Phase 1 Technical Report:
Transforming Public Housing with Deep Energy Retrofits
Open Market ESCO LLC

Project Title

Transforming Public Housing with Deep Energy Retrofits

FOA Topic Area

Topic 1: Integrated Building Retrofits

Points of Contact

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Project Overview

Project Objectives Summary

Open Market ESCO LLC's ("OME") Phase 1 project, Transforming Public Housing with Deep Energy Retrofits, (the "Project") had six original objectives, summarized below:

1. Fully integrate architects, engineers, and other relevant participants of record in DER design process;
2. Engage general contractor and key vendors to participate throughout the design development process to streamline pricing and inform constructability;
3. Identify financing barriers, and solutions, and create a roadmap for new financing and/or grant funding applicable to RAD conversions and low-income housing tax credit (LIHTC) projects;
4. Create a replicable DER design solution for affordable multifamily housing projects pursuing major recapitalization events, such as RAD;
5. Structure a resident and building staff engagement/education/training program that will ensure long term savings and project success;
6. Drive demand in the marketplace by sharing lessons learned with stakeholders, including HUD, state finance agencies, public housing authorities, and owners.

These six objectives were achieved through the project's four main tasks, Integrated Design, Pricing & Contractor Engagement, Financing & Deal Structuring, and Deep Energy Retrofit Scale-Up, as well as the ABC Collaboration activities over the course of the Project.

The Project is unique among other Advanced Building Construction initiatives as it focuses on process and approach, rather than technology R&D. While technology certainly plays a role in the approach itself – laser scanning and panel selection specifically, as explained herein – the Project instead focused on integrated and performance driven design and financing as critical methods for transforming an otherwise "business as usual" ("BAU") renovation into a financed whole building deep energy retrofit. Using a real affordable housing rehab project, planned for the 102-unit Eva White Apartments community in Boston, MA, OME facilitated its entire project team, including Reisen Design Associates (RDA), Keith Construction Inc. (KCI), Castle Square Tenant Organization (CSTO), Urban Ingenuity (UI), and others, to work closely with one another and third-party manufacturers to identify and advance a deep energy retrofit solution - including product design, means and methods, and financing.

Refining the pre-development approach, including design, pricing, resident engagement, and financing is feasible with the appropriate leadership, performance objectives, and most importantly, the deep understanding of financial constraints, existing subsidy sources, and creative deal structuring. OME sought to exhaust all avenues for financing high-cost deep energy retrofits, focused specifically on the Rental Assistance Demonstration (RAD) Program, which will stabilize cash flow and attract new capital to bring public housing into the 21st century. This Technical Report describes how the Project not only achieved its intended objectives, but also helped establish a replicable approach to developing and implementing deep energy retrofits in extremely low-income housing.

Progress by Task

- Task 1: Integrated Design

The Project's Task 1 was design and engineering focused, with four subtasks including commitments, design exploration, due diligence, and design development. Task 1 is complete, with the major deliverable being the Project's drawings and specifications, informed by manufacturer and product research as well as existing conditions of the Eva White building. The Project evaluated numerous building envelope and HVAC systems, all as described in Attachment A, with the final selection of systems/technologies represented in the Project's construction drawings, available here.

- Task 2: Pricing & Contractor Engagement

The Project's Task 2 engaged construction industry experts and trades throughout design development, with the goal of integrating contractor feedback related to pricing and constructability. The Project incorporated feedback from four main vendors and partners, Sunrise Erectors, Superior Plumbing, The Waterproofing Company, and Keith Construction, the Project's general contracting partner. The Project hosted numerous on-site meetings as well as weekly calls to solicit contractor feedback from conceptual to schematic to construction design phases. This task included two Subtasks related to contractor engagement and pricing. Project costs are incredibly high and will continue to prove challenging for deep energy retrofit implementation. The Project identified cost reduction strategies early in the design phase, which helped inform the selected approaches for envelope and HVAC systems. A copy of Eva White's 50% CD construction budget is included in Attachment B attached hereto.

- Task 3: Financing & Deal Structuring

Understanding that construction cost would be a major barrier for whole building deep energy retrofits, the Project spent a considerable amount of effort and time on trying to solve the financing gap. The Project specifically focused on RAD conversions in an effort to support grater project costs through traditional financing sources, including the first mortgage. The Project is underwriting 100% of water and energy cost savings, which is higher than standard best practice yet still insufficient to support the total Project costs. The Project worked with Urban Ingenuity to develop the attached Financing Roadmap (Attachment C) documenting various financing strategies explored throughout the Project, including the final outcome which is a highly replicable solution for the RAD Program. Task 3 included three subtasks focused on identifying and securing gap funding necessary to finance deep energy retrofits in affordable housing.

- Task 4: DER Scale-Up

The Project's 4th task is related to post-retrofit planning and market transformation, including strategizing resident engagement and training, compiling a record of representative building characteristics, estimating costs and savings for potential Phase 2 projects, and engaging industry stakeholders. The Project compiled numerous building characteristics (Attachment D) that can be sorted and evaluated for deep energy retrofit replicability, and applied Phase 1 energy performance modeling against two similar buildings, one of which is included in the Project's Phase 2 proposal, which is being submitted in collaboration with Rocky Mountain Institute. The Project also evaluated numerous buildings in the City of Boston, considering Phase 1 findings against low-income multifamily buildings considering carbon emissions intensity in accordance with the City of Boston's upcoming emissions ordinance. Stakeholder engagement and outreach was achieved through numerous conferences and presentations, as well as printed collateral shared publicly and with key stakeholders, including at the city and state levels (Attachment E).

- Task 5: ABC Collaboration

OME participated in all ABC Collaboration activities, including virtual meetings, summits, data calls, webinar series, and peer review activities.

- Task 6: Down Select Activities

As of the writing of this Technical Report, OME expects to complete Down Select Activities before the end of December.

Results

Project results are presented below, organized by Task.

Task 1 Results:

1. *Design Exploration:* The Project executed agreements with key design team members, after which it initiated weekly scoping sessions and design meetings. It became immediately evident that goal oriented and collaborative design is anything but 'business as usual'. The Project established key performance objectives and requirements, primarily informed by the REALIZE initiative, including the below:
    a. 50% savings compared to baseline;
    b. 75% heating, cooling, and hot water EUI reduction, targeting EUI 7.8;
    c. Occupied renovation, rather than unoccupied;
    d. Full electrification of heating, hot water, and ventilation equipment;
    e. No change in utility metering or billing structure;
    f. Incorporation of pre-fabricated building envelope product;

    With the above goals established, the design team, led by OME, held weekly meetings to discuss conceptual scopes and approaches, similar project examples, capital needs, business as usual or in-kind replacement options, resident displacement, hazardous material abatement, product development, and ventilation strategies. The Project identified, with energy modeling results, the below building envelope specifications:
    - R-30 thermal performance;
    - U-0.26 window performance;
    - 0.2 ACH50 infiltration;
    - R-40 roof insulation.

