BUILDINGENERGY BOSTON

Retrofit, Restore, or Replace: Understanding the Whole Life Carbon of Windows

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Northeast Sustainable Energy Association (NESEA)
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Retrofit, Restore, or Replace

Understanding the whole life carbon of windows

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NSG Pilkington

Description

Windows and glazing play a disproportionate role in a building's performance compared to other parts of the assembly. As we strive to meet our 2030 and 2050 climate goals the **design strategies** for both our **new and existing buildings** must be closely evaluated.

A **case study** of the **Albert Kahn building** will demonstrate how **emerging glass technologies** can play an important role in a building's restoration, maintaining its architectural characteristics, and can create jobs in urban environments. A detailed examination will be paid to the embodied and operational carbon of different design strategies.

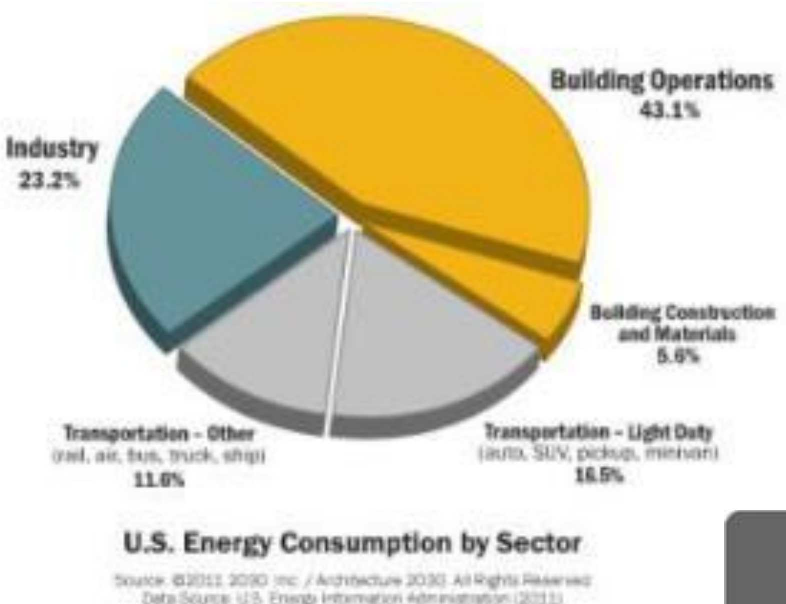
Learning Objectives

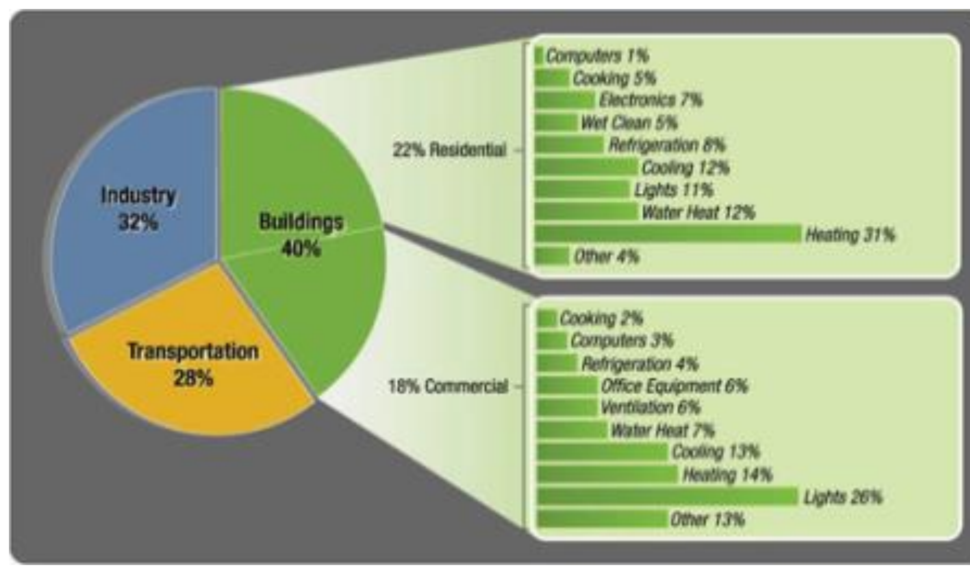
1. Compare the energy reduction challenges of **retrofitting versus new construction**
2. Identify **emerging technologies** that can help upgrade existing buildings and significantly reduce carbon usage.
3. Analyze how the embodied carbon and operational carbon from case studies can be applied to reduce the **whole life carbon** of windows.
4. Maximize **triple bottom line** results - historic restoration, energy efficiency, and equity focused workforce development - while still delivering an effective and cost-efficient project.

Agenda

- Building consumption and window impact
- Window overview – performance, design, and current state
- Baseline expectations
- Albert Kahn building – case study review
- Triple bottom line project management
- Albert Kahn building – energy and carbon impact
- Emerging technologies

