Implementing Deep Retrofits: A Whole Building Approach

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Core Competencies

Energy/Sustainability Managers and Facility Managers
- Building Technologies
- High Performance Building Design

Operating Engineers/Building Technicians
- Energy system design strategies
- Building Lighting Systems
- Building HVAC Systems
- Building Plug Loads
- Building Control Systems
- Building Commissioning
- Building O&M
Results - Expectations

1. Select appropriate facilities for deep retrofits and set performance objectives

2. Employ an integrated design process and end use technology applications for deep retrofits

3. Determine how you will ensure optimal performance

4. Identify DOE and industry resources to support decision making processes
FEMP First Thursday Seminars

Agenda

• Understanding Deep Retrofits
• Deep Retrofit Process
• Optimization
• Financing and Utility Markets
• The Role of Energy Modeling in Integrated Design
• End Use Technologies
• Case Studies
• Tools and Resources
Understanding Deep Retrofits
Advanced Energy Retrofit Guide (AERG) Approach

**Energy Audit**

**PROS:**
- >15% Energy Savings
- Quick Payback

**CONS:**
- Exhaust “low hanging fruit”
- Limited Energy Savings
- Leaves savings “on the table”

**Energy Retrofit**

**PROS:**
- >30% Energy Savings
- Portfolio Strategy
- ESCO Potential

**CONS:**
- Mechanical Focus
- Higher Costs

**Deep Energy Retrofit**

**PROS:**
- >50% Energy Savings
- Right-Timed w/ Other Cap Improvements
- Net-Zero Path
- Passive & Mechanical Solutions – Integrative
- Compelling Business Case

**CONS:** Requires coordinated planning

Source: RMI
Purpose:
Provide energy managers with guidance for planning and executing successful retrofit projects in commercial buildings, tailored to specific building types and climate regions.

Five AERGs in development by NREL and PNNL (three completed thus far)
What is a Deep Energy Retrofit?

**Process Differentiators**

1. Broader conversations with owners
2. Integrative design
3. Advanced auditing, modeling and LCCA
4. Ongoing energy tracking, proof of success
5. Tenant related strategies
6. Considers timing of other planned renovations

**Larger savings and value improvements**

**Improved project economics**
Deep Retrofit Energy Savings Target

- Set energy savings goal based on % reduction in energy use or energy use intensity reduction goal

- ASHRAE Standard 100 – *Energy Efficiency in Existing Buildings*
  - Sets EUI target based on top performing facilities (25\textsuperscript{th} percentile)
  - EUI targets for 48 building types in 16 climate zones
Process
FEMP First Thursday Seminars

Launch
- Set Goals (O)
- Select Team & Align Incentives (O)
- Benchmark & Baseline (SP)
  - Gather Data
  - Build Calibrated Energy Model
  - Document Business-as-Usual Scenario

Design
- Identify Opportunities (O)
  - Define Technical Potential
  - Engage Stakeholders
  - Refine Goals
- Analyze Options (SP)
  - Evaluate Individual ECMs & Create Bundles
  - Create Pathway to Net Zero
  - Address Tenant Opportunities

Implement
- Construct & Commission (SP)
- Performance Accountability & Improvement (O)
  - Measurement & Verification

Verify
- Share Successes (O)

Source: RMI
## Top “Ripeness” Indicators – Timing is Key

1. Planned capital improvement
2. Major system replacement
3. Major envelope project
4. Code upgrades
5. New owner / refinancing
6. New use / occupancy type
7. Large utility incentives/high energy costs
8. Mitigating an “energy hog”
9. Portfolio management

Source: RMI
<table>
<thead>
<tr>
<th>Factor</th>
<th>Description</th>
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<tbody>
<tr>
<td>Policy</td>
<td>Lack of policy creates little to no motivation to make the investment of time and capital to perform deep retrofits</td>
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<tr>
<td>Project analysis tools</td>
<td>Independent engineering and financial analysis tools exist but none that combine and allow for a streamlined iterative process to identify the best mix of ECMs</td>
</tr>
<tr>
<td>Financing</td>
<td>Deep retrofit projects can require the coordinated use of multiple project funding mechanisms. Can be complicated and time consuming to analyze/coordinate.</td>
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</table>

FEMP First Thursday Seminars

Most people start here!

