Energy in the Built Environment

CASE STUDIES OF ULTRA-LOW ENERGY BUILDINGS IN THE PACIFIC NORTHWEST

2016 PNWER ECONOMIC LEADERSHIP FORUM, BOISE IDAHO

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Overview

→ Roadmap to Resilient, Ultra-Low Energy Buildings
→ Case Studies
  → Summary of results
  → Examples of case studies
  → Common design features
→ Conclusions/Recommendations
Benefits from Addressing Energy in Buildings

→ Affordability
  → Reduced energy costs to consumers
→ Comfort
→ Healthfulness
→ Lower carbon emissions

→ Durability
→ Resilience to extreme weather events and natural hazards
→ Increased market value
PNWER Roadmap to Resilient, Ultra-Low Energy Buildings

➔ A document that will seek endorsement by legislators and private sector leaders from 10 PNWER jurisdictions

➔ Goal is to catalyze new energy-efficiency legislation to achieve the desired benefits and specific targets for the year 2030

➔ Provides:

› Information and analysis
› Policy best practices
› Metrics, targets, timelines
› Market-driven solutions

➔ Includes case studies of new and retrofitted buildings that demonstrate best practices throughout the PNWER
Case Study Methodology

→ Case selection criteria:
  › Ultra-low energy (net-zero) new buildings
  › ‘Deep’ energy retrofits of existing buildings
  › Resilient design and design replication potential
  › Must have 2+ years of real utility data

→ Collection of cases
  › NBI Database, NEEA, regional utilities
  › Interviews with owners and/or design team

→ Baselines for analysis
  › Energy (New): DOE Prototype Building Models ASHRAE 90.1 2013
  › Energy (Retrofit): CBECs, RECS, SHEU, SCIEU - energy surveys
  › Costs: RS Means
Average energy savings:

- Houses: -64%
- Educational: -76%
- MURBs: -50%
- Offices: -84%

Average GHG emission reductions across all buildings:

-70% CO$_2$-equiv
<table>
<thead>
<tr>
<th>Type</th>
<th>New/Retrofit</th>
<th>Case Study Buildings</th>
<th>City</th>
<th>State/Prov</th>
<th>Climate Zone</th>
<th>Year Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Homes</strong></td>
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<tr>
<td>New</td>
<td></td>
<td>Factor 9 Home</td>
<td>Regina</td>
<td>SK</td>
<td>7</td>
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<td></td>
<td></td>
<td>Discovery 3 House</td>
<td>Red Deer</td>
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<td>7</td>
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<td>Hutshi House</td>
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<td></td>
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<td>Inuvik</td>
<td>NWT</td>
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<td>2013</td>
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<td></td>
<td></td>
<td>Harmony House</td>
<td>Burnaby</td>
<td>BC</td>
<td>5C</td>
<td>2013</td>
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<tr>
<td></td>
<td></td>
<td>Alaska home</td>
<td>Dillingham</td>
<td>AK</td>
<td>8</td>
<td>2012</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alabama home*</td>
<td>Fairhope</td>
<td>AL</td>
<td>2A</td>
<td>2013</td>
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<tr>
<td>Retrofit</td>
<td></td>
<td>BC Livesmart home</td>
<td>Vancouver</td>
<td>BC</td>
<td>5C</td>
<td>2014</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Idaho home</td>
<td>Boise</td>
<td>ID</td>
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<td>2011</td>
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<tr>
<td>**Educational/</td>
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<tr>
<td>Medical**</td>
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<tr>
<td>New</td>
<td></td>
<td>Bertschi School</td>
<td>Seattle</td>
<td>WA</td>
<td>4C</td>
<td>2011</td>
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<tr>
<td></td>
<td></td>
<td>OHSU CLSB</td>
<td>Portland</td>
<td>OR</td>
<td>4C</td>
<td>2014</td>
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<tr>
<td>Retrofit</td>
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<td>Hood River M.S.</td>
<td>Hood River</td>
<td>OR</td>
<td>5B</td>
<td>2010</td>
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<td>UAF BBC Applied Science</td>
<td>Dillingham</td>
<td>AK</td>
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<td>2014</td>
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<td><strong>MURBs</strong></td>
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<tr>
<td>New</td>
<td></td>
<td>zhHome</td>
<td>Issaquah</td>
<td>WA</td>
<td>4C</td>
<td>2012</td>
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<td></td>
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<td>Ingram Houses</td>
<td>Whitehorse</td>
<td>YK</td>
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<td>2010</td>
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<td></td>
<td></td>
<td>Dorset St*</td>
<td>Waterloo</td>
<td>ON</td>
<td>6A</td>
<td>2006</td>
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<tr>
<td>Retrofit</td>
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<td>Belmont Building</td>
<td>Vancouver</td>
<td>BC</td>
<td>5C</td>
<td>2012</td>
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<tr>
<td><strong>Offices</strong></td>
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<tr>
<td>New</td>
<td></td>
<td>Bullitt Center</td>
<td>Salem</td>
<td>OR</td>
<td>4C</td>
<td>2013</td>
</tr>
<tr>
<td>Retrofit</td>
<td></td>
<td>Painter’s Hall</td>
<td>Salem</td>
<td>OR</td>
<td>4C</td>
<td>2010</td>
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<tr>
<td></td>
<td></td>
<td>Home on the Range</td>
<td>Billings</td>
<td>MT</td>
<td>6B</td>
<td>2006</td>
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<tr>
<td></td>
<td></td>
<td>Rice Fergus Miller Office</td>
<td>Bremerton</td>
<td>WA</td>
<td>4C</td>
<td>2011</td>
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<tr>
<td></td>
<td></td>
<td>Beardmore</td>
<td>Priest River</td>
<td>ID</td>
<td>6B</td>
<td>2009</td>
</tr>
</tbody>
</table>