Buildings use lots of energy…

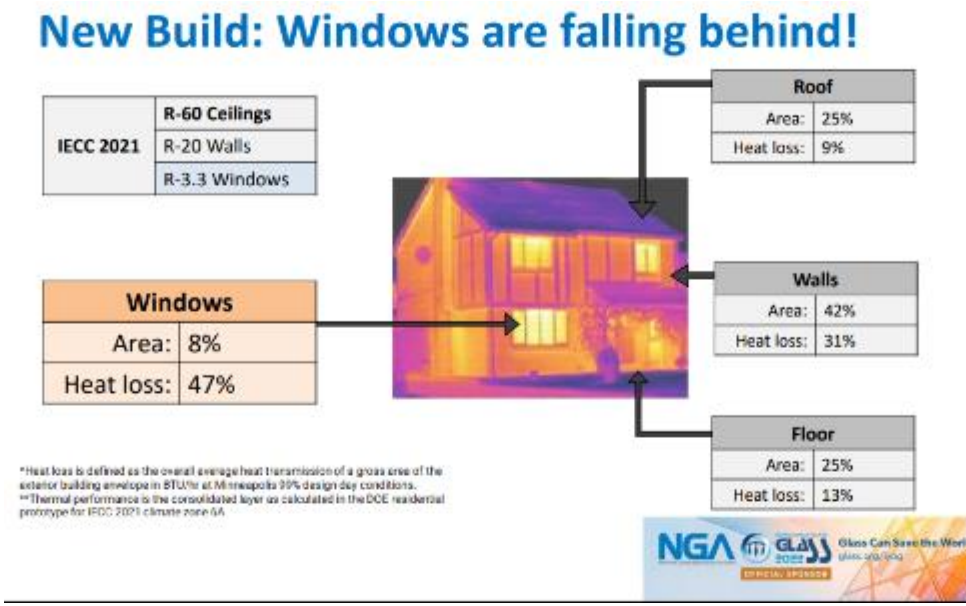




Credit – Architecture 2030, US Energy Information Administration

Windows are huge opportunity…

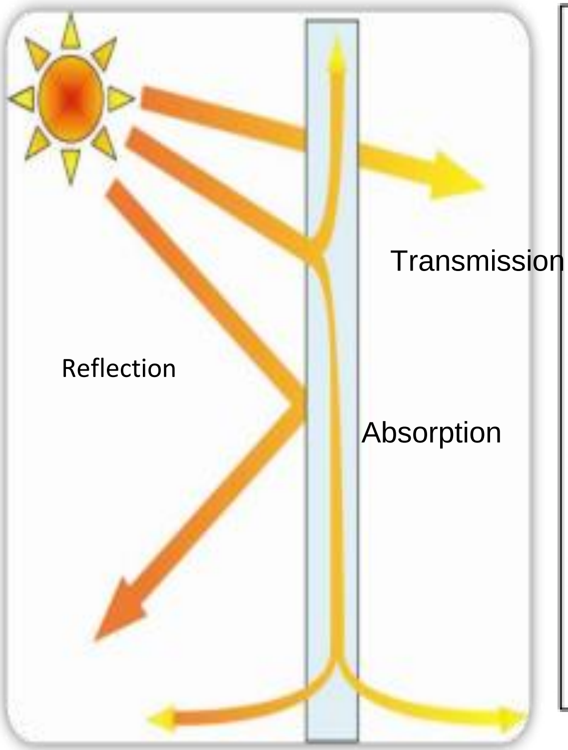
48 million Single-Pane Homes (41%)
*2015 RECS

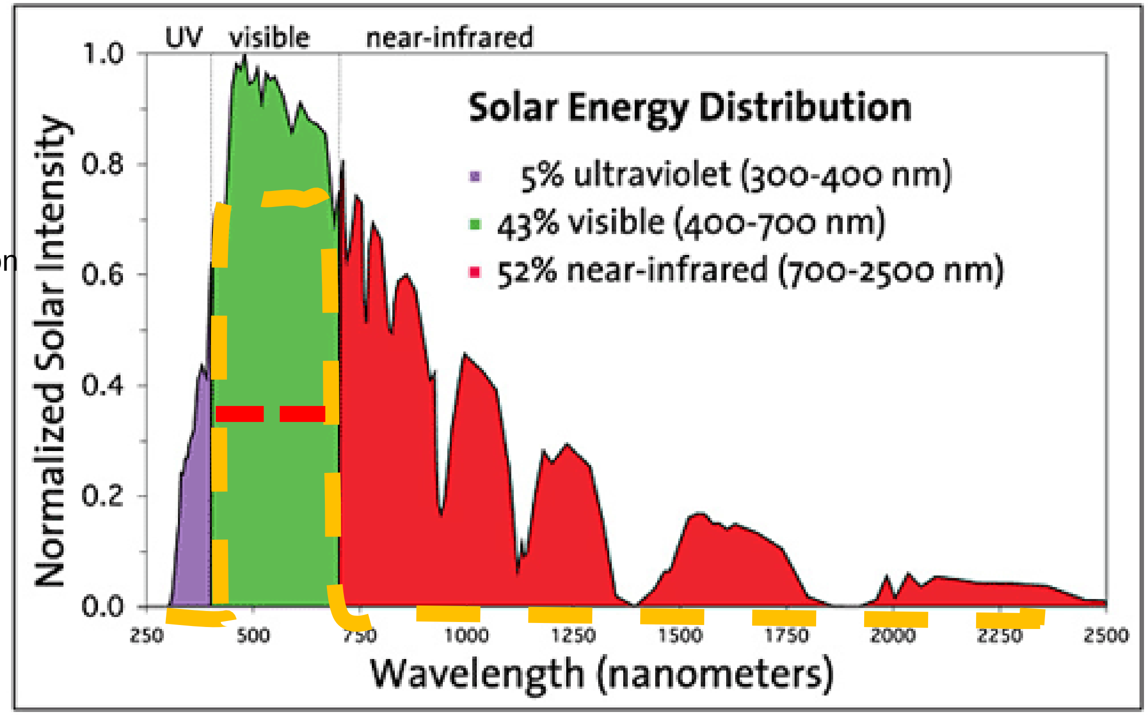


Credit – Steve Selkowitz, LBNL

Performance basics

- Think of coatings in two primary functions
  - Filter - Solar energy, light transmission, reflection, etc.
  - Insulator - Manage re-radiation of absorbed energy (both from sun and from room)
- Potential concerns with color and aesthetics.



