Manufacturer's Roundtable

High Performance Windows

August 26, 2025

CEDA California Energy Design Assistance

nbi new buildings institute

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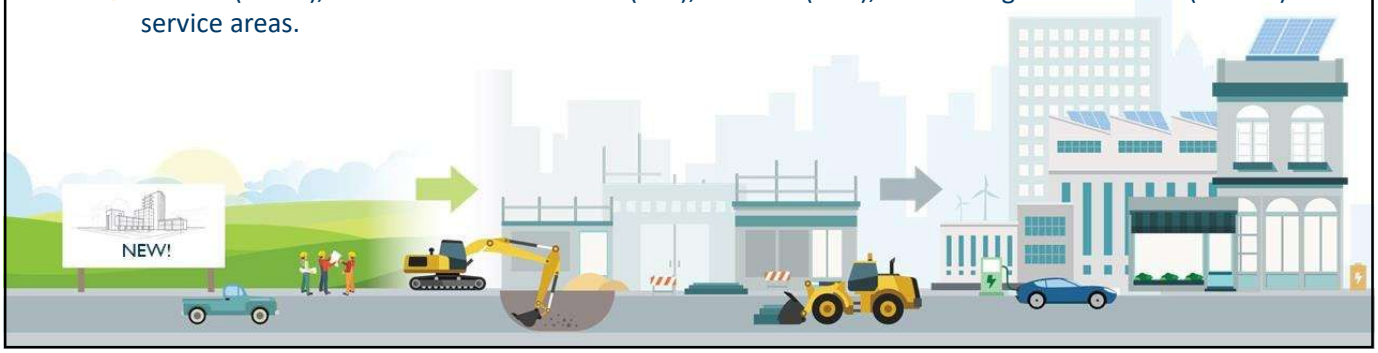
WHAT IS CEDA?

CEDA

The California Energy Design Assistance (CEDA) program is the only statewide utility incentive program for new construction and major renovations.

- Promotes**electrification** and **decarbonization**
- CEDA works in collaboration with project teams to reduce energy demand, consumption, and carbon em iss ions .
- Serves commercial, public, high-rise multifamily,industrial, and agricultural projects in Pacific Gas & Electric (PG&E), SouthernCaliforniaEdison(SCE),SoCalGas(SCG),andSanDiegoGas&Electric (SDG&E) service areas.



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WHY PARTICIPATE IN CEDA?

- Receive complimentary **decarbonization** analysis tailored to project goals to identify most effective measures to implement
- Gain analysis of **energy costs and paybacks**
- Receive **financial incentives**to help offset the costs of decarbonization measures
- Demonstratecommitmenttohigh performance building practices and design

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INCENTIVES

$4,000
+
measurepackage
incentive

- $4000 **Design team incentive** per project as a thank you for participation
- Based on the project measure package the design team chooses for implementation

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HIGH PERFORMANCE MEASURES

CEDA aims to exceed California's decarbonization standards by identifying high performance measures and providing educational opportunities to explore use cases and best practices.

This not only advances the market, but also qualifies participants for

enhanced incentivesthroughourprogram.

Acurrent listof eligible high-performance measures can be found on our website here.

5

HAVE A PROJECT TO DISCUSS?

For more information, please contact our program outreach specialists, visit our website, or fill out an interest form

Scan me to enroll a project

CaliforniaEDA.com

Sean M. Williams | Outreach Specialist swi lliams @willdan.com

Tina Hendrix | Program Outreach Specialist thendrix@willdan.com

760.585.7577

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High Performance Windows

In today's webinar we'll discuss: •The pivotal role of windows in a building's energy profile, directly affecting heating,cooling, ventilation, andlightingdemands.

•Examples and benefits of modern fenestration solutions—such as triple-pane glazing, innovative frame materials, and smart window technologies.

•Market adoption challenges, cost perceptions, and the path toward integrating fenestration strategiesinPassiveHouse and other high-efficiency building standards.

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Today's Panelists

Lisa Bergeron
Jeld-Wen

Alison Ray
Alpen

Katie Allen Cort
Pacific Northwest National Laboratory

Lance Wheeler
National Renewable Energy Laboratory

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IMPACT OF HIGH PERFORMANCE FENESTRATION ON THE BUILDING ENVELOPE A WINDOW OF OPPORTUNITY WEBINAR - NBI

August 2025

JELD-WEN

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Impact of High Performance Fenestration on the Building Envelope

THEWINDOW OF OPPORTUNITY

What you need to know about windows

- They **are** the weakest component on the Building Envelope **BUT**….
- Windows are **biggest opportunity** with fastest payback for builders
- Windows havethebiggestimpact on cooling loads

We must change the narrative from first costs to total costs

Image Source: Home performance Stakeholders C oun c il

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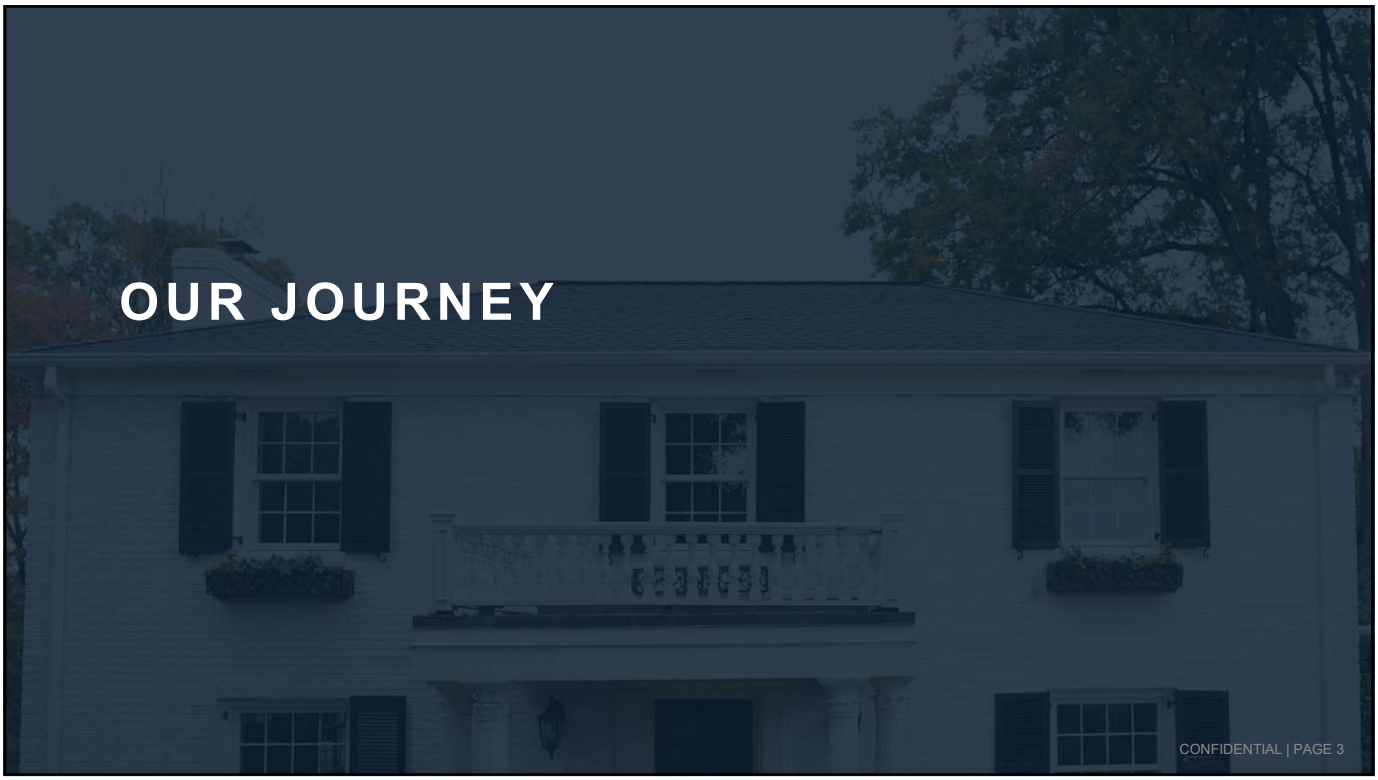

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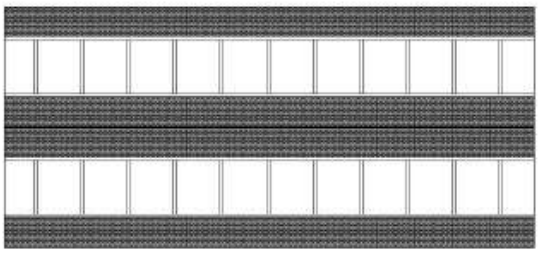
2015 THE THEORY



50% fenestration (R2)
50% wall (R20)
R3.6

Window:	R2	Window:	R4 ↑
Wall:	R40 ↑	Wall:	R20
R_{eff}:	R3.8	R_{eff}:	R6.7

INVESTINGIN BETTERWINDOWSHAS THE BIGGESTIMPACT

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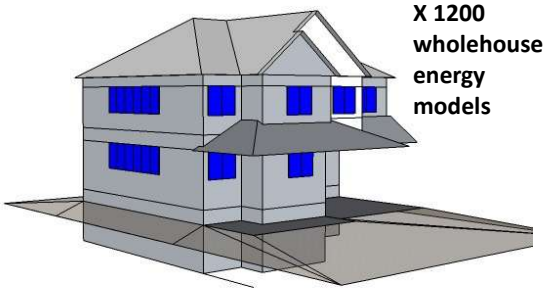
OUR STUDY(2015)

BUILDING KNOWLEDGE CANADA INC.



X 1200 wholehouse energy models

Wewantedto know

1. HowWWRimpactedthetotalwalleffective R values?
2. Werethereanybuilderbenefitsto move to a better window?
3. Were there any homeowner benefits?