*Outside the PNWER
### Resilience Features (non-energy benefits)

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme weather</td>
<td>Rain, drought, wind, heat/cold</td>
</tr>
<tr>
<td>Seismic resistance</td>
<td>(no cases went above code)</td>
</tr>
<tr>
<td>Water savings</td>
<td>Low-flow fixtures, rainwater collection, landscaping</td>
</tr>
<tr>
<td>Improved acoustics</td>
<td>Sound insulation</td>
</tr>
<tr>
<td>Comfort</td>
<td>Thermal, spatial, mental</td>
</tr>
<tr>
<td>Community benefits</td>
<td>Public access, improved neighborhood</td>
</tr>
<tr>
<td>Transportation</td>
<td>Access to public transit, biking (showers)</td>
</tr>
<tr>
<td>Indoor air quality</td>
<td>Low VOC materials, duct considerations</td>
</tr>
<tr>
<td>Other health measures</td>
<td>Access to parks</td>
</tr>
<tr>
<td>Environmental benefits</td>
<td>Sustainable materials, waste reduction</td>
</tr>
</tbody>
</table>
Energy Savings of Case Studies

- Homes (SFDs) 64% av. savings
- Educational 76% av. savings
- MURBs 50% av. savings
- Offices 84% av. savings

Retrofit
New Construction
Home Energy Rating System (HERS) challenges

Case Study: Idaho home

→ HERS index = 74
  › Should be 26% better than average home
→ Yet measured energy consumption was still 89% higher than average
→ Why does HERS not reflect real energy consumption?
  › Prescriptive approach
  › No plug loads or occupant behaviour analysis
  › Program does not verify with measured utilities
EnerGuide for Homes – more challenges

Case Study: LiveSmart BC house

EnerGuide 88 (post-retrofit)

→ But… energy consumption is still 55% worse than average

BC LiveSmart house and Idaho house both improved dramatically from their pre-retrofit energy consumption → included in study
New – EnerGuide Gigajoules/Year Scale

→ **Progress**: A new EnerGuide rating system in Canada has been adjusted to better reflect the reality of houses' energy bills

→ Uses GJ/year scale:

- **85 GJ/year**: This House
- **0 GJ/year**: Best energy performance
- **90 GJ/year**: A typical new house
- **Uses most energy**

→ New scale is much less arbitrary

→ But still no measurement and verification of modeled data
Construction Cost Increase vs Energy Savings

![Graph showing incremental cost increase vs energy savings for new construction, retrofits, and cases with PV.](image)

- **New Construction**: Over 2x more solar panels than others.
- **Retrofits**: Also a lot of solar.
- **Cases with PV**: Baseline cost for new construction.

