U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Implementing Deep Retrofits: A Whole Building Approach

FEMP FIRST THURSDAY SEMIN@RS

What you need to know…online, live, and anytime.

Instructors: Jesse Dean, National Renewable Energy Laboratory
Elaine Gallagher Adams, Rocky Mountain Institute

FEMP Expert: Ab Ream, Federal Energy Management Program

FEMP Federal Energy Management Program

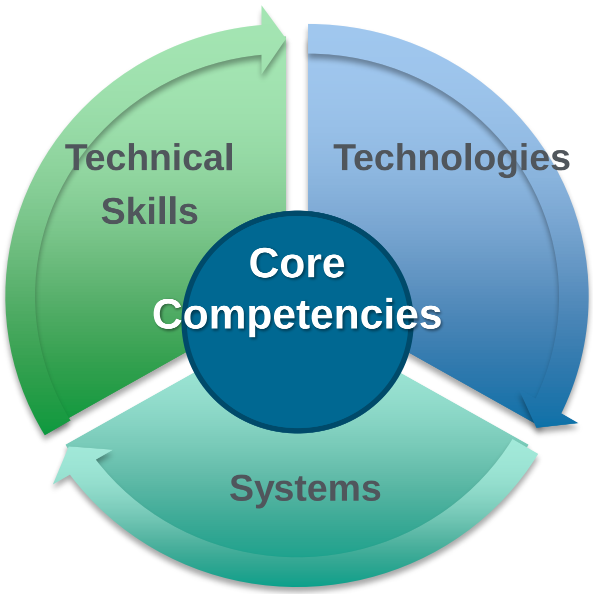
Core Competencies

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

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

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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

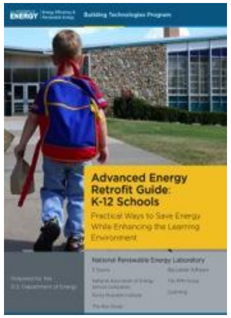
Source: RMI

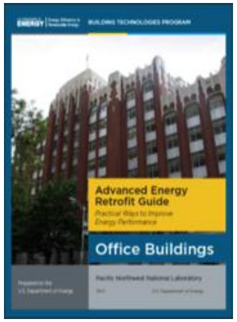
Advanced Energy Retrofit Guides

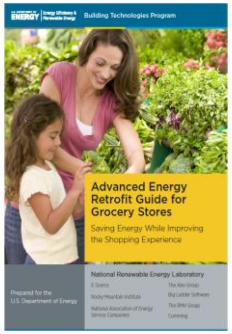
Purpose:

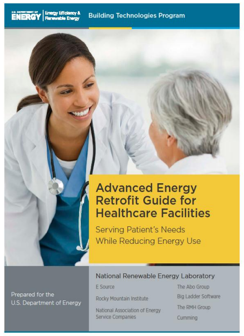
Provide energy managers with guidance for planning and executing successful retrofit projects in commercial buildings, tailored to specific building types and climate regions

Five AERGs in development by NREL and PNNL (three completed thus far)









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What is a Deep Energy Retrofit?

Process Differentiators

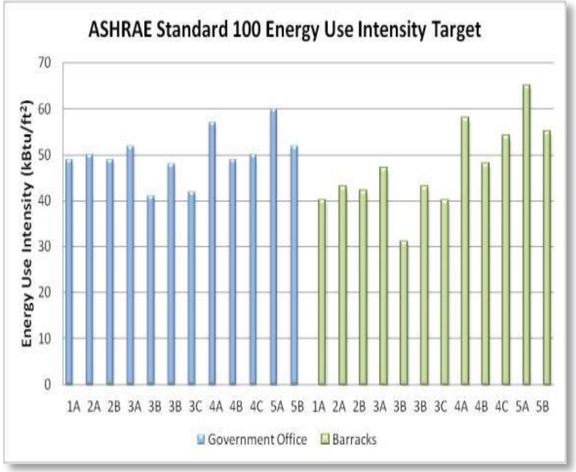
1. Broader conversations with owners
2. Integrative design
3. Advanced auditing, modeling and LCCA
4. Ongoing energy tracking, proof of success
5. Tenant related strategies
6. Considers timing of other planned renovations