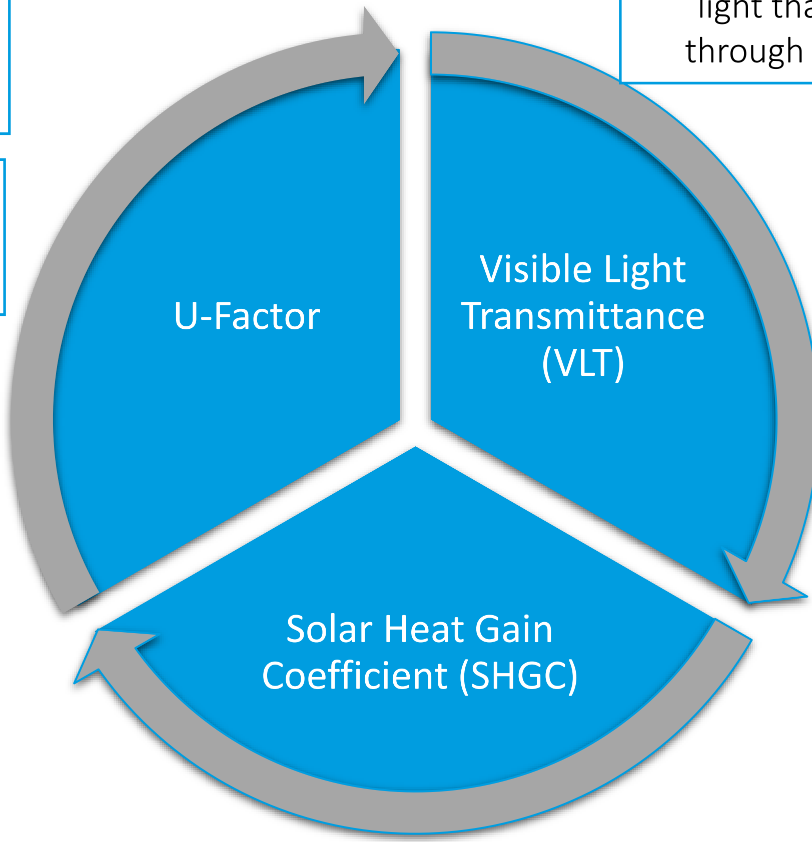


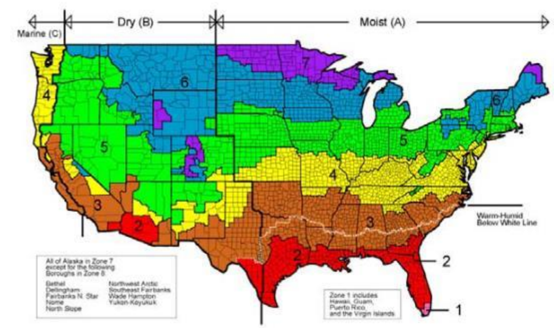
Window performance measurements

The lower the U-Factor, the better the window insulates.

Inverse of R-value
U-Factor = 0.25
R-value = 4.0

The amount of visible light that passes through the glass.





Zones	SHGC		U factor	
	Commercial	Residential	Commercial	Residential
1	0.25	0.25	**0.50**	NR
2	0.25	0.25	**0.40**	0.40
3	0.25	0.25	**0.35**	0.35
4	0.40	0.40	**0.35**	0.35
5	0.40	NR	**0.32**	0.32
6	0.40	NR	**0.32**	0.32
7	0.45	NR	**0.32**	0.32
8	0.45	NR	**0.32**	0.32

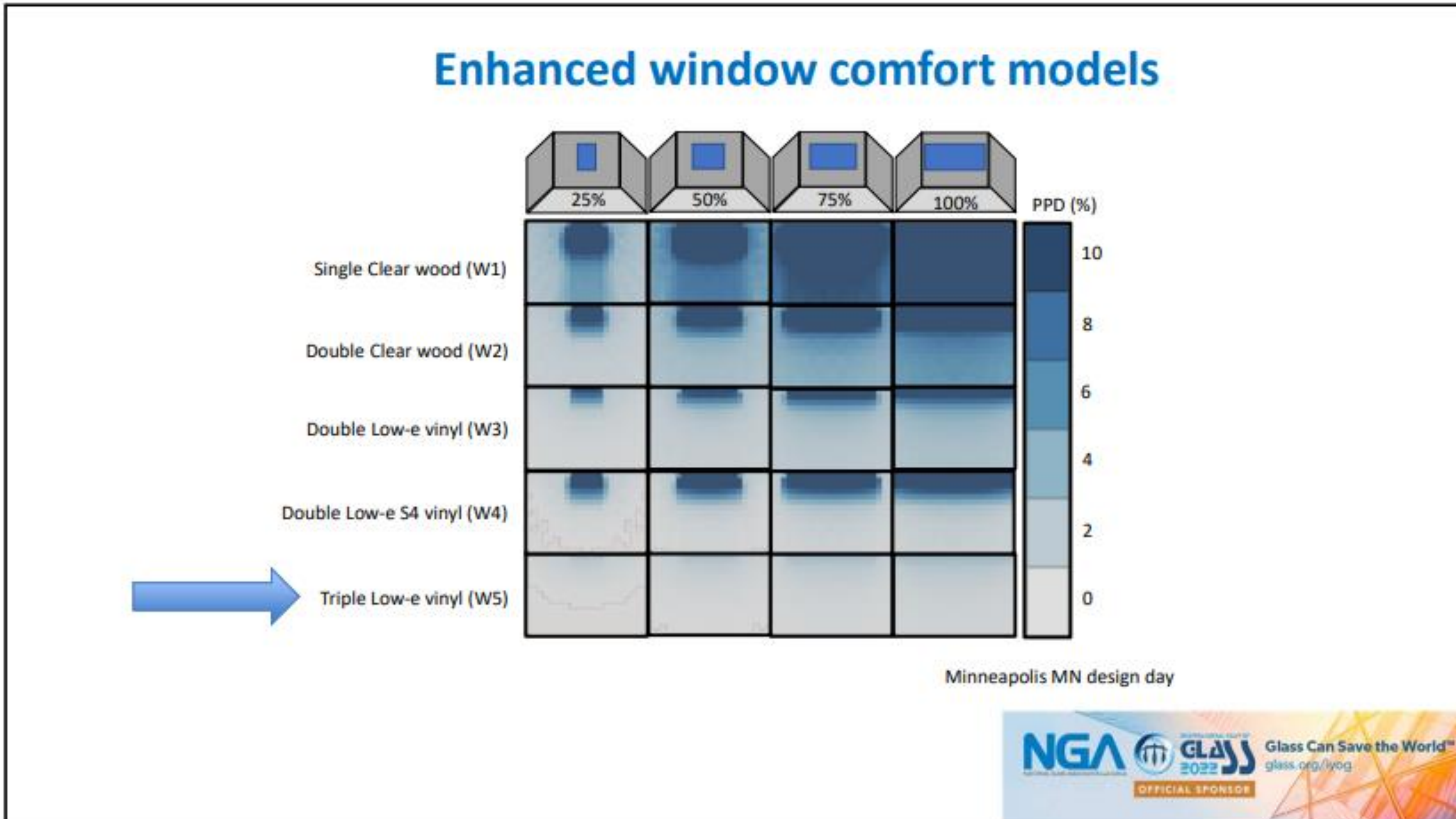
Color and reflection.

