BEST6

National Institute of BUILDING SCIENCES
Innovative Solutions for the Built Environment

Targeting Existing Buildings for Deep Energy Retrofits

Practice 3: Retrofit session

March 19th

Presenters

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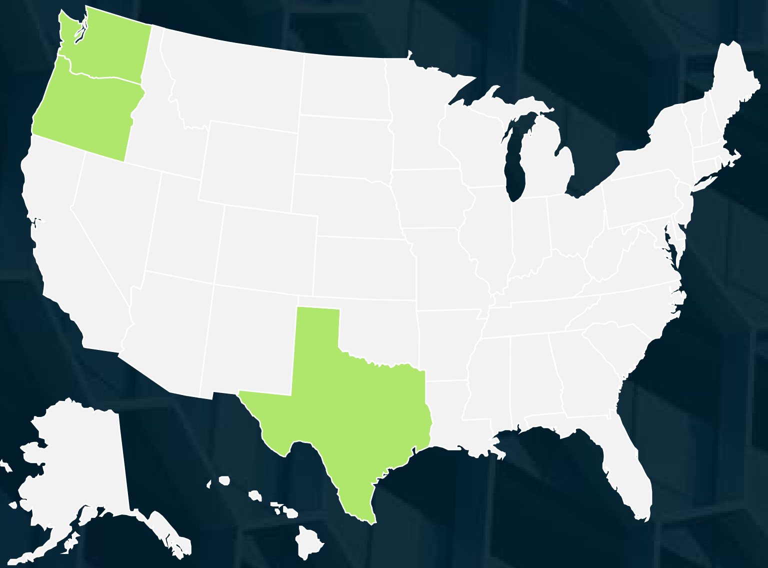


Abstract

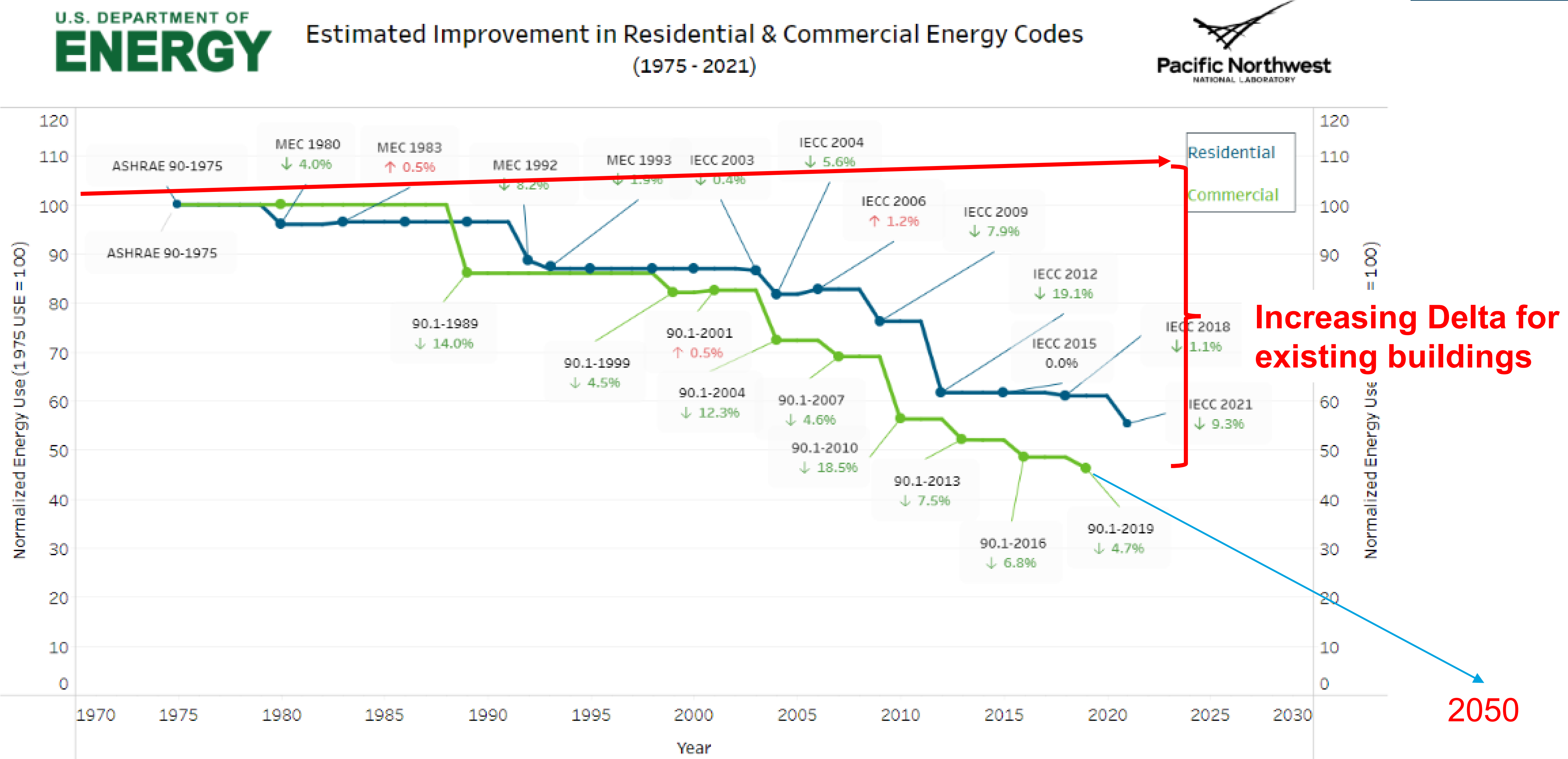
Deep Energy Building Retrofits are likely one of the most significant strategies for meeting our industry's decarbonization targets. However, far too often the costly, complicated, and technical aspects of how to address the underperforming existing enclosures leave them lightly or substantially untouched during retrofit projects. This can result in oversized mechanical systems that need to overcome air leakage, thermal bridging, and occupant comfort issues. Or enclosure renewal work, matching like with like, and done out of sequence with energy retrofit projects.

This presentation outlines new tools and approaches, from lifecycle assessment, component modelling, thermography, to whole building air leakage testing to assess, strategize, optimize, and significantly improve the passive energy components of the building - the enclosure. The presenter uses case studies from Net Zero Carbon studies, Net Zero Energy design competitions, GSA and other Federal objectives, research, energy modelling, and WA State Clean buildings act studies to present a repeatable process for existing building retrofits.

AGENDA

- Why is the Enclosure Important in Building Retrofits?
  - Changing codes,
  - Current Strategies,
  - Getting to net zero,
- How to determine what to do, impact/cost, when and why?
  - Process + Tools
- Case Studies

Changing Code Requirements (for existing buildings)