COMPAREDBETTERWINDOWSTO BETTERWALLSAT DIFFERENTWWRS

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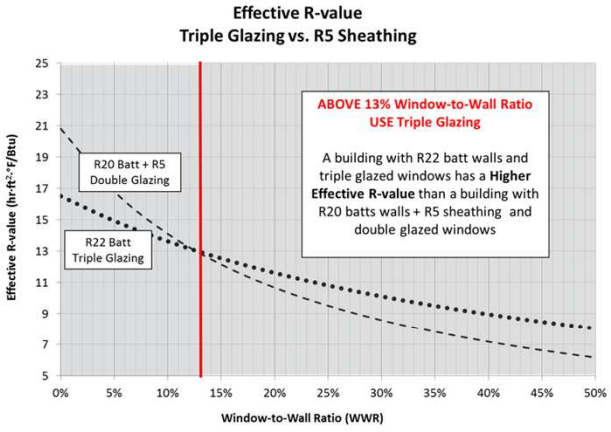
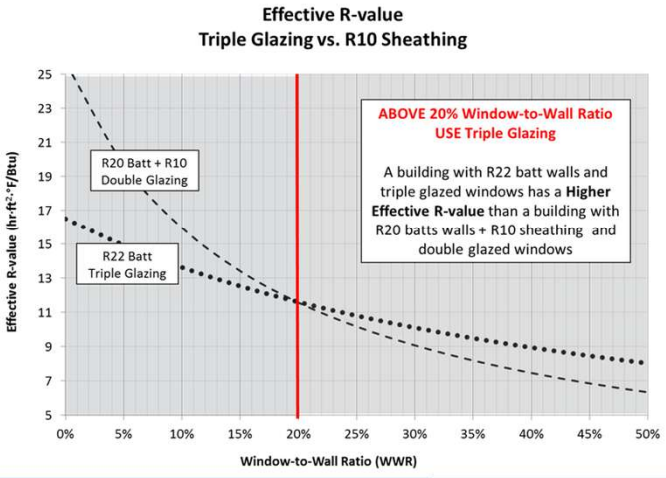
CONCLUSION (2015)





WINDOWS ARE THE CLEAROPPORTUNITY

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CONCLUSION -BUILDER BENEFITS(2015)

- Trading off a better window against a better wall
  - Coulddiminishthe designcoolingloadsby13000BTU meaninga possible reduction in mechanicalsystem of about a ton
  - No learningcurve, lesslabour thanaddingexteriorfoam
- Reduced callbacks
  - Less condensation risks

UPGRADE FOR TRIPANESPAYFOR THEMSELVESIN REDUCTIONOF MECHANICALS

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CONCLUSION -HOMEOWNERBENEFITS(2015)

- Healthier more comfortable homes
- Quieter Homes No short cyclingof
- oversizedmechanicalsystems

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OUR STUDY(2023)

SHOWCASINGOURNEW JWC8500 SERIESWITHA 0.14 U-VALUE

BUILDING KNOWLEDGE CANADA INC.

JWC8500
s eries

Wewantedto know

1. Howdiditstackupagainstbetterwallsand betterair tightness?
2. How didthe new windowstack up to other measureson operationalcarbon?
3. How didthe new windowreducecoolingloads in zones 2, 3 and 4?

COMPAREDWINDOWSTO WALLSAND AIR TIGHTNESSAT DIFFERENTWWRS

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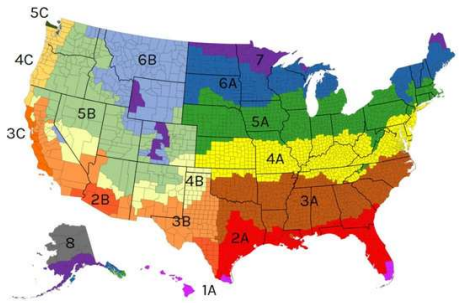
OUR STUDY(2023)

SHOWCASINGOURNEW JWC8500 SERIESWITHA 0.14 U-VALUE

Phoenix (CZ2), Dallas (CZ3), Seattle (CZ4c)



2600 FT² Single detached JW Window versus

1. 2 ACH Air Tightness R5 ContinuousInsulation
2. R7.5 ContinuousInsulation R10 ContinuousInsulation (Seattle only) @12%, 17% and 22% WWR
3.
4.
5.

REFERENCE CODE USED–PHOENIX: 2018 IECC, DALLAS AND SEATTLE: 2021 IECC

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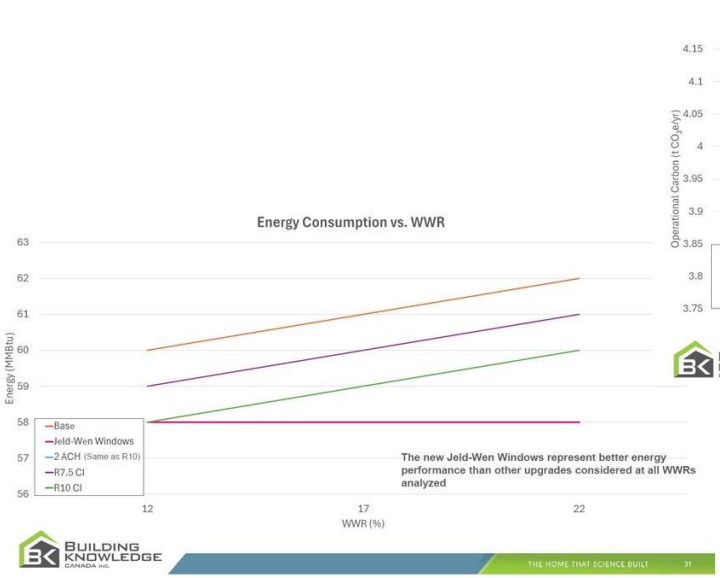
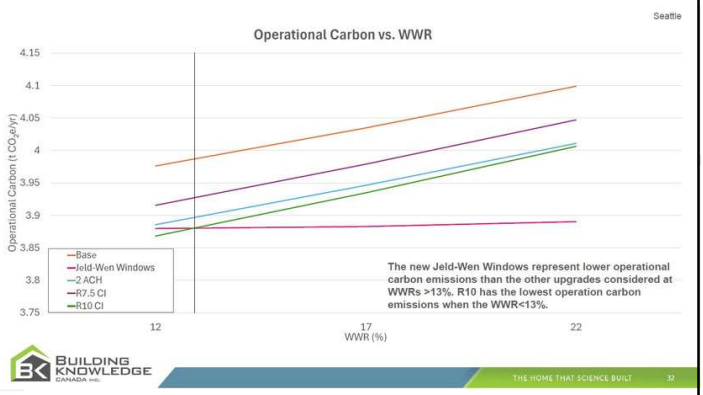
THE RESULTS-SEATTLE





ONLYR10 HAS A LOWEROPERATIONALCARBONAT < 13%WWR

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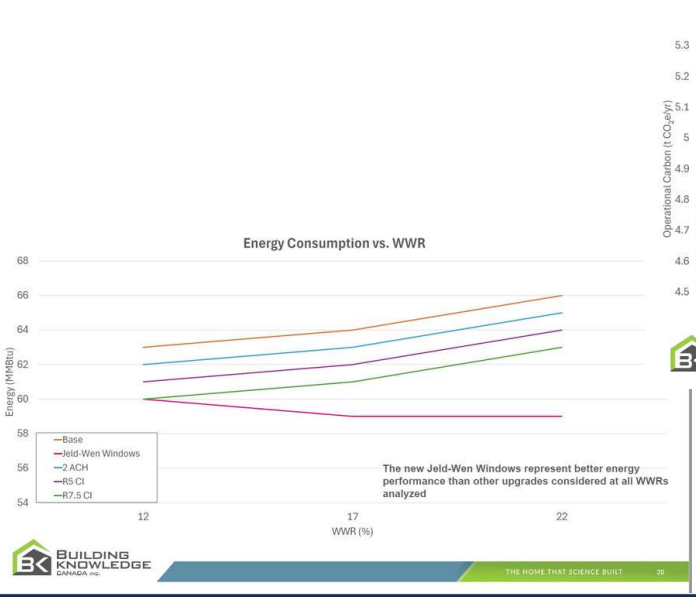
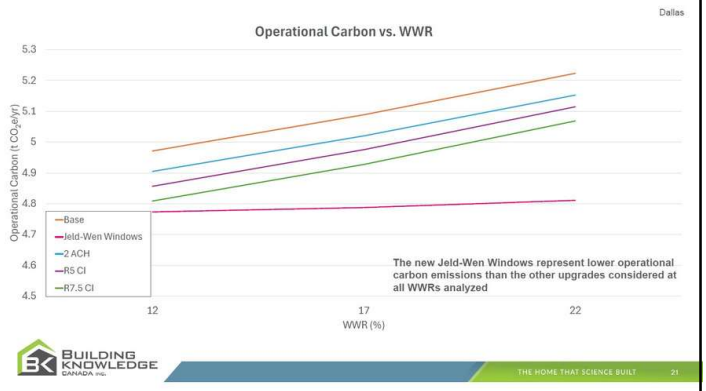
THE RESULTS-DALLAS





JELD-WEN JWC 8500 OUTPERFORMSOTHERMEASURESAT ALL WWRS

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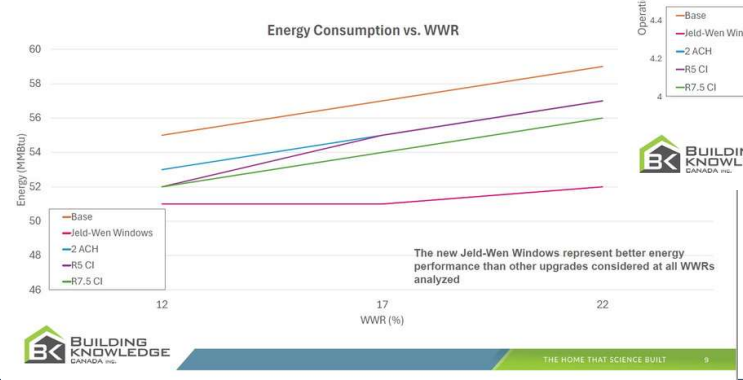
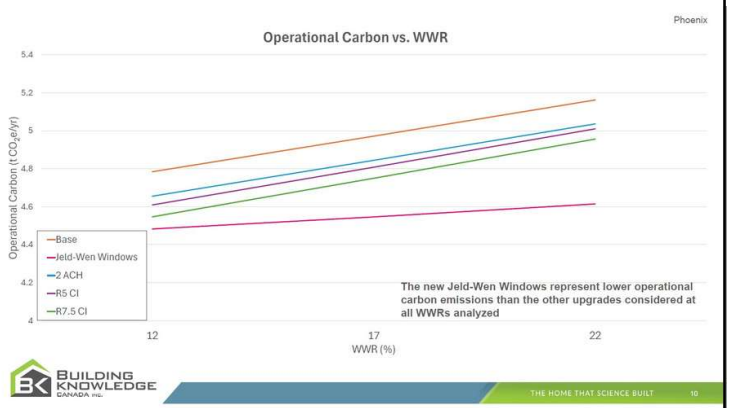
THE RESULTS-PHOENIX