Performance and aesthetics are not mutually exclusive.

SHGC is expressed as a number between 0 and 1. The lower the SHGC, the less solar heat it transmits.


GRILLE
eaks & Seafood

Thermal comfort



Credit – Steve Selkowitz, Robert Hart, LBNL

How did we get here?

Glass complexity

1970

Today

SELECTION TABLE/PLATE/FLOAT GLASS PRODUCTS

	Product	Thickness	Quality	Thickness Tolerance	Maximum Size[1] Standard	Maximum Size[1] Special	Approx. Weight Lbs. per Sq. Ft.	Luminous Illuminant C (Average Daylight) Trans.	Average Solar Radiation Transmittance[2] Ultra-violet Radiation	Average Solar Radiation Transmittance[2] Total Solar Radiation
Polished Plate	PARALLEL-O-PLATE	1/4"	Silvering	[illegible]	up to 25 sq. ft.		3.27	89.1	67.8	79.9
			Mir. Glazing		up to 75 sq. ft.					
			Glazing		124" x 170"	124" x 252"				
	HEAVY DUTY PARA.LEL-O-PLATE	5/16"	Commercial		120" x 170"	120" x 252"	4.08	88.3	64.3	77.2
		3/8"			96" x 120"	120" x 264"	4.90	87.3	60.5	75.2
		1/2"			96" x 120"	117" x 300"	6.54	86.0	54.0	71.0
		5/8"		[illegible]	72" x 120"	108" x 300"	8.17	84.7	51.0	67.1
		3/4"		[illegible]	72" x 120"	108" x 300"	9.81	83.3	47.6	63.3
		7/8"		[illegible]	72" x 120"	108" x 300"	11.45	80.8	45.0	59.3
	REGULAR PLATE	1/8"	Glazing	[illegible]	72" x 74"	74" x 120"	1.64	90.5	75.9	86.1
	PARALLEL-O-GREY	13/64"	Glazing	[illegible]	84" x 120"		2.66	50.1	44.0	52.2
		1/4"			96" x 138"	120" x 192"	3.27	44.2	39.0	46.6
	HEAVY DUTY PARALLEL-O-GREY	3/8"	Commercial		96" x 120"	117" x 264"	4.90	30.0	28.6	32.8
		1/2"			96" x 120"	120" x 300"	6.54	21.3	19.7	24.3
	PARALLEL-O-BRONZE	1/4"	Glazing	[illegible]	96" x 138"	120" x 192"	3.27	48.5	27.5	41.0
	HEAVY DUTY PARALLEL-O-BRONZE	3/8"	Commercial		96" x 120"	117" x 264"	4.90	34.4	16.7	27.3
		1/2"			96" x 120"	110" x 300"	6.54	24.8	10.7	18.5
Rough Plate	Rough Both Sides Regular	[illegible]	Commercial	[illegible]	100" x 144"[3]	124" x 144"[3]	3.82	88.7	65.8	78.3
	Grey							38.9	35.7	41.7
	Bronze							44.2	24.0	37.0
	Heat Absorbing				80" x 144"[4]	100" x 144"[4]		72.7	39.8	43.7
	Polished One Side Regular	[illegible]	Commercial	[illegible]	76" x 124"	96" x 138"	3.47	88.9	67.0	79.1
	Grey							41.3	36.7	44.1
	Bronze							46.1	25.5	38.8
	Heat Absorbing	[illegible]	Commercial	[illegible]	76" x 138"	96" x 138"	3.47	73.8	41.3	45.0
Float	REGULAR	1/4"	Glazing	[illegible]	124" x 170"	124" x 252"	3.27	89.1	67.8	79.9
	HEAT ABSORBING	1/4"	Glazing	[illegible]	96" x 138"	120" x 192"	3.27	74.7	44.9	46.3