Research – Enclosure Focus

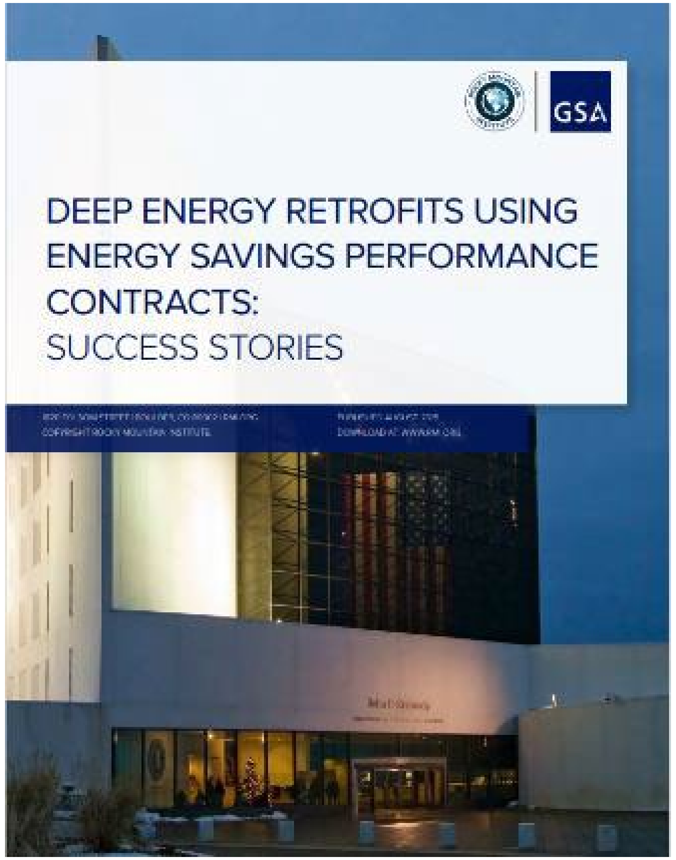
https://www.iea.org/reports

Renovating the existing building stock to a zero-carbon-ready level is a key priority for achieving the sector's decarbonization targets for 2030 and 2050. However, the retrofitting of buildings is a significant challenge since at least 40% of buildings floor area in developed economies was built before 1980, when the first thermal regulations came into force**. Retrofitting 20% of the existing building stock to a zero-carbon-ready level by 2030 is an ambitious but necessary milestone** toward the Net Zero Emissions by 2050 Scenario (NZE Scenario). To achieve this goal, an annual deep renovation rate of over 2% is needed from now to 2030 and beyond.

In buildings, energy is used for a wide array of applications, including heating, ventilation and air conditioning systems (HVAC), domestic hot water (DHW), lighting, household appliances, and electronics. Older, existing buildings are on average inefficient compared to newer buildings. While appliances can be replaced with ones that have greater energy efficiency due to their shorter lifespans, **the building envelope (walls, roof, and windows), as well as technical and mechanical equipment systems, are rarely upgraded since they are high-cost and done on an as-needed basis.** These components also have a longer shelf life at 40-plus years for building envelopes and 15-plus years for technical systems. Nonetheless, these are the building elements whose performance improvement can bring the most significant benefits in reducing CO_2 emissions, especially in regions with very cold or hot climates.

Finding the optimal cost-effective combinations of building envelope renovation solutions with high-efficiency technical systems using renewable and low-emissions energy sources is the main challenge and the focus of numerous research projects. **One of the most significant factors influencing the decision-making process is the initial investment required, which can be very high and often with long payback periods.**

Deep Energy Retrofits (GSA examples)



SEIZING OPPORTUNITY:
KING AND BRICKELL FEDERAL BUILDINGS

KEY ENERGY CONSERVATION MEASURES (ECMs):

- Packaged water AC units
- Lighting upgrades and controls
- Variable air volume controls
- Water conservation and on-site treatment
- Energy recovery ventilation

PROJECT SNAPSHOT:	
Location	Miami, Florida
Building Size	581,000 ft² (2buildings)
Original Construction	1972 (Brickell) and 1993 (King)
Development & Construction Duration	32 months (2012–2015)
Investment Value	$4.4 million
Appropriated Funds	$2.2 million (51%)
Contract Term	15 years
Cost Savings	$249,000/year
Energy Savings	13,326 MmBtu/year (43%)
Energy Service Company	FPL Energy Services, Inc.

James L. King Federal Building
Image courtesy of: *General Services Administration*

LOAD REDUCTION FOCUS

THE NAVY BREAKS THROUGH:
NAVAL AIR STATION OCEANA

KEY ENERGY CONSERVATION MEASURES (ECMs):

- Steam and chiller plant decentralization
- High efficiency HVAC equipment
- Renewables: solar thermal, ground-source heat pump (GSHP) with effluent heat rejection
- Digital controls: over 18,000 measurement points
- Lighting retrofits: over 40,000 fixtures
- Water conservation: over 10,000 fixtures

REVOLUTIONARY RESULTS:
ALMERIC L. CHRISTIAN FEDERAL BUILDING

KEY ENERGY CONSERVATION MEASURES (ECMs):

- Retro-commissioning
- Building automation system (BAS) upgrades and smart building integration
- Lighting upgrades
- Chiller, air handling unit (AHU), and pump replacements
- Window films
- 462 kW solar PV

DEFINING THE BARRIERS TO DEEP ENERGY – ENVELOPE RETOFITS.

- Costly to access claddings, window, roofs,
- Disturbances to existing Occupants & neighboring occupants,
- Heritage protection,
- Difficult to do targeted removal (e.g., just windows),
- Differences in lifcycle / wasted durability (e.g., walls=60+, windows=20, roof=25 years),
- Renovation triggers code upgrades = costs,
- No incentives,
- Cheaper to add bigger HVAC to manage losses…
- “What if we cause a bigger problem?” – confidence in material science.

Heritage Buildings & Code Compliance

In 1966, when Congress passed the National Historic Preservation Act, it formally declared that "**the preservation of this irreplaceable heritage is in the public interest so that its… energy benefits will be maintained and enriched for future generations of Americans**"

These codes do not necessarily fully apply to historic places. Properties listed on a local or state register of historic places, or **listed or eligible for the National Register of Historic Places, need not comply with the IECC if compliance** "**would threaten, degrade or destroy the historic form, fabric or function of the building**" (International Code Council 2018 C501.6).

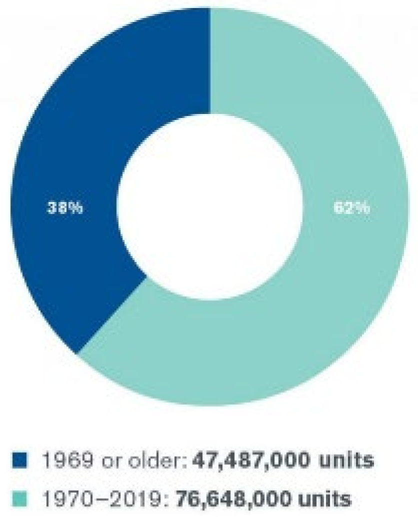
Beyond building codes are a second set of standards relevant to historic building rehabilitation: the Secretary of the Interior's **Standards for the Treatment of Historic Properties** (the "Standards") (36 C.F.R. § 68.3). The Standards offer rules for **four different treatments of historic places: restoration, preservation, reconstruction, and rehabilitation**.

C501.1 Scope. The provisions of this chapter shall control the **alteration, repair, addition and change of occupancy** of existing buildings and structures – Chapter 5, IECC

The National Register recognizes more than **90,000 properties** for their significance in American history, architecture, art, archeology, engineering, and culture.

Behind the facades of old buildings may very well be the secret to accelerating climate progress.
"the greenest buildings"—those already built.