    Further energy modeling iterations (Attachment F) suggested the Project could achieve energy performance objectives with slightly lower performance specifications, including down to an R-22 panel and R-30 roof; however, the project is pursuing an effective panel performance closer to R-28.

2. *Analysis/Due Diligence:* Structural analysis of the building is perhaps the single most significant factor in the planning of a re-cladding project. The existing structure sets the limits and requirements of the panel configuration, setting limits of the panel weight and determining the panel anchoring system and attachment strategy. The Eva White building has a singular location to anchor the wall panels to because of the location of rebar in the building's floor slabs. The panel

anchoring system ultimately had to adjust and be re-designed to accommodate this limiting factor. In addition, wind loading – whether set by code, or building insurance providers - informed the panel structure, including Tremco's interior framing member layout. The building and project specific constraints may be replicable across similar buildings – concrete and block structure, 1960's construction – but every building receiving a mechanically attached panel will require an existing conditions analysis. In addition to working with a structural engineer to verify existing structural constraints, the Project engaged a 3D laser scanning company to establish the consistency of the face of the existing brick veneer and concrete façade. The laser scans were compared to the project's (highly accurate) as-built drawings and used to create a topographic heat maps (Attachment G), which suggested extreme variability – 3" at its worst - in the façade.

3. *Design Development:* The Project developed design narratives, schematic design, and a 50% Construction Document set. Each design iteration captured additional details, uncovered new or unforeseen issues, and triggered technical requirements, with each progressive set of designs uncovering unique details and nuanced project requirements. During the conceptual phase of design development, the Project considered multiple panel options, and only advanced design further upon selecting its approach, based on the above performance requirements and Project objectives. The pros and cons of different panel options and outline of design development is reflected in Attachment A. The Project attempted to design and bid a scope of work based on and around a product still in an R&D phase, which proved extremely difficult for refining and re-working design. The *project* design and *product* design progressed hand-in-hand, which helped advance the product R&D, but added complexity to the project design itself. While the conceptual phase of design considered generic details – panel to panel joints, panel to wall connections, window to panel integration – schematic and construction design led to design discovery and technical detailing related to trimming out window returns, reducing gaps between dissimilar panels or products, window hinge and screen locations, fire stopping, HVAC coordination, compartmentalization between units, and even aesthetic decisions (where joints fall visually, how panel colors are selected, etc.). The resulting drawings reflect a fully constructible and financeable scope of work, integrating all-electric HVAC systems and prefabricated panels (Tremco Revitalite) in an occupied setting. The complete design package may be access here.

