Vermont Weatherization at Scale Coalition
Technical Approaches Working Group Recommendations
December 4, 2023

Introduction

The Technical Approaches Group has developed this set of recommendations to improve on the current best practices and introduce some new ideas for delivering weatherization at scale in Vermont. Every building is unique in its configuration and performance, so these recommendations are intended to present an array of options for weatherization program administrators and implementation contractors to consider when devising the appropriate strategy to weatherize and decarbonize a structure.

These recommendations are guided by the principles of building science to incorporate high insulation levels, lack of thermal bridging, high performance windows and doors, airtightness, and ventilation. As weatherization practitioners, we acknowledge that every project is different and must find necessary balance between the highest possible building performance and other important considerations, such as historic preservation, funding, cost-effectiveness, workforce challenges, lowest carbon intensity, and supply chain constraints. As such, the recommendations included in this report are not appropriate for every building in Vermont but are intended to be adaptable to accelerate the decarbonization of the built environment.

The Technical Approaches Group recognizes the nuances required weatherizing an aging housing stock that includes many culturally and historically significant building structures, styles, and attributes that contribute to the unique character of Vermont communities. We are grateful to Vermont's historic preservation community for their efforts in this process to find common ground between weatherization and preservation. While there is not complete alignment on all recommendations – notably for industrialized weatherization methods – we have a shared goal to improve the energy efficiency and decarbonization of every building and bring the right tools and techniques to each individual project.

-Summary-

The Technical Approaches Group wishes first to recognize that technologies in the climate change mitigation field are constantly evolving and sometimes rapidly changing. Because of this there will always be some tension between more tested strategies such as standard on-site air-sealing and insulation practices, and newer technologies such as building encapsulation, or high efficiency mechanical systems which may somewhat offset the need for maximized shell improvements. We recognize and value the ongoing debate among professionals as they deliberately study and evaluate the strengths and limitations of these various strategies and try to apply them appropriately in advancing the effort to minimize effects of climate change.

Energy Audits and Weatherization Perspectives

- Evolving Issues and Requirements for Weatherization
  Greenhouse gas emission reductions and other issues have become an increasing focus in weatherization work.

- Minimum Requirements for Weatherization Audits and Overviews
  Energy audits and related activities vary greatly, from a focus on low-hanging fruit to comprehensive analysis that includes modeling. As the scope of weatherization activities grow, the need for clarity on what is included in audits and related work grows: creating a roadmap for weatherization and potentially other home improvement requires far different approaches than tightly focused efforts that address separate elements of weatherization and climatization. Details guidelines on this matter are found in the **Appendix on Energy Audits**

Conventional Weatherization Approaches

- Amendments to WAP Manual
  The WAP Manual has served as a reliable source weatherization best practice. Recent progress in understanding the value and importance of moisture management and air sealing has led to a better understanding of ventilation best practices. Ideally the WAP Manual should be amended to embrace best practices of balanced ventilation with energy recovery. Alternatively, Vermont could adopt best practices for balanced ventilation from other sources to supplement the current WAP Manual. Details guidelines on this matter are found in the **Appendix on WAP Manual**

- GHG Emissions from Building Materials
  It has long been understood that gasses used as blowing agents for foam insulation as well other materials used in insulating materials can be sources of GHGs. Recent work by Efficiency Vermont has made the gravity of the problem clear. Vermont building codes should be amended to discourage the use of such building materials, and other methods of discouraging the use of such products should be pursued. The impact of building materials translated in CO2 equivalent values is detailed in the **Appendix on Embodied Carbon**

- Weatherization of Historic Buildings
  Historic buildings benefit from significant embodied energy and often are built with high quality materials that have lifespans that far exceed new construction. Efforts to weatherize historic buildings should pay special attention to moisture management and ventilation. When developing a treatment plan for weatherization of an historic building, consult with a historic preservation specialist and guidance documents prepared by the Vermont Division for Historic Preservation and the Preservation Trust of Vermont. Details can be found in the **Appendix on Weatherization of Historic Buildings**.

- Problems Arising from a Patchwork Approach to Weatherization
  Short-sighted weatherization projects leave longer-payback weatherization options undone along with the barrier of the high costs of planning and organizing a new project. Vermont should create policies to encourage a comprehensive, coherent process for weatherizing every candidate building in order to avoid progress traps created by excessive focus on low hanging fruit or other inefficient weatherization planning methods. For detailed observations please refer to the **Appendix on Patchwork.**

- Windows and Weatherization
  Windows and related issues pose unique and singularly important challenges in a weatherization project or program. Details are found in the **Appendix on Windows**

Encapsulation

- Industrialized Building Encapsulation
  New, highly optimized building encapsulation techniques are rapidly gaining acceptance as a way of comprehensively upgrading thermal envelopes of buildings. These techniques hold promise as a foundational component of getting weatherization programs to scale. Vermont should stay abreast of these developments, seek opportunities to encourage businesses that grow to serve this market, and as the market matures and opportunities arise, adopt these modern weatherization options. Details are covered in the **Appendix to Industrialized Wx**
- Strategic Potential of Scaling Weatherization Efforts using a Range of Building Encapsulation Techniques
  Although new industrialized building encapsulation techniques hold great hope for accelerating weatherization initiatives, there are many other encapsulation options with strong potential for scaling up weatherization efforts in Vermont. Although these encapsulation options are rarely included in weatherization projects, many of them can integrate with weatherization and other building upgrades to achieve superior cost effectiveness and provide other benefits as well. Vermont should encourage a broad view of building improvements to contribute to the cost-effectiveness of weatherization.
  Details are covered in the **Appendix to Encapsulation**

Website Resource for Contractors

Given the rapid evolution in building materials and technologies, the Technical Approaches Group forecasts the need for a trusted information clearinghouse site to prevent the spread of misinformation in the industry. Details on this subject are covered in the **Appendix to Website Resources**

Appendix on Energy Audit

Introduction

Energy Audits in Vermont currently come in all shapes and sizes, and some are more comprehensive than others. Some provide a snapshot in time, and review of all the energy features and liabilities of the home's envelope at the time of the audit, while others focus only on the areas of improvement that may be recommended in a particular work scope.

Since homes, by nature, are long-term assets with long-term energy burdens and liabilities, it makes sense to consider the long-term characteristics of the structure – to recognize that it has an essentially indefinite life span – depending on how it is used and upgraded over the years – and that heating equipment and systems are also long-term investments.

Because of this, it also makes sense that an energy audit provides more than a simple analysis of a limited work scope; that, instead, it effectively provides a roadmap that can be referred to at any time, whether immediately, or at some time in the future, and used to guide and direct a sequence of envelope improvements – as need or economic benefit dictates, as technology improves over time, or as access opportunities arise through construction or remodeling projects.

Energy Audits can also provide an important opportunity for educating the homeowner. Some homeowners will respond to this more than others, but often the broader educational elements of the audit can often be incorporated into boilerplate portions of a report format, that do not have to be customized to the particular house. How much the educational function of an audit report should be developed can be a judgment call on the part of the auditor, but it should not be forgotten or ignored.

Purpose & Functions of an Energy Audit:

1) To assess a structure's envelope with respect to its systemic capacity to
    a. Isolate indoor air from outdoor air;
    b. Contain and control heat loss or heat gain;
    c. Protect the structure itself and its materials from interior and exterior moisture.
2) To assess the structure's HVAC system for safety, efficiency, and effectiveness.
3) To assess other energy using appliances and systems in the house – domestic hot water, household appliances, general electrical loads.
4) To test all systems appropriately.
5) To educate the homeowner about their energy usage.
6) To examine the structure and its systems overall, and its performance as a system
    a. For energy efficiency;
    b. For weather effectiveness and structural integrity with regard to airflow and moisture;
    c. For indoor air quality and occupant health.

Features of an Energy Audit Report:

1) To note immediate hazards, and critical repairs or beneficial upgrades.
2) To report testing results for air infiltration (the blower door test), combustion, and CAZ testing for any combustion-based heating equipment or appliances.
3) To summarize the important features of the envelope and its capacities.
4) To summarize the important features and/or liabilities of the heating system, hot water, and other major appliances.

5) To provide a reasonably detailed list of **Opportunities for Improvement**, along with some cost and benefit analysis that will highlight immediate recommendations an effective roadmap for the homeowner to consider future improvements.

Other useful information, photographs, infrared images, data points or other points of interest regarding the home that may encourage homeowner trust, or add value to the audit, or aid with potential sales.

Appendix to WAP Manual
Amendments to WAP Manual

The WAP Manual is a good starting point for determining a weatherization roadmap. Some amendments are hereby suggested

Heating is by far the dominant energy end use and, therefore, retrofit measures that directly reduce heating demand—such as envelope improvements—are essential to realizing a low carbon future and avoiding future spikes in utility costs.

To meet the demands of a low carbon future we recommend that buildings pursue the Recommended Targets in the following pages and develop long term retrofit plans to coordinate the phasing and interaction of these measures over time. For more detailed retrofit planning we recommend projects use a building performance standard like the Passive House standard for retrofits, as a benchmark to evaluate the total impact of various measures once enacted.

Because the building envelope plays such a critical role in heating demand and overall comfort, additional wall and roof insulation, improvements to airtightness, and the introduction of high-performance windows have the greatest impact on energy use, utility cost, and carbon emission reductions. Envelope improvement in addition to balanced heat recovery ventilation can reduce the heating demand by 51% and implementation of a ASHP can further reduce the heating and cooling demand by an additional 17% for a total reduction on 68% (1)

(1) Steven Winter Ass. 1-3 Story MF Retrofit Playbook

The roadmap suggested by the WAP Manual calls for:

1) Airseal & Insulate Top of Building
to Specified Minimum Standards
2) Airseal & Insulate Bottom of Building
to Specified Minimum Standards
3) Airseal & Insulate Sides of Building
to Specified Minimum Standards
4) Address Health, Safety & Indoor Air Quality Issues
in Accordance with Specified Standards

Our recommendations to these points are:

1) Airseal & Insulate Top of Building

Reduce air infiltration to 0.06 cfm/sqft of total exterior area (6 sides - aprox 0.7 to 1ACH50 calculated based on the interior conditioned area = floor area minus interior walls occupied area), and R 64 – 80 hr.sf.F/Btu or closest possible continuous insulation.
The infiltration specific to the attic can be prorated from the overall six sides area of the building.
An initial and a final bower door test will be required to document the results.
Once this initial insulation of the top of the buildings is achieved, **a balanced heat/energy recovery ventilation system, either centralized, semi-centralized or decentralized must be specified as a next step to achieve adequate ventilation and sanitary indoor air quality.** The balanced ventilation must be sized to provide 18 cfm of fresh air per building occupant. The extract numbers of ≥20 cfm continuous from each bathroom and ≥25 cfm continuous from

kitchens override the 18 cfm/person in cases where extract volumes are larger than the required supply volume, in which cases the supply will have to match the extract.
A balanced ventilation system is also a survivability factor because it filters the outside air that is introduced into the living places, a need of which we are seeing more and more with the persistent wildfires that will be worsening with climate change. People are asked to stay indoors when poor outdoors air conditions occurs, but in many cases the indoor air is worse than the outdoor air.

2) Airseal & Insulate Bottom of Building

Reduce air infiltration to 0.06 cfm/sqft of total exterior area (6 sides - aprox 0.7 to 1ACH50 calculated based on the interior conditioned area = floor area minus interior walls occupied area), and Overhanging Floors (Above Grade) R 40 – 56. Walls & Floors (Below Grade) R 20 – 36 hr.sf.F/Btu or closest possible continuous insulation.
The infiltration specific to the bottom of the building can be prorated from the overall six sides area of the building. An initial and a final bower door test will be required to document the results.

3) Airseal & Insulate Sides of Building

Reduce air infiltration to 0.06 cfm/sqft of total exterior area (6 sides - aprox 0.7 to 1ACH50 calculated based on the interior conditioned area = floor area minus interior walls occupied area), and walls (Above Grade) R 40 – 56 hr.sf.F/Btu or closest possible continuous insulation. The ratio of exterior insulation to interior insulation for the VT climate should be maintained at 50/50 to prevent condensation within the structure. A vapor open assembly is advisable to allow for good hygrothermal behavior.