- **Belmont**: Incremental cost (% compared to baseline)
- **Rice Fergus Miller**: Energy Savings Over Baseline (%)
Case Example 1: The Bullitt Center

- Net positive energy
  -7 kBtu/ft²/yr

- Jurisdiction: Washington
- Building Type: Office
- Construction Type: New
- Construction Year: 2013
- Ratings: Living Building Challenge Certified
## Case Example 1: The Bullitt Center

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Create a new paradigm for 21st century buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVAC</td>
<td>No heating under typical conditions, backup ground source heat pump serves radiant floor system</td>
</tr>
<tr>
<td>Walls</td>
<td>Exterior insulated walls, exterior blinds for solar shading</td>
</tr>
<tr>
<td>Windows</td>
<td>Automated controlled by CO$_2$, temp., RH, wind, and rain conditions, with manual override</td>
</tr>
</tbody>
</table>

→ Net Zero Water  
→ Building life cycle  
→ Irresistible stair  
→ Internal cap & trade  
→ U of W’s IDL collects performance data
Case Example 2: Hood River Middle School

- **Jurisdiction**: Oregon
- **Building Type**: Educational
- **Construction Type**: Retrofit
- **Original construction**: 1927
- **Retrofit completed**: 2010
- **Site description**: Rural, old bus storage barn
- **Ratings**: Living Building Challenge Net Zero Energy Certified, LEED Platinum
Case Example 2: Hood River Middle School

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Fuse sustainable design with teaching curriculum</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVAC</td>
<td>Ground source heat pump and radiant floors</td>
</tr>
<tr>
<td></td>
<td>PV preheats winter air, river water cooling in summer</td>
</tr>
<tr>
<td>Walls</td>
<td>Insulated concrete forms (ICF)</td>
</tr>
<tr>
<td>Windows</td>
<td>Triple glazed windows with wood frames</td>
</tr>
<tr>
<td></td>
<td>Deciduous vines provide seasonal solar shading</td>
</tr>
</tbody>
</table>

→ Rainwater collection minimizes potable water demand by 89%
→ PV → Net Zero
→ Greenhouse for food production and teaching
Case Example 3: Single-family home

- **Jurisdiction**: Alaska
- **Building Type**: House
- **Construction Type**: New
- **Original construction**: 2011
- **Site description**: Remote
- **Ratings**: World Record Academy recognition for *Tightest Residential Building*
- **Champion**: Tom Marsik

Dillingham, AK
Case Example 3: Single-family home

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Small 590 ft², airtight, use passive design principles</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVAC</td>
<td>HRV, heat pump water heater, electric space heater is barely needed (internal heat from occupants, lighting etc.)</td>
</tr>
<tr>
<td>Walls</td>
<td>28” thick walls, air sealed</td>
</tr>
<tr>
<td>Windows</td>
<td>Triple-pane, argon-filled, two low-E coatings, with fiberglass frames</td>
</tr>
</tbody>
</table>

- 0.05 ACH<sub>50</sub> air tightness
- A specialized tool was needed to measure it!
- When it’s 0 °F outside, it’s still 50 °F inside (without heating)
- Solar-ready
Case Example 4: The Beardmore

→ **Jurisdiction**: Idaho
→ **Building Type**: Office
→ **Construction Type**: Retrofit
→ **Original construction**: 1922
→ **Retrofit completed**: 2009
→ **Site description**: Existing historical building
→ **Ratings**: LEED Gold and National Register of Historic Places
→ **Champion**: Brian Runberg
Case Example 4: The Beardmore