(1) Define Needs & Set Goals
(2) Understand the Existing Building
(3) Understand the Scope of Planned Renovations
(4) Reduce Loads
(5) Select Appropriate & Efficient Technology
(6) Seek Synergies
(7) Optimize Controls
(8) Integrate Renewables
(9) Realize the Intended Design

Source: RMI
Find the minimal energy use possible using today’s technology - then add constraints back in (grudgingly)
Integrative Design, Find Synergies

Optimize the WHOLE, not the parts

- Early Intervention
- Goal Setting
- Determine the Technical Potential
- Pursue the Right Steps in the Right Order
- Iterative Energy Modeling and LCCA
- Multiple Benefits from a Single Expenditure
- Tunnel through the Cost Barrier

Source: RMI
Financing and Utility Markets
## Factors for Economic Success

<table>
<thead>
<tr>
<th>Factor</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Facility selection</td>
<td>Not all facilities are good candidates for deep retrofit projects. Select older facilities with pending/budgeted equipment replacements</td>
</tr>
<tr>
<td>Energy costs</td>
<td>Facilities with higher than average cost of energy provide higher ROI for investment in energy efficiency</td>
</tr>
<tr>
<td>Motivation</td>
<td>Facility owner and staff must be motivated to achieve larger than typical reductions in facility energy use: $ savings, environmental benefits, Federal mandates, agency/corporate goals etc.</td>
</tr>
<tr>
<td>Financing strategy</td>
<td>Deep retrofit projects typically require the coordinated use of multiple project funding mechanisms. ESPCs, Budgeted $ for schedule replacement/facility upgrades, sharing/reallocation of utility costs.</td>
</tr>
</tbody>
</table>
Elements of Techno-economic Analysis

Constraints: ROI, Energy/environmental goals, capital

EE Elements
- Operations
- EE Technology
- Controls
- Awareness

What’s the best combination?

Economic Elements
- Capital cost
- Energy related cost savings
- Incentives/Tax implications
- Escalation rates
- Discount rate
- Environmental value
- Tenant utility structure

What’s the priority/motivation?
What’s the confidence level?

Source: NREL
Tunnel Through the Cost Barrier

CUMULATIVE RESOURCE SAVINGS

MARGINAL COST OF EFFICIENCY IMPROVEMENT

COST-EFFECTIVENESS LIMIT

Diminishing returns

STOP

Source: RMI
Eliminate Systems

Source: RMI

MARGINAL COST OF EFFICIENCY IMPROVEMENT

COST-EFFECTIVENESS LIMIT

TUNNEL THROUGH

Diminishing returns

DETOUR AHEAD

 waren
Deep Retrofit and Net Zero Energy Life Cycle Cost

Deep efficiency renovation measures reduce EUI more cost-effectively than a PPA (for an analysis period equal to the duration of the PPA)

Reducing scope of PPA reduces amortized cost of achieving net zero energy

Source: NREL
GSA Renovation Challenge

Goal

- Demonstration projects on how to achieve NZE Buildings using ESPC

- 30 GSA/PBS buildings

Source: GSA
## GSA Renovation Challenge

Workshop (Attendees: GSA, RMI, 16 ESCOs)

<table>
<thead>
<tr>
<th>Topic</th>
<th>Workshop Conclusions</th>
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</thead>
<tbody>
<tr>
<td>Analysis and Integrative Design</td>
<td>Integrative design and whole building analysis not commonly included</td>
</tr>
<tr>
<td>Project Economics</td>
<td>May require blending of ESPC and appropriated funding, LCCA, long term contracting</td>
</tr>
<tr>
<td>ESPC Delivery Process</td>
<td>Needs to be streamlined and consistent</td>
</tr>
<tr>
<td>Occupant Behavior</td>
<td>Potential savings unrealized</td>
</tr>
<tr>
<td>M&amp;T</td>
<td>Interactive benefits need to be accounted for</td>
</tr>
</tbody>
</table>

Source: GSA
The Role of Energy Modeling in Integrated Design
BEopt™ software program description

The BEopt™ software is designed to identify optimal building designs at various energy-savings levels on the path to zero net energy.

Energy savings are calculated relative to a reference.