The infiltration specific to the walls of the building can be prorated from the overall six sides area of the building. An initial and a final bower door test will be required to document the results.

4) Address Health, Safety & Indoor Air Quality Issues

The Health, Safety & Indoor Air Quality Issues in terms of ventilation must have been addressed by this time. The only remaining factor of health and comfort must be addressed with the installation of adequate climate specific and air tight windows that eliminate draft from infiltration and convection, as well as condensation risk that can induce mold formation. For Vermont, the appropriate window is a triple pane casement or fix window with an overall Uw of 0.19 - 0.11 Btu/hr.sf.F. Additional windows information is on the **Appendix to Windows**.

Appendix to Embodied Carbon of Insulation Materials

As we accelerate the number of weatherization projects, the selection of insulating materials based on carbon intensity will be increasingly important to ensure energy retrofits don't lead to counterproductive climate results. Low embodied carbon insulation materials are materials that have a low carbon footprint throughout their lifecycle, from raw material extraction and production to disposal. The lifecycle cost of carbon involved in building construction can be measured by the global warming potential (GWP) associated with the manufacturing and use of each building component. This is measured in carbon dioxide equivalence (CO2e). Utilizing low embodied carbon materials can help reduce greenhouse gas emissions and combat climate change.

European standard EN 15978 https://www.en-standard.eu/bs-en-15978-2011-sustainability-of-construction-works-assessment-of-environmental-performance-of-buildings-calculation-method/ specifies the calculation method to determine the environmental performance of a building through a lifecycle analysis of the building materials through these stages:

Module	A1-A3			A4-A5		B1-B7							C1-C4				D
Life cycle stages	Product stage			Construction process stage		Use stage							End-of-life stage				Benefits and loads beyond the system boundary stage
Processes	Raw material supply	Transport	Manufacturing	Transport	Construction - installation process	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction/ demolition	Transport	Waste processing	Disposal	Reuse, recovery, and recycling potential
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D

Through utilizing Environmental Product Declarations for each type of material, the GWP can be determined to achieve R_{SI}-1 (which is R-5.678 in imperial units). Here's a summary of GWP and R-values for frequently used construction materials developed by EVT https://www.efficiencyvermont.com/Media/Default/docs/white-papers/The_High_GHG_Price_Tag_on_Residential_Building_Materials.pdf :

Material	Form or variant	R-/"	GWP average, kg CO_2e *[A1+A2+A3]* per 1 m² RSI-1	*GWP** average, kg CO_2e *[w/A5+B1]* per 1 m² RSI-1	*GWP** includes
Cellular glass	Aggregate	1.49	3.93	3.93	A5
Cellulose	Blown / loose fill, 1.29 pcf	3.38	0.49	-0.83	A5, carbon
Cellulose	Dense pack, 3.55 pcf	3.56	1.27	-2.16	A5, carbon
EPS (expanded polystyrene)	Board, unfaced Type IX-25psi, graph.	4.70	3.47	3.49	A5
Fiberglass	Batt, unfaced, recycled content	3.64	0.67	0.68	A5
Fiberglass	Blown / loose fill	2.68	1.29	1.30	A5
Fiberglass	Blown / spray	4.00	1.61	1.64	A5
HempCrete	Block	2.14	-7.05	-5.67	A5, B1, carbon
Mineral wool	Batt, unfaced	4.24	3.11	3.25	A5 (1 EPD)
Mineral wool	Board, unfaced, "heavy" density	4.00	4.06	4.06	A5, B1
Phenolic foam	Board, glass tissue faced	7.21	1.54	1.54	Not given
Polyisocyanurate	Board, foil faced	6.53	2.32	2.32	Not given
Spray polyurethane foam	Spray, closed-cell HFC	6.60	3.31	14.86	A5, B1
Spray polyurethane foam	Spray, closed-cell HFO	6.60	3.47	4.00	A5, B1
Spray polyurethane foam	Spray, open cell	4.05	1.42	1.59	A5, B1
Straw	Panel	2.92	-10.95	-10.88	A5, B1, carbon
Wood fiber	Board, unfaced	3.47	-7.13	-7.13	Carbon
XPS (extruded polystyrene), HFC	Board, 25 psi	5.00	20.17	46.51	A5, B1
XPS (extruded polystyrene), HFO blend	Board, 25 psi	5.00	6.37	8.73	A5, B1

Most foam insulation products, such as polyurethane, polystyrene, and polyisocyanurate, are made from petroleum-based products and require significant energy to manufacture. These insulation materials containing hydrofluorocarbon (HFC) blowing agents have the highest global warming potential.

For example, extruded polystyrene (XPS) with HFC has a GWP of 46.51 kg CO_2e per 1 m^2 of R_{SI}-1 worth of material. On the opposite end of the spectrum, carbon-containing insulation materials such as cellulose and wood fiber can have GWP less than zero, as these products have a low energy intensity to manufacture plus offsetting credit for storing carbon in the product itself.

Builders for Climate Action has developed a robust estimation tool https://www.buildersforclimate-action.org/beam-estimator.html to conduct this lifecycle carbon analysis for energy retrofits, renovations, and new construction projects.

Initial research also uncovered this article, which starts to frame out the operational and embodied carbon payback periods: https://mantledev.com/insights/reduces-whole-life-carbon/ .This might be another way to communicate the impacts of various materials.

Another source is from Building Emissions Accounting for Materials https://www.buildersforclimate-action.org/beam-estimator.html

Material	Default Global Warming Potential (kg CO2e /sq.m. RSI-1)	note: RSI-1=R5.68
Cellular glass – Aggregate	3.93	EPD Declaration Number NEPD-2012-889-EN
Cellulose – Densepack	-2.10	
Cellulose – Blown/loosefill	-1.10	
Cork – Board	-6.80	
EPS/graphite - Board, unfaced, Type II – 15psi	2.80	
EPS/graphite - Board, unfaced, Type IX – 25psi, graphite	3.40	
EPS - Board, unfaced, Type I – 10psi	2.80	
EPS - Board, unfaced, Type II- 15psi	3.80	
EPS - Board, unfaced, Type IX- 25psi	4.80	
Fiberglass - Batt, unfaced	0.70	
Fiberglass – Blown/loosefill	1.00	
Fiberglass – Blown/spray	1.93	EPD Declaration Number 4788647002.102.1
Hemp – Batt	-0.50	
HempCrete	-3.00	
Mineral wool - Batt, unfaced	1.70	
Mineral wool – Blown	1.60	
Mineral wool - Board, unfaced, "light" density	3.30	
Mineral wool - Board, unfaced, "heavy" density	8.10	
Phenolic foam – Board	1.54	EPD Declaration Number EPD-KSI-20190072-IBC1-EN
Polyiso - Wall Board	4.10	
Polyiso - Roof Board	2.90	
SPF – Spray, open cell	1.40	
SPF – Spray, closed cell HFO	4.20	
SPF – Spray, high density HFO	4.90	
SPF – Spray, closed cell HFC	13.10	
SPF – Spray, high density HFC	17.00	
Straw – Panel	-6.50	
Vacuum Insulated Panel	7.40	
Wood fiber – Board, unfaced, European	-6.50	
Wood fiber – Board, unfaced, North America	-10.30	
Wood fiber – Batt, unfaced	-2.40	
Wool (Sheep) – Batt	1.00	
Wool (Sheep) – Loosefill	0.80	
XPS – Board, 25psi HFC	55.50	
XPS – Board, 25psi “Low GWP” (HFO/HFC)	4.90	

In 2022, a BETA version of a much-improved new embodied carbon estimator was issued by Skylar Swinford of Energy Systems Consultants (ESCO) **copy of which is attached to this report**. The calculator’s predictions are being monitored in various executed projects. It demonstrates that operational carbon is relevant from day one and not only after 10 years compared with embodied materials’ carbon, as previously thought.
This calculator includes NREL’s Cambium data sets. Cambium data sets contain modeled hourly emission, cost, and operational data for a range of possible futures of the U.S. electricity sector through 2050, with metrics designed to be useful for forward-looking analysis and decision support.
It also includes the e-Grid ubregion Source Energy Conversion Factors and CO2e Emissions Factors, as well as Heat Pump’s refrigerants GWP impacts from refrigerants leaks, and incorporates data from the BEAM estimator.

Appendix on Weatherization of Historic Buildings

Introduction

The sustainability of our communities relies heavily on the proper adaption of our older and historic buildings to meet the growing and changing demands of the 21st century. The reuse, adaption, and protection of valued older buildings and the inherent embodied energy and character-defining features ensure an investment in the future of our homes, communities, and planet.

- ***Embodied Energy*** *is the amount of energy consumed in the process of creating building products. This includes harvesting, manufacturing, transporting, and installing. Measured in Megajoules per Kilogram (MJ/kg), the more processed a material is, the higher amount of energy needed to produce it. For example, plywood is 10.4 MJ/kg, cement is 5.6 MJ/kg, PVC is 80 MJ/kg, and hardwood is 2 MJ/kg. This energy usage can be converted to BTUs to show the energy equivalent, such as one gallon of gasoline is equivalent to the average production, transportation, and installation of eight bricks. More and more companies are now adding embodied energy/carbon to their new building product declaration labels.*

With roughly half of Vermont's housing estimated to date from before 1970, older buildings must be part of the plan to reduce our collective carbon footprint and our reliance on fossil fuels. Weatherizing and maintaining older houses should be the first step in reducing energy usage and lowering operating costs. These small, low-cost/low-impact measures can have large results. Start with the least intrusive and most cost-effective methods. It is important to remember that this work can be done in stages, monitoring progress, and assessing the potential impact of further action.

Key Considerations When Undertaking Weatherization of a Historic Building

When weatherizing for energy efficiency or renovating an older building, remember three main points—reversibility, drying potential, and maintenance:

Reversibility: Alterations made today should be evaluated to determine how and if they permanently impact the building and the materials. Explore the long-term effects and maintenance requirements of alterations and new products used in weatherizing to ensure such activities will not permanently alter the way the material breathes and dries. Such examples may include application of a waterproof sealant or spray foam to masonry, which could expedite decay and potentially cause health risks for occupants. Most materials in older buildings are infinitely repairable but adding irreversible treatments could limit continued repairs and quickly lead to only replacement options.

- **Explore alternatives before commencing the work.**
- **Consult with experience professionals.**
- **Always start with the least intrusive measure.**
- **Do a small test patch before applying throughout.**

Drying Potential*:* The movement of air through wall cavities ensures the drying of materials and proper circulation of healthy air for occupants. When vents, air leaks, gaps, and cracks are improperly sealed and done without investigation of indoor ventilation, water and humidity will commonly be trapped. This trapped moisture assuredly will expediate the decay of structural materials and cause mold to form, leading to what is commonly called **Sick House Syndrome.**

- **Before air sealing, covering/removing vents, or applying vapor barriers, explore and understand the building's existing drying process and indoor ventilation strategy.**
- **When in doubt, contact experts in HVAC and building construction.**

For more information on Sick Building Syndrome:
https://www.epa.gov/sites/production/files/2014-08/documents/sick_building_factsheet.pdf

Maintenance*:* When getting recommendations on weatherizing and energy efficiency upgrades, it is important to explore and question the appropriateness of specific products and how each will interact with (particular) older buildings. Recommendations for replacement windows and modern materials, for example, could merely be an attempt to sell a new product, which might not necessarily be better. A restored single-pane window with a properly installed storm window may be as efficient as a replacement double-pane window and can avoid expending the energy needed for manufacturing a new window unit. Cyclical maintenance, required for both restored and replacement windows, is the best path for longevity of the materials and maintain energy performance.