Larger savings and value improvements

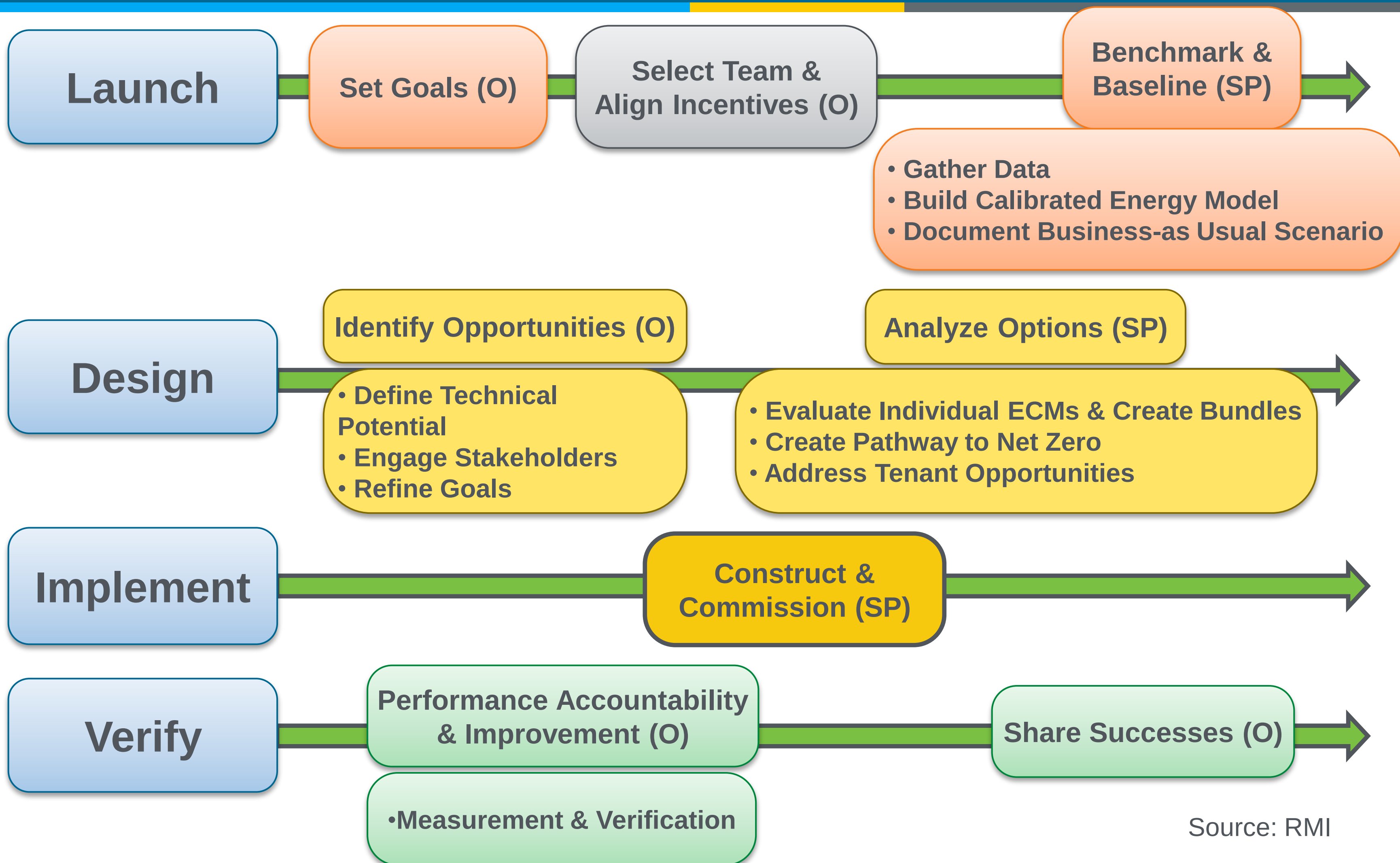
Improved project economics

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 (25th percentile)
  - EUI targets for 48 building types in 16 climate zones



Process


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)
Verify
Performance Accountability & Improvement (O)
•Measurement & Verification
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**

Deep Retrofit Barriers

Factor[1]	Description
Policy	Lack of policy creates little to no motivation to make the investment of time and capital to perform deep retrofits
Project analysis tools	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
Uncertainty of technical and economic performance	Uncertainty of technical and economic performance energy efficiency retrofits creates perceived risk from building owners, developers and financiers. Encourages taking low-hanging opportunities alone.
Financing	Deep retrofit projects can require the coordinated use of multiple project funding mechanisms. Can be complicated and time consuming to analyze/coordinate.

[1] *http://www.esbnyc.com/sustainability_energy_efficiency.asp, accessed 6/14/2012*

Optimization

(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

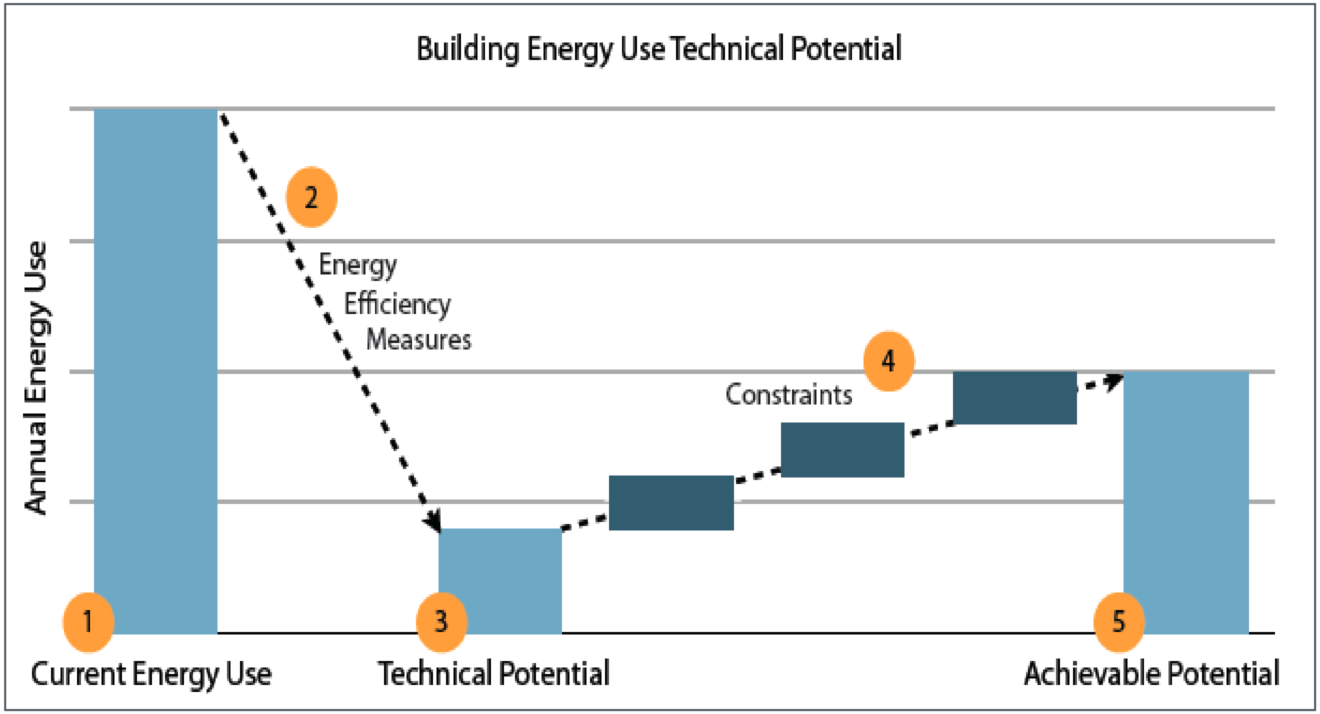
(8) Integrate Renewables

(9) Realize the Intended Design

Most people start here! → (5)

Source: RMI

Find the minimal energy use possible using today's technology - then add constraints back in (grudgingly)



Source: RMI

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

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Financing and Utility Markets

Factors for Economic Success

Factor	Description
Facility selection	Not all facilities are good candidates for deep retrofit projects. Select older facilities with pending/budgeted equipment replacements
Energy costs	Facilities with higher than average cost of energy provide higher ROI for investment in energy efficiency
Motivation	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.
Financing strategy	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.

Elements of Techno-economic Analysis

Constraints: ROI, Energy/environmental goals, capital

What's the priority/motivation?

EE Elements

- Operations
- EE Technology
- Controls
- Awareness

What's the best combination?

