual performance rather than modeled outcomes.
### Sources of Renewable Energy

<table>
<thead>
<tr>
<th>DOE “A Common Definition for Zero Energy Buildings”</th>
<th>International Living Future Institute (NZEB Certification)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Solar</td>
<td>• Solar</td>
</tr>
<tr>
<td>• Wind</td>
<td>• Photovoltaics</td>
</tr>
<tr>
<td>• Hydro</td>
<td>• Solar thermal</td>
</tr>
<tr>
<td>• Wave action</td>
<td></td>
</tr>
<tr>
<td>• Tidal action</td>
<td>• Wind</td>
</tr>
<tr>
<td>• Geothermal</td>
<td>• Hydro</td>
</tr>
<tr>
<td>• Ocean thermal</td>
<td>• Geothermal</td>
</tr>
<tr>
<td>• Biomass</td>
<td>• Fuel cells using renewably-powered, electrolysis-generated hydrogen</td>
</tr>
</tbody>
</table>
Development of Maximum Technically Achievable Energy Targets for Commercial Buildings

- 16 building types, 17 climate zones, 400 measures
- 47.8% reduction from ASHRAE 90.1-2013
- Measure application
  - Reduce Internal loads
  - Reduce building envelope loads
  - Reduce HVAC distribution system losses
  - Decrease HVAC equipment energy consumption
  - Major HVAC reconfigurations
DOE Commercial Prototype Building Models

- Midrise Apartment
- Standalone Retail
- Large Hotel
- Small Hotel
- Large Office
- Small Office
- Stripmall Retail
- Warehouse
- Outpatient Healthcare
- Hospital
- Secondary School
ASHRAE Climate Zone Map

All of Alaska is in Zone 7 except for the following boroughs in Zone 8:
Bethel, Northwest Arctic, Dillingham, Southeast Fairbanks, Fairbanks N. Star, Wade Hampton, Nome, Yukon-Koyukuk, North Slope

Zone 1 includes Hawaii, Guam, Puerto Rico, and the Virgin Islands
Energy Conservation Measures Analyzed in 1651-RP

- LED Exterior Lighting
- Highest Efficiency Office Equipment
- High Performance Lighting (LED)
- Shift from General to Task Illumination
- Optimal Daylighting Control
- Optimal Roof Insulation Level
- Optimal Choice of Vertical Fenestration
- External Light Shelves
- Daylighting Control by Fixture
- High Performance Fans
- High Performance Ducts to Reduce Static Pressure
- Demand Controlled Ventilation/CO2 Controls
- Multiple-zone VAV System Ventilation Optimization
- Optimal Water/Air Cooling Coils
- Occupant Sensors for Air Handling Equipment
- Energy Recovery Ventilators
- Indirect Evaporative Cooling
- High Eff./Var. Speed Packaged DX Cooling
- High Efficiency Heat Pumps
- Ground Source Heat Pump
- High Efficiency and Variable Speed Chillers
- Heat Recovery from Chillers
- High Efficiency Boilers
- High Efficiency Building Transformers
- Chilled/Cooled Beam
- Dedicated Outside Air System with Heat Recovery
- Underfloor Air Distribution
- Hybrid/Mixed Mode Ventilation
- Radiant Heating and Cooling and DOAS
- Variable Refrigerant Flow Air Conditioning.
ASHRAE 1651-RP

- High Efficiency Heat Pumps
- High Performance Lighting
- Heat Recovery Chillers
- Ground Source Heat Pump
- Demand Controlled Ventilation CO2 Controls
- High Efficiency and Variable Speed Packaged DX
- High Efficiency and Variable Speed Chiller
Feasibility of Zero Energy with Max Tech and Roof-mounted PV

Annual Source Energy Use Intensity (kBtu/sf/yr)

- Source Energy - 90.1-2013
Feasibility of Zero Energy with Max Tech and Roof-mounted PV

![Graph showing annual source energy use intensity (kBtu/sf/yr) for different building types. The x-axis represents various building types such as Warehouse, Apartment, Retail, School, Hotel, Office, and Hospital. The y-axis represents the annual source energy use intensity in kBtu/sf/yr. The graph compares Source Energy - Max Tech and Source Energy - 90.1-2013.](image-url)
Feasibility of Zero Energy with Max Tech and Roof-mounted PV