FIGURE 1: HOUSING UNITS OVER 50 YEARS OLD



Source: Author-created graphic from U.S. Census Data 2019 American Housing Survey, General Housing Data for All Occupied Units.

https://kleinmanenergy.upenn.edu/research/publications/aligning-historic-preservation-and-energy-efficiency/

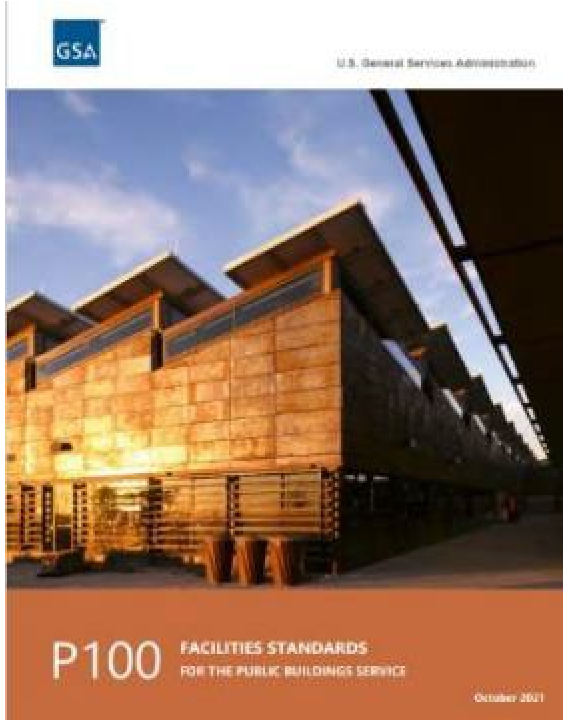
PBS-P100 2021

1.2.1 REPAIRS, RENOVATIONS, MODERNIZATION AND ALTERATIONS Repairs, renovations, modernizations, and alterations are improvements made to existing facilities.
All items within the project's scope of work must be designed in accordance with P100. Repairs in kind are not required to upgrade to the current P100 but must be limited to singular items. The designer must clarify ambiguities in writing before beginning the design.

1.3.4 HISTORIC PRESERVATION The National Historic Preservation Act (NHPA) of 1966 mandates that Federal agencies use historic properties to the greatest extent possible and **strive to rehabilitate them** in a manner that preserves their architectural character, in accordance with the Secretary of the Interior's Standards for the Treatment of Historic Properties.

1.3.3.1 ENERGY ACT OF 2020 REBATES Project teams must pursue utility rebate and incentive programs and any government grant or incentive programs at the local, state, and federal level. Project teams are encouraged to contact the local utility as early in the design process as possible to determine if the project qualifies for a financial incentive or rebate, as local utilities often offer "custom" or unadvertised rebates. Rebate checks must be submitted to GSA. Examples of projects that are typically eligible for rebates or incentives include the following:

- **Building envelope improvements (windows, roofing, doors, weather stripping)**
- HVAC upgrades and new installations (boilers, chillers, VFDs, tune ups, controls, etc.)
- Lighting retrofits (LED upgrades, controls, etc.)
- Appliance purchases (cafeteria equipment, water heaters, etc.)



Research – Enclosure Focus

Research

Decarbonizing Canada's Large Buildings: A Path Forward

January 2022

…a rare and critical opportunity to advance decarbonization.

Enclosure upgrades are a one-time opportunity that can't be missed.

Among energy-demand reduction activities, enclosure upgrades are the highest priority. Enclosure renewals occur very infrequently, typically every 20 to 100 years, depending on the assembly type and condition (most occur after about 40 years). As such, existing buildings are likely to only undergo a single enclosure upgrade between now and 2050. Each enclosure upgrade therefore represents a rare and critical opportunity to advance decarbonization. Upgrades also provide a range of additional benefits including:

Increased energy savings: The enclosure upgrades in the 1970s buildings achieved a reduction of approximately 20 to 50% in energy use, resulting in lower operating costs and less exposure to future utility cost escalation.	**Resilience to climate change** by supporting passive survivability and lessening dependence on grid energy to maintain livable space conditions.	**Building durability**, which can reduce maintenance and repair costs as well as increase building longevity.	**Lower peak demand,** which can enable replacement equipment to be downsized and reduce overall operational costs, especially for building types and locations with high utility demand charges.

Economic Barriers	Market Barriers	Financing Barriers
• Misalignment between carbon savings and energy savings • Long payback periods • Large incremental capital cost requirements	• Lack of energy or carbon awareness • Low return on investment and implementation hassle • Cost-saving split incentives • Lack of confidence in project performance and results • First-mover disadvantage, technological and logistical readiness	• Lack of access to attractive financing • Uncertainty with developing standard investment risk profiles • High loan transaction costs • Availability of secured, on-balance sheet debt

Resiliency & Durability

ROI?

Financing?

Energy Savings

Right size Equipment

Confidence in results?

Service Life Expectancy

BETA VERSION 0.5 | CONTACT

National Performance Based Design Guide
National Institute of Building Sciences High Performance Building Council

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PRINT

4.1 Building Enclosure

SHOW THE KEY

Click the cells below to choose a level of standard for each attribute. Show Tooltips

IN THIS SECTION: Envelope - Protective Security | Envelope - Natural Hazard | Envelope Serviceability | Water Penetration Resistance
Moisture and Condensation Control | Air Tightness | Thermal P...
Enclosure Acoustic Control | Enclosure Service Life

V. DURABILITY

Durability, while very important to many, is very difficult to quantitatively predict, and there are few reliable methods of test and verification. Two targets for each performance level have been identified: the full service life and the time between major rehabilitation. The most important tools are material selection, using experience, and design reviews by third parties, with experience and knowledge related to durability.

Walls

- Baseline: Minimum 50 year full service life / 25 year for major rehabilitation
- ★: Minimum 70 year full service life / 30 year for major rehabilitation 75/30
- ★★: Minimum 100 year full service life / 40 year for major rehabilitation 100/40
- ★★★: Minimum 150 year full service life / 50 year for major rehabilitation 150/50

Roofs

- Baseline: Minimum 20 year full service life
- ★: Minimum 30 year full service life
- ★★: Minimum 40 year full service life
- ★★★: Minimum 50 year full service life

Fenestration

- Baseline: Minimum 30 year full service life / 15 year for major rehabilitation of gasket and seal replacements
- ★: Minimum 40 year full service life / 20 year for major rehabilitation of gasket and seal replacements
- ★★: Minimum 50 year full service life / 25 year for major rehabilitation of gasket and seal replacements
- ★★★: Minimum 75 year full service life / 25 year for major rehabilitation of gasket and seal replacements

Developing a Repeatable Process

Assess:

Visual, Exploratory, Laboratory, Modelling (Thermal, Resiliency, Material, Comfort), Testing, ..

Develop Strategies:

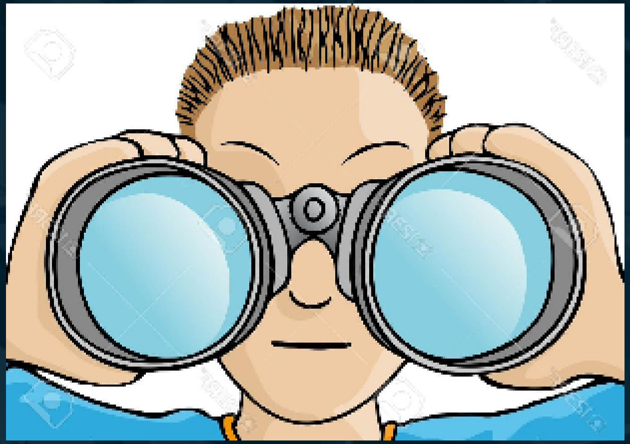
Energy Conservation Measures

Carbon Reduction Measures

Analyze:

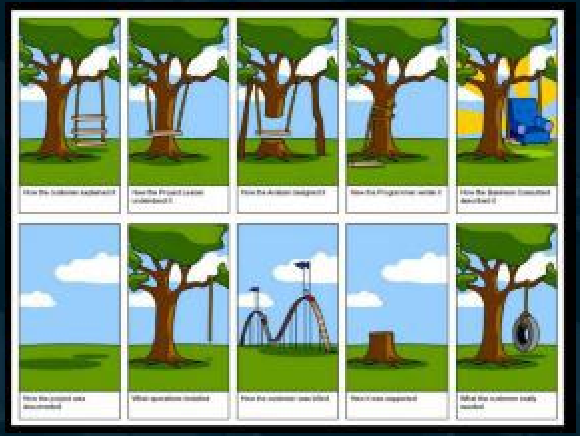
Energy, Resiliency, GHG, Cost, Comfort, …

Assess:
Visual, Exploratory, Laboratory, Modelling (Thermal, Resiliency, Material, Comfort), Testing, etc.