Tuf-flex Tempered Plate and Float

	Product	Thickness	Quality	Thickness Tolerance	Dimensional Tolerance	Maximum Size	Approx. Weight Lbs. per Sq. Ft.	Luminous Trans.	Ultra-violet Radiation	Total Solar Radiation
Polished Plate	REGULAR PLATE	1/4"	Glazing	[illegible]	[illegible]	96" x 120"	3.27	89.1	67.8	79.9
		5/16"	Commercial			96" x 120"	4.08	88.3	64.3	77.3
		3/8"				96" x 132"	4.90	87.3	60.5	75.2
		1/2"				96" x 132"	6.54	86.0	54.9	71.0
		5/8"		[illegible]		96" x 132"	8.17	84.7	51.0	67.1
		3/4"		[illegible]		96" x 132"	9.81	83.3	47.6	63.3
		7/8"		[illegible]		74" x 110"	11.45	80.8	45.0	59.3
	GREY	1/4"	Glazing	[illegible]		95" x 120"	3.27	44.2	39.0	46.6
		3/8"	Commercial			95" x 132"	4.90	30.0	28.6	32.8
		1/2"				96" x 132"	6.54	21.3	19.7	24.3
	BRONZE	1/4"	Glazing	[illegible]		96" x 132"	3.27	48.5	27.5	41.0
		3/8"	Commercial			96" x 132"	4.90	34.4	16.7	27.0
		1/2"				96" x 132"	6.54	24.8	10.7	18.5
Rough Plate	Rough Both Sides Regular	[illegible]	Commercial	[illegible]	[illegible]	96" x 132"	3.82	88.7	65.6	78.3
	Grey							38.9	35.7	41.7
	Bronze							44.2	24.0	37.0
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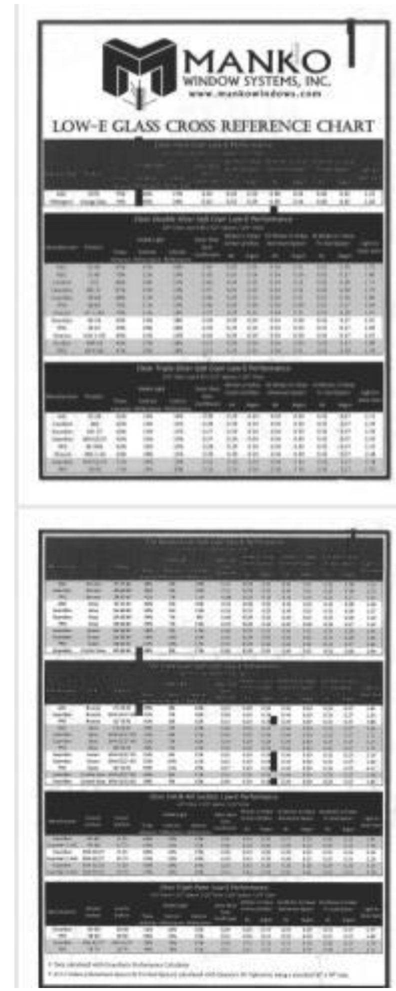
	Polished One Side Regular	[illegible]	Commercial	[illegible]	[illegible]	96" x 120"	3.07	88.9	67.0	79.1
	Grey							41.3	36.7	44.1
	Bronze							46.1	25.5	38.8
	Heat Absorbing							73.8	41.3	45.0
Float	REGULAR	1/4"	Glazing	[illegible]	[illegible]	96" x 120"	3.27	89.1	67.8	79.9
	HEAT ABSORBING	1/4"	Glazing	[illegible]	[illegible]	96" x 120"	3.27	74.7	44.9	45.3

[1] Sizes listed are those which can be furnished. They may be too large in some cases to meet applicable wind load requirements. Refer to graph on pages 18 and 19 for proper thicknesses and maximum sizes for specific wind loads.
[2] Solar radiation values are normal incidence transmittances for source that has energy distribution of the sun at 30° altitude.
[3] For sizes with long dimension greater than 124" glass can be furnished with ribs parallel to long dimension only. For other sizes rib direction can be specified.
[4] For sizes with long dimension greater than 100" glass can be furnished with ribs parallel to long dimension only. For other sizes rib direction can be specified.

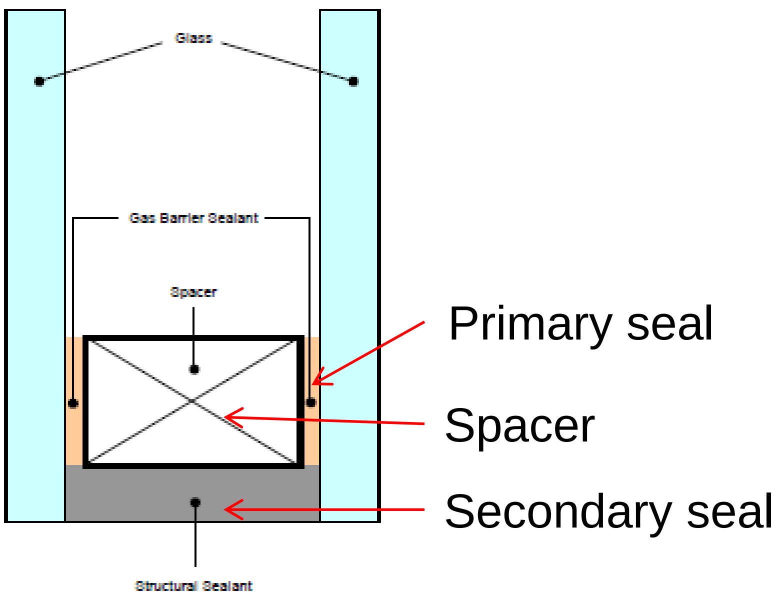
Libbey-Owens-Ford plate and float glass products meet the requirements of Federal Specification DD-G-451c. Tuf-flex tempered plate and float meets the requirements of USA Standard Z97.1-1966.