JELD-WEN JWC 8500 OUTPERFORMSOTHERMEASURESAT ALL WWRS

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CASE STUDY–IMPACT ON COOLINGLOADS

SEATTLE

Archetypes

Archetype 1: 2 Storey Single Detached House
- 22% window-to-wall ratio
- 2600 ft²

Air Source Heat Pump Tonnage / Duct Sizing

Seattle

IECC 2021 w/ ASHP	New Jeld-Wen Window Product
Design Heat Loss = 26,537 BTU/hr Design Heat Gain = 32,846 BTU/hr	Design Heat Loss = 22,087 BTU/hr Design Heat Gain = 21,797 BTU/hr
Duct Size: 24x10	Duct Size: 22x8
3 Ton ASHP / AC	2 Ton ASHP / AC

1 TON REDUCTIONIN MECHANICALSYSTEM

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CASE STUDY–IMPACT ON COOLINGLOADS

DAL LAS

Archetypes

Archetype 1: 2 Storey Single Detached House
- 22% window-to-wall ratio
- 2600 ft²

Air Source Heat Pump Tonnage / Duct Sizing

Dallas

IECC 2021 w/ ASHP	New Jeld-Wen Window Product
Design Heat Loss = 28,658 BTU/hr Design Heat Gain = 32,696 BTU/hr	Design Heat Loss = 24,071 BTU/hr Design Heat Gain = 25,935 BTU/hr
Duct Size: 24x10	Duct Size: 25x8
3 Ton ASHP / AC	2.5 Ton ASHP / AC

1/2 TON REDUCTIONIN MECHANICALSYSTEM

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CASE STUDY–IMPACT ON COOLINGLOADS

PHOENIX

Archetypes

Archetype 1: 2 Storey Single Detached House
- 22% window-to-wall ratio
- 2600 ft²

Air Source Heat Pump Tonnage / Duct Sizing

Phoenix

IECC 2018 w/ ASHP	New Jeld-Wen Window Product
Design Heat Loss = 27,568 BTU/hr Design Heat Gain = 45,699 BTU/hr	Design Heat Loss = 22,411 BTU/hr Design Heat Gain = 34,754 BTU/hr
Duct Size: 30x10	Duct Size: 24x10
4 Ton ASHP / AC	3 Ton ASHP / AC

1 TON REDUCTIONIN MECHANICALSYSTEM

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CONCLUSION

- For Phoenix and Dallas, at all WWRs, the new JWC8500 shows a better energy savings and loweroperationalcarbonemissionsthanotherupgrades considered
- For Seattle –at all WWRs, the new JWC8500 shows a betterenergysavings thanthe otherupgrades considered
- For Seattle, at lessthan13% WWR, onlyR10 CI upgrade performsbetter thanthe JWC8500 for operationalcarbonemissions
- For Seattle at greaterthan13% WWR, JWC8500 performsbetterthanall otherupgrades consideredfor operationalcarbonemissions
- For all climatezones, a reduction in mechanicalsizes and duct sizingwas obser ved

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ENERGY EFFICIENCYISNOT A FUNCTIONOF DESIGN

E Colour	Glass	Jamb	E trim	Interior Color	% increase for energy upgrade	% increase for energy upgrade - less patio doors
White	Dual	4 9/16	none	white	31%	23%
White	Tripane	4 9/16	none	white		
Black	Dual	4 9/16	none	white	26%	20%
Black	Tripane	4 9/16	none	white		
Black	Dual	7 7/8	none	white	23%	17%
Black	Tripane	7 7/8	none	white		
Black	Dual	7 7/8	BM	white	21%	15%
Black	Tripane	7 7/8	BM	white		
Black Hybrid	Dual	7 7/8	none	white	17%	15%
Black Hybrid	Tripane	7 7/8	none	white		
Black Hybrid	Dual	7 7/8	none	Black	15%	13%
Black Hybrid	Tripane	7 7/8	none	Black		

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The Alpen Mission

Scaling the advanced window industry is a critical piece of solving three sustainability imperatives:

1. Decreasing heating and cooling emissions from buildings
2. Reducing the carbon intensity of traditional building materials
3. Enhancing building operating economics by delivering value-driven projects

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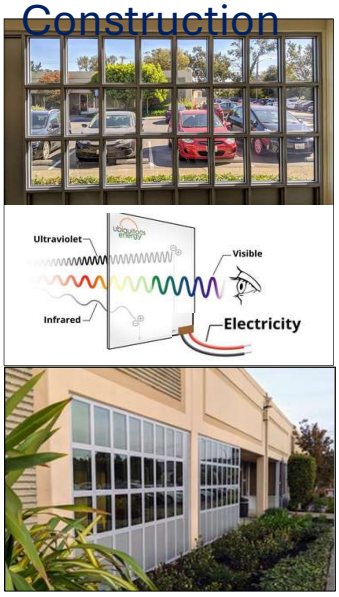
Plenty of Sexy Innovation for New Construction



- Electrochromic Photovoltaic
- Daylight Redirecting Ultra High
- Performance Curtainwall Vacuum
- Insulating Glass
-

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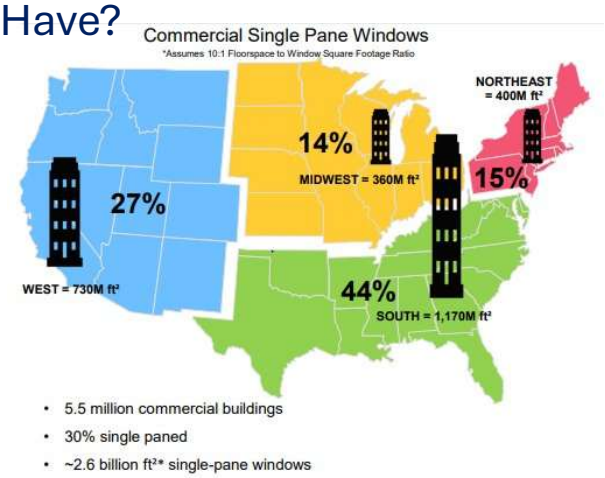
But What About the Windows We Already Have?



- 5.5 million commercial buildings
- 30% single paned
- ~2.6 billion ft²* single-pane windows

Most of our building stock is already built

Most window frames aren't designed for today's high performance glass

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The Implications:

- Full window replacement is **expensive, disruptive**, and **carbon-intensive**.
- Existing frames leave buildings **trapped in low-performing glass -** blocking energy savings and decarbonization.
- The real challenge:

  How do we unlock high-performance retrofits without removing or substantially altering window frames?

- The opportunity:

  Simple innovations like Thinglass IGUs and WinSert

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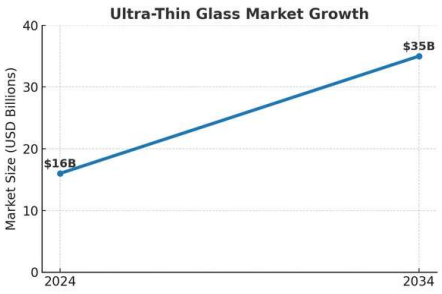
Keeping-it-Simple InnovationThinGlass

:

- Widely used and proven in well-known applications like **solar panels**, **smart phones** and **flat screen televisions**.
- Ultra-thin glass market : ~$16B in 2024 → **~$35B** by 2034
  - Rapid growth & capacity expansion [gmiinghts.com]
- **Strength, flexibility, and global scale** now make thin glass feasible for **architectural applications**.



***Perfect timing** for both **retrofit** and **new-build IGUs**.*

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What is ThinGlass?

- 0.5mm to 1.3mm thick glass
  - 3-4x thinner than typical residential glass
  - 6-8x thinner than typical commercial glass
- Lighter Weight

5.7 mm (¼") = 3 lbs/ft2

1 mm = 0.53 lbs/ft2

- Strength through Flexibility

Outer pane shattered before thinglass at 240mph windspeed (50 ft2 glass unit)

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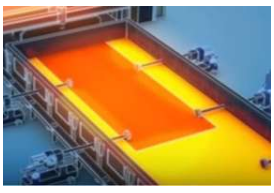
What is ThinGlass?

- Less Energy Intensive and Lower Embodied Energy
  - Glassmanufacturing isan extremelyenergy intensivebusiness
  - Traditional float line glass uses 9.3 million (or more) BTUs of energy **PER TON** of glass
  - More glass area = less energy use per surface area



	Glass Area in One Ton	Embodied Energy	Gallons of Gas
5/32" glass (4mm)	994 ft²	9,300,000 BTU	67.7
1/8" glass (3.2mm)	1,224 ft²	9,300,000 BTU	67.7
Thinglass (0.7mm)	5,553 ft²	9,300,000 BTU	67.7

	thk (mm)	lbs/ft2	ft2 per ton	GWP 1 ft² kgCO2eq/ft2
Thinglass 0.5	0.5	0.25	7,874.2	0.07
Thinglass 1.0	1	0.51	3,937.1	0.15
Thinglass 1.3	1.3	0.66	3,028.5	0.19
3/16"	5	2.54	787.4	0.74
1/4"	6	3.05	656.2	0.89

Lighter, lower-carbon IGUs that fit retrofit and new-build applications

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Application

s

- Center layer(s) of insulating glass Triple and
- Quad in Narrow (or Wide) pockets

- And, ***Winsert***

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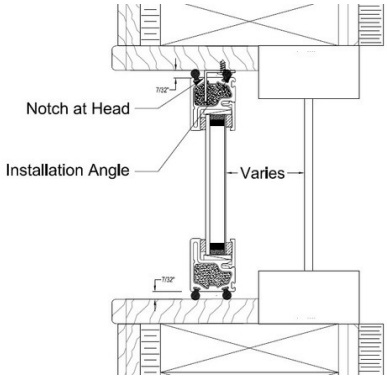
Solution: WinSert

- Lightweight (0.53 lbs/sq ft) Minimal attachment points *Fast* - Installation for 6,000 square feet of windows for an entire 4-story building took just a little over four days from start to finish



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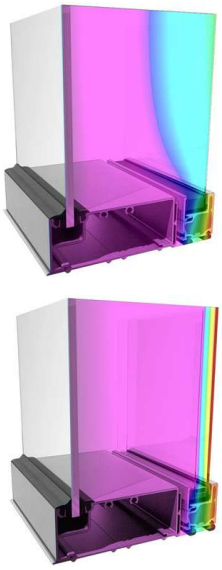
…Significantly Improves Thermal Performance

EXISTING WINDOW
Non-Thermally-Broken
Aluminum Single Pane

U-Value = 1.12
SHGC = 0.72



EXISTING WINDOW + WinSert Lite

U-Value = 0.47 Improved by 2.4x!
SHGC = 0.41 Reduced 43%!