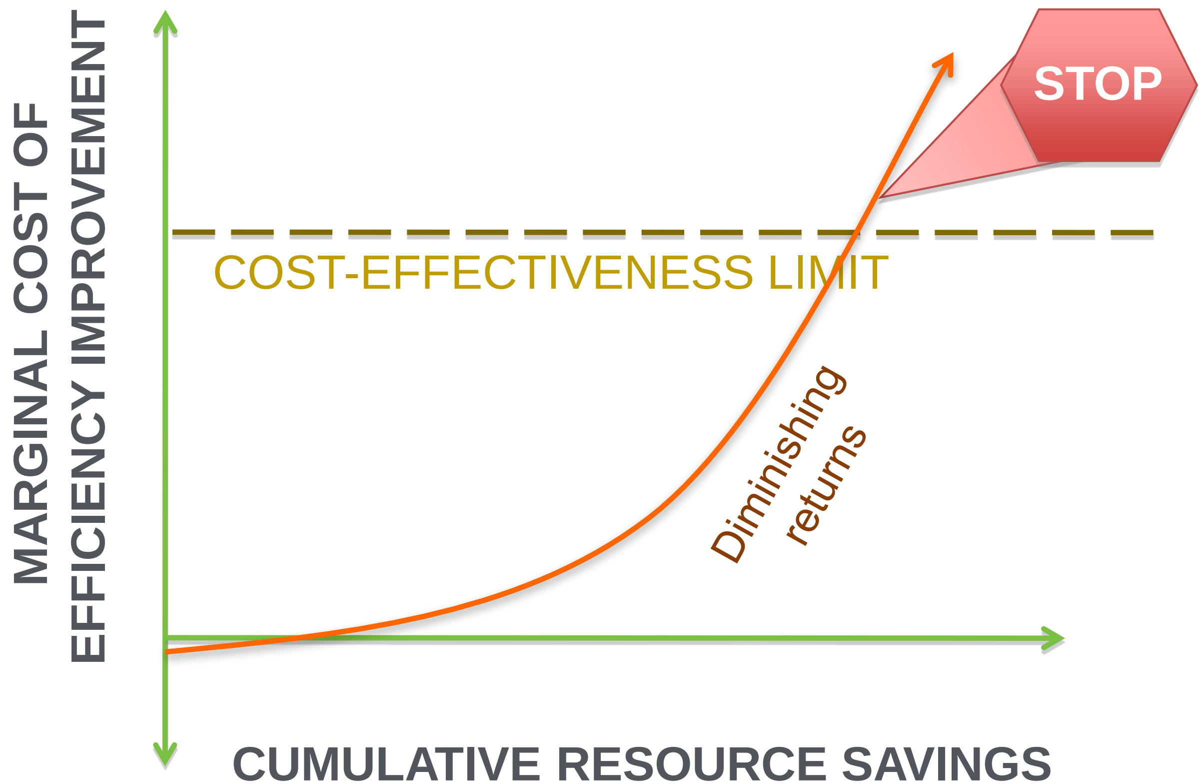
Economic Elements

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

What's the confidence level?