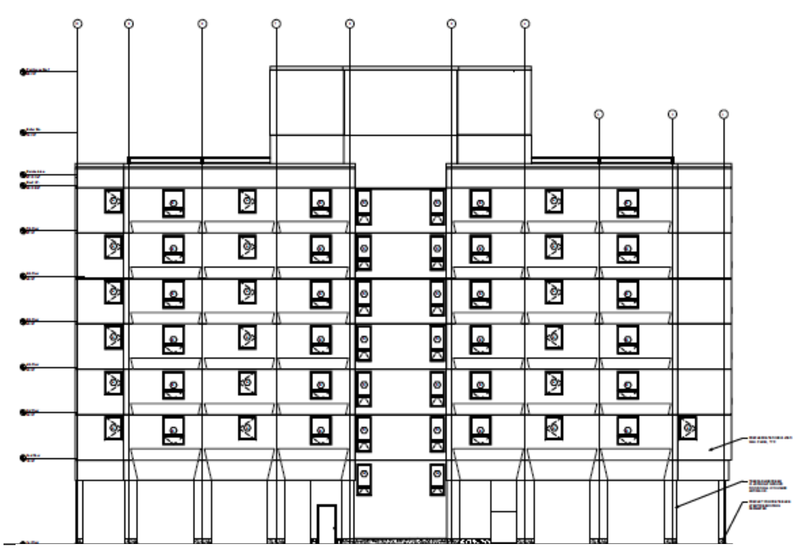


Figure 1: Building Elevation

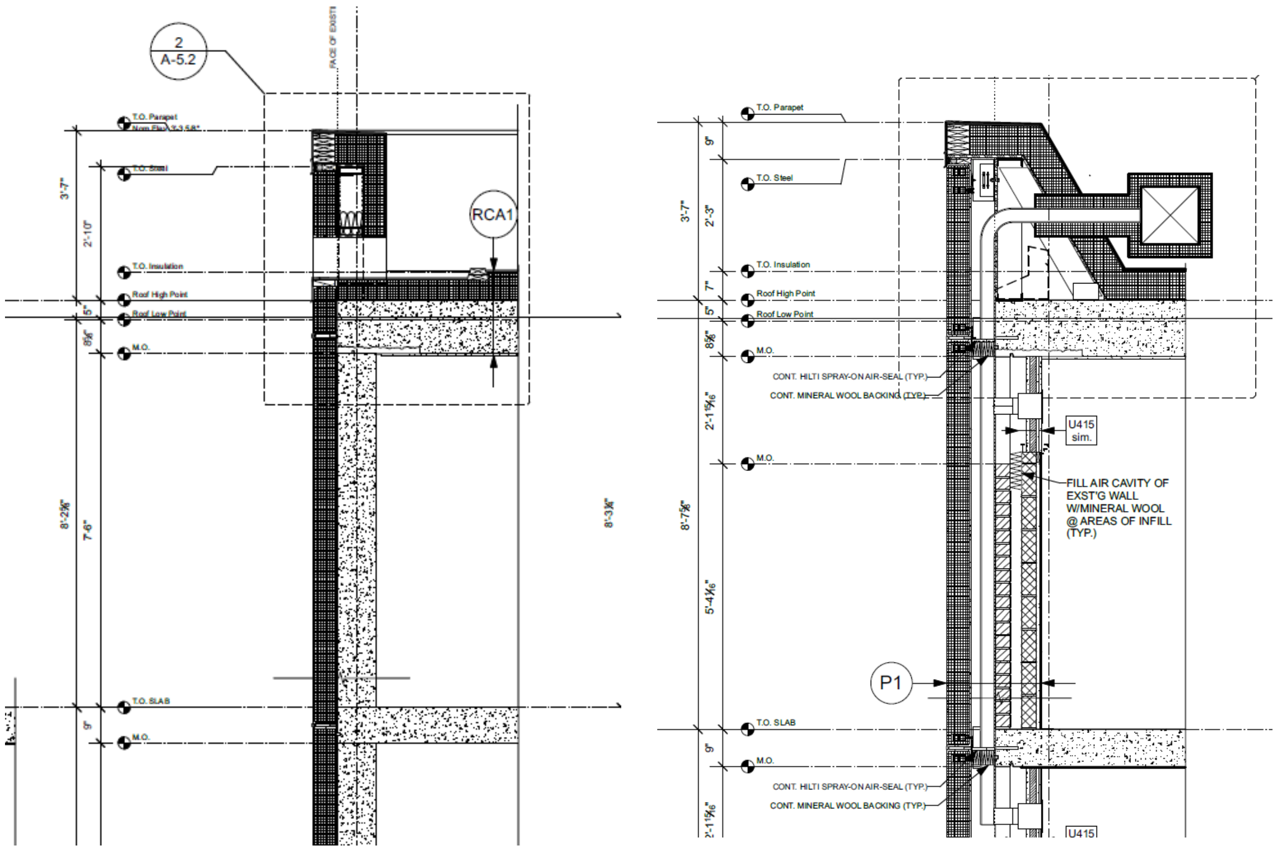


Figure 2: Section detail of "Return Wall" (left) and front and rear elevation with Revitalite (right)

<u>Task 2 Results:</u>

1. Contractor Engagement proved most useful for HVAC system design. The Project evaluated numerous supply air distribution strategies, including in-unit ERVs, interior vertical shaft distribution, and various exterior shaft distribution layouts. The Project invited mechanical contractors to participate in weekly design meetings when new mechanical design approaches were presented, allowing the Project to incorporate immediate, field-based feedback in the design development process, while reducing cost. Contractor feedback and engagement led to the following design decisions:
    a. Exterior distribution preferred for refrigerant and ductwork;
    b. Locate all HVAC on outside wall to avoid in-unit distribution;
    c. Access panels not needed for refrigerant line maintenance;
    d. Fire and smoke damper requirements are extensive and should be avoided when possible;
    e. Roof mounted mechanical equipment requires adequate spacing from roof for snow and ice (which led to parapet structure and height);
    f. Adequate spacing is needed around all panel anchors for proper bolt sequencing, resulting in greater attention to panel and mechanical equipment design coordination;
    g. Cavities at or greater 6" in depth require sprinkler systems, resulting in a maximum cavity depth of 5.75".

The Project also discovered that there are very few contractors and installers familiar with pre-fabricated panel systems. In the case of Revitalite, many panel installers that specialize in curtainwalls and windows were uncomfortable with a product that seemed so similar to EIFS, preferring products perceived to be more durable given their use of steel, aluminum, and glass.

2. Pricing and bidding innovative and unusual projects such as the scope of work developed for Eva White Apartments is nearly impossible in a normal market, let alone during COVID. The Project included Sunrise Erectors, a panel fabricator and installer, early on during conceptual and schematic design phases. Sunrise not only provided pricing support, but also helped develop a schematic design for a pre-fabricated curtainwall system utilizing Kingspan insulated metal panels, and helped explore other products and manufactures, including hosting early meetings and discussions with Nexii. Sunrise helped establish early pricing expectations as well as consulting on site access and sequencing. Pricing was conducted primarily by the general contractor, Keith Construction, who is also overseeing the non-energy aspects of the Eva White renovation. Keith Construction and Sunrise Erectors budgets are included in Attachment B and summarized below.

   a. **Building Envelope Pricing (440 Tremont Only)**

	Baseline	**DER Envelope**	**Notes**
Demo	$68,300	$169,325	Full sill removal
Exterior façade insulation	$0.00	$2,088,100	Aluminum in-kind window replacement vs. Revitalite panel
Windows	$691,900		
Façade repairs, cleaning	$194,900	$80,000	Removed cleaning and crack repairs
Gypsum	$243,640	$517,740	Window infills
Special Construction	$80,000	$148,000	Staging and lifts
Total Cost	**$1,278,740**	**$3,003,165**	**Gap = $1,724,435**

Sunrise Erectors pricing estimates reveal an extremely higher cost for unitized panels compared to traditional 'stick build' approaches:

	Material Cost ($/sf)	**Labor Cost ($/sf)**
Stick Build insulated metal panels	$30	$36
Unitized curtainwall	$84	$63
Revitalite	$64	$45

While programs such as NYSERDA's RetrofitNY initiative strive for a $32/square foot installed cost for unitized panel systems, this Project's pricing work revealed the market is nearly triple this amount today. The Revitalite pricing itself has reduced considerably since the beginning of the Project, as shown below:

	Material Cost ($/sf)
Revitalite ROM – original	$155
Revitalite ROM – 50% CD	$65
% Reduction:	58% Cost Reduction

b. **HVAC Price Estimates (440 Tremont Only)**

	Baseline, no DER	**REALIZE DER**	**Notes**
Mechanical HVAC	$1,032,800	$1,943,600	Boiler → VRF, ERV systems
Plumbing	$376,100	$576,100	Repairs → complete replacement
Electrical	$374,611	$645,850	Power to new equipment
Total	$1,783,511	$3,165,550	Gap = $1,382,039

Task 3 Results:

1. *Gap Funding:* The Project identified the RAD Program, and projects seeking RAD conversions, as an important catalyst opportunity for implementing deep energy retrofits, which will continue to require significant financial resources to implement. Major recapitalization events allow building owners to leverage financial resources from housing programs, such as RAD and the Low Income Housing Tax Credit (LIHTC) and other local or state bonds and subsidies often combined with LIHTC. While energy specific 'green financing' (such as Energy Performance Contracts and PACE) can support certain projects with attractive returns and payback periods, traditional affordable housing finance resources, including long-term, low-interest debt financing, will be much more impactful for underwriting higher cost energy projects. The Eva White Apartments renovation originally included a BAU scope of work – including kitchen and bathroom renovations, roof replacements, window replacements, elevator repairs, and other code upgrades, which cost approximately $15.5m. The difference between the BAU cost and DER cost is the financial gap that the Project needed to solve for.

   The Project evaluated numerous options to fill the gap, all as described in the Financing Roadmap (Attachment C). Ultimately, the Project successfully closed the gap for the whole site, including the rear building, with the following added resources:

   - Utility Incentive: $1,560,000
   - 4% LIHTC Equity (corresponds to cost): $9m construction costs qualifies for additional $468,000 in LIHTC equity, including fixed 4% and 30% QCT basis boost
   - Permanent Mortgage (debt, supported by utility savings and RAD rents): Increased from $5.8m to $16m

2. *Consents and Integration*: Eva White Apartments applied to the Massachusetts Department of Housing and Community Development for 4% LIHTC funding three times. The third application reflected the proposed deep energy retrofit project and additional cost, which required engaging the state finance agency to explain the changes to the project scope and cost. The state agency required a full explanation for the added cost and explanation for how that cost would be financed. Because there was no additional subordinate financing related with the Project, consents were not needed. However, unrelated to gap financing, the Project will require consents from the US Department of Housing and Urban Development (HUD) as well as Bank of America related to air

rights due to the new façade extending beyond the property line, and over an abutting property with both HUD and Bank of America financing.