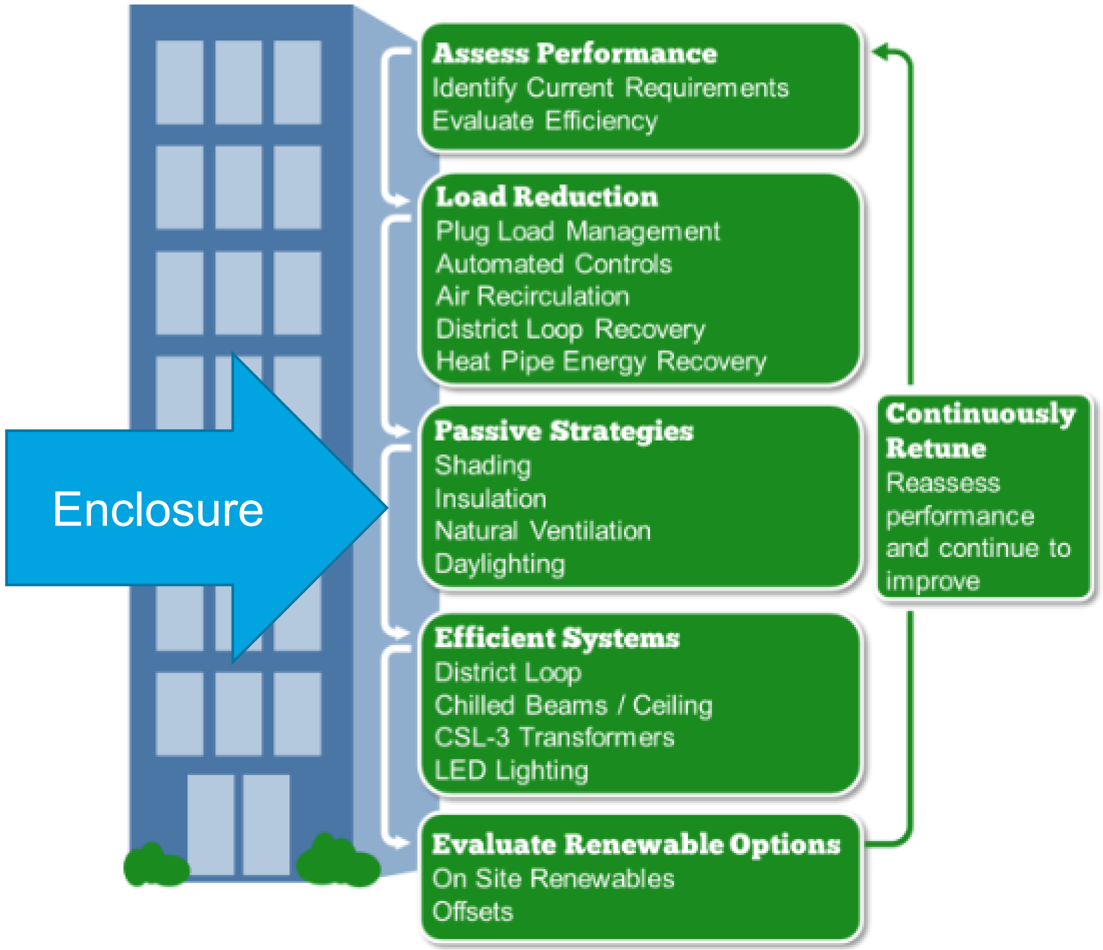
- Interviews
  - Facility Management staff (they know better than you…)
- Visual Review
  - Assemblies,
  - Conditions,
  - Tell-tail signs of aging, deterioration, failures
- Exploratory Openings:
  - Problem source(s),
  - Extent of damage/deterioration,
  - “As-built” confirmation
- Laboratory Testing
  - Confirm performance,
  - Confirm characteristics
- Modelling:
  - Thermal, hygrothermal, Energy, Embodied Carbon, Comfort, Resiliency,
- In-Situ Testing:
  - Establish a baseline,
  - Determine deterioration source(s)

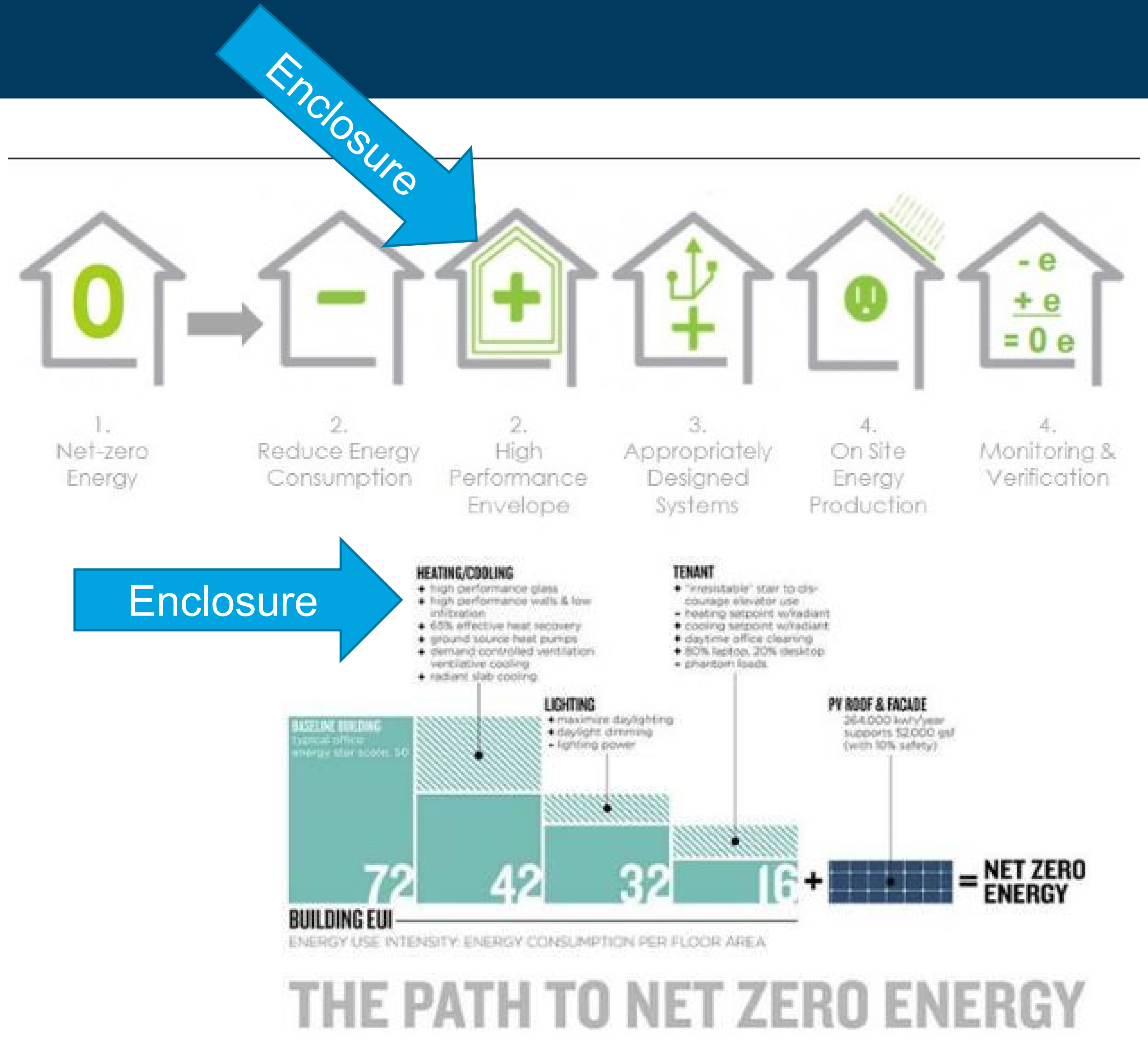
Develop Strategies:
Energy Conservation Measures
Carbon Reduction Measures



- "Fix what's broken." A good place to start.
- Brainstorming sessions – many minds (big and small).
- Use a bookend approach – "do nothing" to "do everything" and something in between.
- Consider Retro-Commissioning.
- Develop Energy Conservation Measures (ECM's)
- Consider Embodied Carbon, or Carbon sinks,
- Synergistic with Architectural (use/function), Mechanical, Electrical, Landscape, etc..