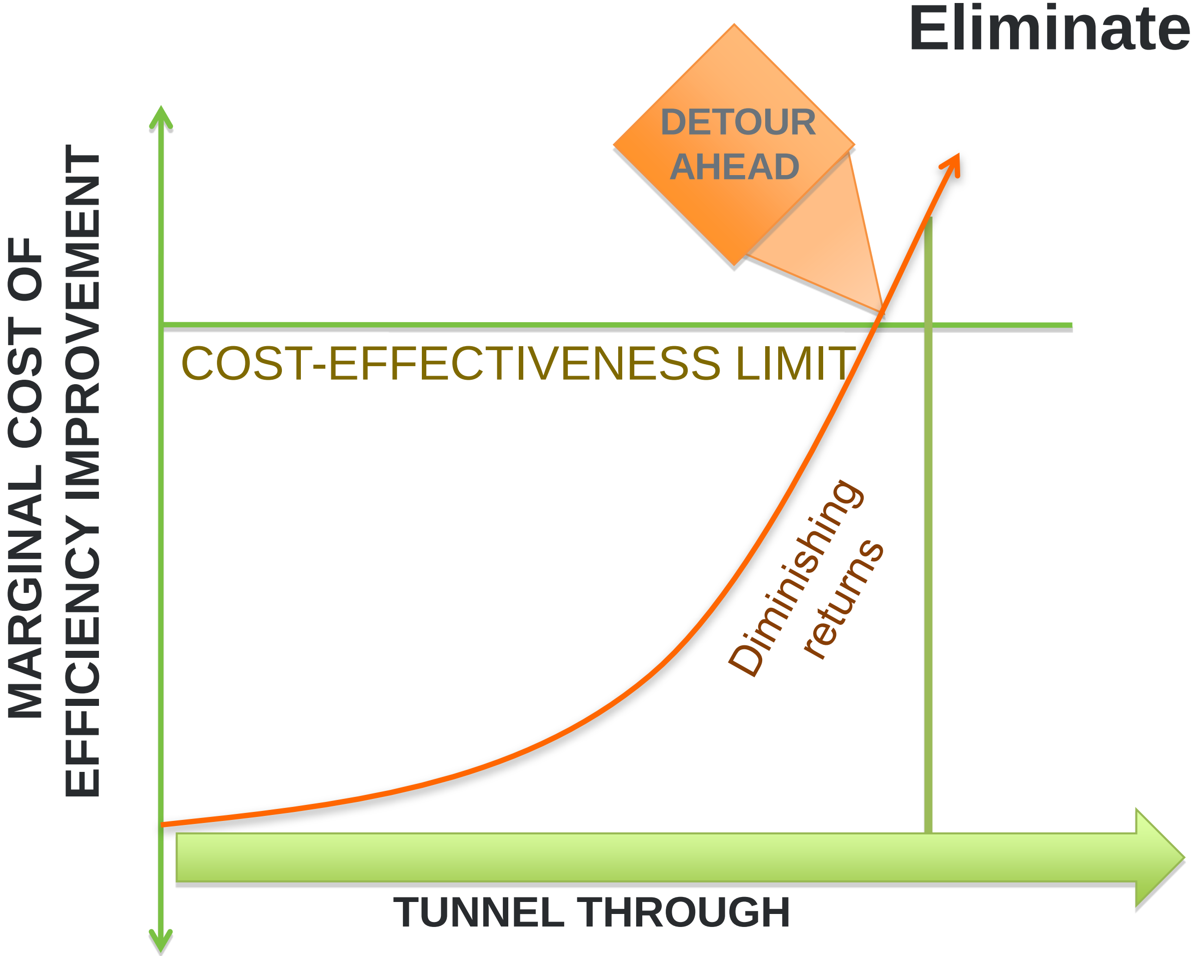
Source: NREL

Tunnel Through the Cost Barrier



Source: RMI

Eliminate Systems

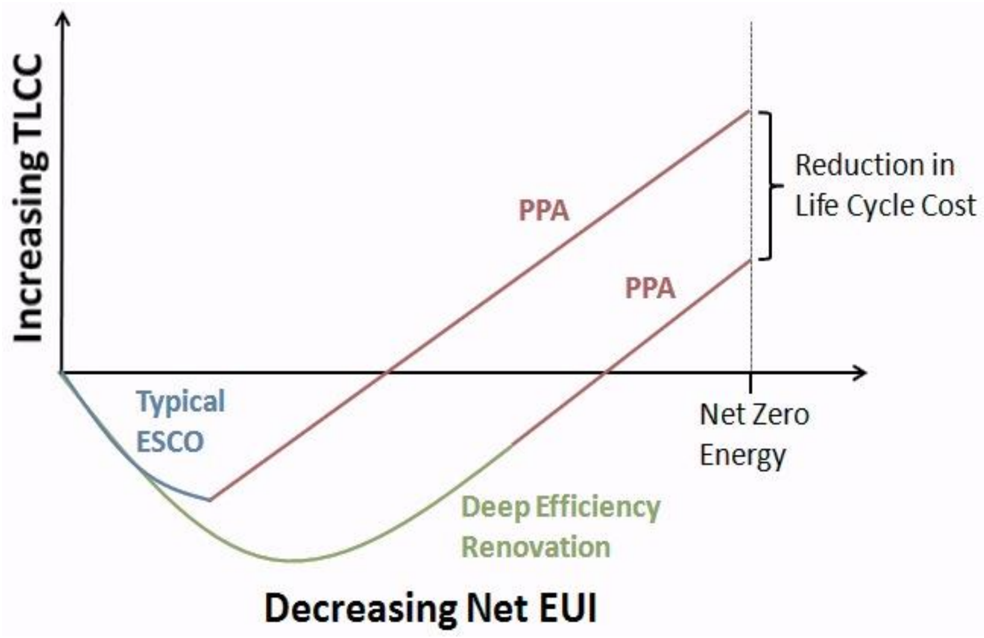


Source: RMI

Deep Retrofit and Net Zero Energy Life Cycle Cost

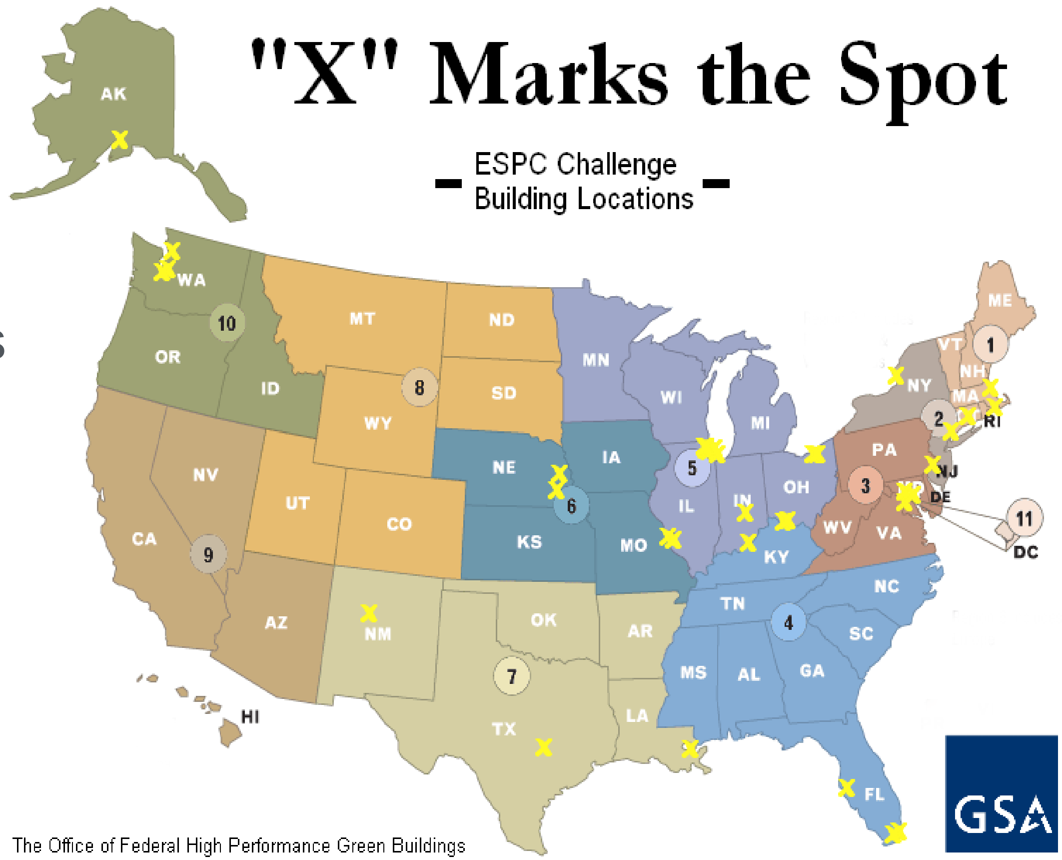
Deep efficiency renovation measures reduce EUI more cost-effectively than a PPA (for an analysis period equal to the duration of the PPA)

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)

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

Source: GSA

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FEMP

Federal Energy Management Program

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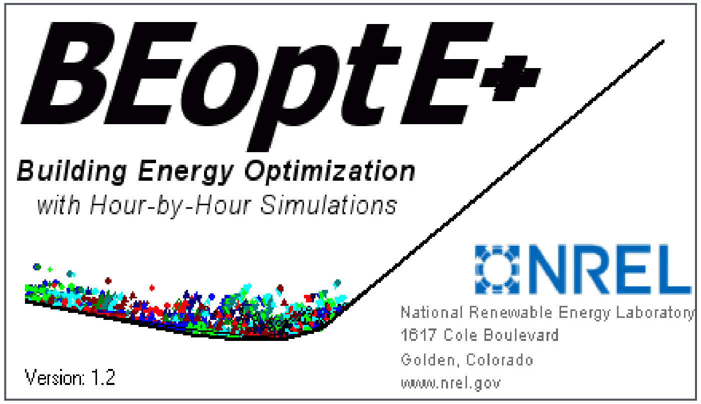
The Role of Energy Modeling in Integrated Design