3. *Financing Roadmap*: The Project engaged Urban Ingenuity, a non-profit Washington DC based energy financing organization to help study the financial pro-forma for the Eva White redevelopment. As evidenced in Attachment H, deep energy retrofits at today's price point and with today's electricity rates will not attract meaningful financing without grant subsidies first reducing the cost. The modeled energy and water costs equal to $60k/year on their own would support $1m in debt (assuming 4% financing with a 30-year term), or approximately 10% of the total added cost of the retrofit project. A carbon tax and/or higher gas costs and/or lower electricity rates could contribute to very different financial outcomes, supporting double or even triple project costs, as demonstrated in Attachment H. Urban Ingenuity also summarized other financial innovations created and explored by Open Market ESCO, including ESA/PPA financing, LIHTC policy changes, and federal tax incentives.

<u>Task 4 Results:</u>

1. Resident engagement will be an important factor for modeling and underwriting energy savings and ensuring the community is receptive to the changes in the building. In the efficiency space, modeled or predicted energy cost savings are never 100% accurate, which can result in higher costs and dissatisfied lenders. Working with the non-profit Castle Square Tenant Organization, the Project held in-person presentations and meetings with residents of Eva White Apartments to help explain the project, request feedback, and document perceived risks, concerns, and desires from the renovation project. The Project discovered the below key findings related to resident priorities and concerns:

    a. Existing exhaust systems are non-functional, creating moisture issues in bathrooms;
    b. The building has inadequate air conditioning in summer months;
    c. The building has inadequate heat in winter months;
    d. Sound and odors from neighbors travels throughout corridors and between apartments (emphasizing non-functional ventilation systems)
    e. Residents are more concerned about workers in their homes than loss of space or functional window area;
    f. Residents are more concerned about comfort and the environment than aesthetics or appearances of the community.

    A standard Green Resident Manual and Green Maintenance Manual describing energy efficiency components on site, including resident facing, such as fan coil units, thermostats, and windows, as well as management/maintenance related, including all central mechanical equipment, in-unit mechanical equipment, and panels will help inform post-retrofit strategies for ensuring long-term savings. Realizing energy savings is more important than modeling savings, and tenant behavior and maintenance of systems are critical for achieving performance objectives. As such, deep energy retrofit projects must have a plan in place to engage residents around *why* certain decisions were made and *how* they can reduce energy/carbon at home, while also planning and budgeting for preventative maintenance and inspections for HVAC systems as well as panel joints.

2. Replicability is critical for scaling projects, so that demonstration projects, like Eva White Apartments, and Phase 2 demonstration sites, are not one-offs, but instead inform and influence dozens of similar projects to come. OME compiled building information through site visits, document collection, public databases, site surveys, and utility costs for a subset of midrise buildings across the WinnCompanies portfolio. The inventory includes twenty-nine buildings, categorizing heating, hot water, ventilation, cooling, lighting, and plug loads. The portfolio data is being analyzed for deep energy replicability, considering the savings potential of ABC technologies. A subset of initial energy saving estimates based on Eva White's modeled performance are represented below:

	Existing EUI	Post REALIZE EUI	Post REALIZE Retrofit Carbon Emissions Intensity (kgCO2/sf)
Walden Square	77	37	2.1
Lockwood Plaza	79	29	2.6
Mission Main	74	25	1.6
Philips Brooks	106	33	2.7
Castle Square	122	36	2.9

Through this analysis, the Project identified Walden Square as a good candidate building for Phase 2, as reflected in Rocky Mountain Institute's *A Recipe for ABC Multifamily Retrofits: Technologies, Financing, and Project Delivery* application.

3. The Project committed resources to outreach in an effort to share lessons learned, inspire other projects and project teams, and help contribute to policy and programming efforts related to utility incentive programs, state housing programs, and federal policy. Key results related to this subtask include:
   a. Public presentations:
      i. PHIUScon
      ii. NH&RA Asset Management Symposium
      iii. ULI Electrification Summit
      iv. Washington DC HAND Webinar
      v. Getting to Zero Forum
      vi. HUD Energy Efficiency Webinar Series
      vii. DOE Better Buildings, Better Plants Summit
   b. The Project worked hand in hand with National Grid, Eversource, Department of Energy Resources, and the MassSave Program to draft a Deep Energy Retrofit Roadmap for the Massachusetts Three Year Energy Efficiency Plan. The Project helped create and secure a $30,000/unit incentive, which can be replicated at other similar projects, such as the Project's Phase 2 demonstration site. The current Three Year Plan, thanks to the Project, includes a specific commitment to develop a custom whole building retrofit program for affordable multifamily housing as a direct result of this Project. Additional information on MassSave's Three Year Plan may be found here: https://ma-eeac.org/plans-updates/

Energy-Savings Potential

The Project utilized both Open Studio/Energy Plus energy modeling and Carrier Hourly Analysis Program (HAP) to estimate whole-building post-retrofit energy performance. Energy modeling helped establish performance specifications for the building envelope and HVAC systems. The Project targeted a 75% reduction in heating, cooling, and hot water EUI and a 50% reduction in overall energy consumption compared to baseline/historic consumption. As demonstrated by the final energy model (Attachment F) and HAP report (Attachment H), the Project satisfied both energy performance objectives, with a modeled EUI of 7.8, exactly 75% below the building typology median (31 kBTU/sqft) as defined in the Department of Energy EUI Targets file.

The Project was not focused on a specific product or technology, nor was it R&D in nature. Instead, the Project's main objective was to identify a constructable and financeable low-carbon retrofit that utilized prefabricated components and could be integrated in a complex affordable housing financing transaction. The Project did not have a prescriptive scope of work, but instead evaluated numerous approaches and strategies to achieve various Project objectives and selected and advanced the most optimal option in terms of market readiness, performance, and cost.