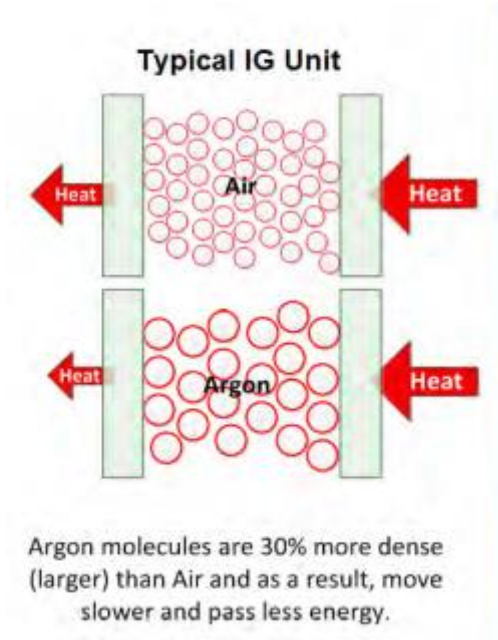
12



IG construction

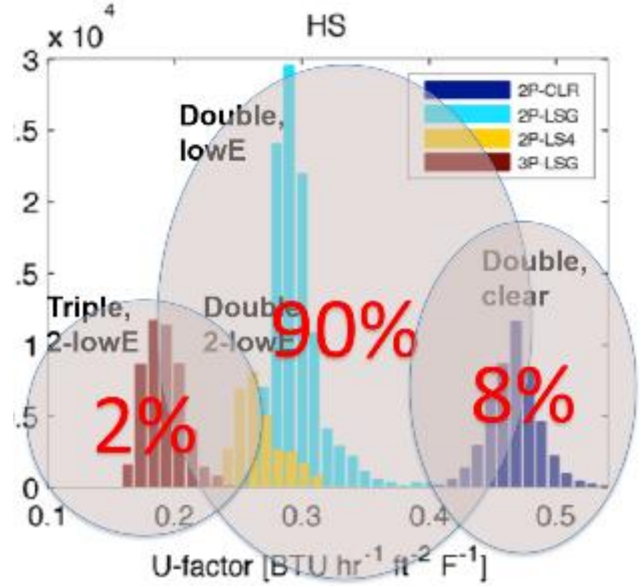
- More than one piece of glass (double glaze, triple glaze)
- Different types of seals used
- Variety of gases to fill space
    - Impacts convection, conduction





- Potential concerns with seal failure, moisture, aesthetics

Upgrade v. replace



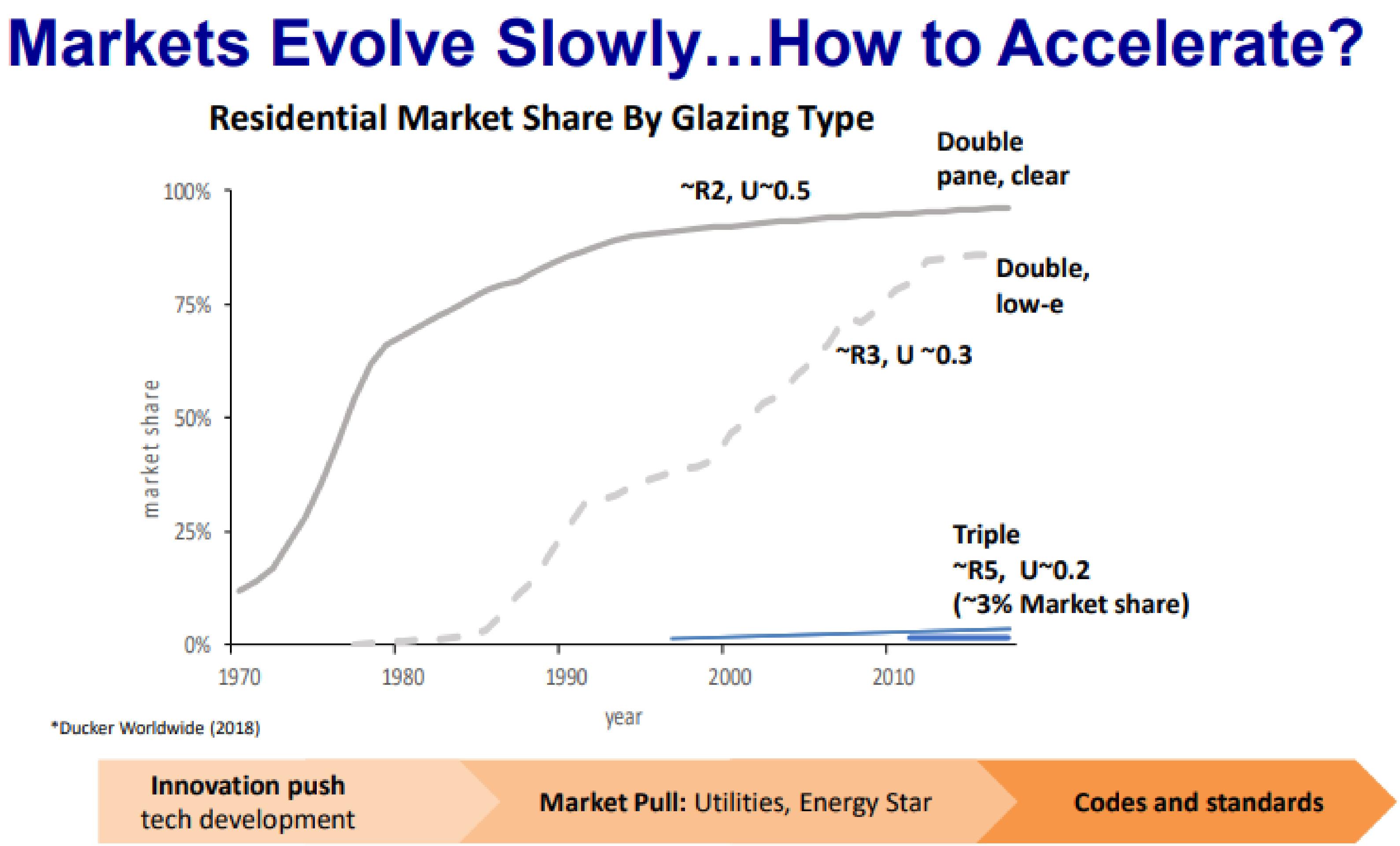
Secondary glazing

U-factor = 1.0 → (<0.5 to 0.35)

SHGC = 0.8 → (<0.70-0.65)