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Reach LEED Gold while maintaining Historical Register</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVAC</td>
<td>Rooftop heat pumps with economizer controls</td>
</tr>
<tr>
<td>Walls</td>
<td>Increased insulation to exterior walls and roof</td>
</tr>
<tr>
<td>Windows</td>
<td>Original wood frames, + low-E coating, additional glazing placed inside to protect historic transom detail</td>
</tr>
</tbody>
</table>

→ LED lights with night setback and occupancy sensors
→ Commissioning, including air tightness testing
→ Solar-ready
Most common high performance design features for new and retrofit buildings
High Performance Features = Energy Efficiency

![Graph showing energy savings over baseline as a function of the number of high performance features.](image)

- **All Cases**: Blue dots
- **Cases with PV**: Orange triangles

Projects include:
- **Discovery 3**
- **Factor 9**
- **Hutshi**
- **Northern Sustainable Harmony**
- **BC Livesmart**
- **Ingram**
- **UAF BBC**
- **Alabama home**
- **Alaska home**
- **Beardmore**
- **Hood River M.S.**
- **Zhome**
- **Home on the Range**
- **Rice Fergus**
- **Bertschi**
- **Miller**
- **Painter’s Hall**
- **Bullitt**

Energy Savings over Baseline (%):
- 0%
- 20%
- 40%
- 60%
- 80%
- 100%
- 120%
- 140%

Number of High Performance Features:
- 0
- 5
- 10
- 15
- 20
- 25
- 30
Unique Design features

Beardmore: DIY Rainwater Collection and Filtration

→ Lined old boiler room with pool liner and filter layers
→ Supplies all WC toilets+sinks

Collaborative Life Science Building: Waste Reduction

→ Paperless!
→ Saved ~$10M
→ Simultaneous, coordinated review

→ Also, salvaged old oil drilling pipes for foundation piles
The Importance of Champions

The energy-efficient case studies all have Champions

For example:

- Alaska home – Tom Marsik (UAF BBC Applied Science)
- Beardmore – Brian Runberg
- Bullitt Center – Denis Hayes, Chris Rogers, Chris Faul

Their roles include:

- Leadership, inspiration, vision
- Ambitious energy goals, targets (net zero buildings, etc.)
- Overcoming barriers
  - Work with city and other regulatory agencies
Conclusions/Recommendations

→ How to achieve energy efficiency in the built environment?
  › Support champions!
  › With an integrated design process (IDP), it doesn’t have to cost more

→ Use common high performance design features:

<table>
<thead>
<tr>
<th>Category</th>
<th>Top Design Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enclosure</td>
<td>High performance walls</td>
</tr>
<tr>
<td></td>
<td>High performance windows</td>
</tr>
<tr>
<td></td>
<td>Air tightness</td>
</tr>
<tr>
<td>Mechanical</td>
<td>Heat recovery ventilation</td>
</tr>
<tr>
<td></td>
<td>Commissioning</td>
</tr>
<tr>
<td>Lighting</td>
<td>Efficient light fixtures</td>
</tr>
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<td></td>
<td>Natural lighting (daylighting)</td>
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<tr>
<td>Resilience</td>
<td>Water conservation</td>
</tr>
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<td></td>
<td>Extreme weather resilience</td>
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</table>
These Case Studies are Paving the Way

Follow the lead of the case study buildings, learn from their success

We are well-positioned to achieve energy-efficiency in the built environment
Future Work - Extrapolation

→ Use the case study analysis, extrapolate to entire PNWER
  → New construction rates from regional surveys
  → Retrofits will ‘piggy-back’ on regular renewal schedule

→ Projections for:
  → Jobs, economic benefits
  → Energy use reduction
  → Greenhouse gas emission reduction

→ Detailed analysis and extrapolation for some regions
  → Depends on funding partners, sponsorship
Questions

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→ www.rdh.com