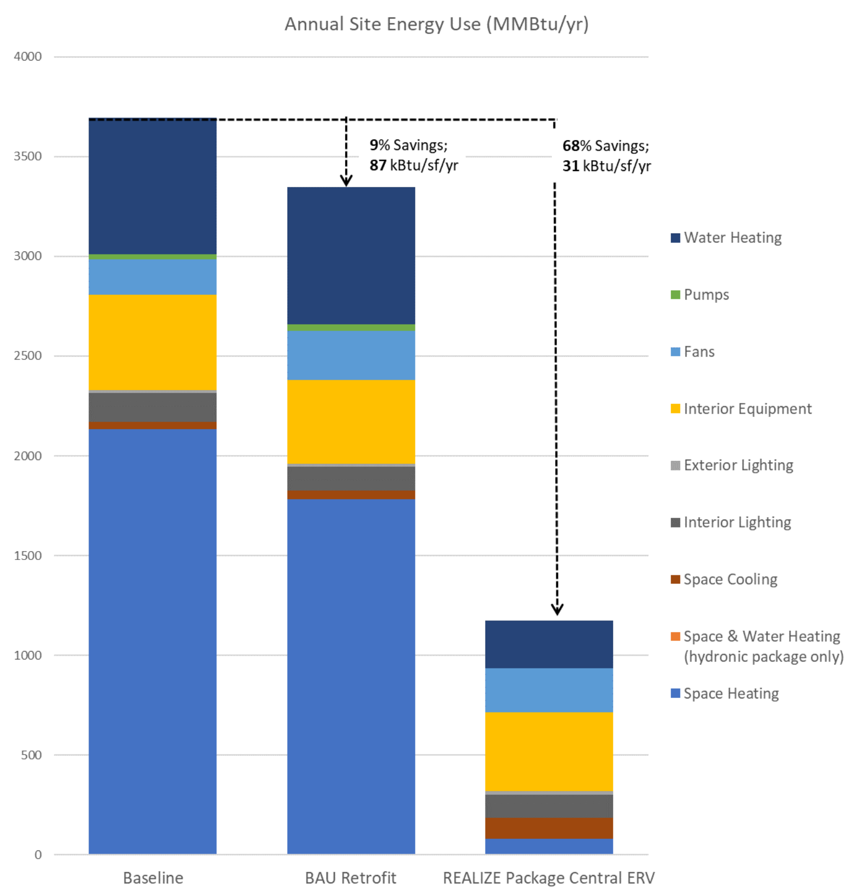


Figure 3: Energy modeling results provided by Rocky Mountain Institute

HAP modeling demonstrates the Project's overall 72% EUI reduction and 74% heating/cooling/water heating EUI reduction to achieve an EUI of 7.8.

Baseline Building and Proposed Building Energy Use Index (EUI) Summary

Table 1. Baseline Building and Proposed Building Total EUI Summary

Building Case	EUI (kBTU/sq.ft.)	% Energy Savings
Baseline	104.2	-
Proposed	29.0	72%

Table 2. Massachusetts DOE Target EUI vs. Proposed Building EUI Summary

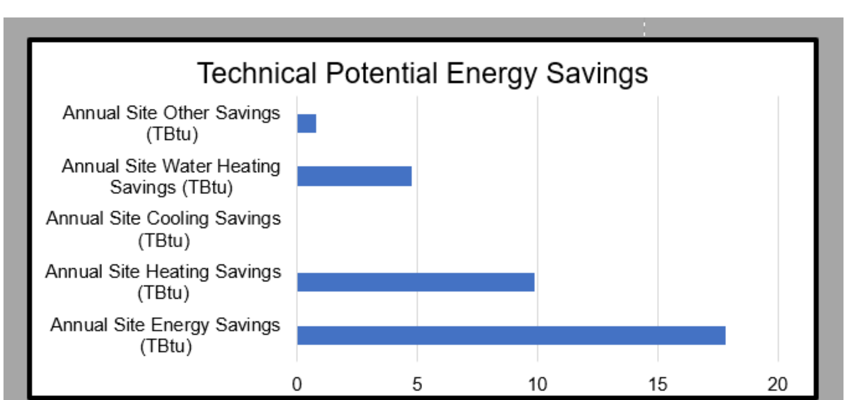
Building Case	EUI (kBTU/sq.ft.)	% Energy Savings
DOE Baseline Target (heating, cooling, water heating only)	30.1	-
Proposed (heating, cooling, water heating only)	7.82	74%

Figure 4: EUI Summary from Eva White Energy Use Summary, generated in HAP

Extrapolating the whole building modeled energy savings from the Project across all mid-rise multifamily buildings containing 5+ units in New England will achieve the following energy savings, based on DOE's Residential Buildings Data Pivot Table:

		Summary			Total Site Energy	Site Energy by End Use			
		Total Homes/Units	Total Buildings	Total Square Feet (Millions)	Total Site Energy (TBtu)	Site Heating (TBtu)	Site Cooling (TBtu)	Site Water Heating (TBtu)	Site All Other (TBtu)
Results:	Total	685,174	54,500	583	26.2	10.3	0.5	7.4	7.9
	% of Total Residential	0.6%	0.1%	0.2%	0.3%	0.3%	0.1%	0.4%	0.3%
	All Residential	118,208,250	92,481,089	237,421	9,114	4,013.7	774.0	1,745.3	2,575.8

Provide below inputs:		Technical Potential Energy Savings	
% Total Site Energy Savings	68%	Annual Site Energy Savings (TBtu)	17.8
% Total Site Heating Savings	96%	Annual Site Heating Savings (TBtu)	9.9
% Total Site Cooling Savings	0%	Annual Site Cooling Savings (TBtu)	-
% Total Site Water Heating	65%	Annual Site Water Heating Savings (TBtu)	4.8
% Total Site Other	10%	Annual Site Other Savings (TBtu)	0.8



Technical/Engineering Design

The Project methodology is transferrable to all affordable housing developers, presenting a tremendous opportunity to leverage the RAD Program to finance deep energy retrofits, while transforming and modernizing extremely low-income housing. In addition to the design and financing approaches studied in this Project, the advanced building technologies themselves, including the pre-fabricated insulated panel system incorporated in the Project, will also help reduce first costs and expedite project development. While the Project did not research and develop a specific product or group of products, it did serve as a test case for a pre-fabricated panel, discussed in technical detail here, and offers important findings toward the integration of ABC requirements and approaches that can operate efficiently across a broad range of buildings.

Project Delivery: The Project's integrated project delivery approach, paired with energy performance driven design objectives, is widely transferrable to development teams – including architects, engineers, contractors, etc. – across the country, regardless of climate zone. Improved design delivery approaches will not only help identify and prioritize energy performance objectives, but can also guide teams toward other project objectives, which may include resiliency, health, equity, accessibility, etc. Nearly every affordable housing project - gut rehab, occupied renovation, new construction, etc. - will choose between competing needs in order to solve a budget gap. With the support of DOE, this Project was able to prove that an integrated team with buy-in and commitment to shared goals could design and adapt and re-design iteratively toward a constructible and financeable solution package. Most projects will not have the time or pre-development resources to replicate the Project, and therefore the introduction of standardized technologies and locked specifications will prove essential for developing a more replicable project delivery model, as proposed for Phase 2.