Retrofits – Strategies (passive then active)





Analyze Strategies:

Energy, Resiliency, GHG, Cost, Comfort, ...

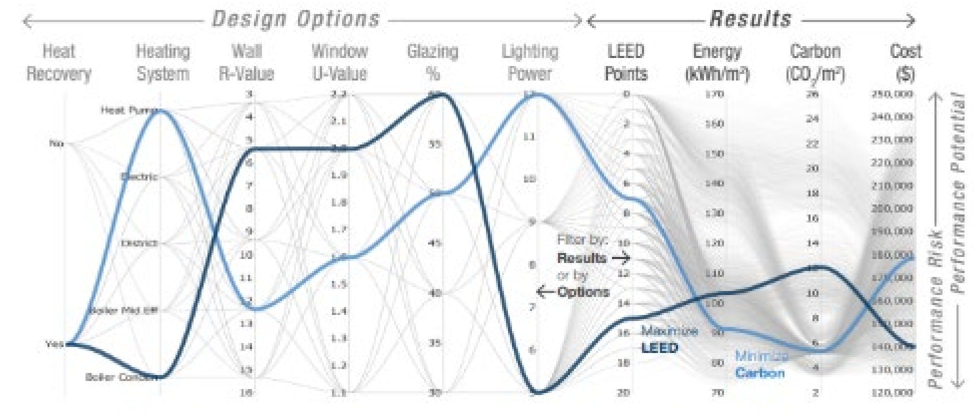


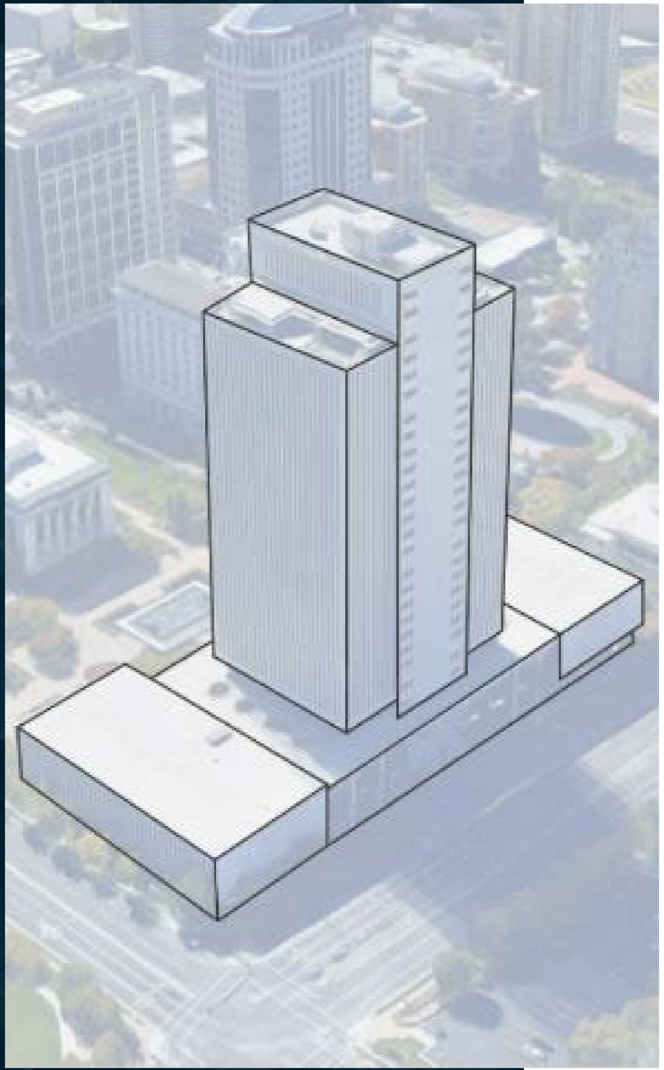
Figure 2 Building Performance Map effectively communicates design criteria alongside simulation results to architects, engineers, owners, and policy makers. Two discrete simulations (design option scenarios) have been highlighted in blue showing relative performance in the context of thousands of other possibilities.

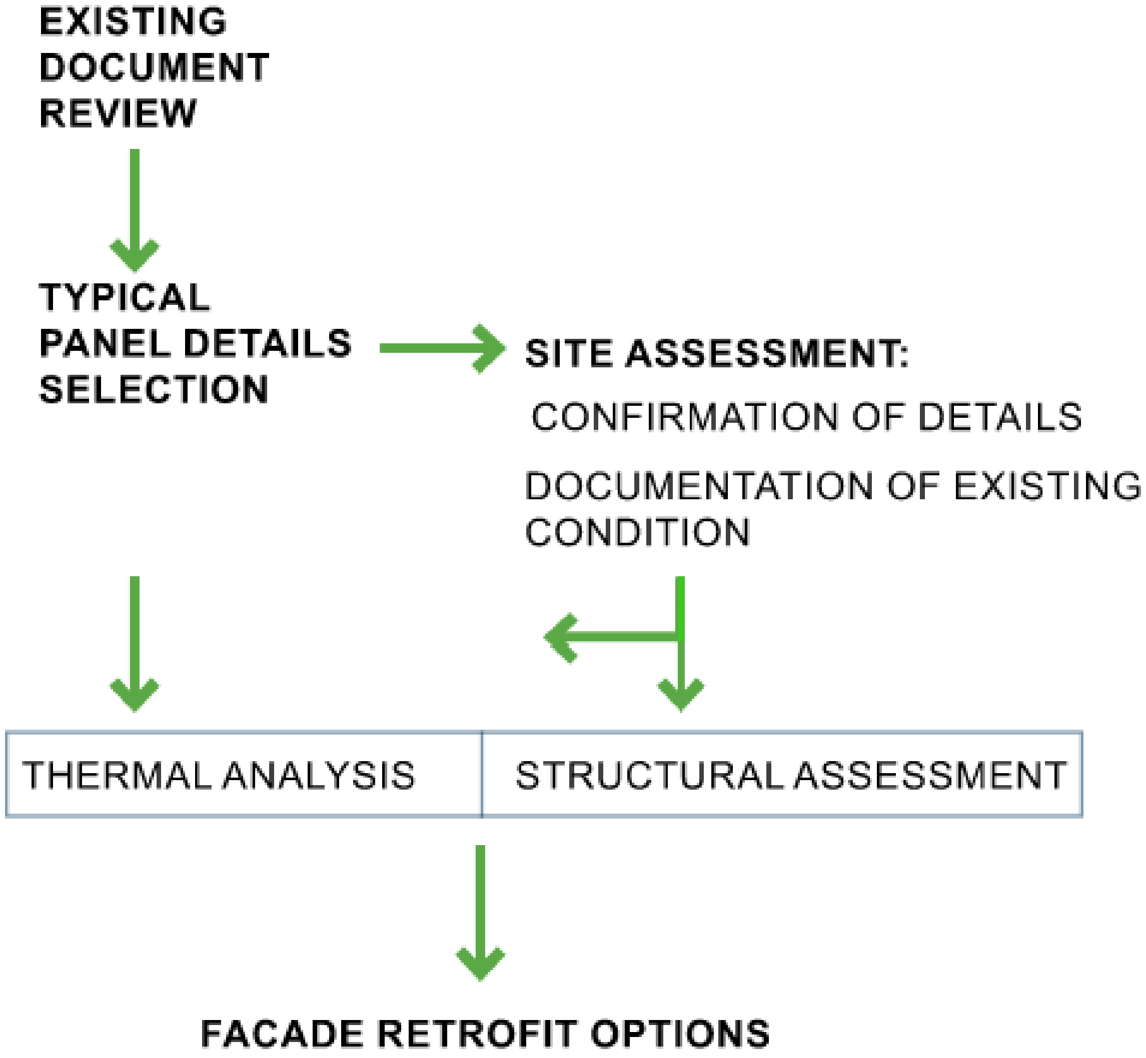
- Modelling:
  - Thermal (THERM),
  - Hygrothermal (WUFI/Delphin),
  - Energy (EUI, GHG, Total vs. Goal),
  - Operational / Embodied Carbon (LCA / GHG),
  - Comfort (ASHRAE 55),
  - Resiliency / Risk assessment (?),
- Cost (Simple payback and LCC)
- Synergies with other non-enclosure Strategies.
- Constructability
- Impact on occupants