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



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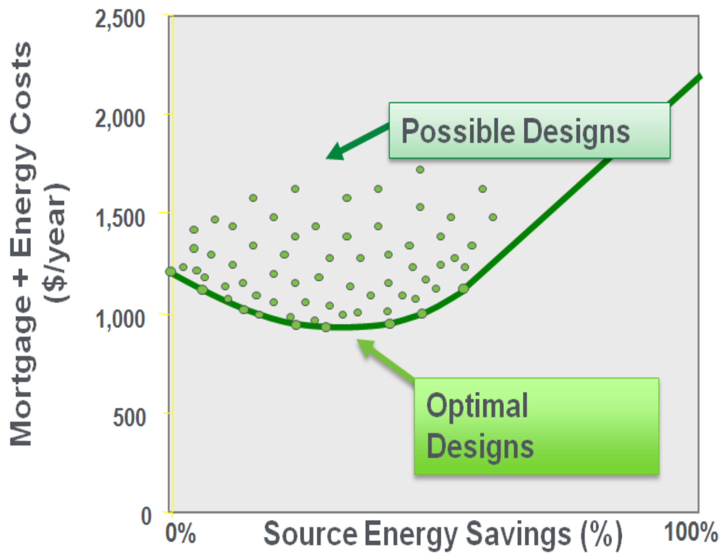
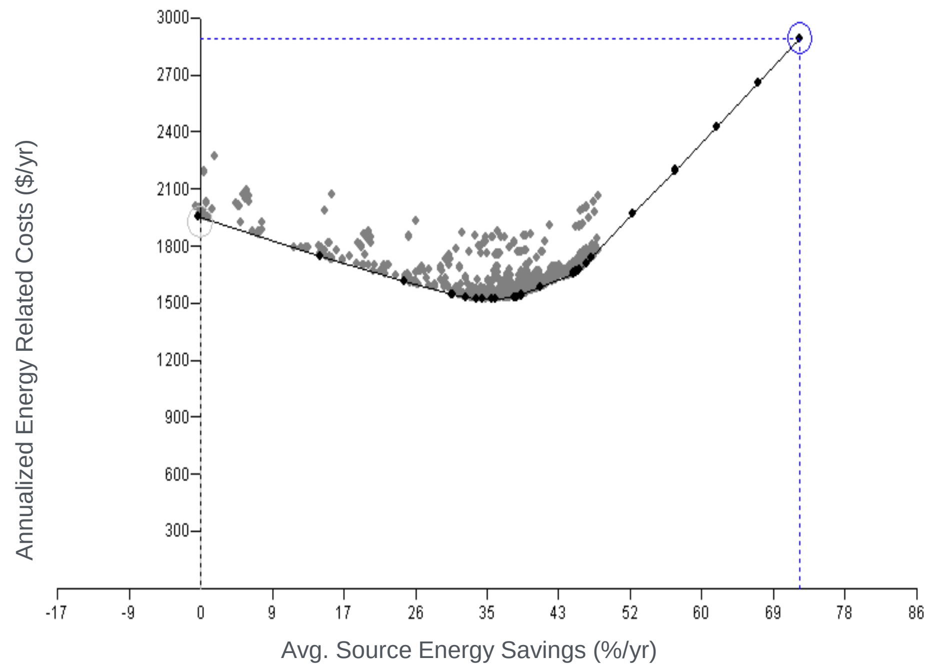
The Path to Zero Net Energy

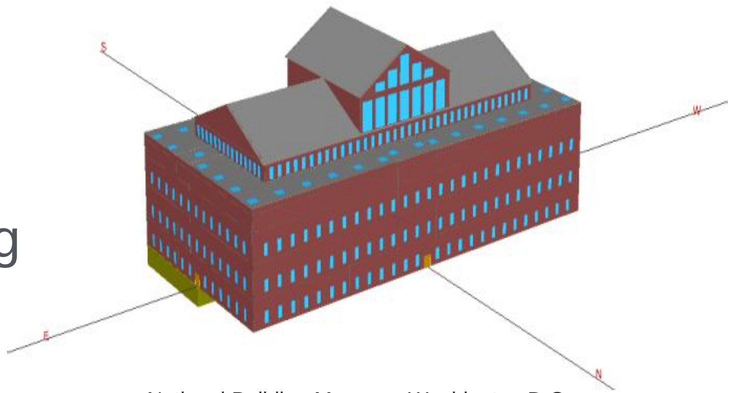




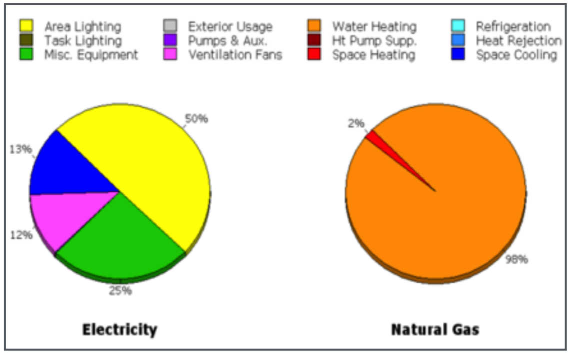
Source: NREL

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



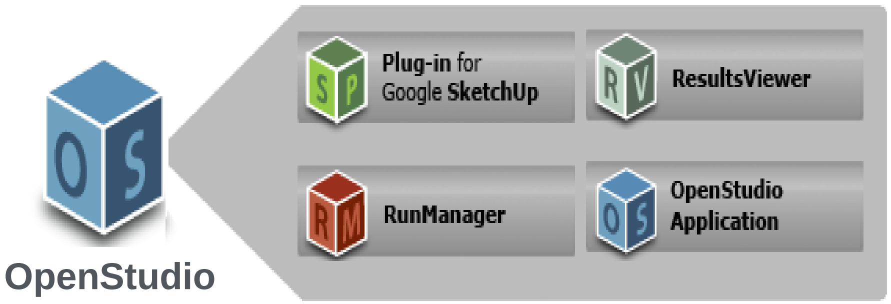
OpenStudio Suite of Tools

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



https://openstudio.nrel.gov/files/openstudio_interface_workflow-070_verE.pdf

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

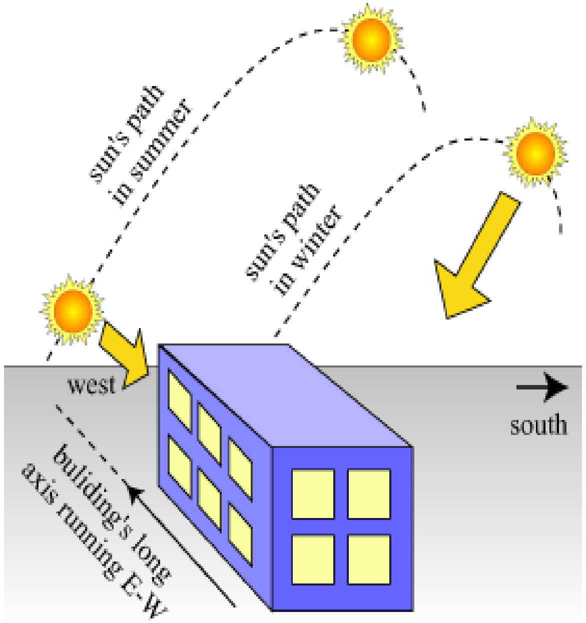
Building Envelope

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

NREL PIX #13397

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)

