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Practices Paper 1157




**CPS 5: Paper Session 5:
Building Retrofit (Practices)**

**Case Studies of Residential Façade
Upgrades in Five Climate Zones**

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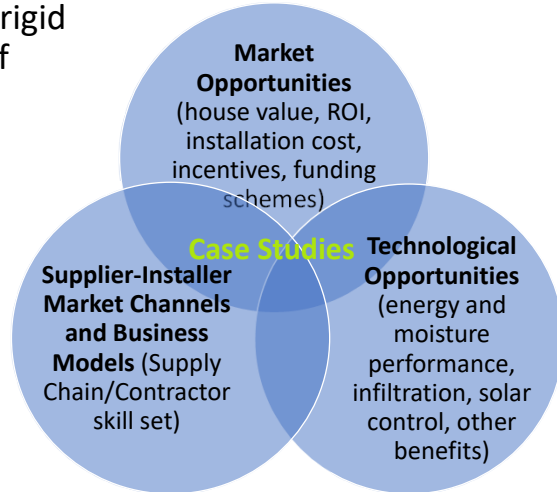
- Phoenix, AZ (Jonathan Waterworth/AZ Energy Efficient Home)
- Kalamazoo MI (Tom Tischler)
- Jackson, MS (Cleo Nichols/C&C Contracting)
- Long Beach, NY (Rick Wertheim/United Way)
- Bellingham, WA (Dan Welch/Bundle Design)

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Five Energy-Efficient Re-Siding and Window Upgrade Case Studies

- Recruited siding contractors: add exterior rigid insulation and window upgrades as part of siding install.
- Assessed
 - Market opportunities
 - Technological solutions
 - Supplier-Installer market channels
- 5 regions targeted:
 - Hot-Dry
 - Marine
 - Cold
 - Mixed-Humid
 - Hot-Humid