- **Standard Features of Project Delivery:**
    - Architect of Record: Owners will continue to rely on and require an architect of record to oversee coordination, structure, and code requirements. While much of the drafting and design work (and cost) can be reduced with standardized panel details and BIM modeling integration with fabrication and shop drawings, the architect's role will continue to be important for whole building energy retrofits. When whole building energy retrofits occur in conjunction with other rehab work, such as kitchen and bathroom renovations, the architect's role will be more traditional, following a typical design, bid, build model.
    - Complex Financing: Affordable housing development projects pursuing financing through RAD and LIHTC will continue to follow programmatic requirements, which have high cost of entry due to serious complexity. Integrating whole building energy retrofits at the time of recapitalization and refinancing will help leverage housing subsidies and reduce incremental construction costs, making the complex affordable housing finance industry a standard step in the energy retrofit space.
    - Design Deliverables: Affordable housing development projects apply for competitive financing, which varies from state to state and program to program. Each state and program may require different types of design packages on different timelines. For example, Massachusetts requires 70% Construction Documents to appl for LIHTC financing, whereas Connecticut requires 90% drawings, and New Jersey requires schematic (30%) sets. These

projects will continue to integrate panel design with standard design deliverables, adding to project soft costs, but also complicating the manufacturer engagement model.

- Code Interpretation: Cladding projects may impact ADA and fire codes, the interpretation of which may vary based on jurisdiction. Demonstration projects in cities like Boston and New York will help inform code reviews for future projects and use cases. The methods for draft stopping and fire stopping around panels or panel components can be standardized, using standard details such as mineral wool and spray sealants or Hilti's pre-formed edge of slab CFS-EOS QuickSeal product.
- Local Review and Approvals: The City of Boston requires design review for projects that exceed a certain size or cost threshold, which would be expected of most large cities. Educating and explaining façade upgrades to city design representatives is a necessary step in project development, and EIFS-like products will continue to be scrutinized based on their history in wood framed buildings. Demonstration projects will be important for proof of concept and for creating more streamlined and standardized review processes for projects with energy performance objectives. The Project worked closely with the City of Boston to explain the Revitalite product and is helping to establish an alternative approach to valuing air rights and easements for projects that are pursuing low-carbon retrofit projects (compared to projects that may be making aesthetic upgrades or building additions, for example).

- **Integration Requirements**
  - Integrated project design can be applied to any project and should start with establishing performance objectives and documenting goals and requirements for the project, ultimately informing an Owner's Project Requirements specification. Owners and developers can effectively lead project design and engineering teams through a performance driven design process on any project, regardless of scope complexity and goals. The Enterprise Green Communities certification standard has defined a useful tool and process for affordable housing developers specifically, which requires project teams to define goals and objectives, assign roles and responsibilities, and track progress through design, construction, and operations.
  - While affordable housing projects require several design iterations and formal submissions, and often take 2-3 years for financing, greater efforts to include subcontractors and manufacturers from Day 1 will help lock in a scope of work, eliminate unknowns and risks, and, ideally, secure better pricing. Subcontractor and manufacturer involvement is difficult for projects that cannot commit to construction contracts, particularly in a competitive and strained marketplace. This risk can be mitigated and whole building retrofits scoped and priced with more standardized products and procurement partnerships that look beyond the project level, and plan for pipelines and portfolios.
  - Integrating deep energy retrofit scope and performance objectives like the Project will add cost to design as well as hard construction costs, requiring greater financial resources. While this Project proves a replicable application of RAD Section 18, more projects will require greater levels of utility incentives and more favorable electric rates to help underwrite greater utility cost savings that can support more debt.
- **Implementation Diversity**
  - Integrated project design can help push higher performance objectives for sophisticated and non-sophisticated teams alike. The demonstration at Eva White will set a higher bar for existing building performance standards and for affordable housing renovations in Massachusetts. As states and cities create their own decarbonization roadmaps, they are looking for demonstration

projects and case studies to help move the market. This Project's scope of work, integrated design process, utility incentive process, and RAD Section 18 blending are all strategies and tools readily available for any project team to take and adapt, allowing for a transformation in the business as usual approach and scope for existing building renovations.

- **Replicability**
  - This Project will inform how WinnDevelopment evaluates all renovation projects across the Northeast and Mid-Atlantic. As a developer, owner, and property manager, Winn can take the learnings from the Eva White project and better evaluate and consider integrating a whole building deep energy retrofit scope of work. The Project has considered the replicability of the integrated, goal-oriented design process, the technical scope of work, and the financing strategy for a subset of Winn's midrise buildings, identifying opportunities at an upcoming LIHTC rehab in Providence Rhode Island, potential RAD opportunity in Lawrence, MA, and Phase 2 demonstration project at Walden Square.

Technology: The Project developed and designed a technical scope of work, which includes a new, patent pending prefabricated insulated panel system manufactured by Tremco as well as an all-electric HVAC solution, including central VRF, heat pump water heater, and energy recovery ventilator (ERV). While the Project evaluated numerous building envelope products, including 'stick build' EIFS, insulated metal panels, unitized curtainwalls, and 'sandwich' panels, the Project selected Tremco's Revitalite panel system for further design development activities. The Revitalite panel is still under development as of the writing of this report, but all major performance testing, specifications, and generic product details are complete or scheduled to be completed by year end. While the Project did not directly lead R&D efforts for the Revitalite panel, specific features of the panel, and its integration with the building, as demonstrated in the Project's 50% construction drawings are described below:

- **Standard Features of Technology:**
  - Revitalite looks and feels like EIFS, incorporating many well documented and known Dryvit products, including EIFS finishes, EPS insulation, and sealant and flashing products. Because Tremco owns so many products in the facade industry, they have a competitive advantage over other early-stage panel manufacturers.
  - Panel to panel connections are made with a two-part Willseal sealant product.
  - Each Revitalite panel includes an internal framing system that supports the full panel weight and structure.
  - Windows are structurally attached to the panel's interior framing system. The Project developed requirements for window detailing to ensure sufficient air and water performance.

- Tremco's patent pending structural attachment method includes a building mounted H-bracket where the panel's rails can hang and be mechanically fastened. The Project required a cavity over 4" deep to accommodate refrigerant lines and supply ductwork, which was easily accomplished with the panel's structural attachment.

Example of iterating 'standard' features of the panel system. The Project team established window integration details, based on new construction window flashing details, working with the panel and window manufacturers. This led to the integration of a continuous L-angle, caulk joint, and drip kerf.