EXISTING WINDOW + WinSert Plus

U-Value = 0.19 Improved by almost 6x!
SHGC = 0.30 Reduced 58%!

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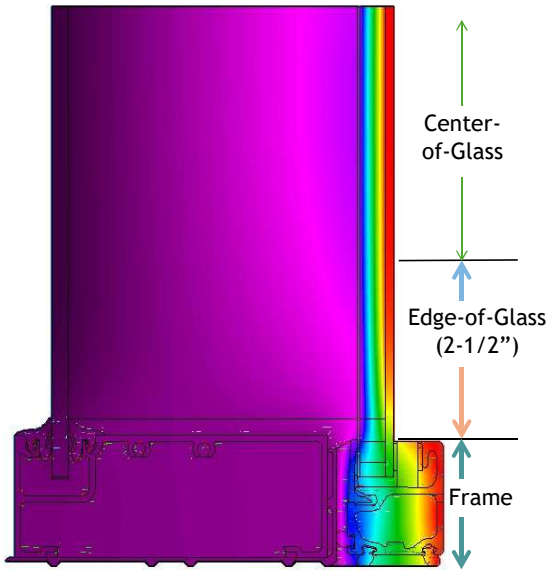
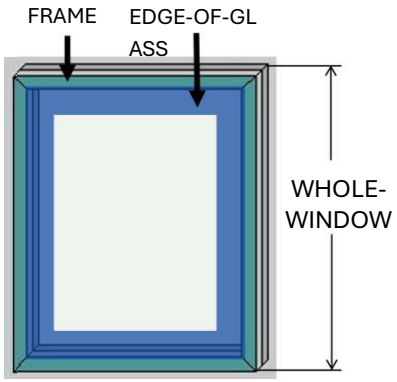
Advantages of WinSert





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WinSert Creates a New Product Category

		Alpen WinSert	Full replacement	Competing 2ndary windows	Window film	Gasket Sealing
COMFORT	Heat loss prevention	●	●	◑	◔	◔
	Cooling loss prevention	●	●	◑	◔	◔
	Air infiltration prevention	●	●	◔	○	◑
	Noise prevention	●	◕	●	○	◔
FEASIBILITY	Low total install cost/sq. ft.	●	○	◕	●	●
	Low weight	●	○	◔	●	●
	Ease of install	●	◔	◑	◕	◔
	Minimal tenant disruption	●	○	◕	◕	●

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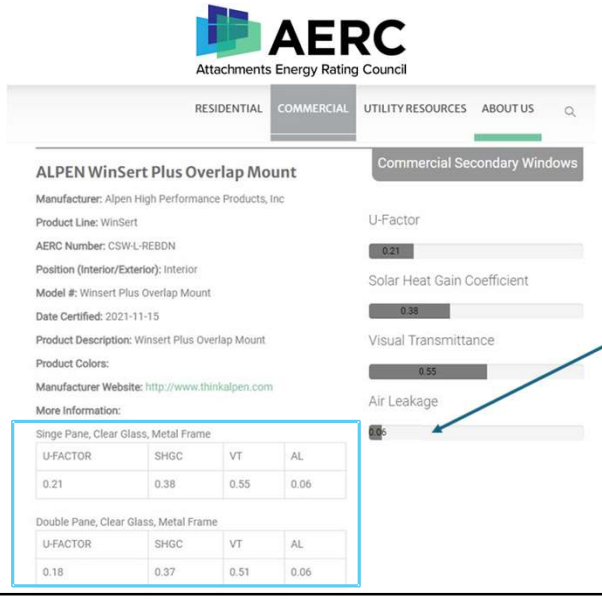
Third Party Tested:

AERC Independent Certification Rating

2x the Thermal Performance of Next Best Alternative



97% Reduction in Air Infiltration Compared to Primary Window

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Studied & Validated - GSA Green Proving Ground

WinSert

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3rd Party Studied & Validated - GSA Green Proving Ground

WinSert

Cost-Effective Across Climate Zones

Positive return on investment at average GSA utility rates, $0.11/kWh and $7.43/mmBtu

Location		Savings from Single-Pane to Double-Pane Insert					
CLIMATE ZONE	CITY	WHOLE BUILDING ENERGY SAVINGS kBtu/ft²/yr	ENERGY COST SAVINGS $/ft²/yr	ANNUAL SAVINGS $/yr	SAVINGS %	PAYBACK* YRS	SIR positive ROI if >1
1A	Miami, FL	8.1	$0.27	$14,480	11%	11.2	1.59
2A	Houston, TX	9.1	$0.30	$16,088	12%	10.1	1.76
2B	Phoenix, AZ	10.7	$0.35	$18,770	14%	8.7	2.05
3A	Atlanta, GA	10.3	$0.35	$18,770	14%	8.7	2.05
3B	Las Vegas, NV	10.8	$0.36	$19,306	15%	8.4	2.11
3C	San Francisco, CA	8.3	$0.28	$15,016	13%	10.8	1.64
4A	Baltimore, MD	12.6	$0.43	$23,060	16%	7.1	2.52
5A	Chicago, IL	13.5	$0.46	$24,669	17%	6.6	2.70
5B	Boulder, CO	13.9	$0.47	$25,205	18%	6.5	2.76
6A	Minneapolis, MN	15.6	$0.54	$28,959	17%	5.6	3.17
AVERAGE SAVINGS		11.3	$0.38	$20,432	15%	8.4	2.2

"This technology performed well. We think it will represent a key tool in our net zero building tool belt."

- Kevin Powell, Director at Center for Emerging Building Technologies

Predicted average whole building energy savings: 15%

Payback: 8.4 years

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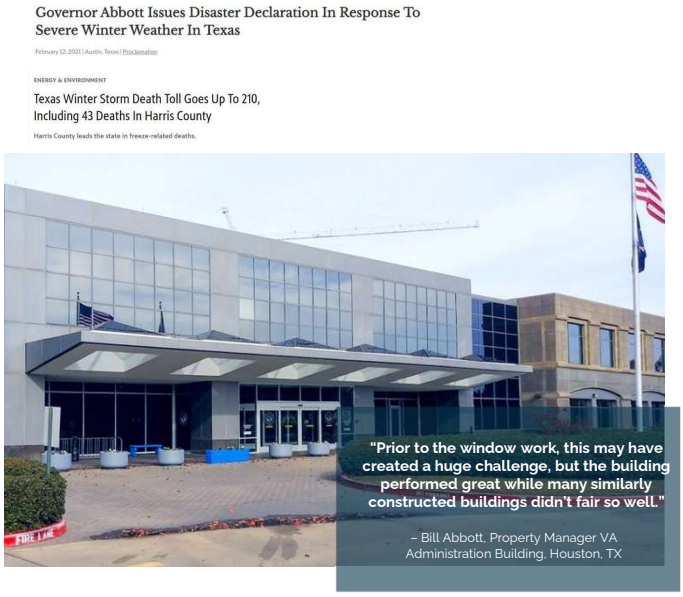
Great Documented Results in Case Studies to Support Building Resilient Design Strategies

Record-Breaking Heat Dome in PNW

Texas Freeze in February 2021



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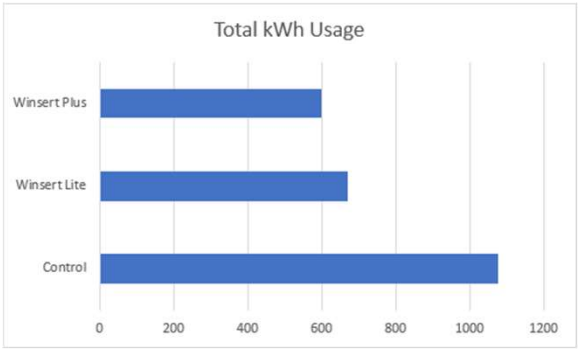
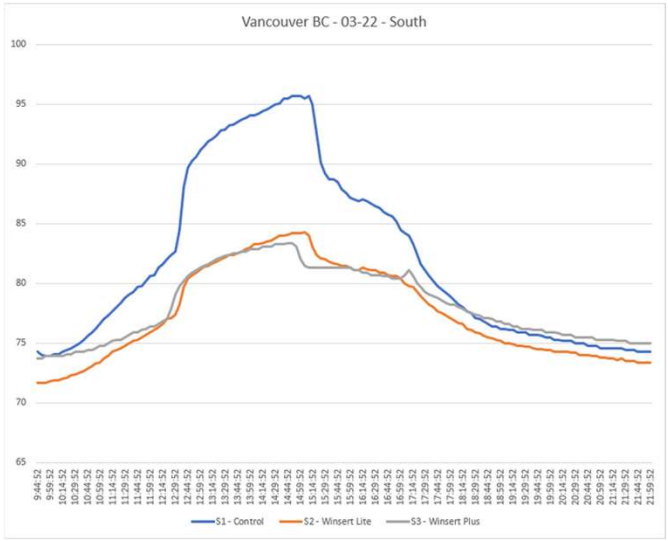
Significantly better comfort performance with FAR LESS energy use