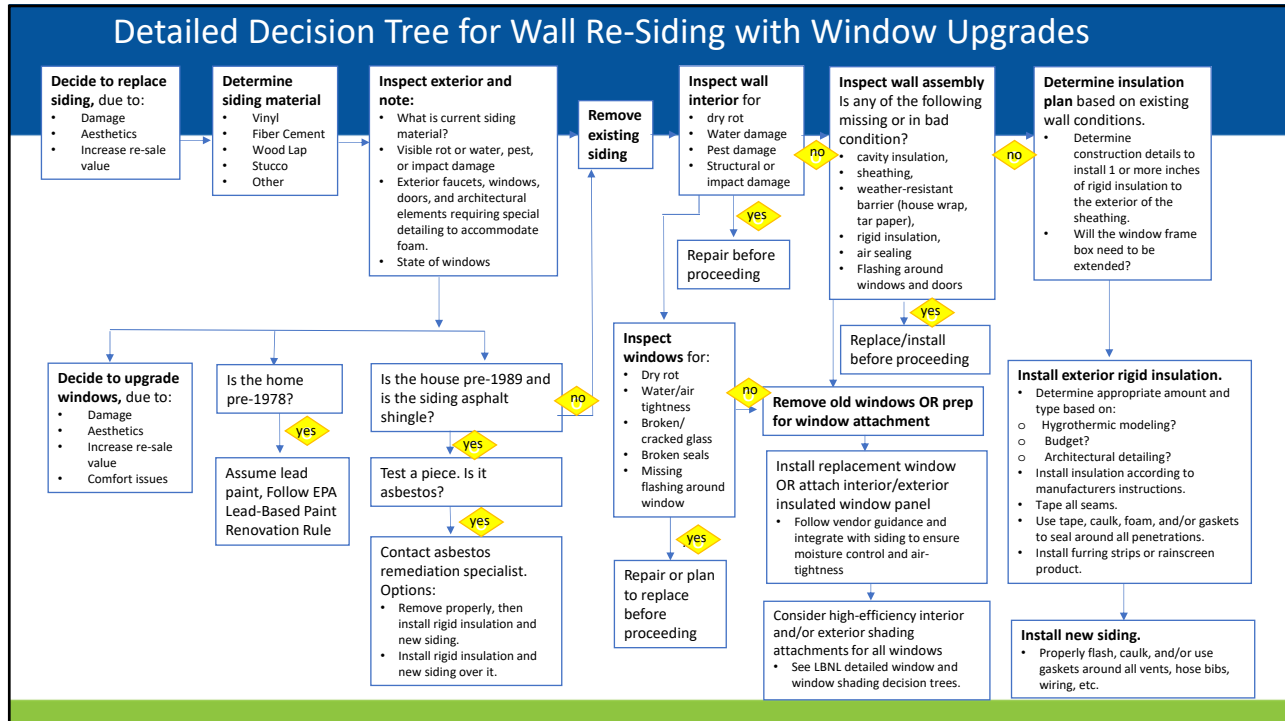


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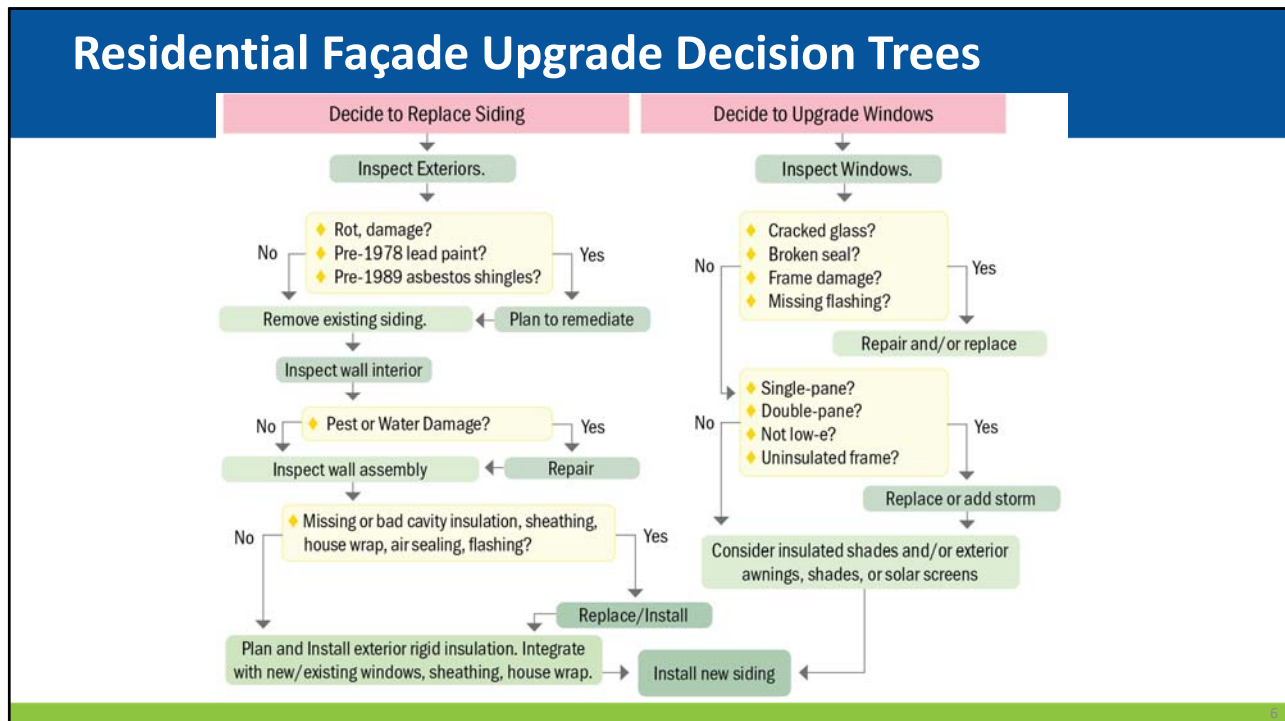
5 Facade Upgrade Case Studies



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Building Characteristics and Performance

Location	Climate Zone	Year Built	Building Size	Pre/Post HES	Pre/Post ACH50
Bellingham, WA	4C, marine	1977	1,959 ft ² ; two-story	1→3	11→8
Jackson, MS	3A, hot-humid	1955	820 ft ² ; single-story	1→9	No data
Kalamazoo, MI	5B, cold	1946	1,500 ft ² ; single-story	7→10	→3 (post)
Phoenix, AZ	3B, hot-dry	1949	1,980 ft ² ; single-story	1→5	10→6

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Phoenix, AZ – Hot-Dry Climate Zone 2



- “Slump block” (concrete block/paint) walls
- No water control, cladding, or insulation
- Previously updated to double-pane windows

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Phoenix, AZ – Decisions



Decide to upgrade siding and windows

Inspect walls and windows

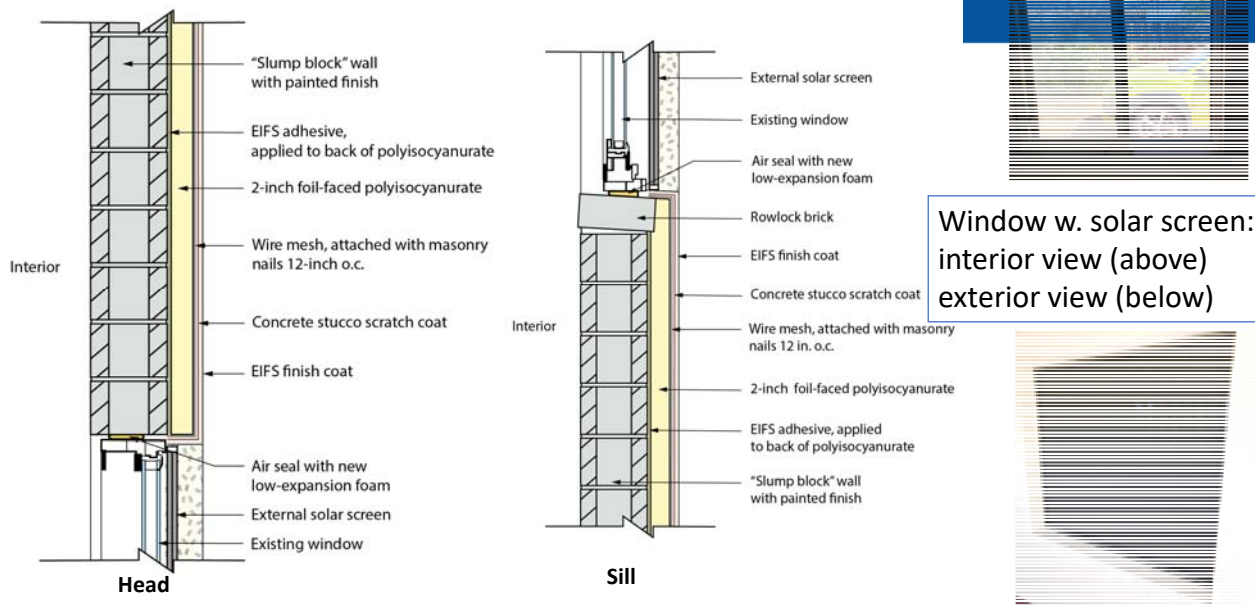
Install rigid foam, lath, and stucco. Integrate with existing windows.