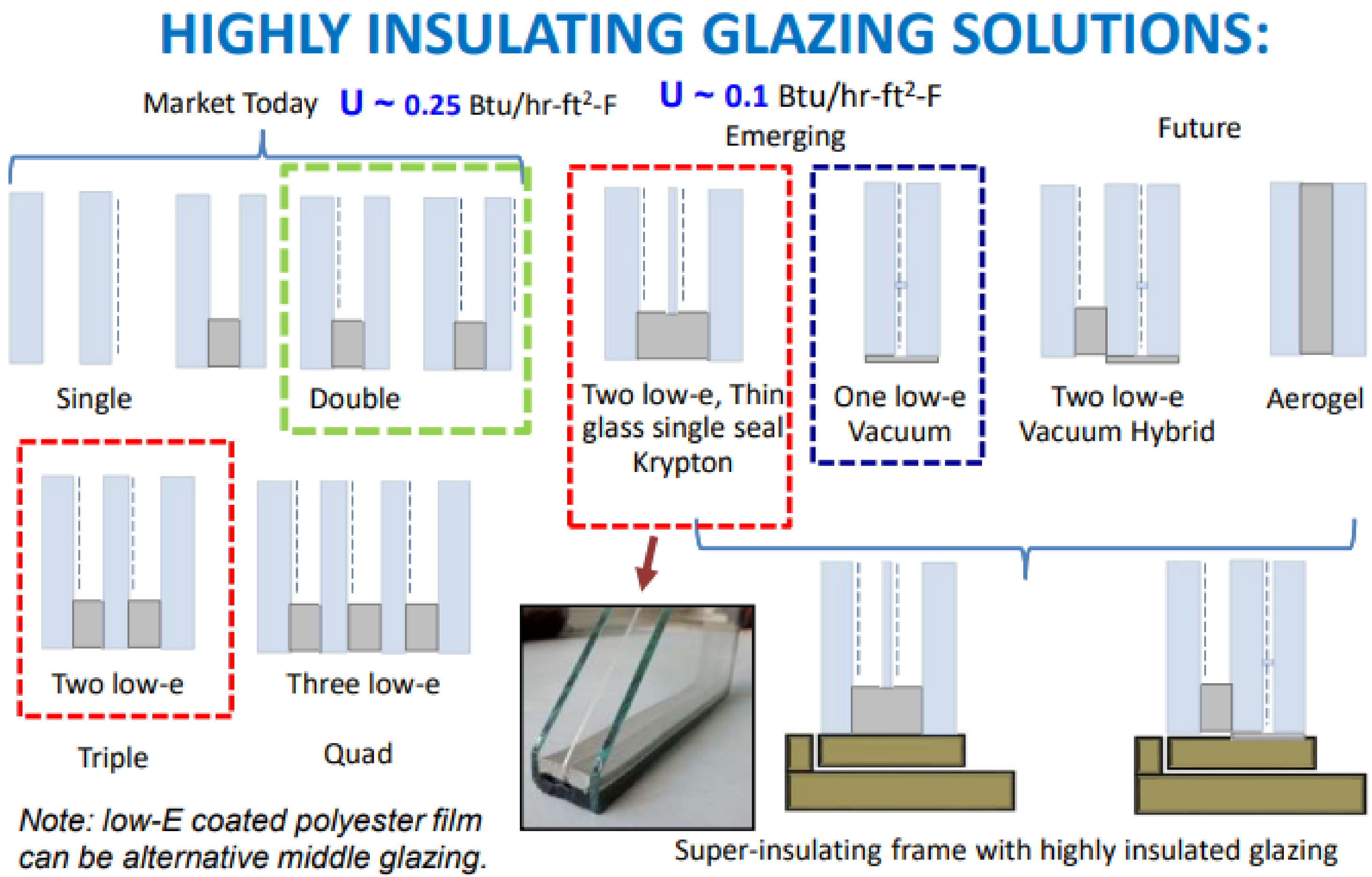
Credit – Steve Selkowitz, LBNL, Kimber Degling - Innerglass