The reference can be either a user-defined base-case building or a climate-specific Building America Benchmark building automatically generated by the BEopt™ software.
The Path to Zero Net Energy

Source: NREL
eQUEST Software Program Description

- Modeling software developed by the DOE that evaluates the energy and cost savings that can be achieved by applying energy-efficiency measures

- eQUEST requires a detailed description of the building envelope (for thermal and optical properties), lighting and HVAC system requirements, internal loads, operating schedules, and utility rate schedules

National Building Museum, Washington D.C. Credit: James Salasovich NREL
OpenStudio Suite of Tools

Collection of energy modeling tools capable of doing whole building energy modeling using EnergyPlus

OpenStudio is an open source/cross platform project

OpenStudio applications include:
- Google SketchUp Plug-in
- SystemOutliner
- RunManager
- ResultsViewer

Ensuring Persistent Savings

• Utilizing energy modeling programs to find effective ECMs
• Commissioning of retrofit measures
• Operations and maintenance (O&M)
• Measurement and tracking (M&T)

Source: Greening America
End Use Technologies
Building Envelope

**Standard Retrofit**
- Added Roof Insulation
- White Roof
- Air Sealing
- Blow-in Wall Insulation

**Deep Retrofit**
- Optimize Passive Opportunities
- Shading
- Roof insulation/radiant barrier/cool roof
- High Performance Window
- Wall Insulation/infiltration reduction
Building Envelope – Roof Retrofit

- **Roof Insulation R-Value (attic and other category)**
  - Baseline = R-30 to R-49 (ASHRAE 90.1 - 2010)
  - Target = R-30 to R-60 (30% AEDG)

- **Roofing Types**
  - White Roof
    - Absorptance less than 0.25
  - Green Roof
    - Provides insulation
    - Absorbs rainwater
    - Cool roof
Building Envelope – Wall Retrofits

Wall Insulation R-Value
(steel frame category)

- Baseline = R-13 to R-13 + R 7.5 c.i. (ASHRAE 90.1-2010)
- Target = R-13 to R-13 + R-21.6 c.i. (AEDG)
Building Envelope – Window Retrofit

- **Retrofit Options**
  - Install internal blast windows
  - Refurbish window
  - Install new window

- **Window Specifications**
  (metal framing category)
  - **Baseline (ASHRAE 90.1-2010)**
    - U-Value = 0.40 to 1.20 (center of glass)
    - Solar Heat Gain Coefficient (SHGC) = 0.25 to 0.45
  - **Target (AEDG)**
    - U-Value = 0.33 to 0.56 (center of glass)
    - Solar Heat Gain Coefficient (SHGC) = 0.31 to 0.49
  - **DOE R-5 Window Bulk Purchase**
Lighting

**Standard Retrofit**
- Retrofit Existing Fixtures
- Install Occupancy Sensors
- Replace Exit Signs

**Deep Retrofit**
- Determine Visual Needs of the Occupants
- Install Optimized Lighting Systems
- Implement Day-lighting Strategies
- Implement Advanced Controls
Lighting - Daylighting

The goal is to block direct sunlight while allowing uniform skylight or reflected light into a space in order to offset electrical lighting

- Shading devices allow daylight into space while reflecting direct sun (glare)
- Light shelves allow daylight to penetrate deeper and more uniformly into a space
- Solution must be balanced with essential need to provide views and visual connection to outdoors

Lighting Re-Design Considerations

- Design for **total** illuminance levels (daylighting, ambient, task)
- Establish lighting power density (LPD) targets

### Building Area Type LPD (Watts/ft²)

<table>
<thead>
<tr>
<th>Building Area Type</th>
<th>LPD (Watts/ft²)</th>
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<tbody>
<tr>
<td>Office</td>
<td>0.90</td>
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<tr>
<td>Gymnasium</td>
<td>1.00</td>
</tr>
<tr>
<td>Dormitory</td>
<td>0.61</td>
</tr>
<tr>
<td>Motel</td>
<td>0.88</td>
</tr>
<tr>
<td>School</td>
<td>0.99</td>
</tr>
<tr>
<td>Warehouse</td>
<td>0.66</td>
</tr>
<tr>
<td>Parking Garage</td>
<td>0.25</td>
</tr>
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</table>