Upgrade windows with solar screens.

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Phoenix – Window Details



Window w. solar screen:
interior view (above)
exterior view (below)

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Phoenix: Key Take-Aways

- Insulation outboard of the concrete → thermal mass benefits
- Non-drained vapor-impermeable stucco system: OK in hot-dry climate Phoenix.
- Risky → in other climates use drained foam stucco (e.g., EIFS)
- Existing double-glazed windows → exterior shading
- Builders help guide shading decisions (right shading for the right windows)

Phoenix Project	Siding ¹	Windows ²
Planned Material Cost	\$5,338	\$655
Planned Labor Cost	\$12,445	\$275
Total Planned Cost	\$17,783	\$930
Added Upgrade Material Cost	\$1,857	\$2,606
Added Upgrade Labor Cost	\$625	\$400
Upgrade Incremental Cost	\$2,482	\$3,006
Total Project Cost with Upgrades	\$20,265	\$3,936

¹ Add stucco over 2 inches polyiso insulation.

² Add solar screens to all windows, and replace one single-pane window.

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Bellingham, WA – Marine Climate Zone 4



Slanted cedar siding → moisture issues

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Bellingham, WA – Decisions



Decide to upgrade siding and windows



Inspect walls and windows



Remove old siding, deck, windows, rotten sheathing

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Bellingham, WA – Decisions



Replace rotten plywood. Install new self-adhered air-water barrier and 2 inches of cork insulation.



Install new windows.



Install plywood furring strips, new and reused cedar, fiber-cement, and metal siding.

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Bellingham – Before and After Walls

Bellingham Pre-Retrofit

- 1/8-inch gypsum board
- Existing 2x6 wall with fiberglass batt insulation
- Existing 3/4" wood fiber sheathing
- No drainage layer
- Diagonal wood siding
- Fiberglass batt insulation

Bellingham Post-Retrofit

- Existing 2x6 wall with dense pack cellulose insulation
- New 1/2-inch plywood, tape all seams
- Vapor permeable self adhered membrane
- 2 Inches rigid insulation (Cork, R-8)
- 3/4-inch borate-treated plywood furring strips
- Horizontal wood siding
- Fiberglass batt insulation

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Bellingham – Window Details

Head

- Water control layer positioned behind cork insulation board (can be combined with air control layer as shown in this detail)
- Plywood sheathing
- One layer of 2-inch cork insulation board
- Cedar board siding
- Borate-treated plywood strips, 2 inches wide
- Cladding vent between furring strips window head
- Sloped metal drip edge over top of head trim
- 2x4 cedar rough opening extension, installed on shims to allow for drainage
- Self-adhered head flashing, with top edge sealed with compatible sheathing tape
- Sealant and backer rod joint at interior perimeter between window and rough opening (air control layer)

Sill

- Continuous sealant (air control layer)
- Sealant and backer rod joint at interior perimeter between window and rough opening (air control layer)
- Pan flashing with sloped sill
- Plastic shim
- Sealant between window and sill trim to minimize water penetration at sill joint
- Blocking as needed to allow for trim attachment
- 2x4 cedar rough opening extension, installed on shims to allow for drainage
- Fully-adhered membrane or sheathing tape extends into rough opening (air control layer)
- Borate-treated plywood strips, 2 inches wide
- One layer of 2-inch cork insulation board
- Beveled siding sloped sill
- Cedar board siding
- Water control layer positioned behind cork insulation board (can be combined with air control layer as shown in this detail)

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Bellingham Project	Siding ¹	Windows ²	<h2>Bellingham: Key Take-Aways</h2> <ul style="list-style-type: none"> ▪ Lack of overhangs + high rainfall climate → moisture problems, high risks ▪ Vapor-impermeable self-adhered roof & wall membranes → lack of drying risks ▪ Window improvements >> wall insulation impact ▪ Cork insulation: dimensionally stable, watertight, Class II vapor retarder, sustainable ▪ Durability, indoor air quality, and moisture performance - as important as energy savings in renovation ▪ Streamlining installation of exterior insulation (one pass) saves time & money
Planned Material Cost	\$6,800	\$8,954	
Planned Labor Cost	\$5,750	\$1,450	
Total Planned Cost	\$12,550	\$10,404	
Added Upgrade Material Cost	\$3,847	\$3,555	
Added Upgrade Labor Cost	\$1,100	\$0	
Upgrade Incremental Cost	\$4,947	\$3,555	
Total Project Cost with Upgrades	\$17,497	\$13,959	
<p>¹ Add 2 inches of cork rigid insulation. ² Use triple rather than double pane. No window larger than 3X5 on this project, so no incremental labor cost as installation still manageable with two people.</p>			

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Kalamazoo, MI – Cold Climate 5



1940s kit home:
incremental
upgrades by owner

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Kalamazoo, MI – Decisions



Decide to upgrade siding and windows

Inspect walls and windows

Remove old siding, house wrap, and fiberboard sheathing. Keep double-pane windows with new interior trim.

Air seal, a lot.

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Kalamazoo, MI – Decisions



Install mineral wool batts, house wrap, and 2-in. polyiso. Tape.