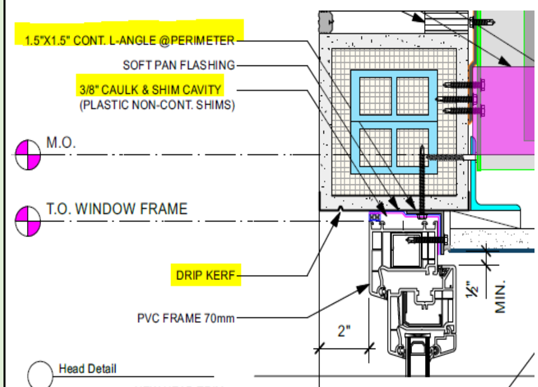


Figure 4: Iterative window integration detail

- Fire stopping will be required at the perimeters of all window openings, which will be achieved with fiberglass batt insulation.
- The Revitalite panel will satisfy the below standard specifications:
  - 9 PSF
  - Incorporates a U-0.26 or better window
  - R-25+ thermal performance
  - Air Testing: ASTM E283
  - Water Testing: ASTM E331 2 hours at 6.24 PSF
  - NFPA 285 certified
  - Maximum dimensions: 10' x 15'

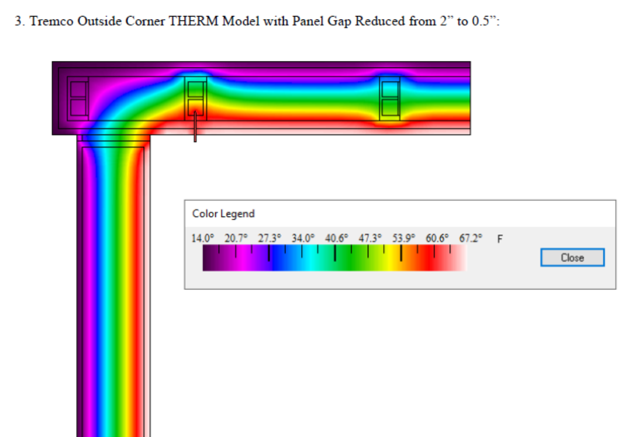
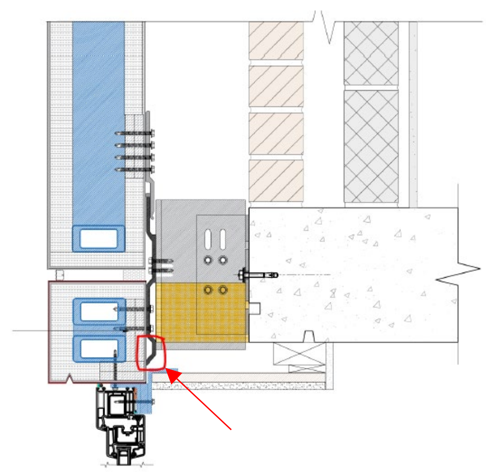


Figure 5: Continuous thermal barrier from panel to panel (see Attachment I for Therm modeling)

- **Integration Requirements**:

The technical integration of prefabricated panels – especially prefabricated panels still in R&D – in existing building renovations is very complex. The fundamental requirements for integrating the Revitalite panel, and any prefabricated panel, are driven by existing conditions, including: structural conditions, wind loads, building dimensions, and window dimensions. While the make-up of a panel and the way it attaches to a building can be standardized – exterior finishes, panel joints window integration, insulation, and attachments -- the existing building itself will determine the layout of the attachments themselves, the dimensions of the panels, the location and frequency of joints between panels, and window rough opening dimensions.

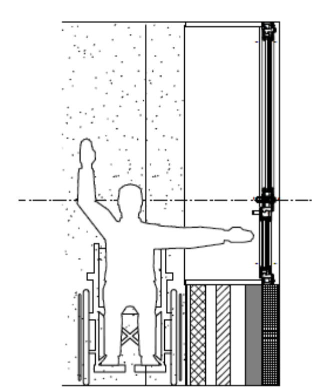
The Eva White building's existing conditions drove much of the panel integration design work, including the location of anchors (the building's concrete floor slabs), window dimensions (reduced head height to accommodate structure at top of panel), and panel dimensions (height = slab to slab; width = vertical bay to vertical bay). The 50% construction documents provide details of how the panels will be sized, laid out, and attached back to the building, which is the result of many months of design iterations that could be simplified with standardized panel details. The Project spent the most time evaluating the best way to finish the window trim detail – i.e. how the exterior panel ties back to the building interior.



Because the Project pursued central HVAC equipment with certain distribution systems outside the existing face of the building, the panels had to be hung at least 4" off the existing façade, but less than 6" to avoid sprinkler and fire safety issues. The gap between the existing façade and new panel presents one of the more complicated integration details at window openings, that must be trimmed to the building interior. The Project worked with Tremco to evaluate numerous approaches to help simplify the interior trim installation, including factory installed blocking and L-angles to attach window returns to, all of which adds to the panel cost and complexity of field work, particularly with residents in place. Even after the 50% Construction Documents were developed, the Project continues to evaluate alternative methods for pre-fabricated MDF window boxes that will eliminate direct, hard connections to the panel from the interior, to avoid cracking concerns, while also reducing wood blocking in the rough opening. The Project faced numerous ripple effects as certain panel details were refined, and similarly as building details were uncovered. For example, the detail above shows how a modified attachment rail, with an approximately 1.5" extension circled in red, changed the interior window trim, resulting in a flipped and exposed L-angle and window frame screws, presenting new aesthetic concerns.

Other relevant integration requirements include how the panels affect property lines, ADA accessibility, compartmentalization, and fire/smoke control, as summarized below:

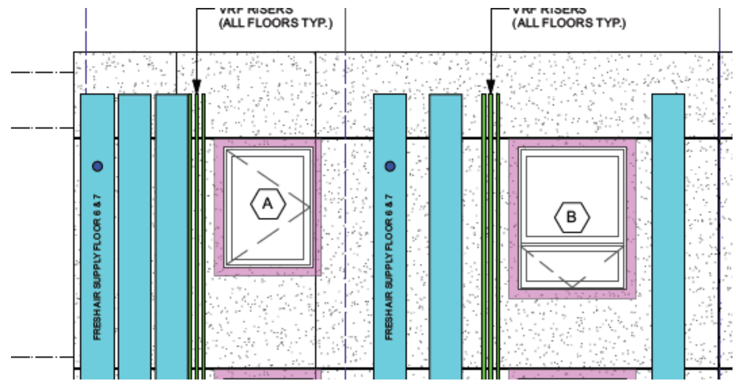
- *Site Lines*: Any re-cladding project in dense urban environments can expect to encounter property line issues. Eva White is located on a zero lot line, meaning the building takes up the entire footprint of the site, resulting in the new 6" panel, held off the wall 5.75", extending over abutters' property. The Project has fourteen such occurrences, requiring review, agreements, valuation, and consents from several entities, including the Boston Planning and Development Authority, US Housing and Urban Development, and Bank of America. Integrating new cladding scope of work will require legal title review and negotiations with abutters.
- *ADA Accessibility*: The Project considered ADA accessibility concerns early in design development. The new windows located in the new panel assembly with be approximately 18" past the interior wall surface, requiring a resident to reach quite far to open and close their window. In an elderly property, it is particularly concerning to ask



3 Section

residents to lean and reach for their windows. To help mitigate this concern, the Project worked directly with the window manufacturer to lower the height of the window handle and specified an inswing model that could be operated with one hand.