MH Façade Retrofit Study - Utah

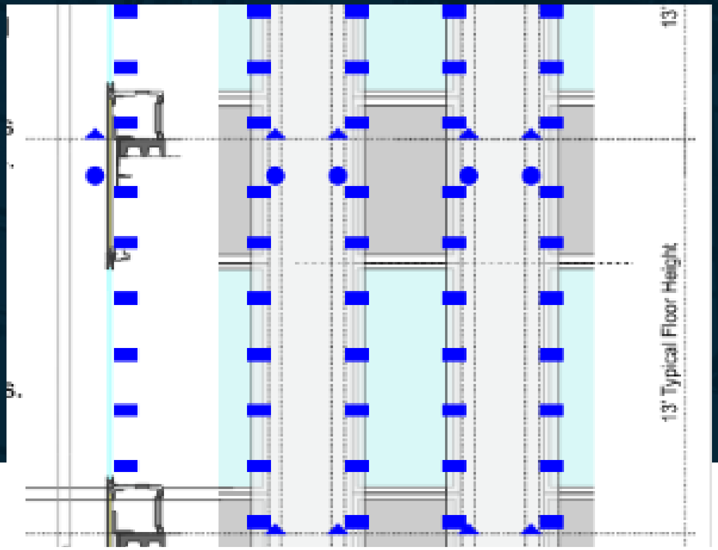
1972 Building, 28 story, cold climate. Steel-framed structure, architectural precast, aluminum-framed curtain wall.

Study Purpose: Focused on Structural and Thermal performance, develop repair strategies, enhance overall façade performance.

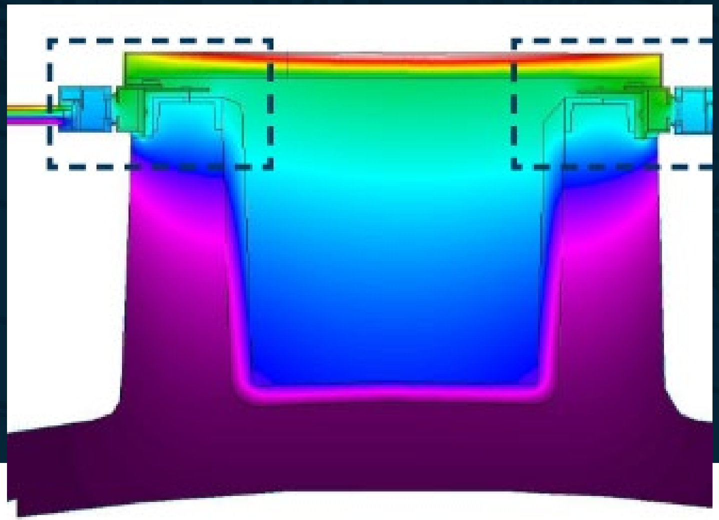




MH Façade Retrofit Study - Utah



Structural Assessment of anchors and precast



Thermal Modelling (THERM)

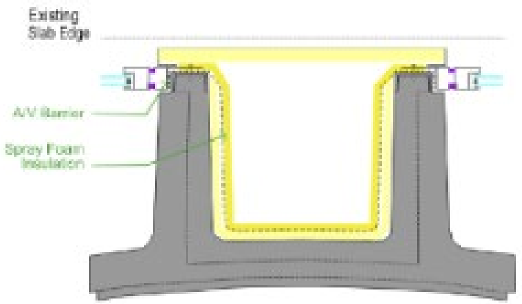
Thermography

MH Façade Retrofit Study - Utah

Facade Retrofit Options

OPTION 01 $

Existing Facade
+ Spray Foam and Air Leakage Reduction



Area weighted **U factor: 0.47** Btu/hr-ft2-°F

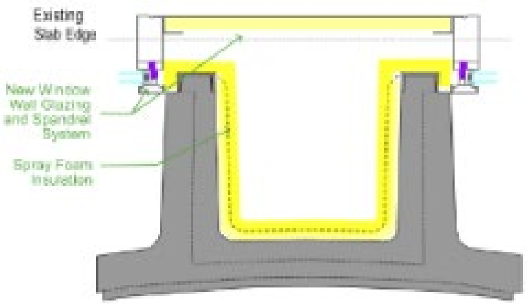
28% Reduction

Pros
- Cost effective on the short term
- Upgraded perimeter seals
- Air leakage reduction

Cons
- High air leakage
- Low thermal performance
- High thermal bridging
- Minimal facade movement
- Maintenance safety
- Facade replacement needed in the next 10 years

OPTION 02 $$

Existing Precast Panel
+ Additional Spray Foam Insulation
+ New Window Wall Glazing System



Area weighted **U factor: 0.40** Btu/hr-ft2-°F

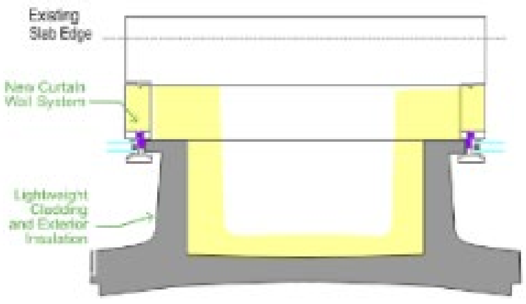
39% Reduction

Pros
- Upgraded glazing system with better thermal performance
- Continuous air barrier
- Upgraded continuous sprayed insulation
- Reduced thermal bridging
- Separation of glazing system load from precast panel

Cons
- Precast panels lifespan
- No seismic movements provided for the precast panels
- Cost for glazing replacement can vary $80-$120/sf

OPTION 03 $$$

New High Performance Curtain Wall
+ Additional Exterior Insulation
+ Lightweight cladding



Area weighted **U factor: 0.25** Btu/hr-ft2-°F

62% Reduction

Pros
- High performance facade
- Continuous air barrier
- Higher thermal performance for opaque assemblies
- Reduced thermal bridging
- Lightweight precast cladding options: UHPC* or FRP/C**
- Movement tolerances within opaque and glazing system
- Cladding profile open to redesign

Cons
- Higher cost for full facade replacement can vary $100-140/sf

*UHPC - Ultra High performance Concrete
**FRP/C - Fiber Reinforced Polymer/Concrete

Balancing Retrofit Options

Considering

- Structural,
- Thermal,
- Cost.