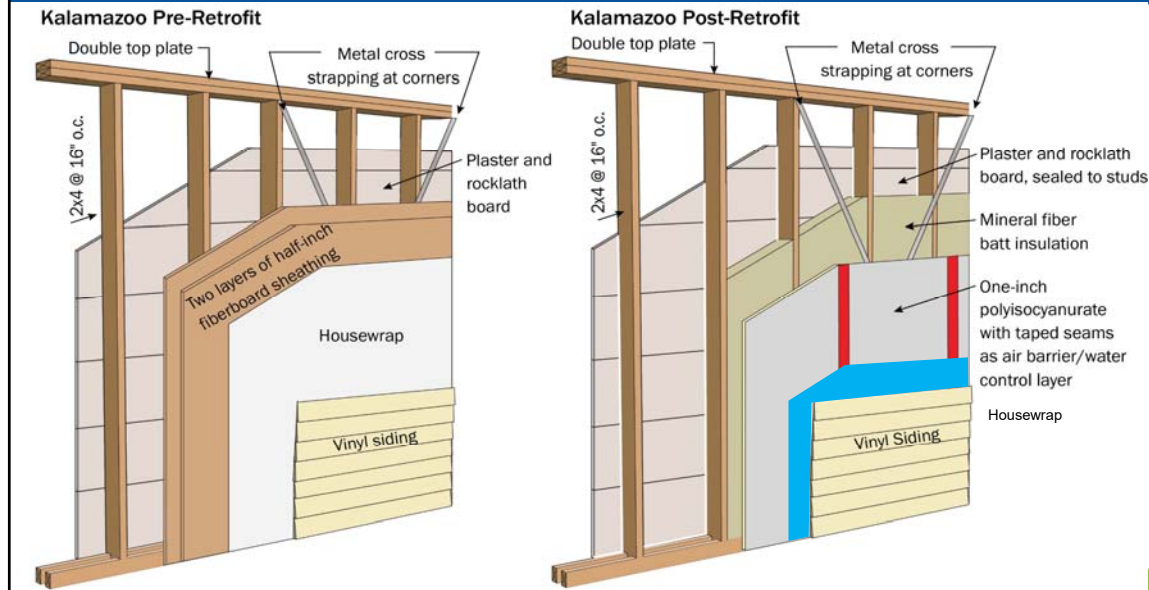
Install new vinyl siding.

Add interior low-e storm windows

Addresses condensation/frosty windows

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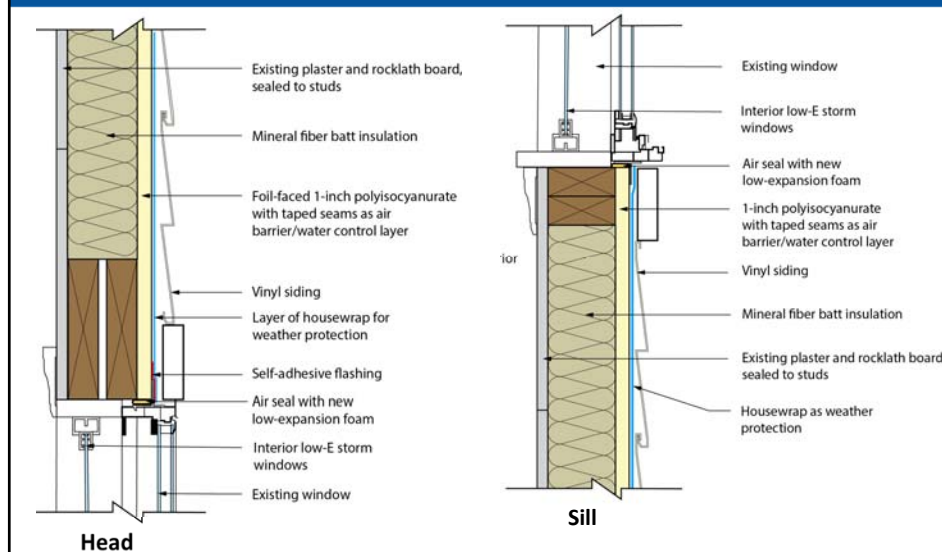
Kalamazoo – Before and After Walls



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Kalamazoo – Window Details



Interior low-e operable secondary window panels (storm windows) after siding replacement.



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Kalamazoo: Key Take-Aways

- Retrofit air sealing by hand—distributed leaks
- Greater airtightness → mechanical ventilation
- Retrofit of storm windows (interior or exterior)
- Cold climate window upgrades: reducing condensation/mold potential >> energy efficiency
- Higher performance glazing: can address condensation and outdoor noise
- Existing window integration with replacement rigid foam sheathing

Kalamazoo Project	Siding ¹	Windows ²
Planned Material Cost	\$2,000	\$0
Planned Labor Cost ³	\$5,000	\$0
Total Planned Cost	\$7,000	\$0
Added Upgrade Material Cost	\$2,600	\$1,594
Added Upgrade Labor Cost ³	\$3,500	\$250
Upgrade Incremental Cost	\$6,100	\$1,844
Total Project Cost with Upgrades	\$13,100	\$1,844

¹ Add 1 inch of foil-faced polyiso continuous exterior foam insulation.
² Install interior low-e storm windows.
³ Estimated labor.