Annual Source Energy Use Intensity (kBtu/sf/yr)

- Warehouse: 1
- Apartment/Midrise: 4
- Retail/Stand-alone: 1
- Retail/Stripmall: 1
- School/Secondary: 1
- School/Primary: 2
- Hotel/Small: 1
- Hotel/Large: 4
- Office/Small: 6
- Office/Medium: 1
- Office/Large: 3
- OutPatient/HealthCare: 13
- Hospital: 6

Legend:
- Exported Source Energy
- Source Energy - Max Tech
- Source Energy - 90.1-2013
Maintaining performance (Persistence)
“More feedback is needed from actual building performance results to design phase energy modeling. The current variability between predicted and measured performance has significant implications for the accuracy of the prospective life cycle cost evaluations for any given building. Better feedback to the design community is needed to help calibrate energy modeling results.”

Figure ES-5: Measured versus Proposed Savings Percentages
Feedback is important

We need this to operate a car…

… so why operate a building with this?
Importance of Sub-metering

**Spirit of Metering:** “You can’t manage what you don’t measure.”
LEED 2009: Measurement & Verification

<table>
<thead>
<tr>
<th>Energy Type</th>
<th>Electricity</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error Metric</td>
<td>CV(RMSE)</td>
<td>NMBE</td>
</tr>
<tr>
<td>As-Built Model</td>
<td>38.3%</td>
<td>39.1%</td>
</tr>
<tr>
<td></td>
<td>CV(RMSE)</td>
<td>NMBE</td>
</tr>
<tr>
<td></td>
<td>15.7%</td>
<td>11.4%</td>
</tr>
</tbody>
</table>
Model Calibration Process

- Actual Weather Data
- More appropriate internal load schedules
- Reflect Actual HVAC Control Operations
  - Economizer
  - Exhaust Fans
  - Supply Air Temperature Reset
- More appropriate part-load performance curves
  - Supply & Return fans
- Test Unknown Values
  - Plug loads
  - Infiltration

**AHU 01 SAF**

\[ y = 23.628x^3 - 55.817x^2 + 44.87x - 11.796 \]

**AHU 01 RAF**

\[ y = -1.6611x^3 + 6.4781x^2 - 5.1626x + 1.3457 \]
Calibrated Model Gives Actual Savings

<table>
<thead>
<tr>
<th>Energy Type</th>
<th>Electricity</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error Metric</td>
<td>CV(RMSE)</td>
<td>NMBE</td>
</tr>
<tr>
<td>Calibrated Model</td>
<td>10.7%</td>
<td>4.3%</td>
</tr>
</tbody>
</table>
M&V Results

- Electric savings worse than predicted
- Natural gas savings better than predicted
- Trend analysis identified economizer, humidifier, and boiler control and operation can be improved

<table>
<thead>
<tr>
<th>Utility</th>
<th>Designed Proposed</th>
<th>Baseline</th>
<th>Savings</th>
<th>Calibrated Actual</th>
<th>Baseline</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>$ 700,087</td>
<td>$ 859,747</td>
<td>18.6%</td>
<td>$ 794,299</td>
<td>952,284</td>
<td>16.6%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>$ 186,952</td>
<td>$ 174,608</td>
<td>-7.1%</td>
<td>$ 174,895</td>
<td>165,729</td>
<td>-5.5%</td>
</tr>
<tr>
<td>Total</td>
<td>$ 887,039</td>
<td>$1,034,355</td>
<td>14.2%</td>
<td>$ 969,193</td>
<td>$1,118,013</td>
<td>13.3%</td>
</tr>
</tbody>
</table>
LEED v4 EA Credit: Advanced Energy Metering

- Process Loads: 19.1%
- Space Cooling: 28.4%
- Space Heating: 18.4%
- Fans - Interior: 15.9%
- Interior Lighting: 15.6%
- Service Water Heating: 0.6%
- Heat Rejection: 1.8%
- Pumps: 0.2%
## LEED v4: Monitoring Based Commissioning (MBCx)