Source: Jesse Dean/NREL

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**

Source: Jesse Dean/NREL

Lighting

Standard Retrofit

Retrofit Existing Fixtures

Install Occupancy Sensors

Replace Exit Signs

Deep Retrofit

Determine Visual Needs of the Occupants

Install Optimized Lighting Systems

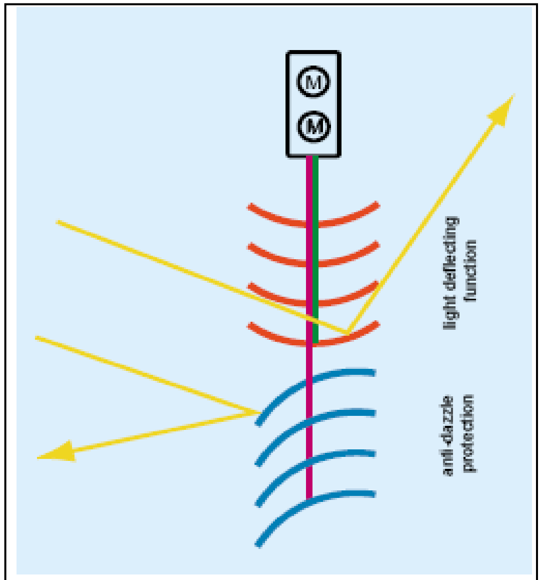
Implement Day-lighting Strategies

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



Curtain for deflecting daylight, with two independent sections

IES Handbook

http://www.warema-electronic.de/Dateien/e_Soschu.pdf

Lighting Re-Design Considerations

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

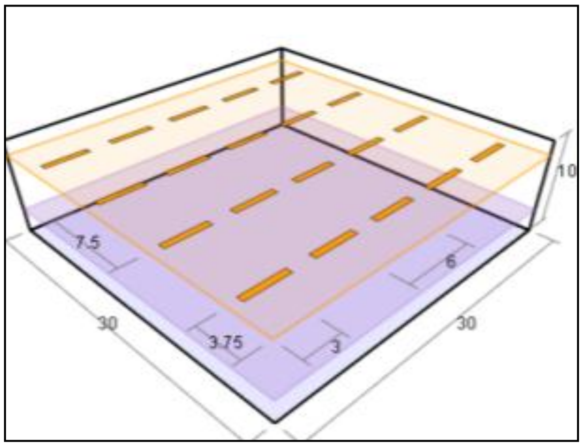
Building Area Type	LPD (Watts/ft^2)
Office	0.90
Gymnasium	1.00
Dormitory	0.61
Motel	0.88
School	0.99
Warehouse	0.66
Parking Garage	0.25

ASHRAE 90.1 2010

IESNA Recommended Illuminance	
Space Type	Illuminance (fc)
Open Office	30 – 50
Private Office	50
Conference Room	30
Corridor	5
Restroom	10

Lighting Layout with Different Design Illuminance

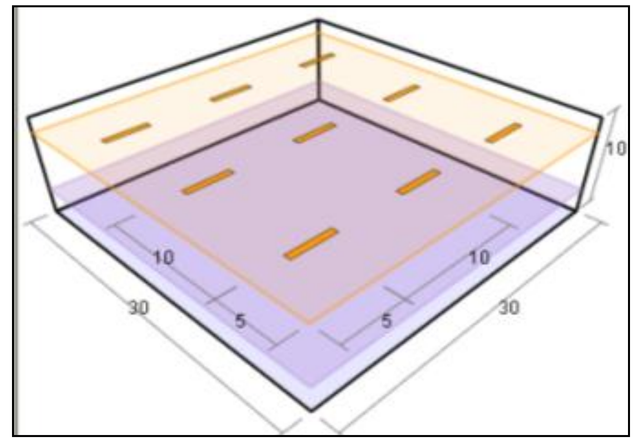
Design Target 90 fc



Result

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

Design Target 30 fc



Result

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

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/ft^2 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/ft²) for Office Space**
  - Baseline = 0.75 W/ft² (ASHRAE 90.1 - 2004)
  - Target = 0.55 W/ft² (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)

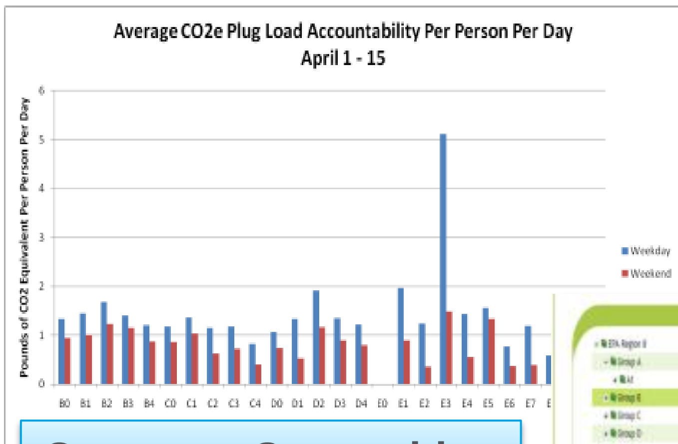
NREL Pix #10851

Energy consumption data from http://www.sust-it.net

Plug Loads- Behavioral Change

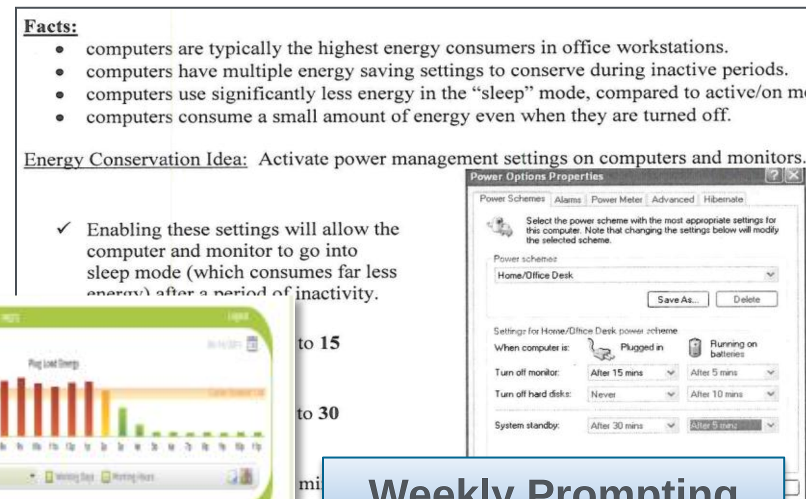
Behavioral Change

- Occupant education and awareness are critical



Occupant Competition

Real-time Feedback


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 mo
- 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.