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Jackson, MS – Hot-Humid Climate Zone 2



The builder said “tear it down” but it has sentimental value for the homeowner

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Jackson, MS– Decisions



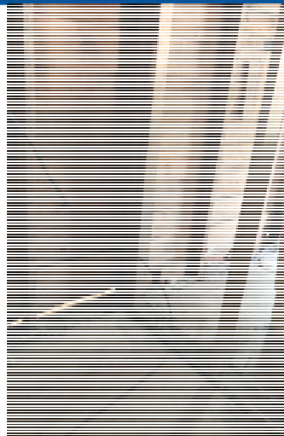
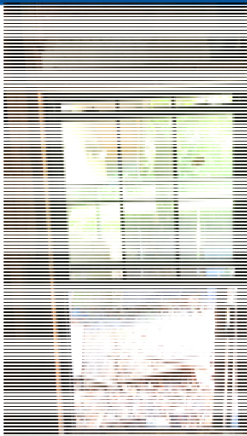
Decide to upgrade siding and windows

Inspect walls and windows

Remove old aluminum siding, windows, board sheathing, drywall, paneling, flooring. Fix pier foundation. Re-set wall studs to 16-inch on-center.

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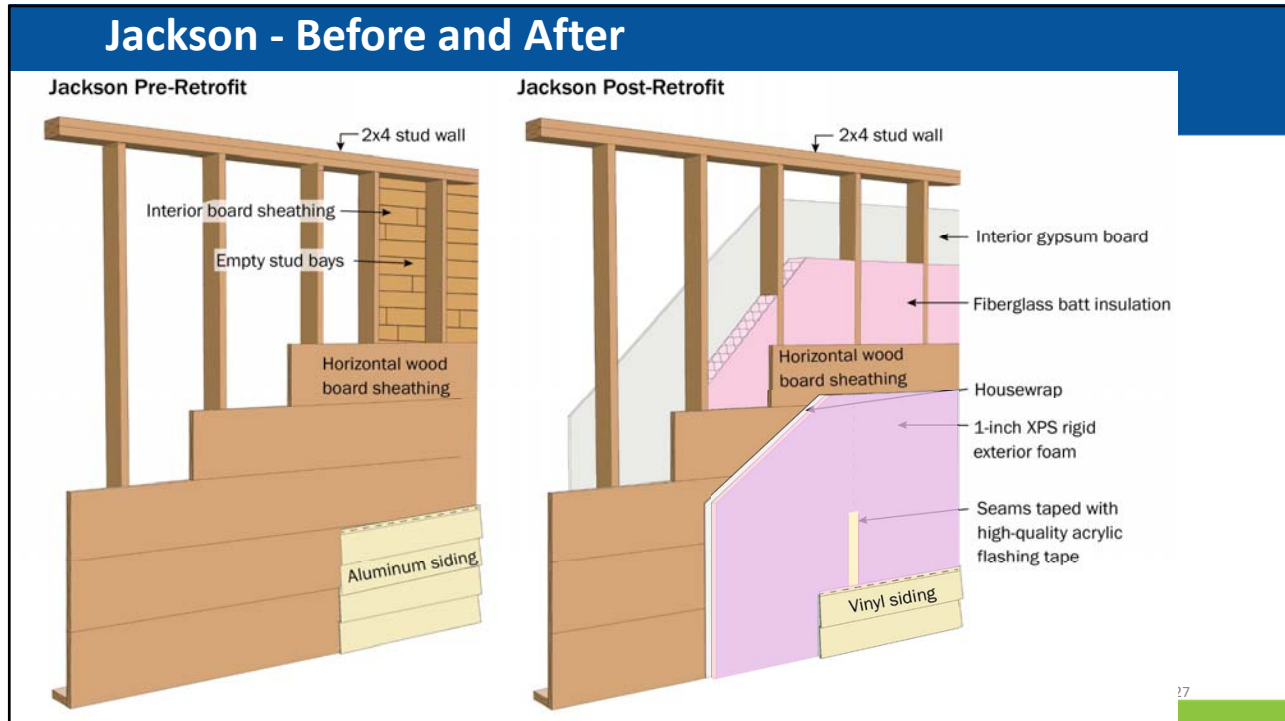
Jackson, MS – Decisions



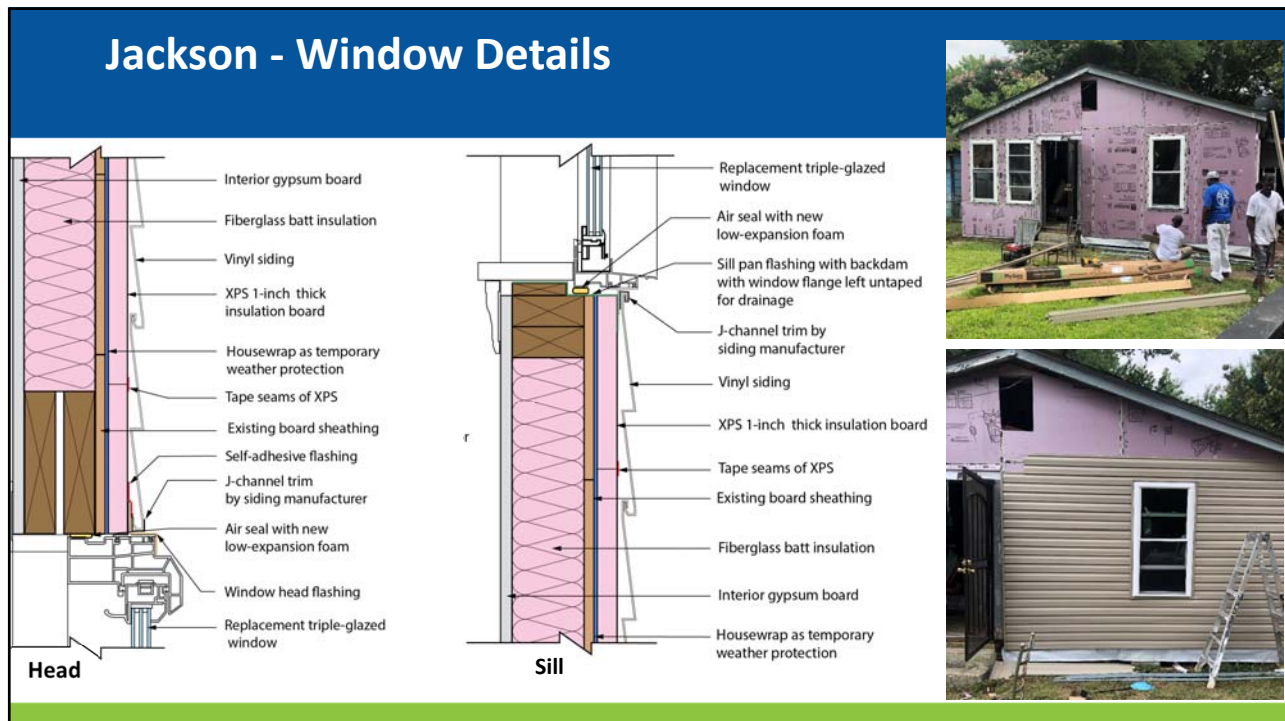
Kept the exterior board sheathing, added house wrap and 1 inch of XPS rigid with taped seams. Installed triple-pane windows and vinyl siding.