<table>
<thead>
<tr>
<th>MBCx Activity</th>
<th>Responsible Party</th>
<th>Phase</th>
<th>Deliverable/ Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification of metered points, method of measurements, method of calculating energy savings</td>
<td>SSRCx</td>
<td>Design</td>
<td>MBCx Plan (this document)</td>
</tr>
<tr>
<td>Include appropriate energy metering, trending, and reporting in BAS and Energy Information System</td>
<td>Smith Seckman Reid</td>
<td>Design</td>
<td>Design Documents</td>
</tr>
<tr>
<td>Design-phase Baseline and Proposed energy models</td>
<td>SSRCx</td>
<td>Design</td>
<td>Energy Analysis software outputs</td>
</tr>
<tr>
<td>Installation of required metering and reporting tools</td>
<td>Turner Construction, and its sub-contractors</td>
<td>Construction</td>
<td>As-built drawings</td>
</tr>
<tr>
<td>Spot measurements of kW demand during TAB</td>
<td>Turner Construction, and its sub-contractors</td>
<td>Construction</td>
<td>TAB reports</td>
</tr>
<tr>
<td>Commissioning of building systems, including meters and BAS trending</td>
<td>SSRCx</td>
<td>Construction</td>
<td>Cx Plan, FPT</td>
</tr>
<tr>
<td>Compilation of utility bills, BAS trend data, and scheduling information during the MBCx period (and given to Energy Analyst)</td>
<td>Methodist Health</td>
<td>Operations</td>
<td>Monthly delivery; trend data format determined by Energy Analyst</td>
</tr>
<tr>
<td>Provide recommended corrective actions</td>
<td>SSRCx</td>
<td>Operations</td>
<td>Final MBCx Report</td>
</tr>
<tr>
<td>Perform corrective actions as needed</td>
<td>Turner Construction (if during the warranty period) and Methodist Health</td>
<td>Operations</td>
<td>Work Orders</td>
</tr>
</tbody>
</table>
### Ensure Sufficient Data Trending

<table>
<thead>
<tr>
<th>System</th>
<th>Measure / Verification Component</th>
<th>Verify Measure / Condition</th>
<th>Monitoring Points</th>
</tr>
</thead>
</table>
| Hot Water  | Variable-flow loop; hot water pumps equipped with VFDs.                                        | - variable-flow operation, to maintain pressure differential set point between supply and return heating water piping mains  
- interlocked with boiler operation; two minute delay on boiler disable             | - VFD speed  
- pump status  
- differential pressure between supply and return  
- water flow rate  
- heating water supply and return temperatures                                        |
| Chillers   | Equipped with VFDs. Reset chilled water supply temperature to maintain air handler discharge air temperature. | - chiller efficiency (NPLV = 0.50)  
- chiller VFD operation  
- chilled water supply temperature reset from 48°F to maintain air handler discharge air temperature | - chiller power  
- chiller efficiency (calculated point) or/  
- CHWS/RT  
- CHW flow                                           |
Conclusions

• Energy codes and standards continue to get more stringent.
• Building technology and design continue to evolve with design assistance tools such as energy simulation software.
• Zero energy buildings are within reach, but the prices of energy sources (both renewable and non-renewable) still have a major impact.
• Maintaining high performance through M&V and monitoring-based commissioning will be critical for a zero energy future.
Links / Resources

- Architecture 2030
- [www.energycodes.gov](http://www.energycodes.gov)
- PNNL, “ASHRAE 90.1 Determination of Energy Savings: Quantitative Analysis”
- ASHRAE / IBPSA-USA / RMI; Building Energy Modeling Training Workshop
- U.S. DOE; Commercial Building Energy Consumption Survey; 2012
- University of Washington’s Integrated Design Lab & Solarc Architecture & Engineering; “Targeting 100! Energy Use and Model Calibration Study: Legacy Salmon Creek Medical Center – Executive Summary”; 2011
- [https://flowcharts.llnl.gov/](https://flowcharts.llnl.gov/)
- [http://living-future.org/netzero](http://living-future.org/netzero)
- [https://maps.nrel.gov/femp/](https://maps.nrel.gov/femp/)
- USGBC, Leadership in Energy and Environmental Design (LEED) v4
Thank you!

Clark Denson
cdenson@ssr-inc.com
Smith Seckman Reid, Inc.