to 15

to 30

mi

Weekly Prompting

HVAC Systems

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

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

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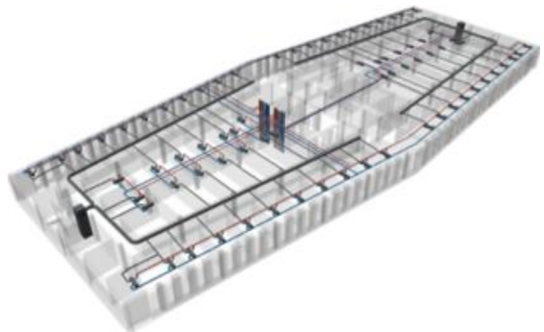
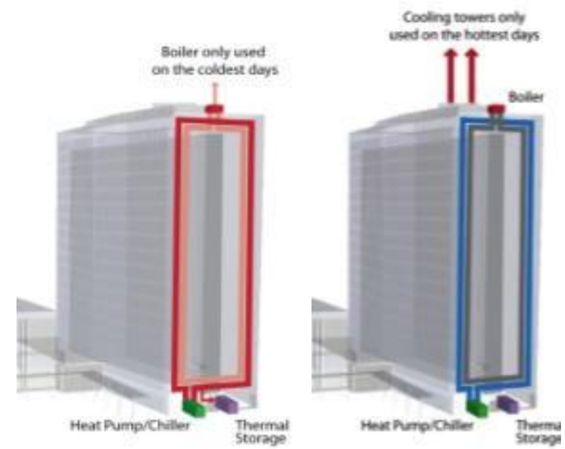
Existing building orientation is poor. How do we take advantage of it?



Chilled beam system throughout building

Heat reclaim & thermal storage

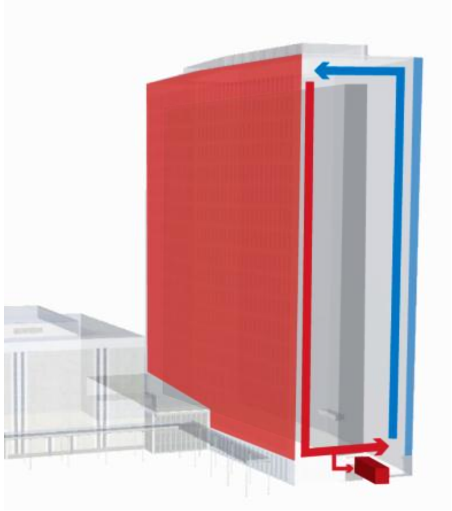
Byron Rogers Hybrid Heat Pump System



Heating Mode

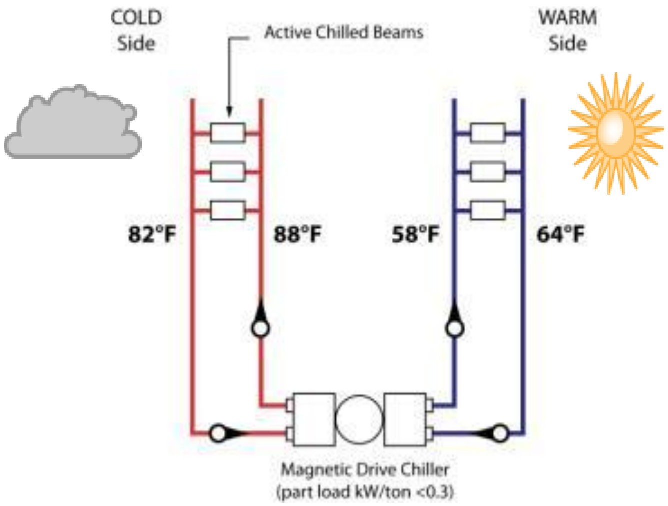
Cooling Mode

HVAC Case Study: Byron Rogers



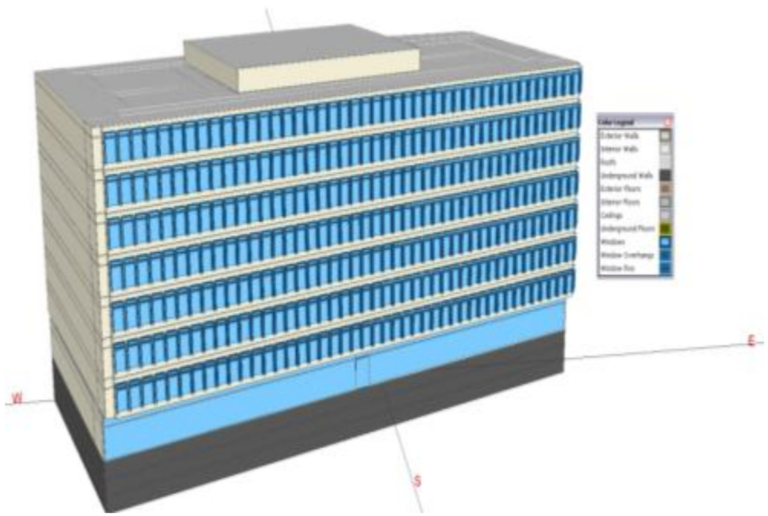
Expected EUI Reduction = 60% - 70%

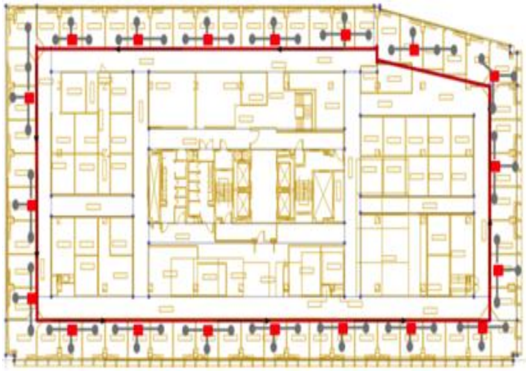
- Energy efficient chiller with heat pump mode
- Hot Water Boiler
- Heat storage tank