### IESNA Recommended Illuminance

<table>
<thead>
<tr>
<th>Space Type</th>
<th>Illuminance (fc)</th>
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<tbody>
<tr>
<td>Open Office</td>
<td>30 – 50</td>
</tr>
<tr>
<td>Private Office</td>
<td>50</td>
</tr>
<tr>
<td>Conference Room</td>
<td>30</td>
</tr>
<tr>
<td>Corridor</td>
<td>5</td>
</tr>
<tr>
<td>Restroom</td>
<td>10</td>
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</table>

ASHRAE 90.1 2010
## Lighting Layout with Different Design Illuminance

### Design Target 90 fc

- **Average Illuminance**: 97 fc
- **Number of Fixtures**: 20 fixtures
- **Lighting Power Density**: 1.3 Watts/ft²

### Design Target 30 fc

- **Average Illuminance**: 42.6 fc
- **Number of Fixtures**: 9 fixtures
- **Lighting Power Density**: 0.58 Watts/ft²

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*Analysis developed using AGI32*
Plug Loads

Standard Retrofit
- Laptop Computers
- LED Monitors
- Remove Personal Printers
- Remove Desktop Appliances
- Computer Power Management
- Energy Star Appliances
- Vending Machine Misers and Delamp Advertisement Lighting

Deep Retrofit
- **Energy Policies**
  - Power Density (W/ft² or W/person)
  - Workstation Allowance (W/workstation)
- **Advanced Controls**
  - Schedule Timers
  - Load Sensing
  - Occupancy Sensors
- **Low Energy Computing**
- **Behavioral Change**
Plug Loads

Energy Policies

• **Power Density**
  
  (Watts/ft$^2$) for Office Space
  
  – Baseline = 0.75 W/ft$^2$
    (ASHRAE 90.1 - 2004)
  
  – Target = 0.55 W/ft$^2$
    (ASHRAE 50% AEDG)

• **Workstation Allowance**
  
  (Watts/workstation)
  
  – Target = 60 W/workstation
  
  – Eliminate all unnecessary electronics and appliances

Credit: Matthew Luckwitz/NREL
Plug Loads

*Typical desktop uses 80-120 Watts when active!!*

**Energy Efficient Desktops:**
- HP Compaq Elite (28.6 Watts)
- Acer Veriton (18.8 Watts)
- Apple Mac mini (9.2 Watts)

**Laptops:**
- Sony VGN (10 Watts)
- Acer Aspire (7.89 Watts)
- Apple MacBook Air (4.3 Watts)

Energy consumption data from http://www.sust-it.net
Plug Loads- Behavioral Change

Behavioral Change
- Occupant education and awareness are critical

**Facts:**
- Computers are typically the highest energy consumers in office workstations.
- Computers have multiple energy saving settings to conserve during inactive periods.
- Computers use significantly less energy in the “sleep” mode, compared to active/on mode.
- Computers consume a small amount of energy even when they are turned off.

**Energy Conservation Idea:** Activate power management settings on computers and monitors.

- Enabling these settings will allow the computer and monitor to go into sleep mode (which consumes far less energy) after a period of inactivity.

**Weekly Prompting**

**Occupant Competition**

**Real-time Feedback**
HVAC Systems

Energy conservation measures which effect internal loads should be implemented **before** new equipment is sized/designe

**Standard Retrofit**

Convert constant volume pumping to variable speed pumping

Install variable frequency drives on HVAC equipment

Air systems – economizer, demand-controlled ventilation, etc.

Controls commissioning/upgrades, water temp resets

**Deep Retrofit**

**Performance Goal**

- Design system based on EUI reduction target
- Integrated design

**Design Options**

- Convert CV to VAV
- Install downsized high efficiency heating and cooling systems
- Install dedicated OA AHU
- Install energy recovery
- Install heat pumps
- Install radiant heating/cooling
HVAC Case Study: Byron Rogers

Existing building orientation is poor. How do we take advantage of it?