On the interior, removed board sheathing, filled the stud bays with fiberglass batts, and installed drywall.

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Jackson: Key Take-Aways

- Foundation (crawl space) problems impact all other retrofits
- Educate homeowner on time & cost of retrofitting to code given current conditions: do structural/exterior issues before interior retrofit
- Contractor will make added insulation standard practice with siding replacement (for energy efficiency + comfort)
- Triple glazing retrofit for noise issues (train tracks) rather than energy savings
- Triple glazing long lead time in hot-humid climate.

Jackson Project	Siding ¹	Windows ²
Planned Material Cost	\$2,600	\$3,378
Planned Labor Cost	\$1,600	\$800
Total Planned Cost	\$4,200	\$4,178
Added Upgrade Material Cost	\$975	\$3,524
Added Upgrade Labor Cost	\$3,200	\$0
Upgrade Incremental Cost	\$4,175	\$3,524
Total Project Cost with Upgrades	\$8,375	\$7,702

¹ Add 1 inch of foil-faced polyiso continuous exterior foam insulation.
² Install interior low-e storm windows.

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Long Island, NY – Mixed-Humid Climate Zone 4



Italianate 1920s two-story stucco home – renovate and upgrade for new use

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Long Island, NY – Decisions



Decide to upgrade siding and windows

Inspect walls and windows. Plan to bore hole test framing at likely spots for rot.

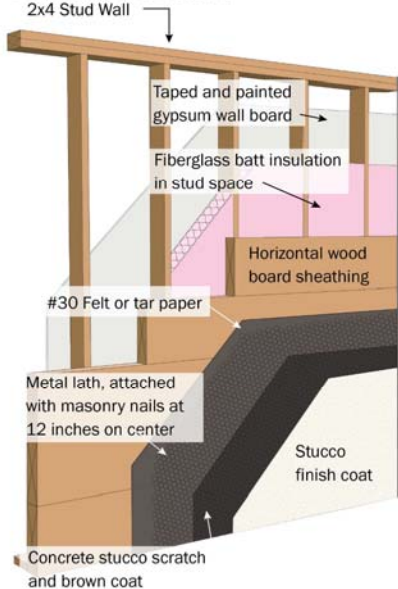
Keep lead-painted stucco and windows in place. Drill and fill walls.

Cover stucco with rigid skinned EPS foam, tape, then EIFS or vinyl. Install exterior storm windows over double-pane windows.

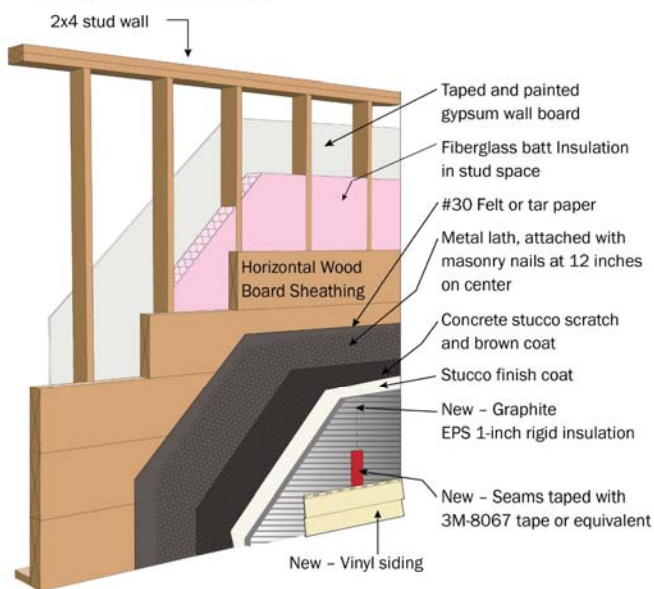
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Long Island - Before and After Walls