- **Learn to repair before replacing.**
- **Knowledge of how to properly care for older building will ultimately cost less, retain the building's historic features, save energy, and keep materials out of the landfills.**

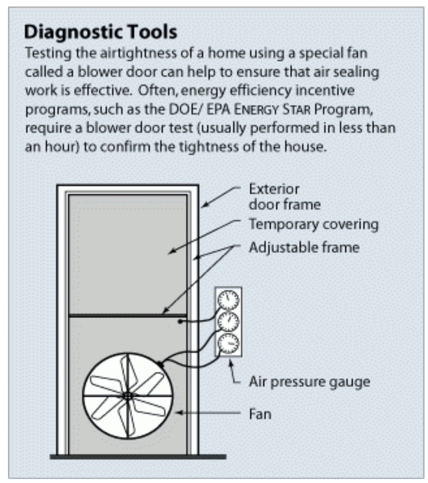
A guide for maintenance: https://www.nps.gov/tps/how-to-preserve/briefs/47-maintaining-exteriors.htm
Advice on when to repair or replace windows from Efficiency Vermont:
https://www.efficiencyvermont.com/blog/how-to/when-to-repair-or-replace-your-windows

Planning

Before beginning any energy efficiency project, it is best to have a plan. Background information on the building's original construction date and design influences, structural system, subsequent alterations, and current conditions/maintenance needs will save on costs and time, as well as inform next steps. For example, a balloon-framed house, a platform-framed house, and a masonry dwelling each require different insultation techniques to ensure energy efficiency success and not cause unforeseen negative effects.

To aid in identifying and understanding of older buildings, please visit:

- Vermont Division for Historic Preservation https://accd.vermont.gov/historic-preservation/identifying-resources
    - For existing survey documentation, please refer to the Online Resource Center: https://orc.vermont.gov/Resource_MultiTown/Show-Resource-MultiTown-Table.aspx
- Historic New England- https://www.historicnewengland.org/preservation/for-homeowners-communities/your-old-or-historic-home/architectural-style-guide/
- *A Field Guide to American Houses: The Definitive Guide to Identifying and Understanding America's Domestic Architecture*- By Virginia Savage McAlester (New York: Alfred A. Knopf, revised 2013).



A blower door test is conducted during an energy audit to quantify air circulation and heat loss. Courtesy of the US Dept. of Energy.

Home Energy Assessments: A roadmap to energy efficiency upgrade is one of the first steps. Contact a trained professional to perform an energy audit of the building. This technical audit will highlight the problem areas to tackle first.

Efficiency Vermont- https://www.efficiencyvermont.com/services/energy-assessments/home-energy-assessments

Weatherization

Weatherization or weatherproofing is the practice of protecting an older building from the elements, particularly from sunlight, precipitation, and wind, and the act of modifying a building to reduce energy consumption and optimize energy efficiency.

- **Always start with the small and non-invasive steps and advance as needed.**
- **Always test a new material or product on a small section/sample before applying throughout.**

Sealing drafts and gaps is an easy way to reduce the loss of conditioned air and increase comfort. Simple tasks like applying a bead of caulking or adding weather stripping can save about 10% on heating and cooling bills.

- ➢ Apply caulking to gaps around frames of windows and doors, where the bottom sill meets the foundation, and around utility penetrations (gas, electric, dryer vents, cable, telephone, etc.). Spray foam should be used sparingly and in select situations due to its potential to cause irreversible damage to historic materials or diminish the drying potential in wall cavities. Check with your insurance company since not all companies will insure properties that have been spray foamed.

- Install or replace weather stripping on exterior doors. Most weather stripping is intended to be replaced periodically; inspecting and replacing damaged or worn weather stripping should be part of a cyclical maintenance schedule.
- Seal chimney flues if not used.
- Add backer-rod or insert fiber insulation in larger gaps.
- Install foam socket seals behind electrical outlets.
- Insulate or block unused mail chutes.

For guidance on air sealing:

- https://basc.pnnl.gov/checklist-focus/air-sealing
- https://www.energy.gov/sites/prod/files/guide_to_air_sealing.pdf

Diagram of common sources of air leaks and heat loss at the attic. Courtesy of US Dept. of Energy.

Insulation

Older buildings sometimes have no insulation or may be loosely insulated with anything from newspaper, corn cobs, or bricks. Properly insulating an older house can have the greatest impact on your energy loss, but there are several things to consider before starting an insulation project.

- **Always start with the small and non-invasive steps and advance as needed.**
- **Before adding insulation or a vapor barrier, be sure to know your building assembly's drying potential and where moisture will condense. The health of your building and your family depends on it!**
- **Exterior insulation is never recommended for historic buildings.**

- Begin insulation projects in areas that are easily accessible and do not require cutting into materials like plaster, wallboard, or siding. Some of the easiest places to begin are in unfished attics and crawl spaces.

Example of cellulose insulation in a timber-framed attic. Courtesy the Preservation Trust of Vermont.

- There are several types of insulation, each serving a different purpose.
  - Use cautious when considering spray foam insulation because of its permanence and possible negative effects on building materials.
- In attics, insulation alone will have little impact on comfort or reducing energy bills without addressing all the air leaks. Hot air rises so sealing the air leaks will stop the chimney effect of drafts rising through the house and out the attic.
  - Before insulating, seal all potential leaks between heated and unheated spaces such as an attached garage, porch, and attic. These air pathways carry moisture, as well as heated or cooled air, that affects comfort, increases ice damming, and raises operational costs.
  - Fibrous insulations such as cellulose and fiberglass do not stop the flow of air. To find air leaks under existing fiberglass insulation examine where the fiberglass is dirty, because that is where it is acting like an air filter.
- Contact a certified professional before adding insulation to walls, sealing vents, or adding vapor barriers, because of these actions could have serious repercussions.
  - Testing and modeling are available that can identify specific insulation and breathability solutions.
- Before removing or disrupting existing insulation, know what type of insulation it is. Many older houses can have vermiculite with asbestos or other harmful materials. Be aware of the local building codes and disposal requirements.
- Collect guidance on how much insulation is necessary to address energy efficiency needs specific to the building. Over insulting can be costly and create other maintenance issues.

For guidance on insulation types: https://www.energy.gov/energysaver/weatherize/insulation/types-insulation
Efficiency Vermont is a great resource for all weatherizing and insulation question: https://www.efficiencyvermont.com/tips-tools/guides/a-homeowner-s-buying-guide-to-insulation
A brief guide to insulating: https://www.oldhouseonline.com/repairs-and-how-to/7-insulation-tips

INSULATION TYPE / MATERIAL		COST	PERFORMANCE & COMMENTS
RIGID / BOARD	**Polyiso (Polyisocyanurate)**	High	High insulating value for relatively little thickness.
	EPS (Expanded Polystyrene)	High	Can block thermal short circuits when installed continuously over frames or joists.
	XPS (Extruded Polystyrene)*	High	An effective vapor barrier.
	Mineral wool (semi-rigid board, rock or slag)**	High	Foil-faced mineral wool and fiberglass when taped provide an interior vapor barrier.
BLOW-IN (loose or dense-fill)	**Cellulose**	Low to Moderate	Good for adding insulation to existing finished areas, irregularly shaped areas, and around obstructions.
	Mineral wool (rock or slag)**	Low to Moderate	Good for adding insulation to existing finished areas, irregularly shaped areas, and around obstructions.
	Fiberglass (formaldehyde-free recycled content)	Low to Moderate	Energy performance of cellulose fill is comparable to high-density fiberglass batts, and more effective than batts at controlling air leakage and convective and radiant heat. Cellulose can have high recycled content, very low embodied energy, and low/no-toxicity fire retardants.
SPRAY FOAM (low density)	**Icynene™** **Soy** **Cementitious foam (Aircrete)** **Polyurethane Foam (closed-cell)***	Moderate to High	Good for adding insulation to existing finished areas, irregularly shaped areas, and around obstructions.
BLANKET (batts & rolls)	**Mineral wool (rock or slag)****	Low	Suited for standard stud and joist spacing, which is relatively free from obstructions.
	Cotton	Low	Suited for standard stud and joist spacing, which is relatively free from obstructions; low- or no-toxicity fire retardant.
	Cellulose	Low	Can have high recycled content, very low embodied energy, and low- or no-toxicity fire retardants.
	Fiberglass (formaldehyde-free recycled content)	Low	Does not provide the degree of air seal that blown cellulose does.

Source: Based on DOE EERE EnergySavers.gov

Determining the right insulation and where to apply it can be a difficult decision. The guide provides a brief overview of the options and where they are best suited. Courtesy of the US Department of Energy.

Windows and Doors

Windows and doors on many older buildings are important aspects of the architectural character. The design, craftsmanship/workmanship, and other qualities may make them worthy of preservation and, with some minor upgrading, can provide energy efficiency. As with all building materials, proper and cyclical maintenance are necessary. Consider repairing and improving before replacing, which sends most historic building features to the landfill.

Windows

Windows should be considered significant to a building if they are original, reflect the original design intent for the building, reflect period or regional styles or building practices, reflect changes to the building resulting from major periods or events, or are examples of exceptional craftsmanship or design. Once the evaluation of significance has been completed, it is possible to proceed with planning appropriate treatments, beginning with an investigation of the physical condition of the windows. Window repair and rehabilitation can range from routine maintenance, stabilization, or parts replacement. The best window repairs consider energy efficiency with appropriate weather stripping to reduce air infiltration.

- **Weather stripping is available in many different forms and styles. Some are applied seasonally while others are permanent. For more information on the pros and cons of the varying types of weather stripping, visit The Department of Energy's website**

Older wood windows require maintenance and can be infinitely repairable. Routine maintenance could include new weather stripping, reglazing where necessary, repainting (including removing excess and peeling/flaking paint), frame repairs, reinstallation of the sash, repositioning of the sash weights, and new sash cords/chains.

- Learning just a few basics of window maintenance can prolong the life of windows.
- Most heat loss occurs around the perimeter of a window, through infiltration rather than through the actual glass. Keep seals tight and in good repair, checking sealant at all window muntins as well.
    - Insulating the weight pockets, where the sash cord/chains and weight are houses, will have little energy efficiency effect as these cavities were designed to be open.
- Keep exterior surfaces painted, including putty. Recommend using durable, low VOC (volatile organic compounds), exterior grade paints.
- Add weather stripping to your windows to increase its energy efficiency as much as 50%.
- Check the window lock, an important element ensuring that the rails and sashes are held together tightly to reduce air infiltration.
- If glass in older windows needs to be replaced, consider Low-E glazing that reduces heat transfer and can be more energy efficient than regular glazing. It also helps with reduce the damaging effects of sunlight on fabrics.
- Window stops, wood on the sides of the jamb that abut the lower sash held in place by screws and washers, are intended to be moved in or out to allow the sash to move freely or to form a tight seal against the parting bead. In the winter, push the stop tightly against the sash to air seal the window.

- Draft blockers, window snakes, and curtains/blinds are a cheap way to limit air leaks and drafts.
- Always practice lead safety when working with older windows or painted materials. http://www.leadsafevermont.org/download/Field_Guide.pdf

For a step-by-step guide to window repairs:

- https://www.nps.gov/tps/how-to-preserve/briefs/9-wooden-windows.htm
- https://www.popularmechanics.com/home/interior-projects/how-to/a8043/how-to-reglaze-a-window/.
- https://thecraftsmanblog.com/how-to-restore-old-windows/

Storm Windows

Storm windows create dead air space between the window and storm, which improves energy efficiency by reducing air flow through the window glass and around the window frame. Moreover, storm windows provide protection for older and historic windows. When properly installed, storm windows on the exterior or interior of single-pane windows can last longer and be just as energy efficient as double-pane replacement windows. Storm windows can come in a variety of types, styles, materials, colors, and prices.

- Custom wood storm windows with weather stripped provide increased protection and are in keeping with the historic character of 19th-century buildings.
- High-quality metal storms designed with low profiles and clean lines for better aesthetics.
- Multi-track storm windows can provide more benefits in the long run with energy cost savings, noise reduction, control of dust/allergens, and provide a level of security.
- Interior storm windows need to be monitored at the start of winter for trapped humidity.

For a guide to installing storm windows:

- https://www.energy.gov/energysaver/services/do-it-yourself-energy-savings-projects/savings-project-install-exterior-storm
- https://www.efficiencyvermont.com/tips-tools/guides/how-to-choose-and-install-storm-windows

Doors

Older doors should be treated similarly to windows, attended to with cyclical maintenance plans and storm doors to ensure longevity and energy efficiency.