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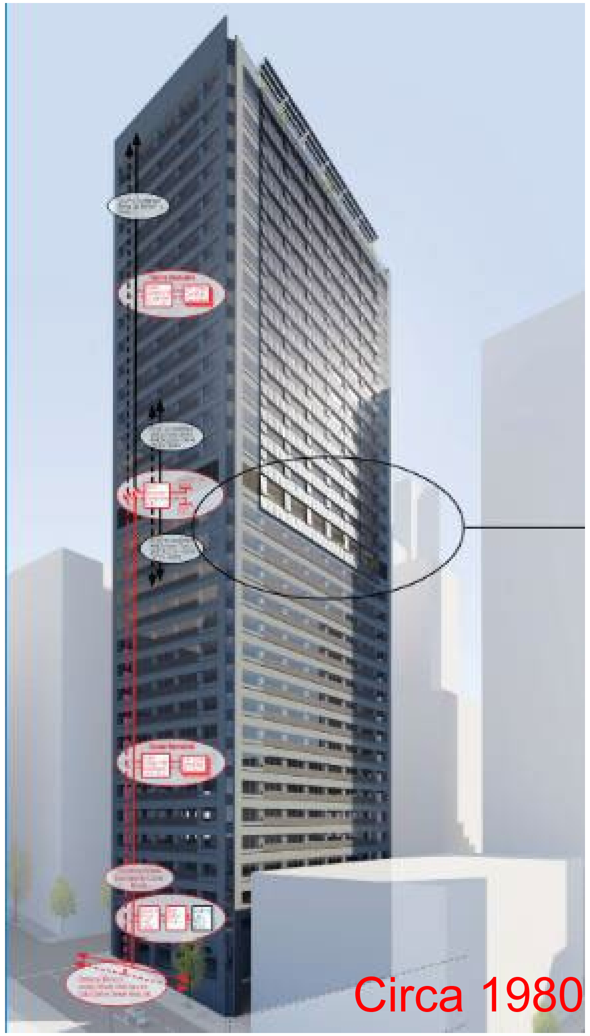
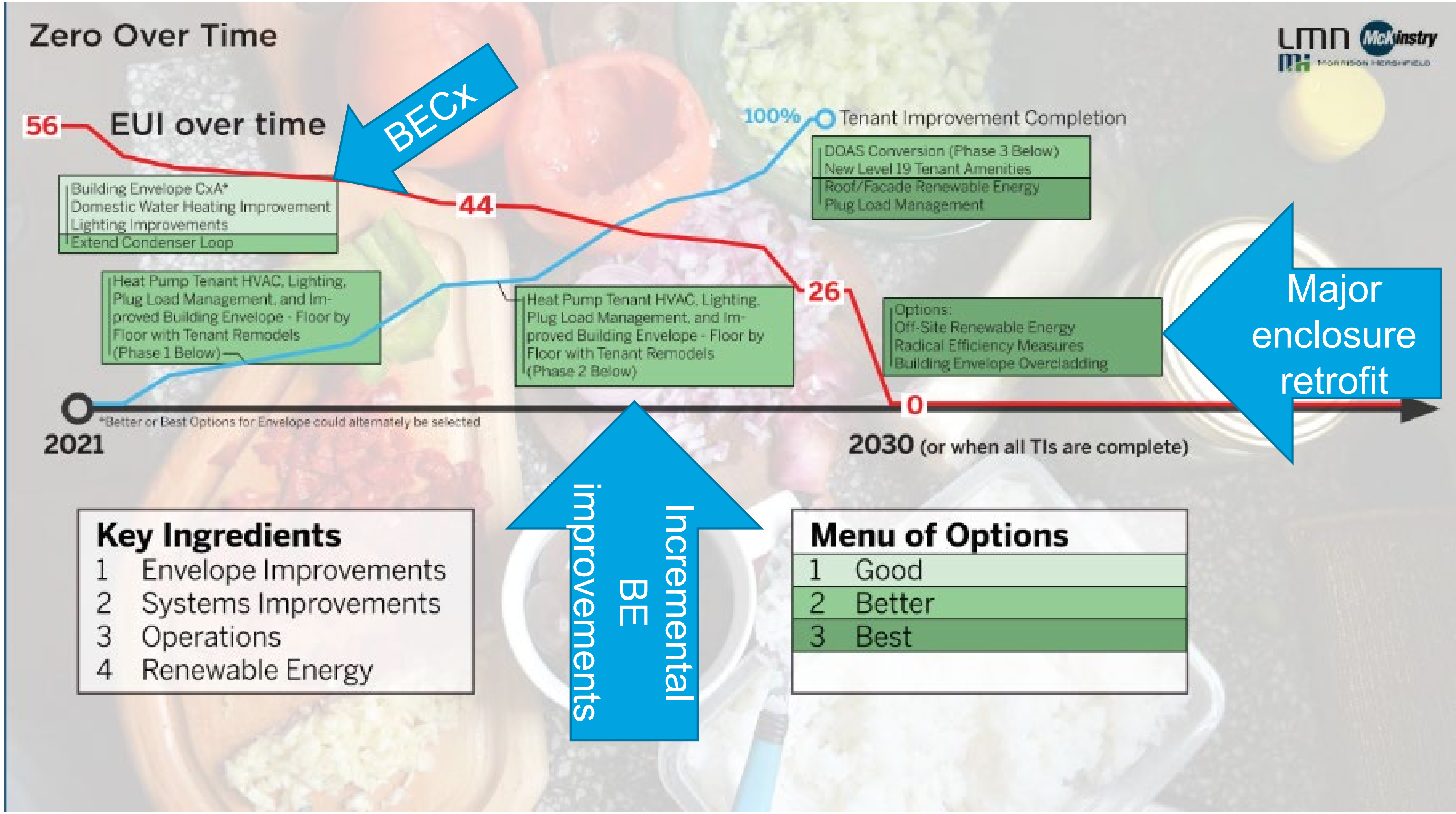




2030 District Design Competition 2021 – Seattle, WA

Building Envelope Commissioning

Good #1
0.5 EUI
$

Perform Building Envelope Commissioning (BECx), including air sealing from exterior to <1.0 cfm/sf. No change to walls, exterior water sealing, or roof insulation. Thermography will be used to identify focus areas for improved thermal performance (thermal bridges) and air leakage to address with the BECx work.

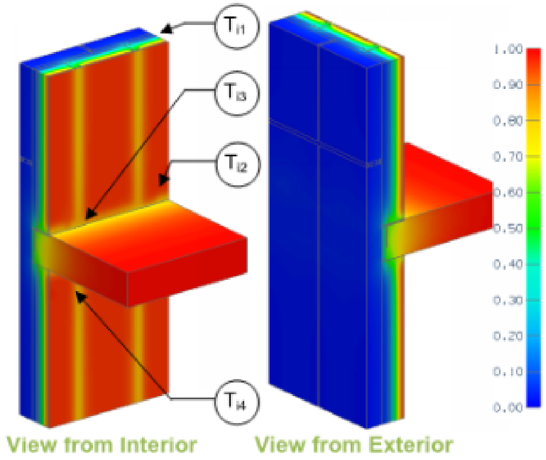
Benefits: Reduces building energy use and required mechanical sizing for heating, which will reduce the cost of upgraded mechanical systems described in other strategies.