38% reduction in space heating energy use for Winsert Lite

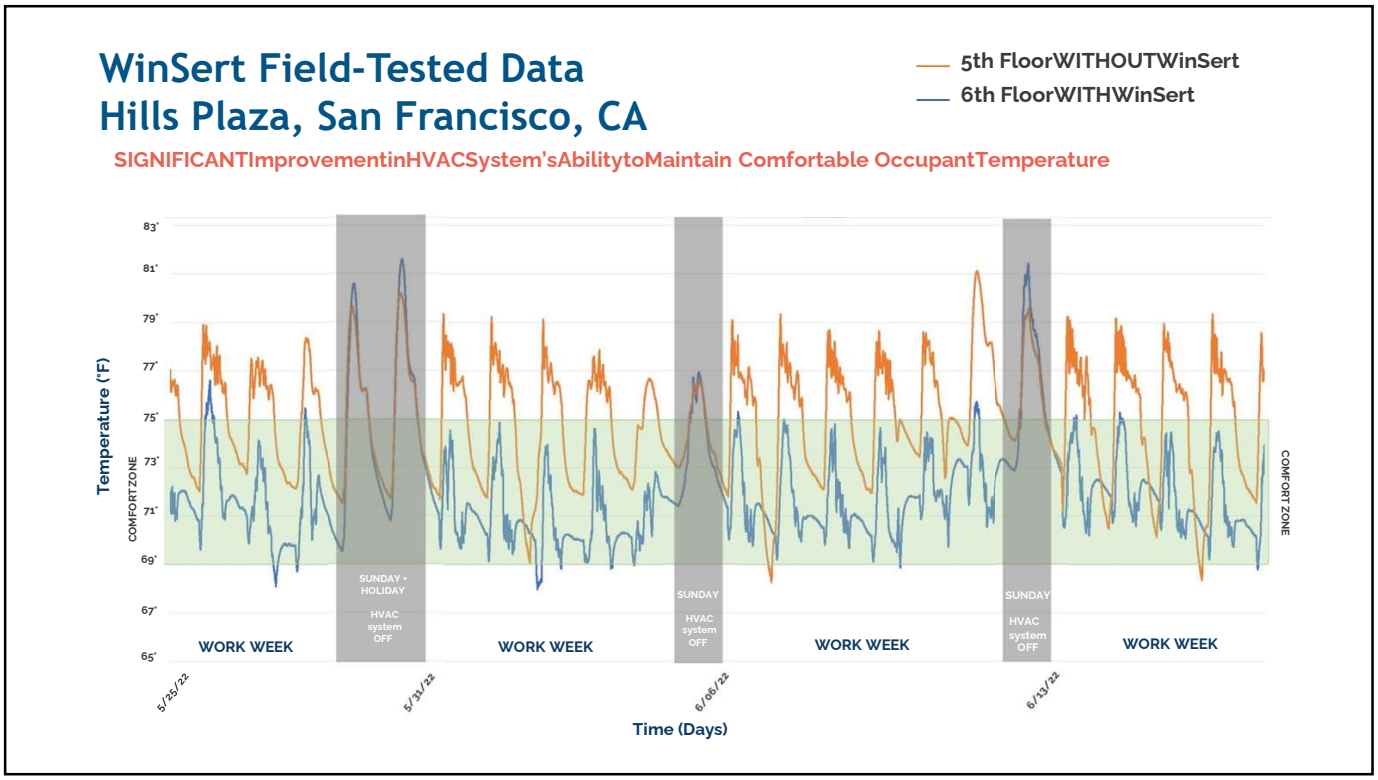
45% reduction in space heating energy use for Winsert Plus

10 F average temperature reduction on sunny days

48


Aesthetically Invisible
Retrofit Solution
Before WinSert
After WinSert

49


WinSert Field-Tested Data
Hills Plaza, San Francisco, CA
5th FloorWITHOUTWinSert
6th FloorWITHWinSert
SIGNIFICANTImprovementinHVACSystem'sAbilitytoMaintain ComfortableOccupantTemperature
Temperature (°F)
83°
81°
79°
77°
75°
73°
71°
69°
67°
65°
COMFORT ZONE
COMFORT ZONE
SUNDAY + HOLIDAY
HVAC system OFF
SUNDAY
HVAC system OFF
SUNDAY
HVAC system OFF
WORK WEEK
WORK WEEK
WORK WEEK
WORK WEEK
5/25/22
5/31/22
6/06/22
6/13/22
Time (Days)

50

51

ALPEN
HIGH PERFORMANCE PRODUCTS

Questions or Follow Up?

ALPEN HIGH PERFORMANCE PRODUCTS WWW.THINKALPEN.COM

303-834-3600

PIERRE GRAAS, SALES ENGINEER | PGRAAS@THINKALPEN.COM | 303-834-3554

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High Performance Windows –a View from the Field

Katie Allen Cort
Pacific NorthwestNationalLaboratory

NBI High Performance Windows Manufacturers Roundtable
August 26, 2025

U.S. DEPARTMENT of ENERGY BATTELLE
PNNL is operated by Battelle for the U.S. Department of Energy
PNNL-SA-215448

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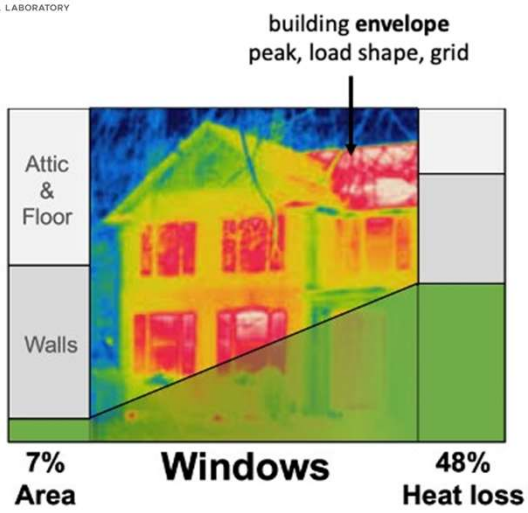
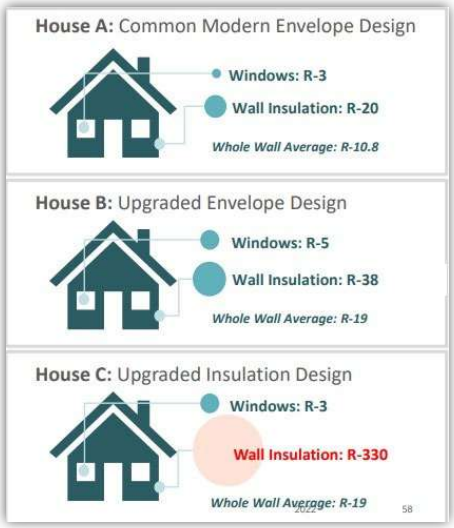
Why Windows Matter: We can't have better buildings without better windows!



Berkeley Lab window heat transfer analysis for IECC 2021, based on DOE residential prototype buildings



54

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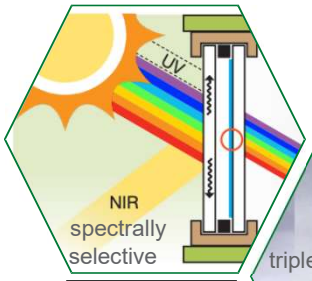
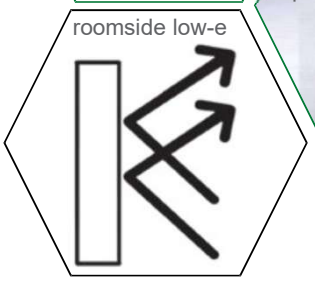
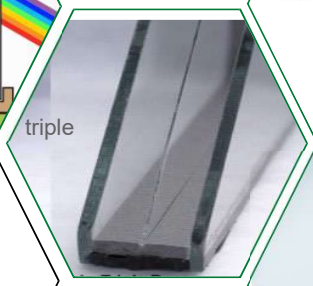
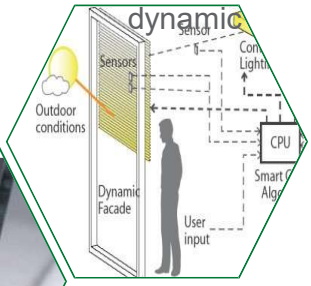
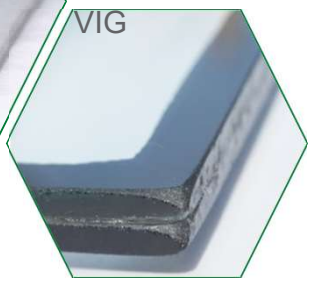
Latest Advancements in Window Technologies











Aerogels

55

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Experimental Questions and Field Validation Studies

Experimental Questions/Topics	Validation Study Approach
•How much energydothin triple-panes save in the field? •Are there peak demand savings and grid benefits associated with thin triple-pane windows? •Are thin triple-pane IGUs “drop-in” feasible with multiple brands of double-pane frames/sashes? • Are thin triple-pane windows cost-effective for new construction and/or retrofit applications? •What co-benefits (in addition to energy savings) are associated with the installation of triple-pane windows?	      

4

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Field Testing Platforms

PNNL Lab Homes Testing Platform

- Represents existing manufactured and stick-built housing
- All-electric with 13 SEER/7.7 HSPF heat pump central HVAC +
- R-22 floors, R-11 walls, & R-22 ceiling with composition roof
- 1,500 ft2 ; 195.7 ft2 (13%) window area
- Double-pane clear glass aluminum-framed windows

Occupied Home Field Sites

Enable observations of real-life factors:

- Varied climate zones and house types
- Varied baseline windows
- Installation and cost realities
- Occupant interactions

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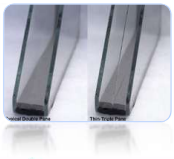
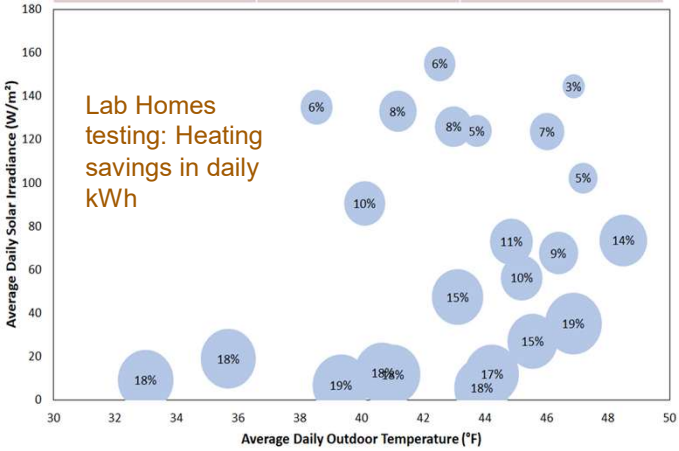
Thin Triple Pane Performance Validation



Heating Savings	Cooling Savings	Annual Savings
12% (7.8 kWh)	28% (5.5 kWh)	19% (7.4kWh)



Thin Triples versus Double-Pane Clear

Hunt, W., et al. "Evaluation of Thin Triple-Pane Windows in the PNNL Lab Homes," April ٢٠٢١, PNNL-٣١١١٥

58

Validated Feasibility of "dropping in" thin triple pane IGU into standard double-pane frames

- Alpen thin triple IGU with Kensington (Vandergrift, PA) vinyl frames and stainless-steel spacers installed in a new home site (Twin Cities, MN)

- Alpen thin triple IGU with Kensington vinyl frames and foam spacers installed in a retrofit site (Yonkers, NY)

- Alpen thin triple IGU with Paradigm (Portland, Maine) vinyl frames and a Quanex foam spacer are installed in a new multi-family site (Rotterdam, NY)