- Wood stops on door jambs should be adjusted to properly sit against door.
- Install or replace existing weather stripping to form an airtight seal.
- Adjust striker plate and tab/tang to ensure a solid close.
- Add a sweep at the bottom of door to decrease draft.

Appliances and Technology

Upgrading to energy efficient appliances and heating units is an effective way to lower energy usage and maintain occupant comfort.

- Before spending money to insulate, first consider investing in an efficient heating unit or water heater.
- Smart technology like thermostats and lighting can help monitor and lower energy usage.
- Install water-saving fixtures that lower energy and water usages.
- Replace florescent light bulbs with LED bulbs.

For appliance and technology options, explore Efficiency Vermont:

- https://www.efficiencyvermont.com/products-technologies/smart-homes
- https://www.efficiencyvermont.com/products-technologies/heating-cooling-ventilation

HOMEOWNER DIY ENERGY EFFICIENCY CHECKLIST

Date: ____________________

Air Sealing-Caulk

- ☐ Door and Window Trim-Interior
- ☐ Door and Window Trim-Exterior
- ☐ Utility Penetrations (gas, electric, cable, etc.)
- ☐ Outdoor Faucets and Sillcocks
- ☐ Soffit Trim
- ☐ Seam of Sill and Foundation

Air Sealing-Other

- ☐ Foam Pad on Electrical Outlets behind Plates
- ☐ Repointing Small Holes in Foundation
- ☐ Gaps in Attic
- ☐ Closed Fireplace Damper when Not in Use/Cover Chimney if Not in Use

Windows and Doors

- ☐ Applied Weather Stripping and/or Sweeps
- ☐ Tightened Window Stops
- ☐ Made Window Hardware Operational
- ☐ Installed Storm Windows Tightly with Weather Stripping
- ☐ Reglazed Windows or Door Glazing

Insulation

- ☐ Installed Insulation in Unfinished Attic or Crawlspace
- ☐ Insulated Rim-Joist in Basement

Appliances and Technology

- ☐ Installed Energy Efficient LED Bulbs, Smart Thermostat, and Appliances
- ☐ Upgraded Heating Unit or Water Heater

Safety and Preservation Considerations

- ☐ Identified the Style, Age, and Condition of Building
- ☐ Conducted Energy Audit of Building
- ☐ Utilized Inherently Efficient Building Features (shutters, storm windows, shade trees, etc.)
- ☐ Ensured Roof or Soffit Vents are Not Sealed
- ☐ Contacted Certified Professional Before Insulating Building
- ☐ Explored Alternatives to Application of Damaging Products to Existing Materials
- ☐ Contacted Certified Professional Before Applying Vapor Retarder or Waterproof Shield

Appendix to the Patchwork Approach to Weatherization

Vermont's weatherization practices were first developed to save money and reduce demand for fossil fuels, largely in response to the first oil crisis in the 70's. As climate change has grown into a critical global problem, weatherization has taken on a new role – cutting GHG emissions – and has grown more urgent. Vermont's response to the new urgency has largely focused on trying to scale up weatherization efforts.

Fundamentally, there are two ways to scale up weatherization efforts. Either the number of projects can be increased, or the reductions achieved in each project can be increased. The impulse to weatherize a building should never be discouraged, but if overall GHG reductions are to be maximized, it is important for the quality of weatherization projects to be maximized.

The reason for this is a bit complicated. Doing a quick and easy weatherization job may well create useful savings at a low cost while providing quick payback times. Since such projects focus on the easiest work, they will rarely maximize economic benefits, energy savings, or carbon emission reductions. Not including more challenging weatherization options will lower the project cost and shorten payback times. In theory, these options could be implemented later. However more challenging options rarely save enough to pay for costs of a new construction project (including planning, estimating, management, getting workers set up and working smoothly, and cleaning up when they are done). These costs are relatively fixed, and cannot be justified by the smaller payback from more challenging weatherization options. In addition to fixed costs, some work (especially finish work) may need to be redone, making follow-on projects even less economical.

For these reasons, the most economical way to do most construction projects is to combine as many tasks as possible together into a single project. Projects can be phased to work around all kinds of challenges, including scheduling challenges for building occupants. But shutting down one project and starting new ones later to finish a body of work – a patchwork approach – is usually an expensive way to complete that work. Sometimes good planning can help reduce costs for multiple, independent projects, but will almost inevitably either raise total costs, sacrifice some desirable results, or both.

When a simple, easy weatherization project prevent larger savings, it is a progress trap – it traps the building in a less-efficient condition. Good planning and management of comprehensive weatherization projects and programs are the best way to avoid progress traps.

Combining weatherization with other construction projects (increasing the scope and scale of the project) may in many cases create yet another economy of scale. However, such economies usually come at the cost of complexity.

Training and Certification

Given the complex options for weatherization and associated issues, assembling a plan for the most effective weatherization projects and programs requires expert input. The required expertise includes a solid foundation in weatherization-related building science, advanced skills in optimization among factors such as insulation types and amounts, HVAC systems functionality and costs (specifically including moisture control), and alternative methods of heating, ventilating, and air conditioning. These must be combined with a strong understanding of energy costs, incentives and supports, and regulatory requirements. While it may be possible to acquire the required expertise by oneself, training is normally needed. And if the state or other authority is to assure competence in these skills, certification is a requirement.

Fortunately, excellent training and certification programs exist. Efficiency Vermont offers its own, excellent discussion of these issues and provides recommendations. In addition to its recommendations, the Technical Approaches would add:

- BPI programs
- HERS rater training and certification– this program is strong on building science, but provides little help on HVAC issues. Through modeling of a building, an energy efficiency rating is generated.
- Passive House Institute US (PHIUS) training and certification - PHIUS provides training for certification as Passive House Consultant, Builder or Trade Person. These trainings address:
    - The five basic principles of a Passive House building
    - Climate-specific insulation practices
    - Thermal bridge-free construction
    - Climate-specific high-performance windows to prevent condensation and increase comfort
    - Stringent air tightness standards
    - Balanced mechanical ventilation with heat/energy recovery
    - Building science principles for sound hydrothermal building components
    - Energy modeling which addresses load optimization, orientation, shading, and other issues

The fundamental skills acquired through competent training, combined with experience gained from years of working in the field, are the best guarantee of good results from every weatherization project, and therefore, all weatherization projects.

Conclusion

Quick and easy weatherization initiatives often lead to a patchwork approach to energy efficiency and carbon emissions reduction. Decades of experience have shown that good planning based on deep and wide knowledge about weatherization and related issues provides the best assurance of good results. In order to do the best possible job of meeting the objectives of Vermont's Weatherization at Scale program, skills are essential.

The appeal of a patchwork approach is undeniable, but Vermont should encourage and support high standards of weatherization planning, management and execution of weatherization projects and programs.

Appendix to Windows

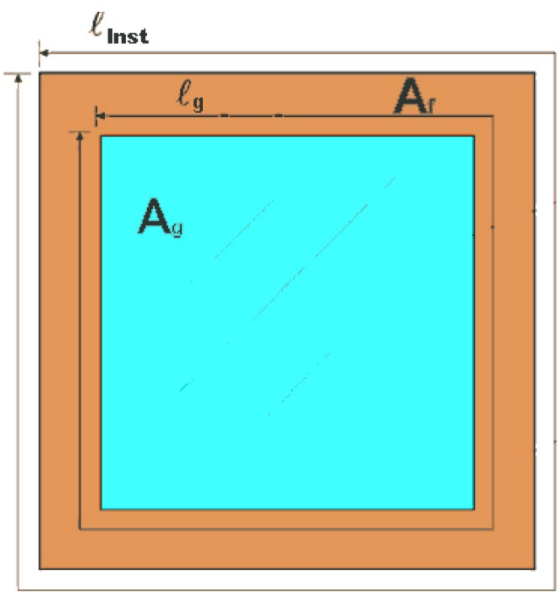
The U-value of the window U_w is calculated taking into account the:

- U-value of the glazing U_g and the dimensions of the glazed area A_g,

- U-value of the frame U_f and the projected area of the frame A_f,

- The linear thermal transmittance at the edge of the glazed area Ψ_g (which largely depends on the quality of the edge bond) and the length of the glass edge l_g,

- The additional thermal bridge due to the installation of the window in the external wall Ψ_{inst} and the length of the installation edge l_{inst}.



This image shows the relevant values:

glazed area A_g;

frame area A_f;

glass edge l_g;

installation edge l_{in}

All these heat losses need to be factored in to avoid overestimating the window quality. The window U-value is calculated based on the following formula:

Uw = [Ag * Ug + Af * Uf + lg * Ψg (+ linst*Ψinst)] / (Ag + Af)

The quality of a window depends then on two essential characteristics:

- The U-value of the window U_w, reflecting the heat losses; especially since windows should not have any cold surfaces even on cold winter nights. The U-value should be as low as possible. For VT climate should be 0.19 - 0.11 Btu/hr.sf.F
- The g-value of the glazing, reflecting the potential solar heat gains. The g-value should be as high as possible with common values around 0.5.

The Window Comfort & Condensation Risk according to Phius can be assessed with their calculation tool on line at: https://ssccust1.spreadsheethosting.com/1/bc/830791e0e82174/Window%20Comfort%20and%20Condensation%20v3.6/Window%20Comfort%20and%20Condensation%20v3.6.htm

There is a window retrofit option available, which is the energy panel system for increased u-values and a full weather seal retrofit for infiltration reduction for all double hung, single hung, casement windows that have single pane glass or pre-1980 IGU's. This covers about 70% of the existing housing stock in Vermont. This recommendation does not include windows of historic significance which is addressed under a separate category. This recommendation is a departure from the industry practice of adding exterior storms, interior storms, double glazed inserts or full replacements or triple pane full replacement windows. The following is the reasoning behind the recommendation. Opensash is currently the only company that offers this option, but it is available to any company that follows the products and process outlined in Process 1 and 2.

Weather seals and Infiltration

The process of adding weather seals to existing windows is well established and very effective if installed correctly, so that needs no explanation.

Storm windows interior and exterior

The argument for energy panels over interior and exterior storms rests on the principle that air movement in between the added glass layer of storm windows is too thick to limit internal convection effectively. Storms windows are also inconvenient, making them less likely to be adopted or used correctly, interior and exterior. Also storm windows, either interior or exterior, can create moisture issues that are detrimental to the primary sash.
The Question for the committee is, do we recommend keeping existing exterior and interior storms in place. Not sure of the answer to this question.

Full Replacement and inserts double and triple pane.

The purpose of weatherization has changed over the years from a single focus on improving efficiency to also reducing carbon emissions. It has been shown that, especially in new construction, efficiency of buildings has gone up, but the carbon emissions have stayed the same or increased because the size of buildings has increased, the life span of buildings and products have gone down and the embedded carbon has gone up.

Recommendation are based on the following criteria

In order to reduce carbon emissions in the thermal sector as quickly as possible we must:

#1 Reduce net carbon emissions
#2 Manage costs
#3 maintain or improve comfort, health, and consumer satisfaction

Carbon Reduction

Carbon reduction has two parts, operational and embedded. Operational carbon is easily quantified by u-value and cfms. Embedded carbon includes the carbon it takes to make the product, ship it and install it as well as the life cycle of the product. Although it is very difficult to quantify and more research is needed, there are already accurate carbon emissions calculators and operational vs embodied estimators available in the industry as stated in the Appendix to Embodied Carbon.
The carbon reduction value of a weatherization product or process is a function of the operational carbon plus embedded carbon divided by its life span. In order to meet near term goals for carbon reduction, rapid reductions of emissions and increases in carbon sequestration in buildings are important, but long- term goals also require that the life span of construction processes and products be large.

The following scoring system, which is intuitive without full available quantitative support, provides a way to combine the three criteria listed above to help balance their role is minimizing operational and embedded carbon emissions.