- **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





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

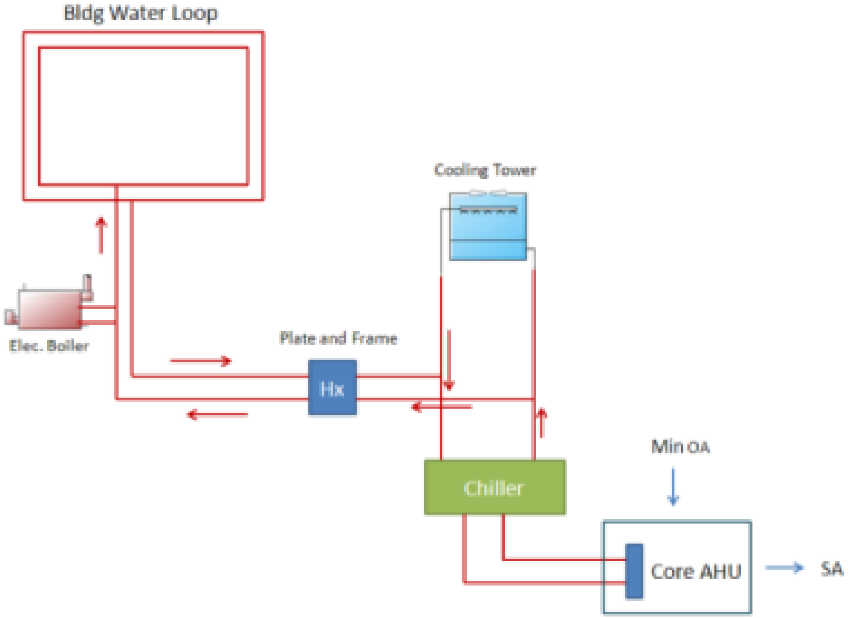
Current Condition:

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

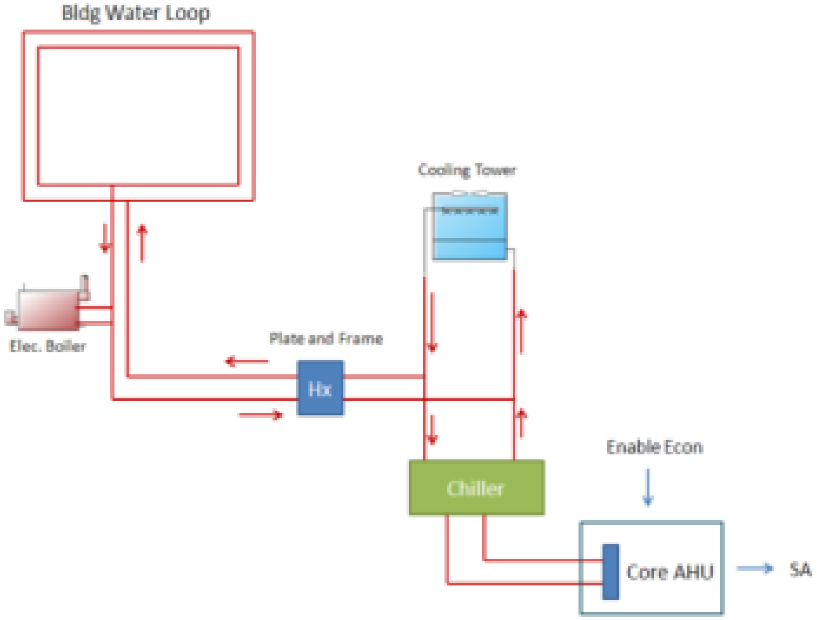
Credit: Jesse Dean/NREL

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

Renewable Energy

Planning, Programming & Budgeting → Building Design → Project Construction → Commissioning → Operations & Maintenance

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**
  http://www1.eere.energy.gov/femp/reconstructionguide/
- **Planning and integrating renewables in major renovation – 7/31/12**
- **Net Zero Energy Military Installations: A Guide to Assessment and Planning**
  http://www.nrel.gov/docs/fy10osti/48876.pdf

RE Options by ECM Type	Daylighting	PV	SWH	Solar Vent Pre-heat	Passive Solar Heat	Geothermal Heat Pump	Biomass	Wind	RE Ready
Lighting	x	x							x
Plumbing			x		x	x			x
Electrical	x	x							x
HVAC			x	x	x	x	x		x
Roof	x	x	x						x
Interior Construction	x		x	x	x				x
Building Envelope	x	x		x	x				x
Utility Svc Upgrade		x						x	x
Site Parking		x	x			x		x	x
Other (e.g., fire protection, IT/Telecom)		x	x						x

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Case Studies

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

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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

Source: City and County of Indianapolis

via opportunity charrette + ESPC implementation

Case Study: Wayne Aspinall Building

Source: GSA

Grand Junction, Colorado

- Historic Office Building and Courthouse
- Constructed 1918, Major addition in 1939
- 42000 ft^2 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/ft^2)
- **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

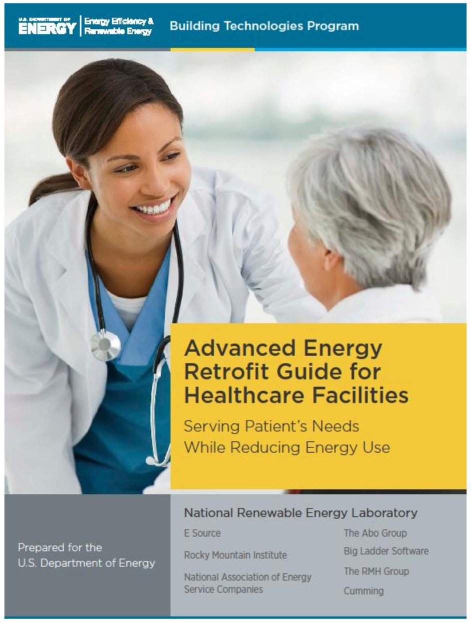
Grocery Stores
http://www.nrel.gov/docs/fy12osti/54243.pdf

Office Buildings
http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-20761.pdf

Retail Stores
http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-20814.pdf

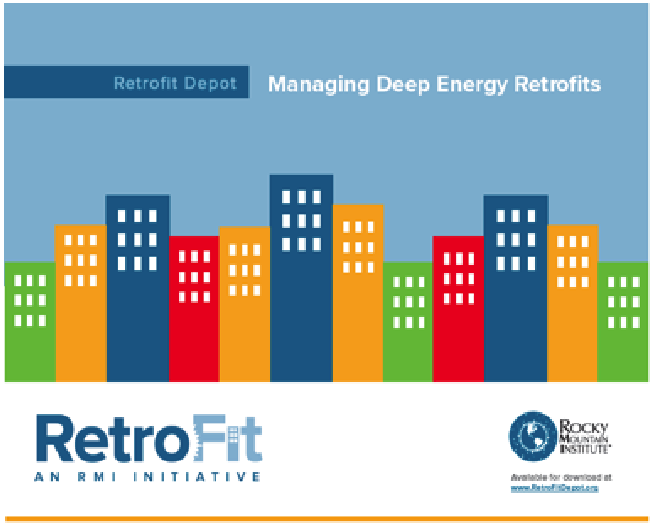
K-12 Schools (Coming soon)

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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