- Cardinal thin triple IGU into an Alpine double pane vinyl frame with ¾" overall thickness glazing pocket (Pasco, WA)

7

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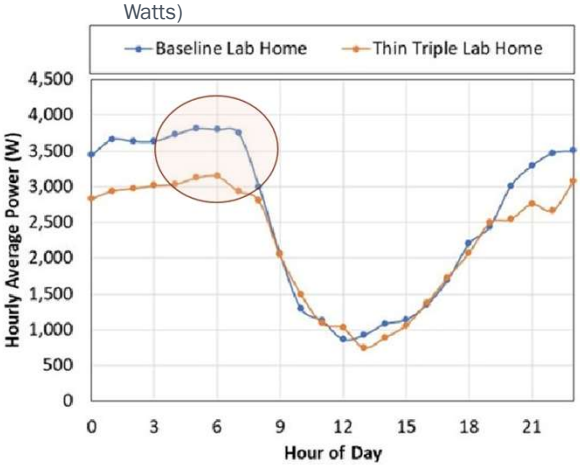
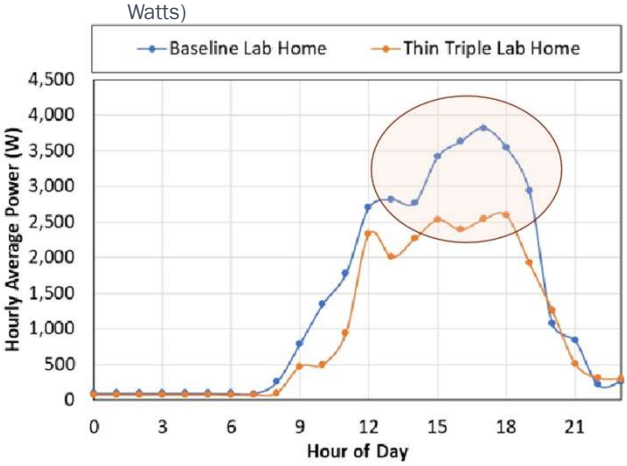
Lab Homes Load Shapes and Peak Savings: Heating & Cooling Seasons

WINTER Average Peak Electrical Load Reduction (650 Watts)



HVAC Load **Heating** Season

SUMMER Average Peak Electrical Load Reduction (1,200 Watts)

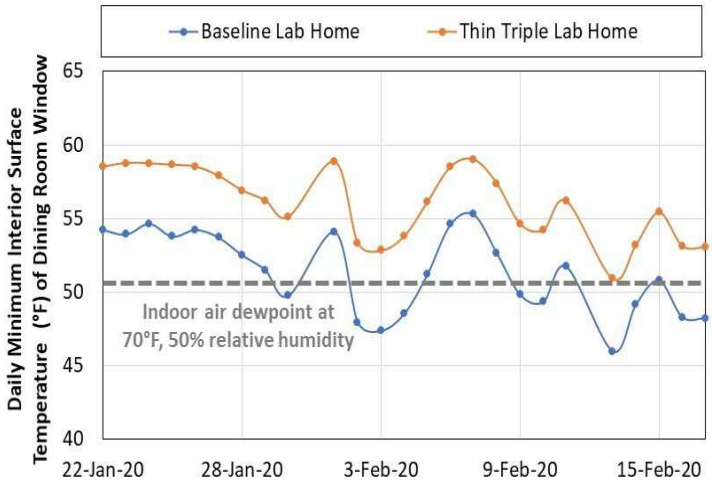


HVAC Load **Cooling** Season

8

60

Co-Benefits Validated in the Field: Condensation Buildup



Condensation and ice buildup on interior surface of Helena, MT home field site (double-pane window).

Same window after replacement with thin triple pane.

March 2021

9

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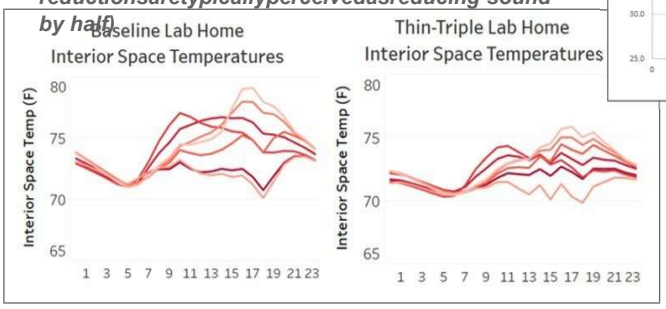
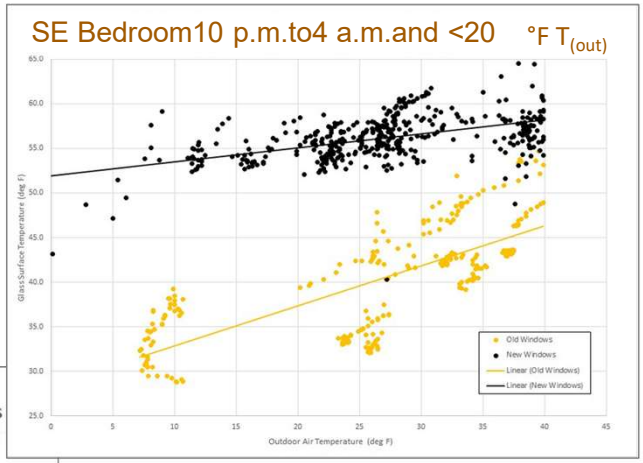
Co-benefits Validated: Improved thermal comfort, improved acoustics

- Thermal comfort: Warmer interior glass temperatures (in winter) and more even temperature distribution throughout the home observed with triple pane windows
- Acoustic testing: Thin triple-pane windows reduced sound infiltration by ~10 dB relative to baseline double-pane windows

(6-10 dB reductionsaretypicallyperceivedasreducing sound by half)





Boulder, Colorado Retrofit

NighttimeIndoor c.o.g. GlassSurface Temperature vs. T(out) SE Bedroom

10

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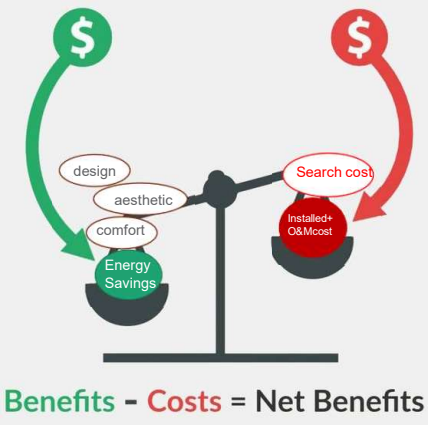
Factors Influencing the Window Purchasing Decisions of High-Performance Builders

- Most high-performance buildersalready installingR-5 (triple-pane) windows. Reasons include:
  1. Performance (i.e., meeting high performance specs)
  2. Flexibility in design (HVAC and envelope)
  3. Marketable benefits: comfort, acoustics, condensation reduction, larger window size with low utility bills.
- Factors influencing choice to not install R-5 windows (or barriers encountered when switching to R-5):
  1. Material Costs
  2. Search/Acquisition costs for Reliable Supply
  3. Not required for ENERGY STAR, Zero Energy Ready Homes, and other high-performance programs
  4. Installation Costs



Gilbride, Theresa L., et al. "Double or Triple? Factors Influencing the Window Purchasing Decisions of High-Performance Home Builders." Jun. ٢٠١٩. https://doi.org/١٠.٢١٧٢/١٥٥٧٨٦٢

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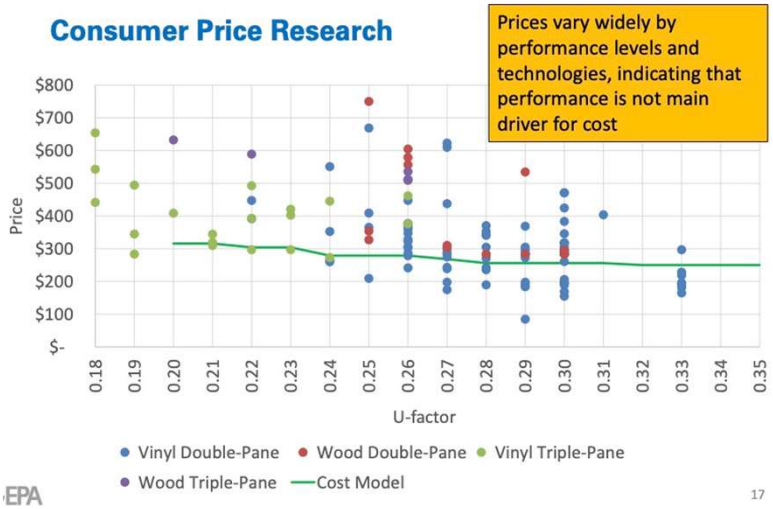
Window Material Costs

Factors Influencing Builders to not install R-5 windows (or barriers encountered when switching to R-5).

1. Material Costs
2. Search/Acquisition costs for Reliable Supply
3. Not required for ENERGY STAR, Zero Energy Ready Homes, and other high-performance programs
4. Installation Costs



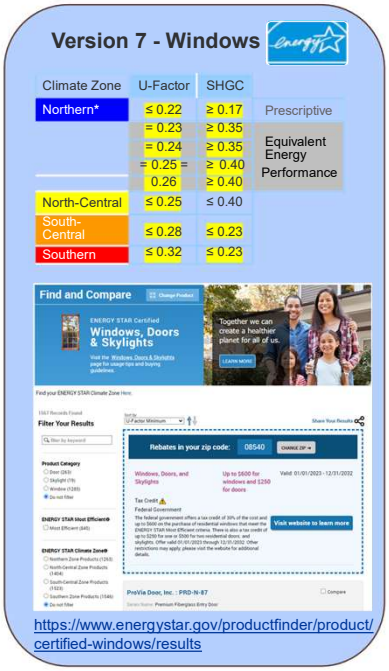
Anderson, Doug. "ENERGY STAR Windows, Doors, and Skylights: NFRC Fall Membership Meeting Update." October ٢٣, ٢٠٢١. EPA

64

Window Acquisition/Search Costs

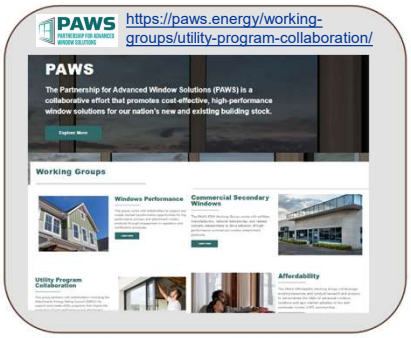
Factors Influencing Builders to not install R-5 windows (or barriers encountered when switching to R-5).