- *Compartmentalization*: Once the panel passed its NFPA 285 test for fire resistance, the Project had enough information in hand to engage the Boston Fire Department and Inspectional Services Department to discuss fire and smoke spread concerns related to the 5.75" cavity and ductwork connections from floor to floor within that cavity. Because the ducts extend vertically across several floors, typically they would require a 2-hour shaft wall with fire/smoke dampers at each shaft penetration (780 CMR Sections 713.4 & 717.5.3). Due to high cost and technical limitations of the fire/smoke dampers, the Project requested an alternative design utilizing a concept contained in 780 CMR Section 717.6.1, which allows a duct penetrating a single floor assembly to be protected by a fire damper at the floor line in lieu of a shaft enclosure. Because our project could not locate a fire damper at the floor level (the panel is 5.75" from each floor slab), the Project requested to locate the new fire dampers where the duct penetrates the existing brick and block wall, while also introducing draft stopping measures around all window openings and certain vertical stacks. Initial feedback from BFD and ISD was encouraging and allowed the Project to pursue its coordinated panel and HVAC design work, incorporating fire stopping at window openings and fire dampers at ventilation supply ducts.



- **Implementation Diversity:** The proposed technical solution, including pre-fabricated panel system (Revitalite) and central HVAC systems (VRF, ERV, HPWH) is an appropriate solution for larger buildings with structural capacity to support the mechanical fastening of panels that weigh between 8-10 PSF. Pricing feedback suggests pre-fabricated panelized retrofits are most appropriate for buildings over nine-stories, while traditional stick build approaches to insulating facades is more cost effective for smaller buildings 1-8 stories. This is mostly driven by site access and construction logistics – smaller buildings have less space to store large panels and accommodate the equipment necessary to hang panels in place, leading to inefficiencies on site. Utilizing a pre-fabricated structural panel, rather than EIFS or smaller insulated metal panels, accommodates a larger cavity between the existing façade and new panel, which is critical for running central distribution equipment from mechanical systems. Integrating central equipment and distribution behind the new panel will be especially important for projects with inadequate space inside apartments and where utilities should remain master metered, which is particularly common amongst public housing.
- **Replicability:** The panel and HVAC system designed for the Project is expected to reduce site energy use by over 60%, operating extremely efficiently. Similar efficiencies are expected for any building that incorporates a continuous exterior insulation panel and all-electric heat pump systems. This scope of work will prove most cost effective in larger buildings with minimal or no existing insulation, sound existing structure, and simple building geometry.

Cost Modeling and Analysis.

As discussed above, the Project updated construction pricing as the design progressed, using more detailed drawings to help inform more accurate – not always less expensive – pricing. Major costs of the Project are the panel and the HVAC system. Using a real building on a structured, owner driven financing and construction timeline improved contractor participation and gave panel manufacturers the opportunity to price real project costs, rather than hypothetical project estimates. All costs are based on actual designs and details, developed from in depth building analysis and engineering, as well as field measurements.

The below panel pricing is based on Eva White Apartments, reflecting unitized insulated panels are above $100/SF installed, compared to $75/sf for non-unitized insulated metal panel solutions. If the unitized panel market will complete with traditional panels and punched windows, it must reduce costs from approximately $110/SF to less than $75/SF. This should be attainable for larger buildings where time and building access can present a competitive advantage for unitized systems over stick build solutions. The business-as-usual façade costs, including window and structural repairs, was $1.2m, helping to offset the total incremental or added cost of the panel system.

Product/System	**Material ($/SF)**	**Labor ($/SF)**
Stick Build, Peerless G500 Inswing Casement and Kingspan 4" Optimo Series Insulated metal panel	$35	$40
Unitized Curtain Wall with Peerless G500 and Kingspan Designwall series on full backup framing span floor to floor	$84	$63
Tremco Revitalite	$65	$45
Dextall	$61	$45

The business as usual and deep energy retrofit pricing comparison is presented below, showing a roughly doubling of project construction costs. This pricing was obtained from the general contractor based on quotes from three different mechanical subcontractors, as well as involvement from Mitsubishi (the VRF and HPWH manufacturer) and Tremco.

	Baseline, no DER	**REALIZE DER**
Revitalite Panel	$1,278,740	$3,003,165
Mechanical HVAC	$1,032,800	$1,943,600
Plumbing	$376,100	$576,100
Electrical	$374,611	$645,850
Total	$3,062,251	$6,168,715
Cost Per Unit:	**$61,245**	**$123,374**

Typical affordable housing rehab projects addressing capital needs, deferred maintenance, and interior upgrades cost between $85k/unit and $120k/unit. At a total construction cost of $25m, Eva White's per unit cost is approximately $250k/unit, of which approximately $120k/unit is associated with the building envelope and MEP systems (note: all costs are Prevailing Wage). The Project was able to support this added cost with replicable financing solutions – utility incentives, higher debt – but such housing subsidies are only available for a subset of the built environment, limiting the overall reach of the Project to affordable housing (arguably an extremely important market segment). If Projects like this sized funding to energy cost savings alone, as is often the case amongst market rate developers and owners, the per unit cost would need to be reduced to less than $10,000/unit (in order to achieve a 15-year simple payback), which is impossible given the complexity of the scopes of work. Unlike low-hanging fruit, single measure energy efficiency measures, whole building deep energy retrofits cannot be financed based on energy cost savings alone. As such, greater innovation not only in reducing technology costs but also in delivering new financial tools to support carbon savings is needed for market transformation. OME looks forward to working toward such outcomes in another successful phase of Advanced Building Construction.

Appenices:

A. New Ecology DER Playbook
B. Construction Budget Documents
C. Urban Ingenuity Financial Roadmap
D. Building Characteristics Inventory
E. Example Case Study Collateral
F. Energy Modeling Output (Open Studio)
G. Topographic Heat Maps
H. HAP Modeling Outputs
I. THERM Models