Carbon Scores
Triple pane window
    Low- operational (5) u-value of 0.20
    High embedded (2)
    Score = 7
Double pane full replacement
    Medium operation (4) u-value 0.27
    High embedded (2)
    Score = 6
Double pane IGU inserts
    Medium operational (4) 0.27
    Medium embedded (3)
    Score =7
Energy Panels
    Medium operation (3) .35
    Low embedded (5)
    Score= 8

Cost
There are three choices for converting single glaze to double glaze.
1) **Full window replacement Triple pane**- Jambs and sills. Old windows are removed to the studs. Cost (not including install or painting or delivery) $50-$70/sq. ft. Install painting and delivery. Cost $40-$50/sq.ft. Total cost = $90- $120/sq.ft

2) **Full window replacement double pane** =$40-$60/sq. ft.
installation cost = $40-$50/sq.ft. Total cost = $80-110/sq.ft

3) **Insert replacement windows** fit into existing jambs (not including install painting or delivery) $30-30 sq/ft. Install painting and delivery cost $20-$30/ sq.ft.
   Total Cost $50-$70/sq.ft.

4) Energy panels plus weather seals - Attached to existing sash. Not including installation, painting or delivery) $10/sq.ft (install, painting and delivery) $30-$40/sq.ft
   Total cost $40-$50/sq.ft.

   Cost scores:
   Triple pane =1
   Double pane =2
   Double pane insert=3
   Energy panels = 5

Comfort health convenience

Triple pane= 5
Double pane = 4
Double pane inserts = 4
Energy panels= 3

Total scores

Full Triple pane = 13
Full Double pane = 12
Double pane inserts = 14
Energy panels = 16

Process 1: Prescribed method of weather sealing existing wooden double hung windows

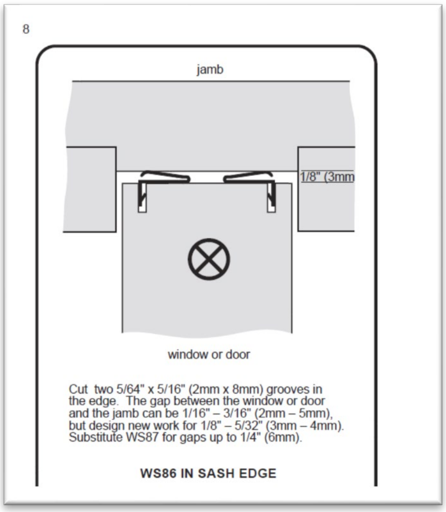
A two-vinyl-leaf seal curffed into the edges of the stiles
1 bulb seal on the bottom of bottom sash rail
1 brush seal on the upper sash meeting rail

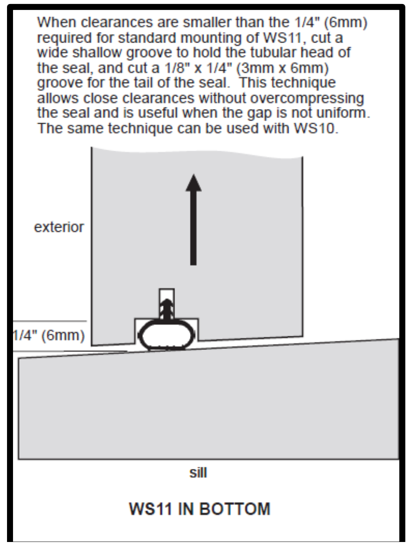
Weatherization

Weather Sealing Lower Sash

This includes

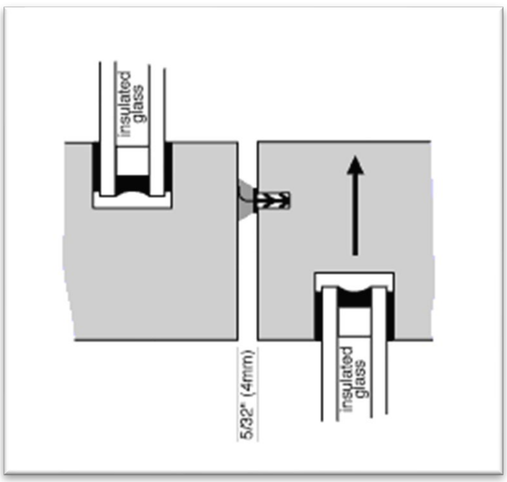
1) sizing the windows.
2) Adding two sets of **leaf seals** on the sides of the sash. Seals are not visible and are easily replaceable.
3) A bulb seal on the bottom of the lower sash
4) A brush seal at the meeting rail between the upper and lower sash.
5) We add a parting bead seals if necessary.





Leaf seal

Bulb seal.



Brush seal.

The Upper Sash

Fixed in place and air sealed with caulk and held in place with full length external stop

Adding glass panel upper and lower sash

This includes

1) Adding a ¼ wood frame to the outside of the sash
2) Aluminum trimmed glass energy panel. Ssb low-e glass
3) Panel is cleaned on both sides
4) Exterior and interior glass of the primary sash is cleaned
5) The wooden frame is primed and painted with high quality 2x coats of exterior latex.

The Energy Panel is removable for cleaning. It can be left on all year or taken in out on a seasonal basis.

Screen Set up

Lower sash and exterior stops set up to receive screens.

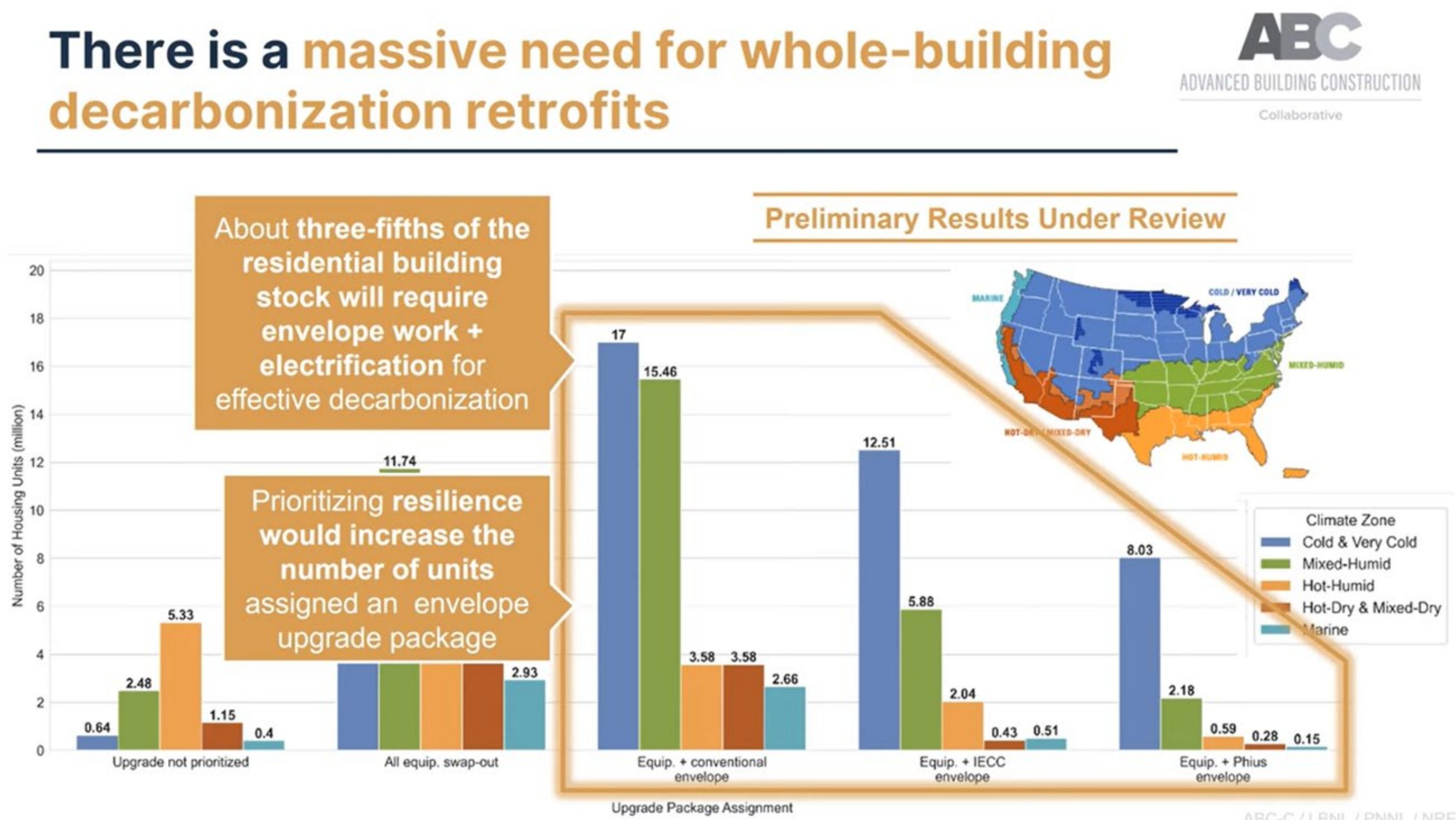
Process 2:

Glass energy panel should be low-e glass
Sitting on a frame attached to the exterior of the window.
The glass panel (energy panel) is trimmed in aluminum
The trim on the glass follows the edge where the glazing meets the sash.
The energy panel is secured in place with a flange at the top and clips at the bottom
The frame for the panel is ¼ thick.

Note: The term embedded carbon does not refer to the amount of carbon in a product. Carbon rich materials like wood do not increase carbon emissions as long as it remains sequestered in the product and is not released through disposal or decay.

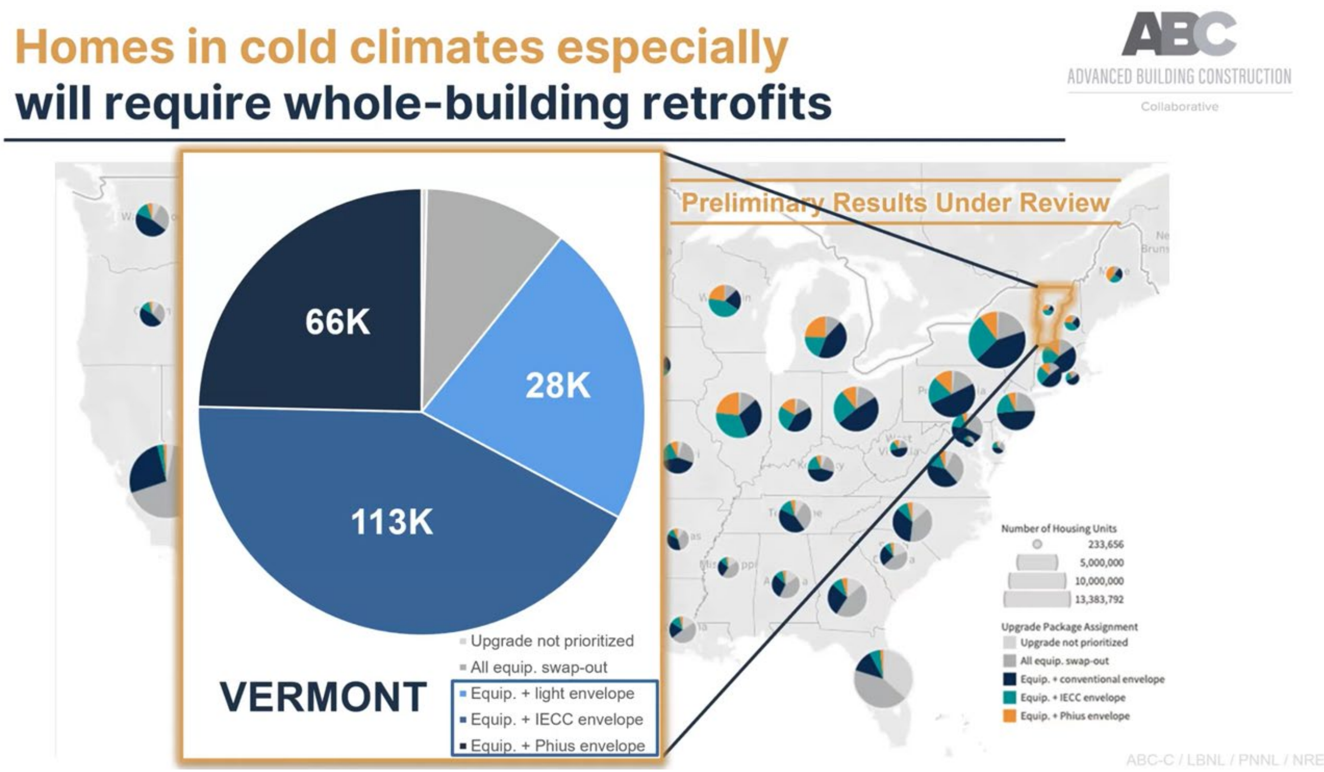
Appendix to Industrialized Wx

The industrialized weatherization approach presents a great opportunity to expedite the job of weatherizing and decarbonizing the existing stock as demonstrated in the joint study that the Rocky Mountain Institute RMI conducted together with LBNL, PNNL and NREL, which produced an accounting of the number of units in the nation that will require an energy retrofit of some sort from now until the year 2045, as shown on Slide 1 of RMI's Advanced Building Construction initiative.