Impact to Occupants: Minimal - no removal of finishes

Risks: Current building is face-sealed, which is more vulnerable to rainwater leaks. Other strategies propose better insulation to reduce interior cold surfaces and condensation and improve thermal comfort.

Cost-Payback: $

EUI Improvement: 0.5 kbtu/sf/year



2030 District Design Competition 2021 – Seattle, WA

Improved Building Envelope

Going beyond ‘Building Facade Commissioning,’ as Tenants upgrade their space to the new HVAC system, they can improve opaque walls with 2” rigid insulation or spray foam on interior, improve thermal resistance at floor slabs, upgrade airtightness to current code (<.35 cfm/sf) and improve glazing (U=0.24 with 2 low-e coatings; glazing could be done as one effort or with each tenant improvement). The overall building could include new rainscreen sealant joints and increase roof insulation to 8” depth.

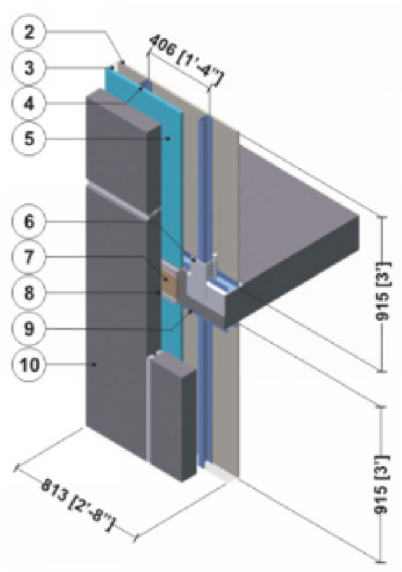
Benefits: Significantly improved thermal comfort, size reduction in mechanical heating and cooling plants. Reduction in airborne moisture intrusion risk.

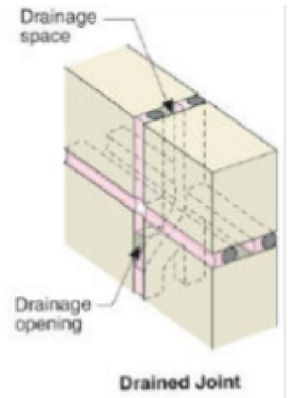
Impact to Occupants: Requires replacement of glazing, and removal of interior finishes, with an opportunity for a seismic upgrade. Could be completed with Tenant HVAC remodels to reduce disruption.

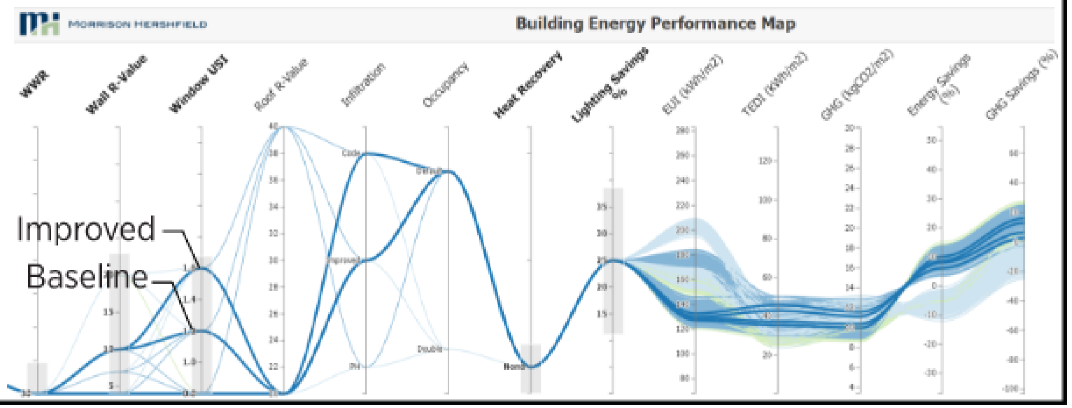
Cost-Payback: Walls/Glazing/Roofing: $$

EUI Improvements: 9% based upon similar building, climate and M&E systems.

Better #6
3 to 4 EUI
$$







2030 District Design Competition 2021 – Seattle, WA

Building Envelope Overcladding

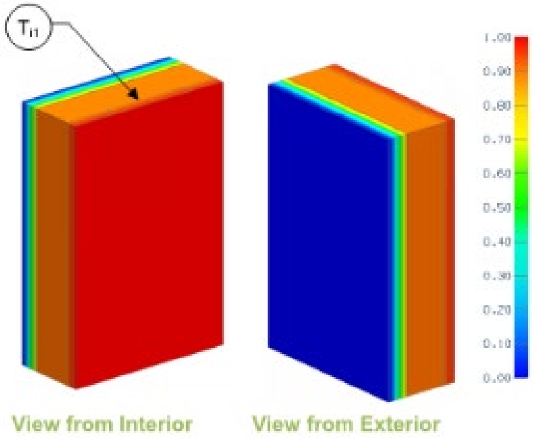
Best #3
-12 EUI
$$$$

Going beyond 'Building Facade Commissioning' and 'Improved Building Envelope,' an extremely high performance envelope would require overcladding or re-cladding, bringing the opaque wall up to R20-R35+ with 2" rigid insulation or low-GWP spray foam, air sealing to Passive House levels at 0.06 cfm/sf, and improving glazing to triple pane (U=0.11), potentially with electro-chromic glazing.

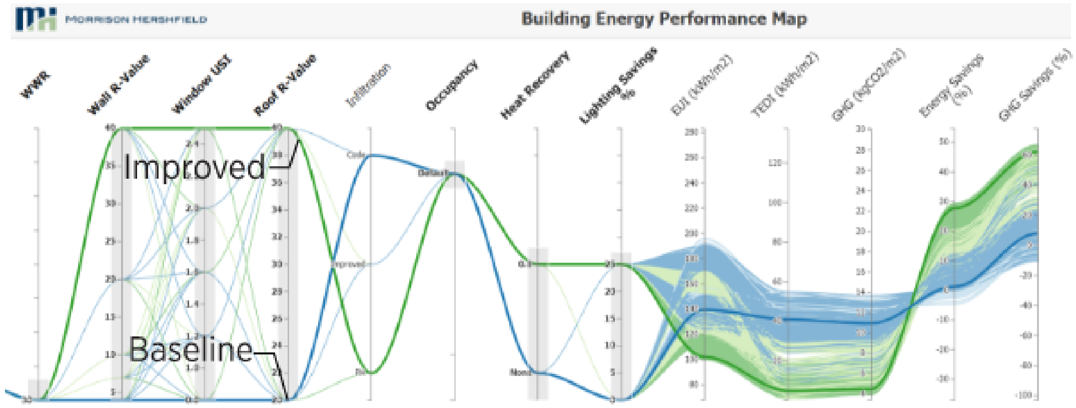
Benefits: Significant thermal comfort improvements and HVAC system size reductions. Reduces risks of moisture in air, leaks, and thermal comfort issues.

Impact to Occupants: Requires replacement of Glazing, and removal of interior finishes + new exterior aesthetic appearance

Cost-Payback: Walls/Glazing/Roofing: $$$$



EUI Improvements: reduced EUI by 25% from baseline based upon similar building, climate and M&E systems.



Study Findings

Envelope Retrofits are important to:

- Reducing loads,
- Improving resiliency,
- Improving thermal comfort,
- Meeting net zero / high performance / Ownwer Goals and targets

Initial cost / payback calculations are typically unfavorable and hence major envelope improvements should be aligned with Component Service Lives

The A/E Industry has:

- The knowledge (air, vapor, thermal, moisture movement/control) to reduce risk,
- The analysis tools to evaluate strategies,
- The modeling tools to illustrate Cost/Carbon/Thermal Comfort,
- ...but we need to find better financial options and opportunities.

Thank You