1. Material Costs
2. Search/Acquisition costs for Reliable Supply
3. Not required for ENERGY STAR, and other high-performance programs
4. Installation Costs



https://www.energystar.gov/productfinder/product/certified-windows/results

https://efficientwindows.org/window-selection-tool/



https://paws.energy/working-groups/utility-program-collaboration/

65

PAWS High-Performance Window Manufacturer-Builder Meet Up: EEBA Summit 2024

Builders are Optimizing **Time, Cost,** and **Quality**

- **Timing** just-in-time delivery is often needed to meet project deadlines
- **Affordability is key**
  - **Material costs** important
  - **"Hidden" acquisition costs** including reliable lead times, streamlining ordering, sizing to rough opening, pricing transparency
- **Quality Metrics/Drivers** (in addition to U-factors):
  - **Condensation Resistance**
  - **Air-leakage** and **durability over time**
  - **Moisture Control**
  - **Sound insulation**

2024 14

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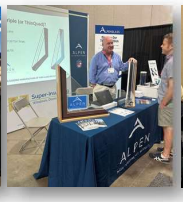
How the building community can help pull the market for high performance windows

- Strengthen the Demand Signal:
  - Specify higher performance windows •Tell a window dealer near you that you want more high-performance options
- Up Sell clients -- better windows and window attachments and shades with automation
- Engage with Workshops, Pilots, Field Tests to Validate Performance
- Take Advantage of Rebates, Incentives
  - https://www.efficientwindows.org/
  - https://paws.energy/
- Provide Feedback on "The Builder Experience"
  - **Theresa.Gilbride@pnnl.gov** or **Katherine.cort@pnnl.gov**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Thank You

PacificNorthwest National Laboratory

Katie Allen Cort
Senior Economist

509.372.4374, e-mail:
katherine.cort@pnnl.gov

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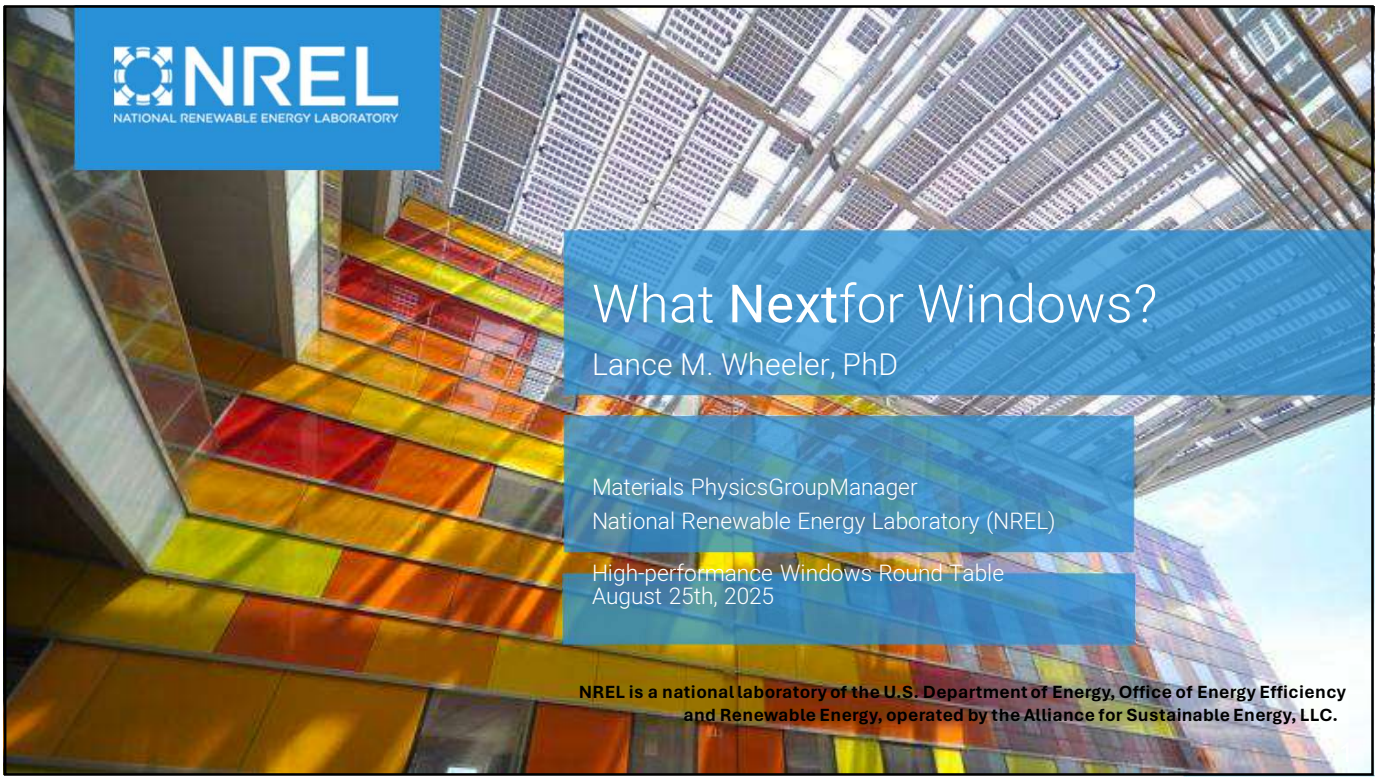


69

THERE ARE 3 MAIN AREAS OF INNOVATION

1) Increased Insulation

Courtesy of NREL

2) Dynamic/Chromogenic

Courtesy of Glass Dyenamics, Inc.

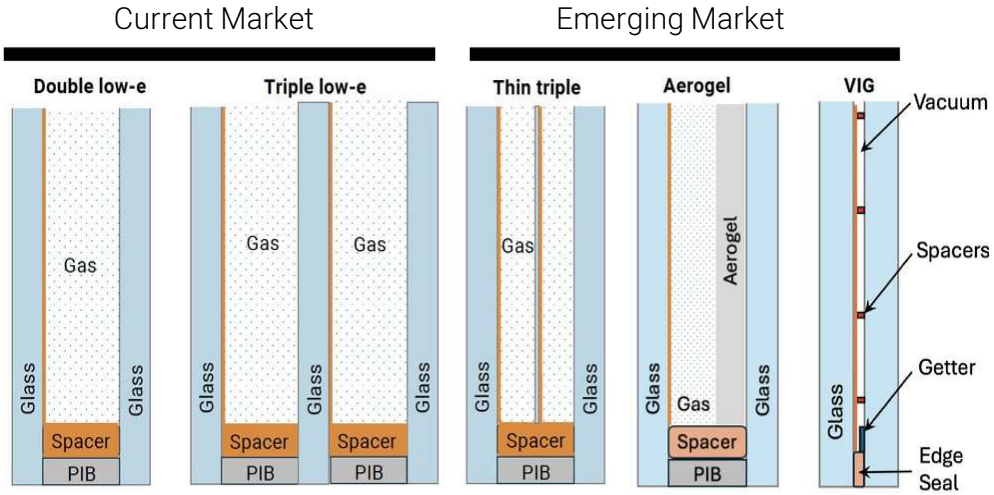
Courtesy of Tynt, Inc.

3) Photovoltaic

Courtesy of NREL/UbiQD

70

THERMAL PERFORMANCE EVOLUTION IN WINDOWS



htt ps:/ /w ww.w sj. com / busi ness/ corning -w indow-gori ll a-glass - 4f443b07

71

VIG IS GAINING MOMENTUM

- Concept of VIG proposed by Zollerin 1913
- U of Sydney concept became the basis for the first commercial VIG from NSG- Pilkington in the late 19 90' s

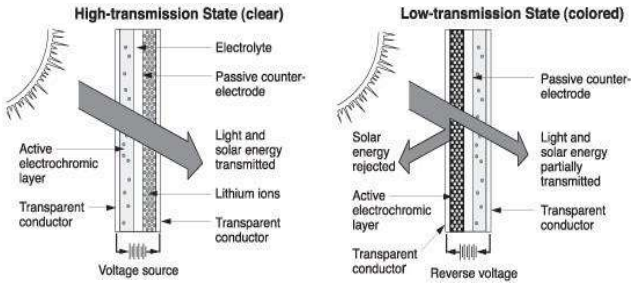
72

DYNAMIC GLAZING MODULATES SUNLIGHT

Electrochromicwindows

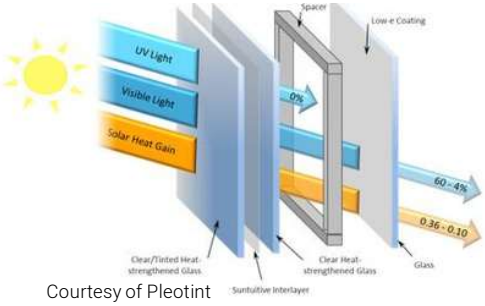
Dreamliner (Gentex)

- Voltage driven • Flexible control strategy
- Occupant control possi
- Requires multiple trades for installation
- Commercialized



Thermochromic windows

- Temperature driven
- Simplified installation
- Control strategy defined at point of manufacture
- Occupant has no control
- Com merc ia l iz ed



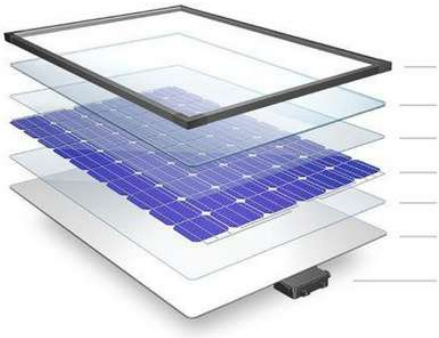
Courtesy of Pleotint

NREL 5

73

PV WINDOWS PIGGBACK ON MATERIALS COST

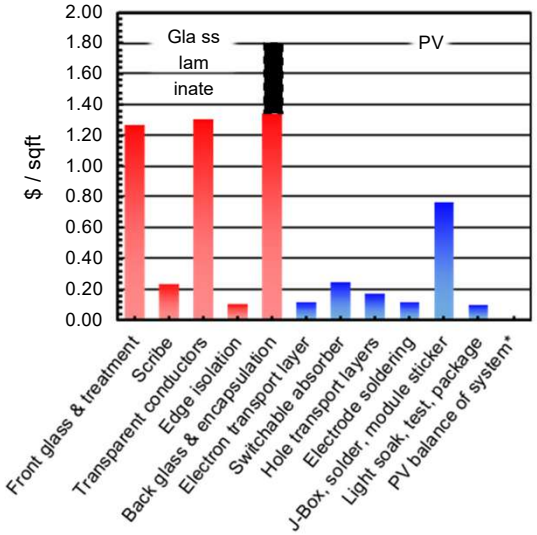
PV laminate



Frame Glass
Encapsulant (PVB/EVA)
Solar Cells
Encapsulant
Backsheet (more glass!)
Junction box