Slide 1

According to the study, the number of homes that will require whole-building retrofits In Vermont accounts for 207,000 units. Those will require either a combination of equipment + light envelope, equipment + IECC envelope or equipment + Passive House envelope, as seen on Slide 2
In this context, the greater the priority it is on resilience to withstand weather events originating power outages, the greater the need to implement the Passive House standard of retrofit for survivability.

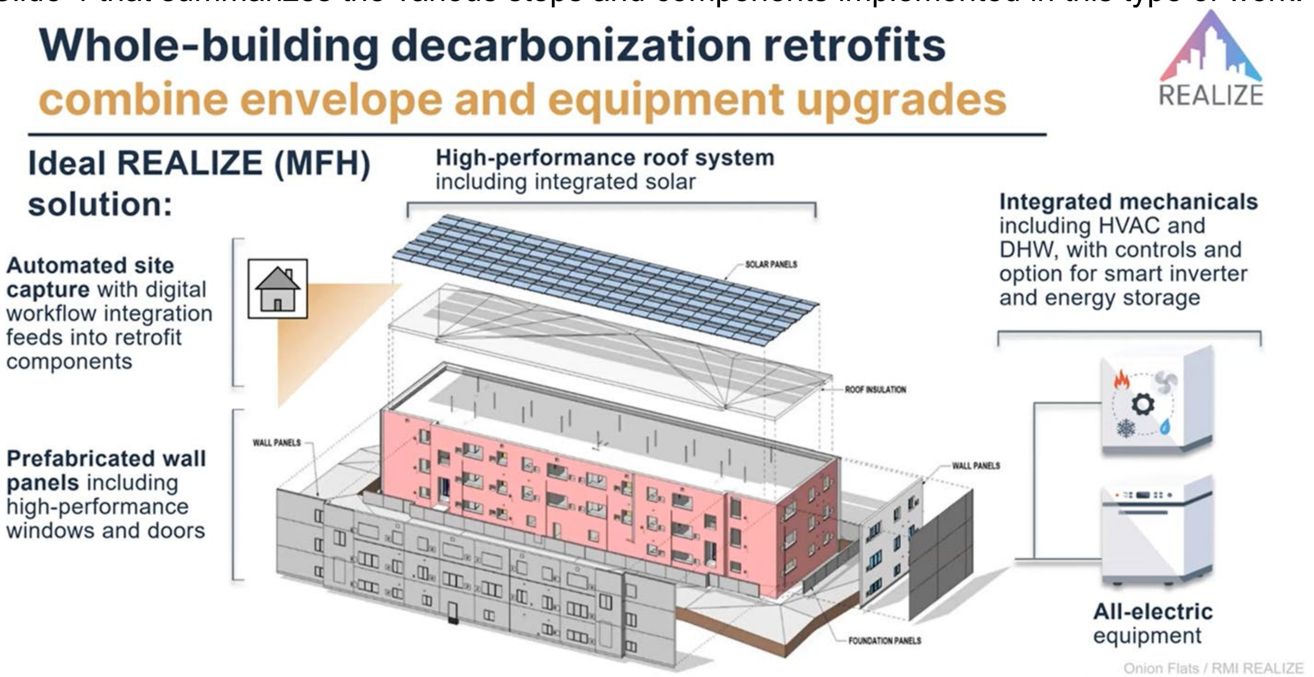


Slide 2

There is where energy efficient building decarbonization meet the advantages of industrialized weatherization as see on Slide 3

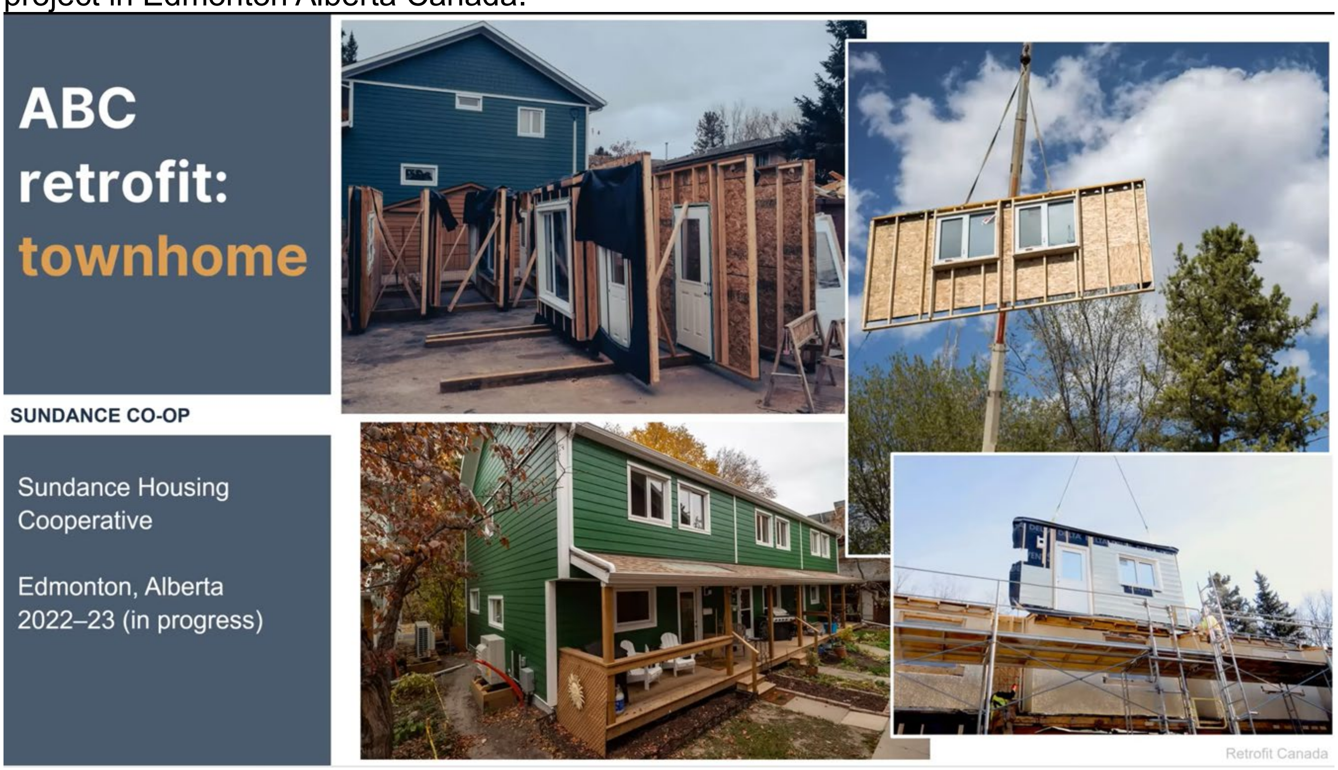
Slide 3

One of the hurdles for hiring new weatherization workforce is the fact that it is a dirty job that does not create scalable skills that the worker can extrapolate to other industries. The industrialized retrofit approach will bring the weatherization workforce to an advanced level of skills that can be applied to other areas of industries and services providing a wider field of opportunities for the individual, like laser scanning, fabrication drawings' generation or industrial machinery operation skills, as shown on Slide 4 that summarizes the various steps and components implemented in this type of work.

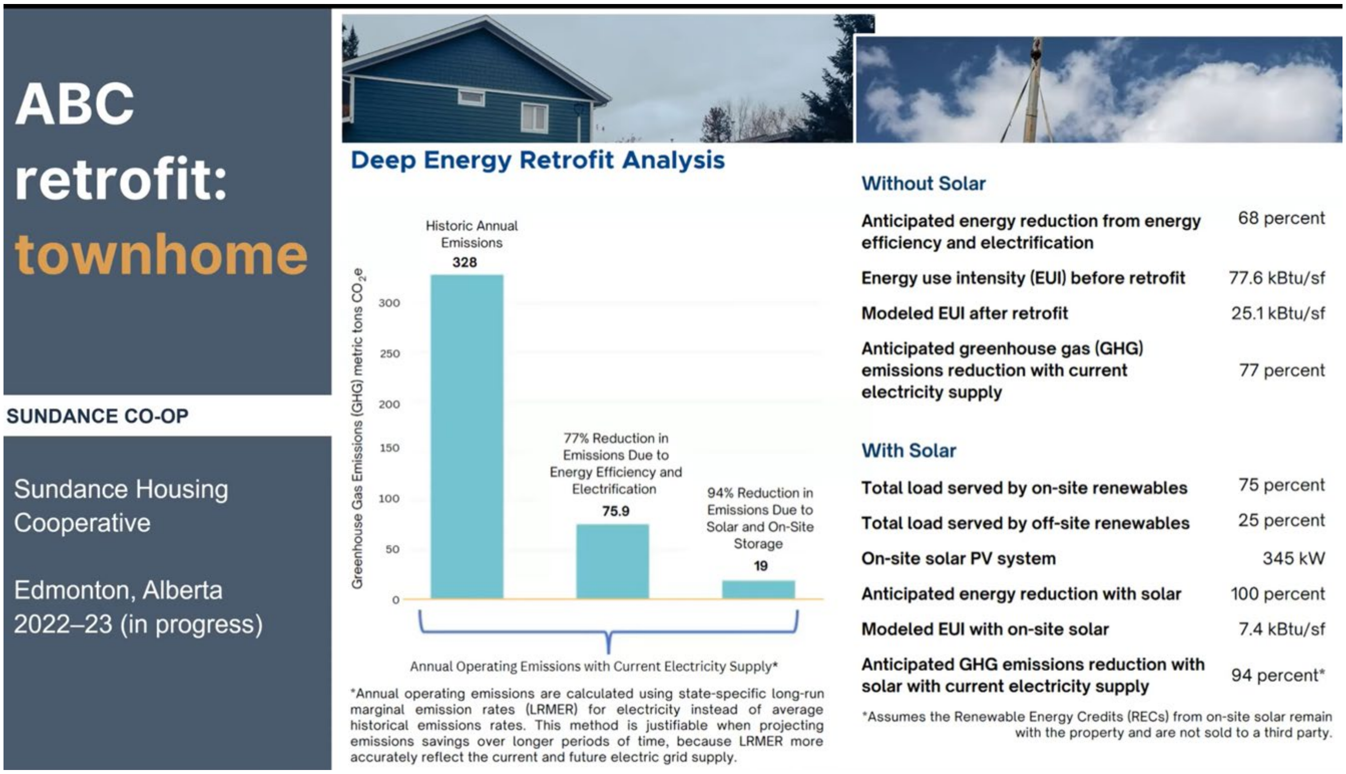


Slide 4

The technology applies also to smaller scale typology buildings such as those found in VT with hybrid execution utilizing manufactured panels with assembled windows and doors combined with air sealing and on-site cellulose insulation blowing as shown on Slides 5 and 6 from an example of a project in Edmonton Alberta Canada.