Long Island Pre-Retrofit

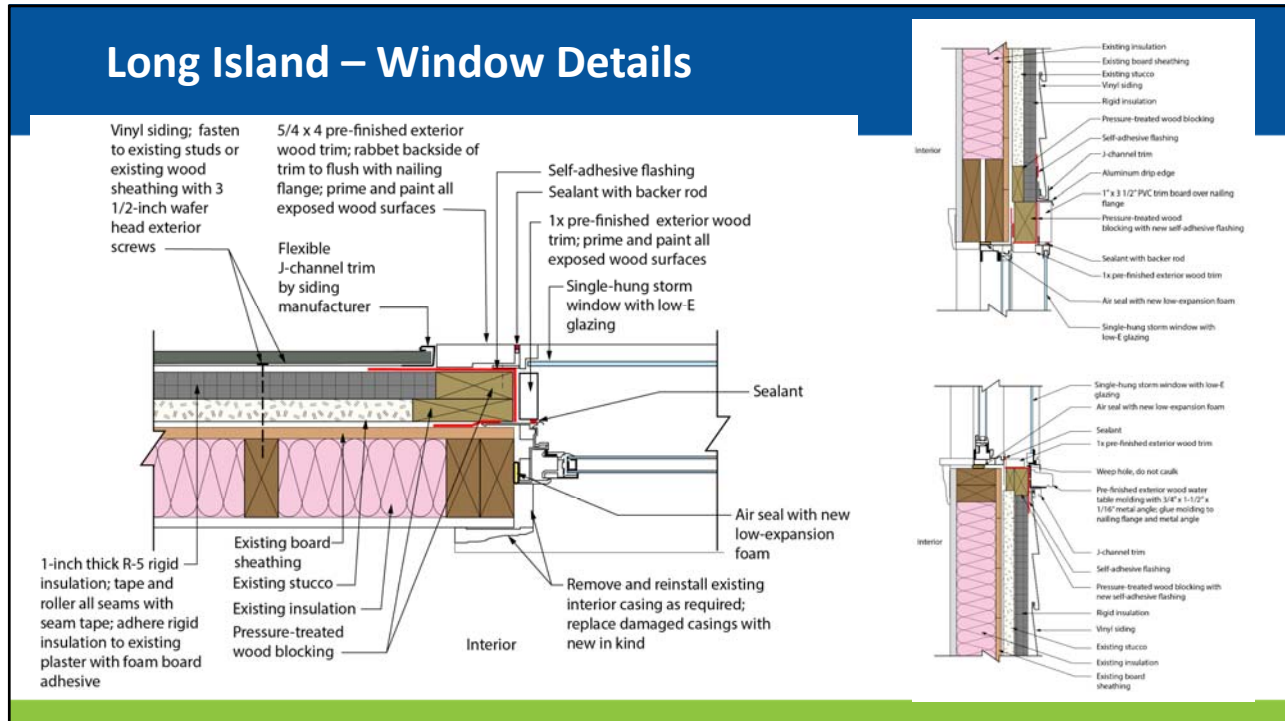


Long Island Post-Retrofit



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Long Island: Key Take-Aways

- Non-profits: fundraising for building vs. ongoing utility bills
- Rigid foam over the existing stucco avoided lead paint removal and drill & fill through cement stucco
- Installation decisions must make sense in the local market in terms of costs and contractor and materials availability (why not EIFS)
- Architect or designer drew details for water management and air sealing and reviewed
- Project did not move forward

Long Island Project	Siding ¹	Windows ²
Planned Material Cost	\$5,000	
Planned Labor Cost	\$10,000	
Total Planned Cost	\$15,000	
Added Upgrade Material Cost ³	\$2,500	\$6,400
Added Upgrade Labor Cost ³	\$2,050	\$4,800
Upgrade Incremental Cost ³	\$4,550	\$11,200
Total Project Cost with Upgrades ³	\$19,550	\$11,200

¹ Add stucco over 2 inches polyiso insulation: 60 polyiso boards + tape.
² Exterior storms. 32 windows x \$350/window.
³ Materials and labor costs are estimates. Retrofit was not completed.

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Conclusion

- Contractor survey: could you sell this?
- Million+ houses are re-sided each year in U.S.
- Only small fraction add exterior insulation
- Lost opportunity - ideal time for energy retrofits

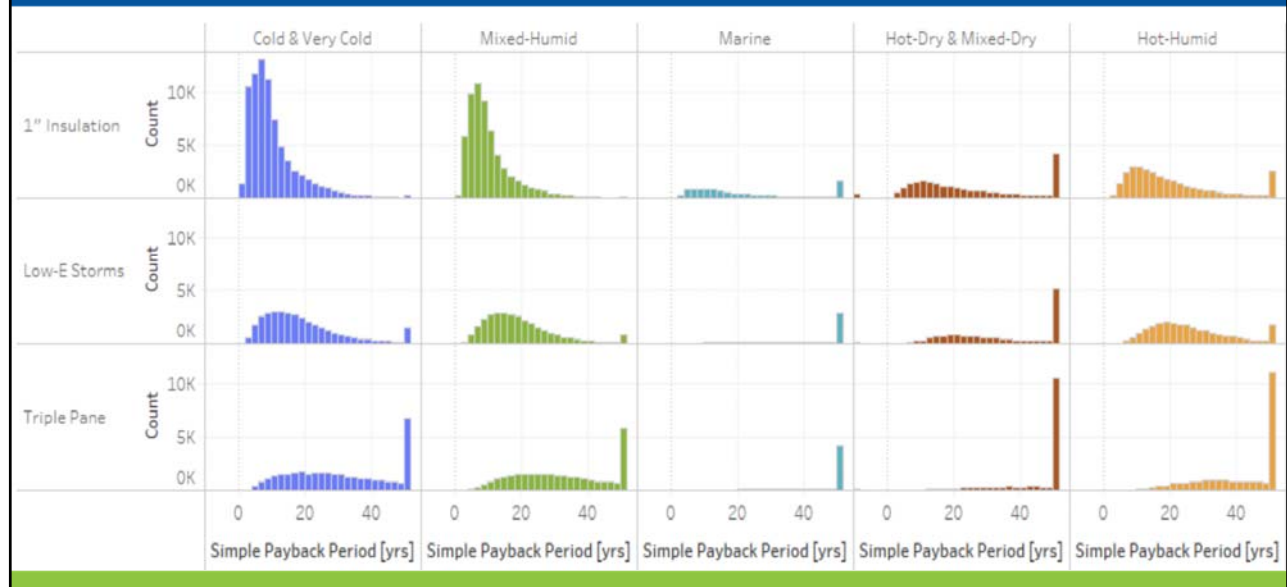
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Upgrade Percentage Energy Savings (NREL 2021)