State-of-the-art panel: Power conversion efficiency (PCE) = 20% Warranty = 25 years (<8% power decrease)

us.sunpower.com

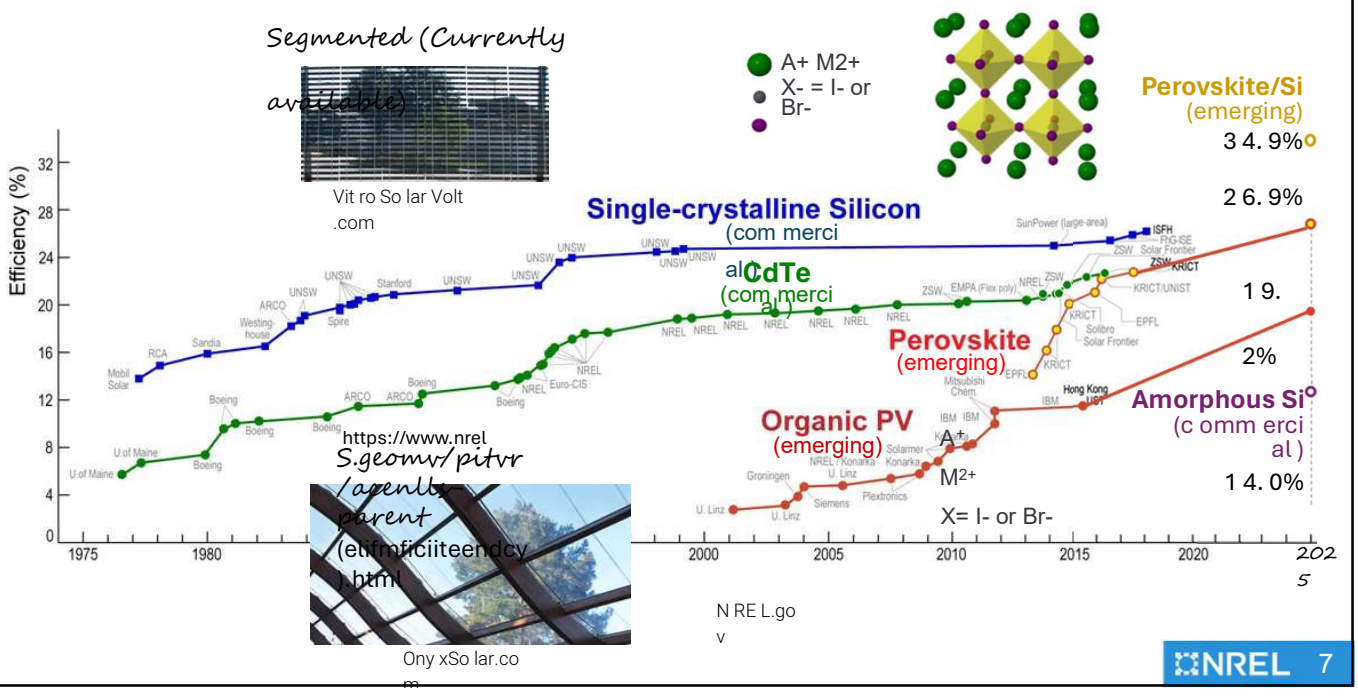


Bailie, C. et al. Preliminary Technoeconomic Analysis of Single-Junction Perovskites and Perovskites-on-Silicon. in (2015).

NREL 6

74

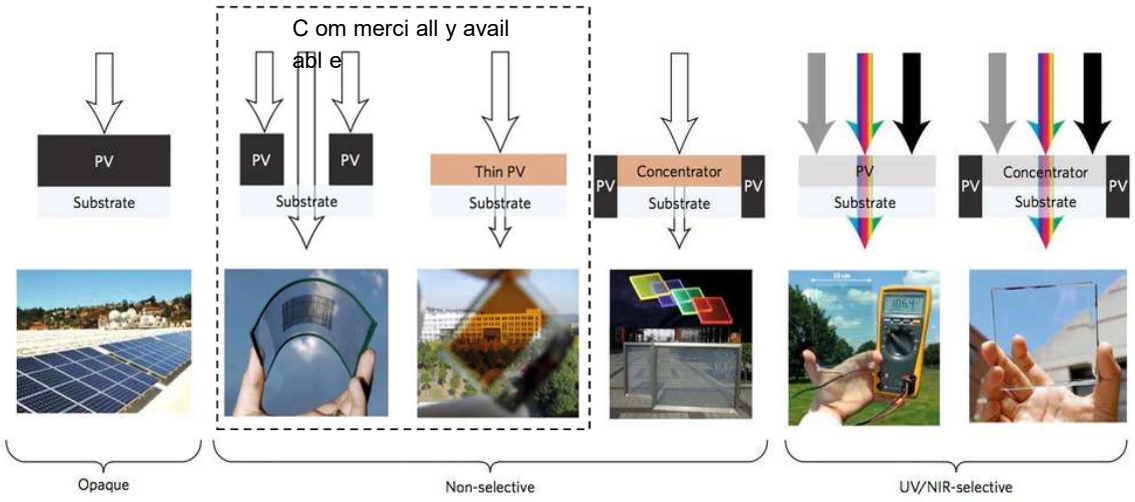
PV EFFICIENCY HAS IMPROVED STEADILY



NREL 7

75

THERE ARE MANY WAYS TO ADD PV TO YOUR WINDOW

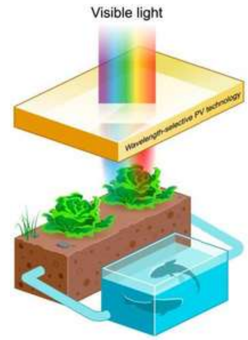


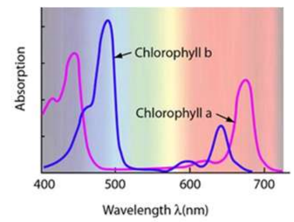
Traverse, C. J., Pandey, R., Barr, M. C. & Lunt, R. R. ***Nat. Energy*** 1–12 (2017).

NREL 8

76

OPV ABSORPTION IS TUNABLE





Ma Lu S. et al. Wavelength-selective solar photovoltaic systems to enhance spectral sharing of sunlight in agrivoltaics. Joule 8 (2024) 3H-2522

rphysics.com

NREL.gov

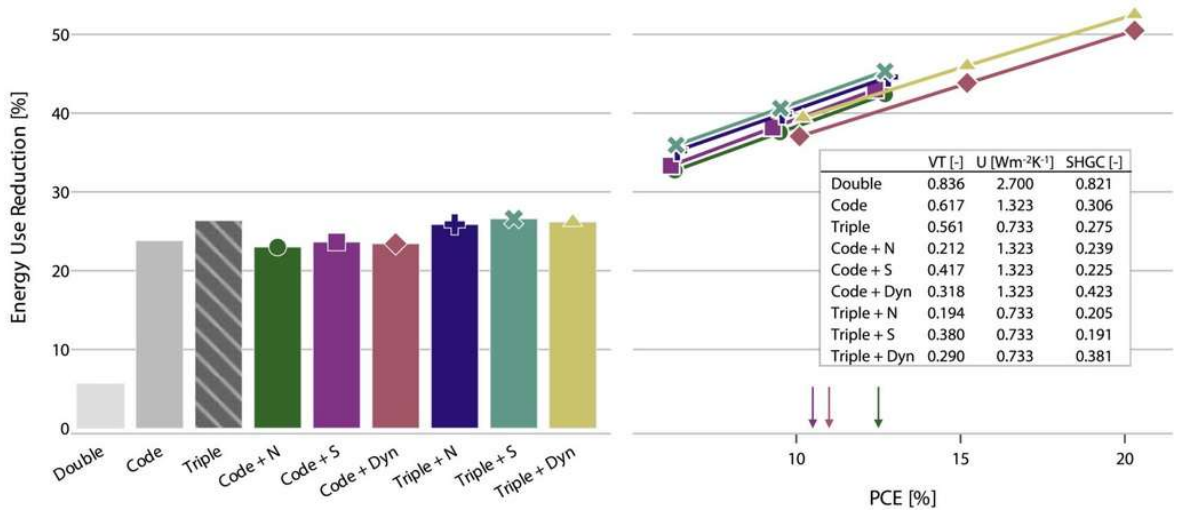
NREL 9

77

1

78

PV WINDOWS SAVE ENERGY IN SIMULATION



	VT [-]	U [Wm⁻²K⁻¹]	SHGC [-]
Double	0.836	2.700	0.821
Code	0.617	1.323	0.306
Triple	0.561	0.733	0.275
Code + N	0.212	1.323	0.239
Code + S	0.417	1.323	0.225
Code + Dyn	0.318	1.323	0.423
Triple + N	0.194	0.733	0.205
Triple + S	0.380	0.733	0.191
Triple + Dyn	0.290	0.733	0.381

Wheeler, V. M. *et al*. Photovoltaic windows cut energy use and CO2 emissions by 40% in highly glazed buildings. *One Earth* **5**, 1271–1285 (2022).

NREL 11

79

ARCHITECTURAL SOLAR EDUCATION FOR DESIGNANDCONSTRUCTIONPROFESSIONALS

ASA ARCHITECTURAL SOLAR ASSOCIATION

NREL NATIONAL RENEWABLE ENERGY LABORATORY

We have lots of content on Youtube:

https://www.youtube.com/channel/UCR20A1hG1I2bWn2g-xfFJBw

All thanks to the help from the following supporting organizations;

Gensler LUMOS IEA PVPS BIPV boost Vitro Architectural Glass SOLARPLAZA Mayfield Renewables Activ'Glass U.S. DEPARTMENT OF ENERGY SOLAR AWARDEE™ MITREX Walters&Wolf NEXT heatspring NRECA Kiss + Cathcart, Architects PGAL onyx SOLAR SKYRISE

NREL 1

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