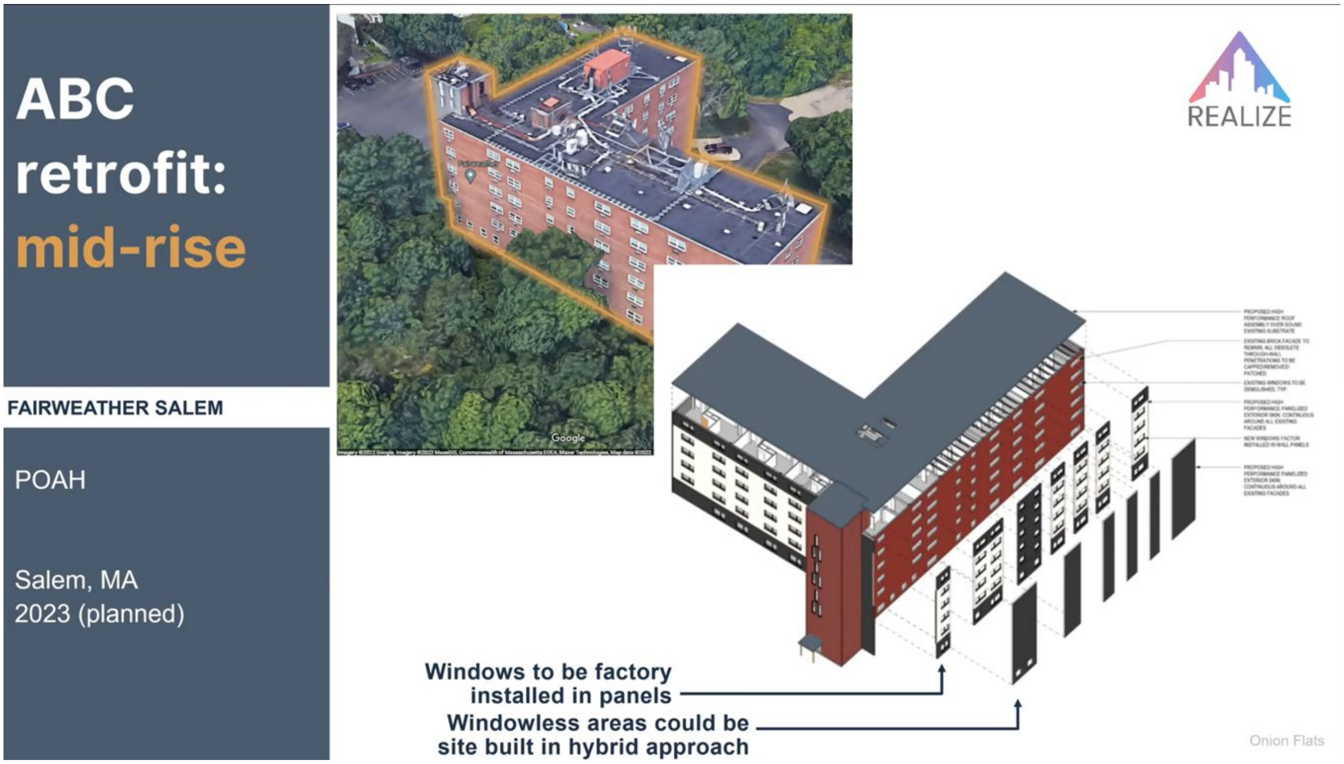


Slide 5



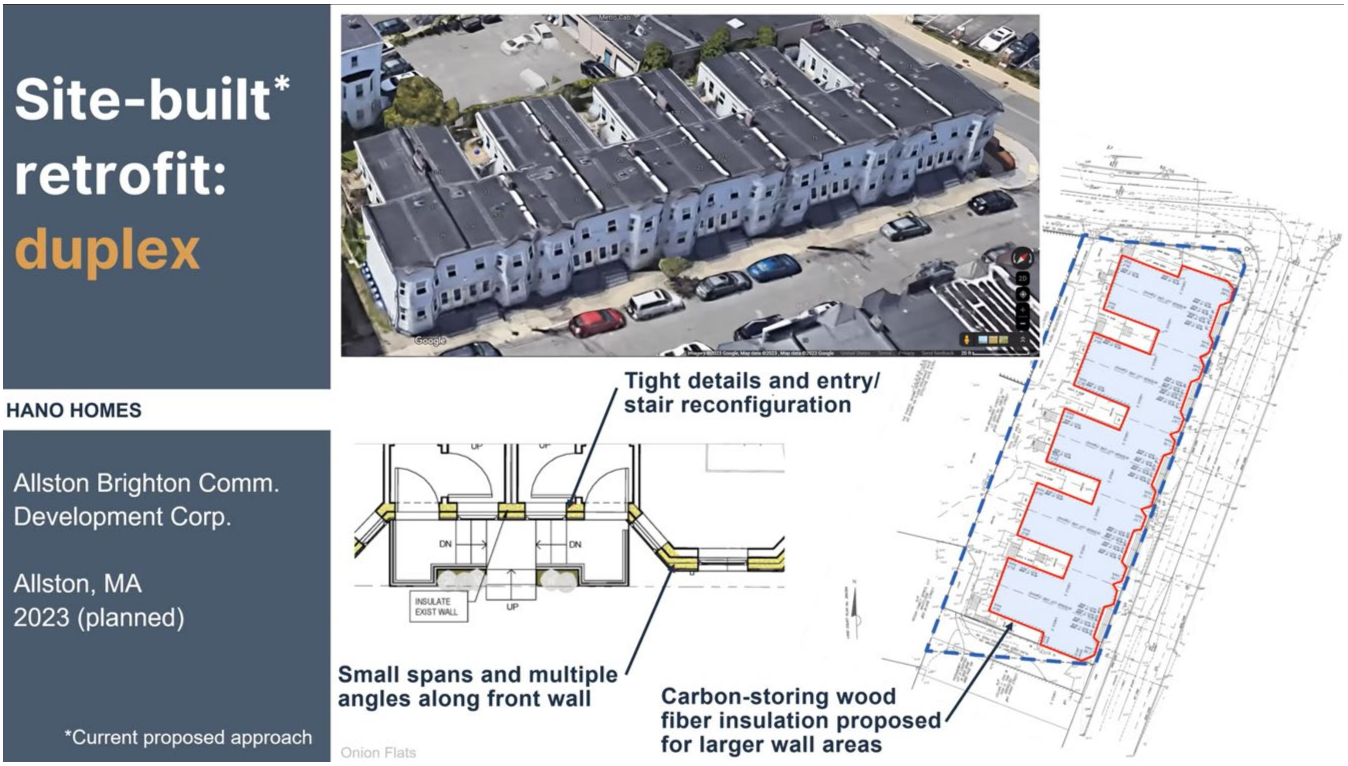
Slide 6

Other cases of hybrid approaches use factory made panels with installed windows while windowless areas are site built like the example of the Preservation of Affordable Housing project shown on Slide 7

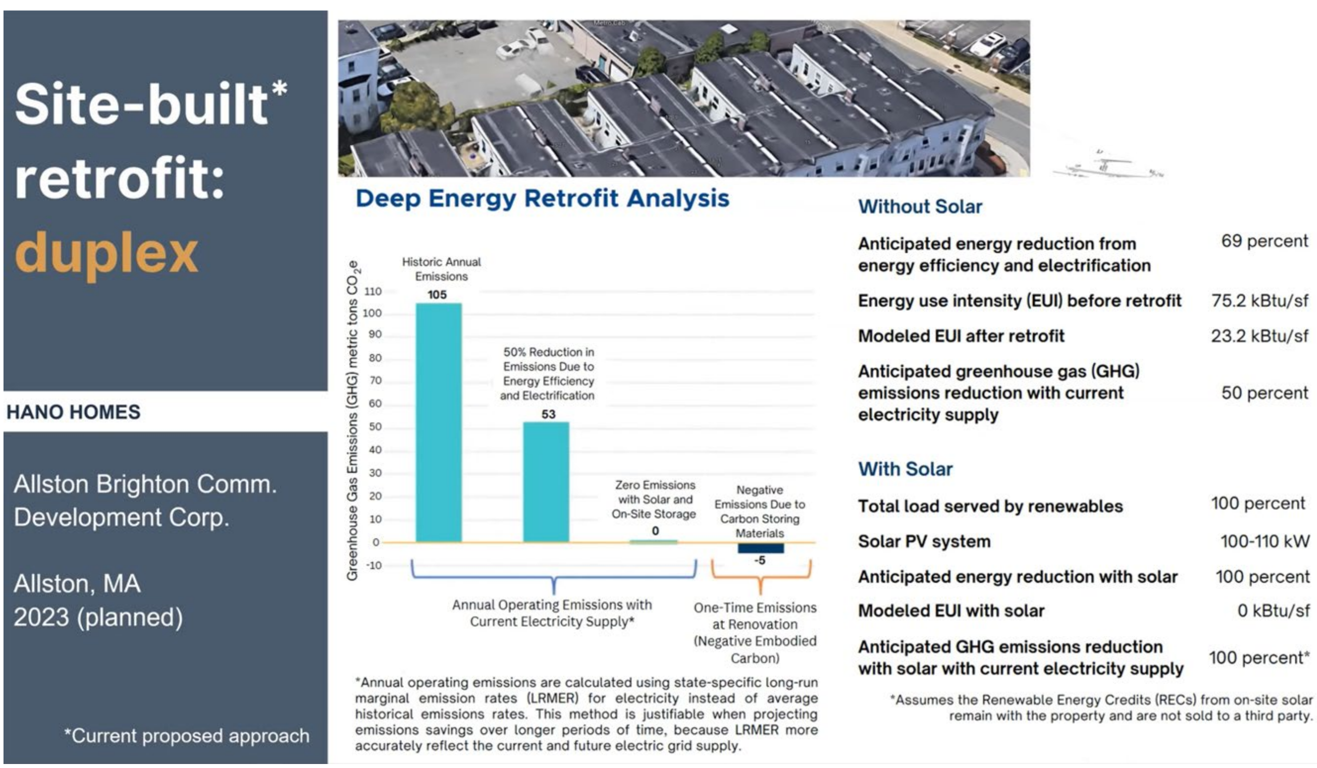


Slide 7

Very complex geometry buildings evidently are not suited for a typical industrialized approach but still can benefit from some factory-made components like window bucks and wood fiber panels for larger wall areas, which also contribute to carbon sequestration as shown on Slides 8 and 9.



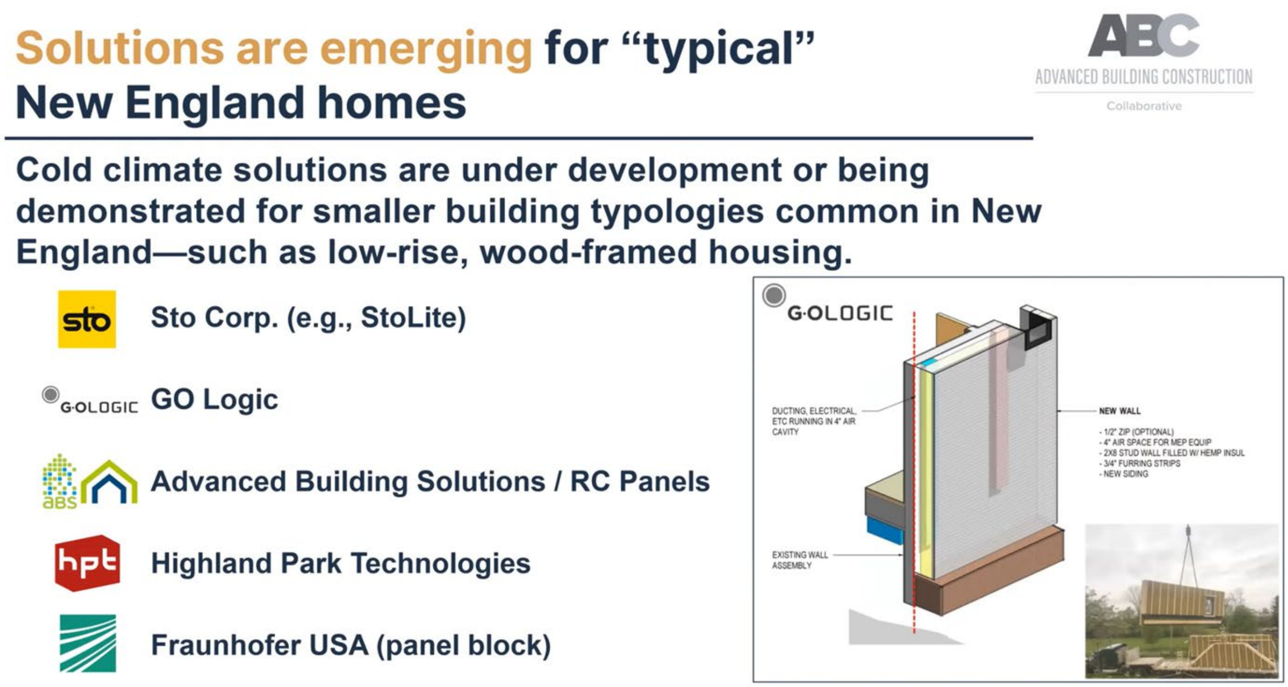
Slide 8



Slide 9

There are already solutions for typical VT cases of smaller building typology as shown on Slides 10, 11 and 12