Building America Climate Zone	Vintage Range	1" Insulation	Low-E Storms	Triple Pane	1" Insulation & Low-E Storms	1" Insulation & Triple Pane	2" Insulation & Low-E Storms	1" Insulation & Low-E Storms & Shading
Cold & Very Cold	Before 1950	20.9% (sd 4.9%)	8.9% (sd 3.1%)	16.2% (sd 5.3%)	24.8% (sd 6.3%)	28.1% (sd 9.0%)	28.6% (sd 7.1%)	23.5% (sd 5.7%)
	1950-1969	20.0% (sd 4.7%)	8.4% (sd 2.9%)	15.3% (sd 5.2%)	23.3% (sd 5.9%)	26.2% (sd 8.5%)	26.9% (sd 6.6%)	22.3% (sd 5.4%)
	1970-1989	12.6% (sd 3.2%)	8.9% (sd 3.3%)	16.5% (sd 5.9%)	15.4% (sd 5.3%)	18.4% (sd 8.5%)	17.9% (sd 5.7%)	14.3% (sd 4.7%)
Mixed-Humid	Before 1950	19.7% (sd 4.6%)	7.9% (sd 2.7%)	14.4% (sd 4.9%)	23.4% (sd 6.1%)	26.6% (sd 8.6%)	26.9% (sd 6.7%)	22.4% (sd 5.4%)
	1950-1969	18.7% (sd 4.3%)	7.3% (sd 2.5%)	13.5% (sd 4.8%)	22.1% (sd 5.6%)	25.0% (sd 8.0%)	25.3% (sd 6.2%)	21.3% (sd 5.1%)
	1970-1989	12.3% (sd 4.8%)	7.6% (sd 2.9%)	14.0% (sd 5.5%)	15.6% (sd 6.2%)	18.7% (sd 8.6%)	17.8% (sd 6.8%)	14.9% (sd 5.7%)
Marine	Before 1950	17.5% (sd 6.7%)	5.8% (sd 3.2%)	11.3% (sd 5.5%)	20.3% (sd 8.0%)	23.0% (sd 10.0%)	23.5% (sd 9.2%)	18.3% (sd 7.4%)
	1950-1969	15.8% (sd 6.4%)	4.9% (sd 3.0%)	9.6% (sd 5.3%)	18.1% (sd 7.5%)	20.4% (sd 9.2%)	21.0% (sd 8.7%)	16.4% (sd 7.1%)
	1970-1989	11.4% (sd 5.8%)	5.0% (sd 3.3%)	10.3% (sd 6.0%)	13.6% (sd 6.9%)	16.2% (sd 8.8%)	15.9% (sd 7.9%)	11.5% (sd 6.8%)
Hot-Dry & Mixed-Dry	Before 1950	13.1% (sd 6.7%)	4.6% (sd 2.9%)	8.6% (sd 5.1%)	15.6% (sd 8.1%)	17.8% (sd 9.8%)	18.0% (sd 9.3%)	14.5% (sd 7.5%)
	1950-1969	13.5% (sd 6.7%)	4.7% (sd 2.8%)	8.7% (sd 5.0%)	16.2% (sd 8.0%)	18.4% (sd 9.8%)	18.5% (sd 9.2%)	15.3% (sd 7.5%)
	1970-1989	9.0% (sd 5.7%)	5.5% (sd 3.1%)	10.0% (sd 5.6%)	12.4% (sd 7.0%)	15.3% (sd 9.2%)	14.2% (sd 8.0%)	12.0% (sd 7.0%)
Hot-Humid	Before 1950	13.2% (sd 5.1%)	6.4% (sd 2.4%)	11.3% (sd 4.6%)	17.8% (sd 6.4%)	21.1% (sd 8.4%)	20.1% (sd 7.2%)	18.3% (sd 6.1%)
	1950-1969	12.1% (sd 5.1%)	5.9% (sd 2.4%)	10.2% (sd 4.5%)	16.4% (sd 6.3%)	19.4% (sd 8.3%)	18.4% (sd 7.1%)	17.1% (sd 6.0%)
	1970-1989	8.0% (sd 4.5%)	6.4% (sd 2.7%)	10.8% (sd 5.1%)	12.5% (sd 5.9%)	15.6% (sd 8.0%)	13.8% (sd 6.5%)	13.6% (sd 6.0%)

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Energy Savings Simple Payback (NREL 2021)



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Bibliography

Cort, K., T. Gilbride, C. Antonopoulos, K. Ueno, W. White, and J. Elton. 2022. Case Studies of Residential Façade Upgrades in Five Climate Zones. Presented at the 2022 Buildings XV Conference, Clearwater Beach, Florida, December 5 - 8.

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Questions?

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