Chilled beam system throughout building

Heat reclaim & thermal storage

Byron Rogers Hybrid Heat Pump System

Heating Mode

Cooling Mode
Expected EUI Reduction = 60% - 70%
- Energy efficient chiller with heat pump mode
- Hot Water Boiler
- Heat storage tank

- Warm side of building used to heat cold side of building
- Cold side of building used to cool warm side of building
- Excess heat stored for night or weekend heating in thermal flywheel tank
NYA Federal Reserve

Current Condition:
- Perimeter induction units
  - Chilled water/Electric heat
- Core zone served by AHU
  - Terminal units do not close <80%

- Perimeter Zone 33%
- Interior cooling loads all year (1/2 of heating load in January)
NYA Federal Reserve Perimeter Heat Pumps

Water Loop Design – Heating Mode

Water Loop Design – Cooling Mode
Controls

**Standard Retrofit**

**HVAC Controls**
- AHU’s
- Heating/Cooling Plants
- Terminal Units/ Zone Temp

**Lighting**
- Occupancy Sensors
- Central Lighting Controls

**Deep Retrofit**

Controls all energy systems with EMCS

Controls multiple functions with each end use
- HVAC Controls
- Lighting Controls
- Plug Load Controls
Integration Methodology

- Renewable technologies should be planned for in major renovation
  - Sized to meet reduced load – integrated whole building design
  - Consider Building type
  - Consider Renovation type
  - Historic preservation

- Guide to Integrating Renewable Energy in Federal Construction

- Planning and integrating renewables in major renovation – 7/31/12

## RE Options by ECM Type

<table>
<thead>
<tr>
<th>RE Options by ECM Type</th>
<th>Daylighting</th>
<th>PV</th>
<th>SW</th>
<th>Solar Vent Pre-heat</th>
<th>Passive Solar Heat</th>
<th>Geothermal Heat Pump</th>
<th>Biomass</th>
<th>Wind</th>
<th>RE Ready</th>
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<tr>
<td>Other (e.g., fire protection, IT/Telecom)</td>
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Indianapolis City County Building (1959)

59% Energy Cost Savings ESPC
LEED EB Gold Target

DRIVERS –
• Dark Work Spaces / High Lighting Load
• City Wants to Model Efficiency
• Unbalanced HVAC
• Energy Security

Source: City and County of Indianapolis
Indianapolis City County Building (1959)

Measures –
• Retrofit Curtainwall Shading
• Upgrade Lighting & Controls
• Open Loop Geo-Exchange (Groundwater)
• Open Office Space Retrofits
• Occupant Awareness / Green Leases
• Datacenter Heat Recovery

via opportunity charrette + ESPC implementation
Case Study: Wayne Aspinall Building

Grand Junction, Colorado
- Historic Office Building and Courthouse
- Constructed 1918, Major addition in 1939
- 42000 ft² and 3 stories

Deep Retrofit
- Funded by American Recovery and Reinvestment Act
- $15 million
- Building will be fully occupied throughout project
- Targeting LEED Platinum
- First Net Zero Energy Building on National Register of Historic Places
- Project scheduled completion in 2013
Wayne Aspinall Building Deep Retrofit

- **HVAC** – Ground Source Heat Pump, Variable refrigerant flow, Indirect evaporative cooling, dedicated outdoor air system with heat recover, demand control ventilation
- **Controls** – Wireless building automation
- **Envelope** – Spray foam wall insulation
- **Envelope** – Interior storm window and solar film
- **Lighting** – LED and fluorescent lighting (0.7 W/ft²)
- **Lighting** – Daylighting controls and occupancy sensors
- **Controls** – Lighting controls and monitoring
- **Plug Loads** – Plug load management
- **Renewables** – 123 kW PV roof and canopy system
Tools and Resources

EERE
http://www.eere.energy.gov/topics/buildings.html

Advanced Energy Design Guides
http://www.ashrae.org/standards-research--technology/advanced-energy-design-guides
Advanced Energy Retrofit Guides

Grocery Stores
http://www.nrel.gov/docs/fy12osti/54243.pdf

Office Buildings

Retail Stores

K-12 Schools (Coming soon)

Healthcare Facilities (Coming soon)
RMI RetroFit Guides

http://www.rmi.org/retrofit_depot_download_the_guides

Managing Deep Energy Retrofits

Identifying Opportunities for Deep Energy Retrofits

....Building The Case (Coming soon)
Contacts and Questions

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