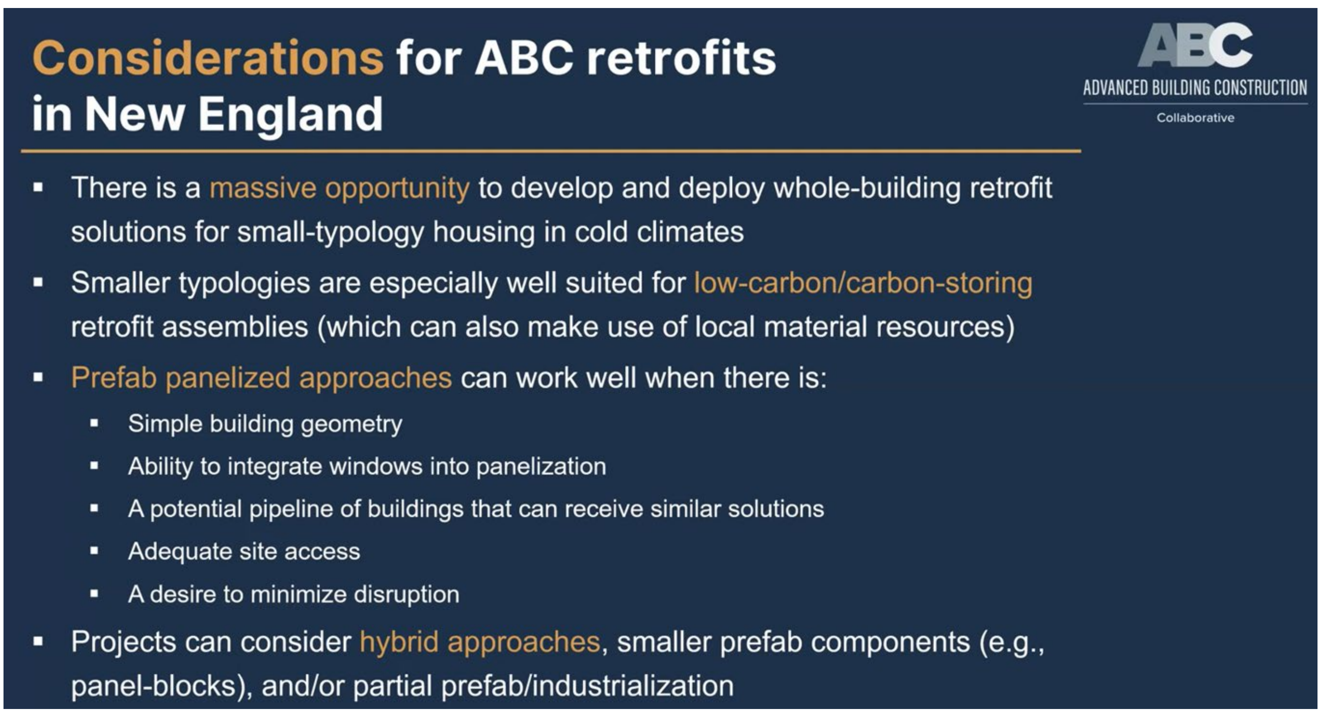
Slide 10



Slide 11

Slide 12

The considerations for the industrialized approach are summarized on Slide 13



Slide 13

The Advanced Building Construction Collaborative Network includes a great number of business and institutions across the country as seen on Slide 14 and VEIC is a member of the network, something VT can benefit from.

Slide 14

Conclusion

The industrialized approach can help in expediting the weatherization challenge that VT is facing while substantially reducing the impact on global warming that buildings are inducing along with liberating VT from its dependence on costly fossil fuels. It can improve the professional level of weatherization workforce, be an economic development and innovation driver and create equity healthy living spaces for Vermonters.

One thing is certain; the problem cannot be solved by simply banning gas and swapping all gas burning equipment for heat pumps. The problem here is that if we were to simply electrify our existing buildings as they operate today, replacing all gas with electricity, we would need a grid many times larger in terms of peak capacity!
Even if we believe the grid will magically decarbonize by 2050 despite such huge increases in demand (and that's before electric cars), there are no silver bullet energy sources on the horizon that could make that possible. Therefore, demand reduction is imperative, before everything else.

Appendix to Encapsulation
Weatherization Techniques Using Encapsulation

Most weatherization projects in Vermont combine a variety of techniques to provide cost effective results. A common test for what should bin included in a weatherization job is whether it provides a quick return on the initial investment. The focus on quick payback times tends to be high. Better weatherization projects will generally accept a longer payback time in the pursuit of higher thermal performance and a larger ultimate economic benefit.

From the viewpoint of maximizing greenhouse gas reductions, these projects are hampered by two things – subsidies which cut energy prices, and ignoring subtler but still real economic benefits of weatherization projects. Some building owners are sophisticated enough that they appreciate the subtle benefits of more extensive weatherization, and a few will go beyond these standards in pursuit of altruistic or other goals that are not strictly economic in nature.

Encapsulation

For the purposes of this discussion, encapsulation will be considered to consist of modifications applied to the surfaces of a building's thermal shell that improve its performance. Mostly, such improvements involve additions to the exterior surface of a building, although it might be argued that certain additions to the inside surfaces of the exterior shell assembly, especially in a cellar, might be included.

Encapsulation approaches can be classified as follows:

1) Encapsulation using an industrialized approach: pre-fab panels are produced at a factory from drawings generated by a laser scanning of the building (See Appendix to Industrialized Wx)
2) Encapsulation using an on-site approach: this approach is similar to the industrialized approach except that all work (measuring, fabrication, installation, etc.) is done on site.
3) Hybrid of 1) and 2)
4) Encapsulation by addition, including adding a new room or rooms, one or more stories to the top, and connecting adjacent buildings together via an addition.
5) Natur Hus: a new shell, separate from the original structure

Industrialized Encapsulation: The greatest recent successes with encapsulation (mostly in Europe) have come from a process that starts by using high-tech approaches to precisely measure a building's exterior. That data is transferred to a factory that specializes in pre-fab exterior panels (including new window and door assemblies). When completed, these panels are shipped to the construction site and installed flush to the exterior walls and roof. Careful preparation and rapid installation minimize disruptions to the building's users.

On-site Encapsulation: Projects similar to the one described above have been done, with the difference that they use conventional building techniques (including conventional measuring techniques and on-site fabrication). This approach has not caught on generally, although examples can be found in Vermont.

Encapsulation by Addition: Partial encapsulation of existing buildings is commonly achieved by installing additions. Additions convert an existing external wall or ceiling into an internal surface. Good additions can provide similar benefits to complete encapsulation for the areas where they attach to the original buildings.

The most common addition involves adding one or a few rooms to one side of a building.

An addition with greater potential to reduce energy consumption is one which adds one or more stories to an existing building. Since so much heat is normally lost through the roof of a building, replacing an existing roof with a structural expansion that includes one or more stories and a new roof is an excellent opportunity to significantly boost a building’s efficiency.

When new stories are added to buildings, it should normally be possible to cantilever the additions outward, beyond the existing walls. Doing so should significantly reduce the cost of then encapsulating the walls of lower stories. However, we know of no examples where this has been done.

Especially if two buildings are close together, it is possible to build an addition which, in some sense, merges them into a single building. Examples of this are fairly common. A simple form of this process is the addition of an enclosed entryway that is then shared by two buildings. This type of project typically cuts energy losses from both buildings.

Projects that more completely merge buildings can take many forms. Such projects are normally undertaken because they are cost effective. However, such projects also provide an excellent opportunity for extensive weatherization.

The fifth classification (natur hus, which is Swedish for ‘nature house’) covers practices implemented in Sweden starting around 1976. In a natur hus, a new shell, separate from the original structure, is added. In most cases to date, this new thermal shell has been a greenhouse. Experience shows that such projects cut energy heating demand by about 50%. Due to high costs, such projects rarely generate positive economic returns, although many adopters place a high value on the new protected spaces created between the original building and the greenhouse. This technique also comes with challenges in terms of ventilation and moisture management. As discussed at length in other sections, effective moisture management and ventilation are crucial to the long-term durability and healthy living environments in buildings.

Appendix to Website Resources

At our last TAG meeting we had some discussion around the problem that contractors working in the field face in keeping up to date both with new approaches and technologies, and new concerns (whether real or fabricated) surrounding the weatherization and shell improvement business, especially with its potentially rapid expansion as we try to build up our workforce and contractor base. Technology keeps evolving, and contractors and other professionals with a wide range and variety of backgrounds also are getting into the business, sometimes in competing arenas and with varying points of view. Competing information, insufficient information, and disinformation are easily shared and easily spread. This is especially true in areas such as moisture management and product liabilities in buildings, and questions surrounding minimization of embedded carbon vs operative carbon.

As we consider rapidly scaling up weatherization efforts and capacity in Vermont to confront the need to minimize carbon emissions, we believe that in addition to training, both for acquiring and maintaining certifications, there is a particular need for a regularly updated resource – most likely an interactive website (i.e. one that will allow for questions, comments, and discussion) – that would promote the advancement of trusted, accurate and very up-to-date information.

We saw a huge amount of distrust in the course of the COVID emergency. Much of the distrust was manufactured, but there was also quite a bit of it generated by genuine confusion because of a lack of recognition about how scientific understanding of a problem advances, and how public protocols necessarily change and evolve throughout that process.

We are, we believe (and hope), further along in our understanding of building science, and systems performance with respect to building envelopes, but there is still plenty of complexity, and debate – and evolving science – especially as new technologies come into play, and as we have opportunities to study buildings which have been upgraded using various strategies under the protocols of the past few decades. The climate emergency will provide plenty of fodder both for general confusion, and for alarmist sensibilities and disinformation. Contractors in the field will have to address all of these, adding to the general stress of operating their businesses and selling their products and services in good faith.

A website providing up to date information and resources – designed specifically to accommodate weatherization contractors in Vermont (or the northeast) – should be considered. Specifically, it should provide the following:

- A respectful reminder of the way scientific method works and how it is applied in building science, and where that science is strongest and weakest at this point in its development.
- A general list of specific references and resources, for follow-up or better review or understanding of the various nuances of building science;
- A forum for discussion, and posing specific questions;
- A list of consumer-friendly resources that will support building science and systems approaches to weatherization, to which contractors can point their clients;
- Immediate responses to trending disinformation – citing the specific elements of the disinformation that are false, and again, if possible, citing sources for better understanding – both for the contractor and for the consumer;
- Immediate highlighting of specific concerns or red flags with products, technologies, or approaches as they arise or are discovered – with respectful and nuanced discussion of the issue, of the open questions surrounding it, and of the unknowns surrounding it – again with space for feedback and commentary.
- Recognition of areas where professionals disagree, and the nature and reasons for that disagreement.

- A recognition of the site's own limitations – whether to resolve a question generally, or to answer some specific question, and some potential follow-up strategies or contacts for better information or recommendations for managing a specific concern on a specific project.

At the recent Energy Action Network Pre-Summit, there was also some discussion of developing a clearinghouse of some sort for information – both for consumers and for contractors – that would place a high-value on trust. This website would be a similar trusted clearinghouse – focusing on supporting trained weatherization contractors and their employees by strengthening their confidence in carrying out their work, and in conveying valid information to their customers.
Who would undertake or support such a website is not clear to us at this time. Primarily, we wish to recognize and observe the need for such a website, and recommend that the Steering Committee give some consideration to how it could best be developed and maintained.