Market status



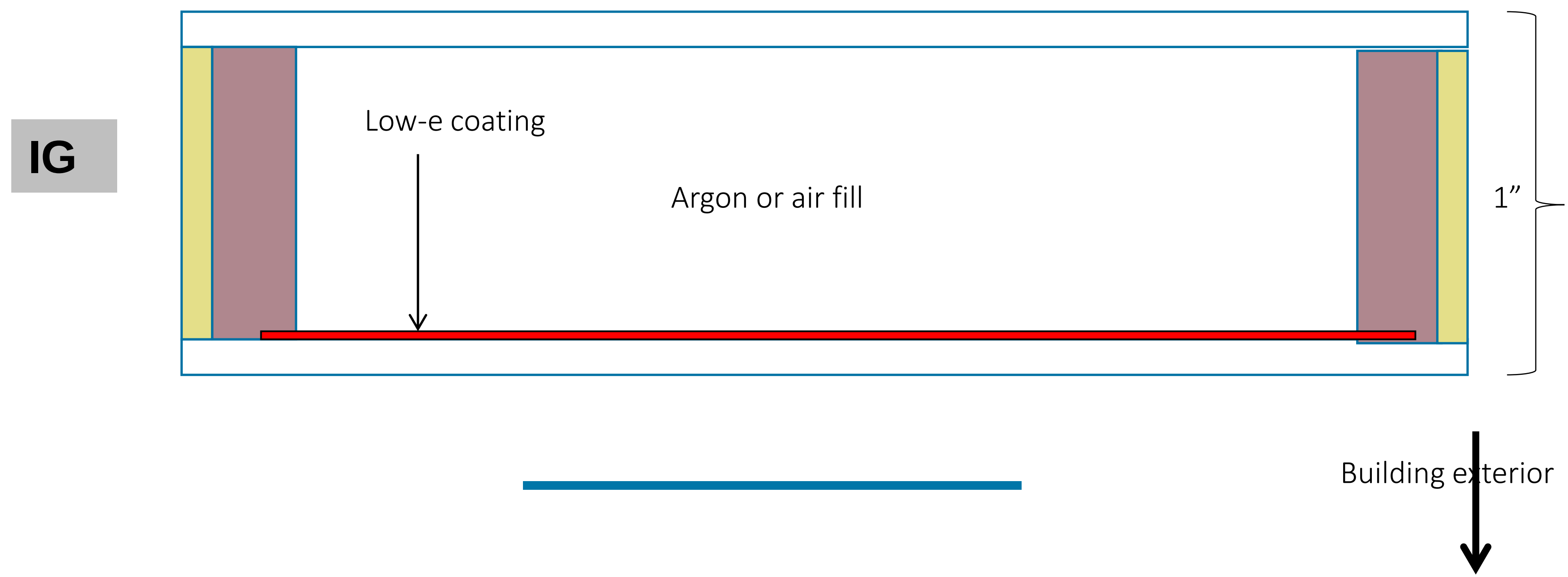
Credit – Steve Selkowitz, LBNL

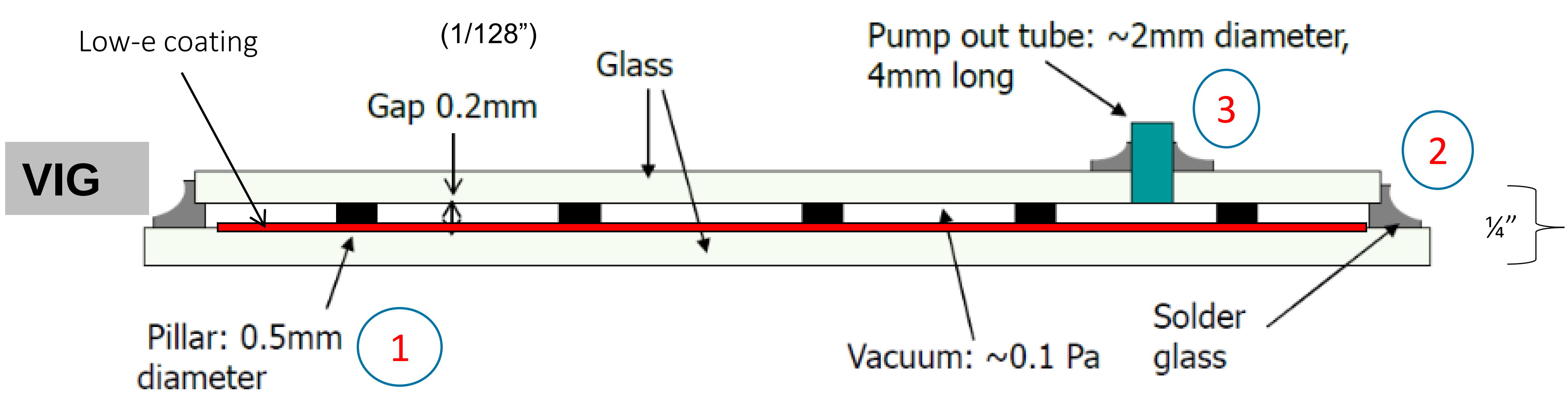
Higher performance available



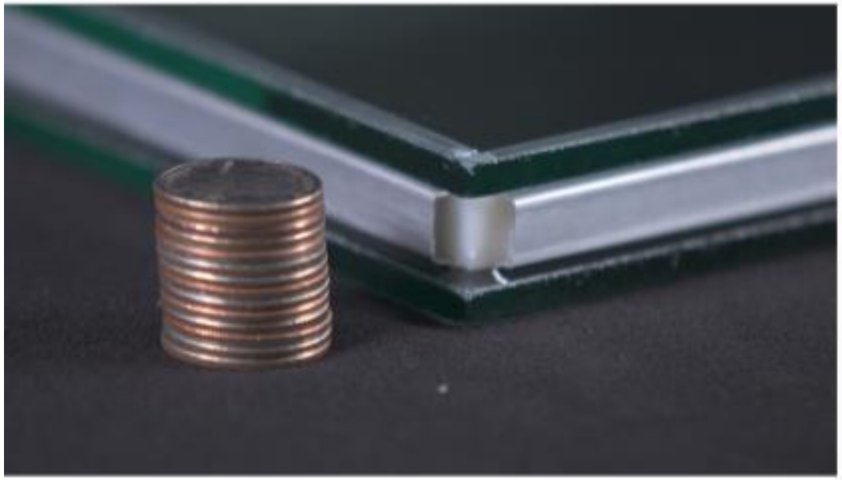
Credit – Steve Selkowitz, LBNL

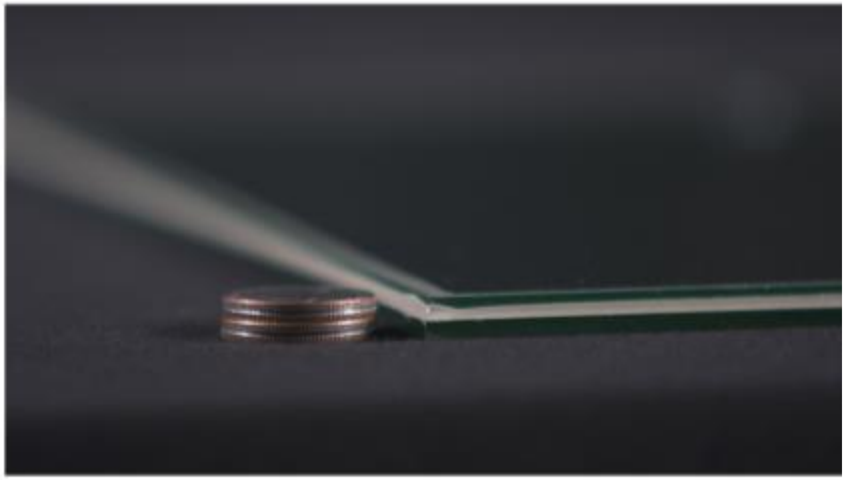
IG versus VIG construction





IG versus VIG construction



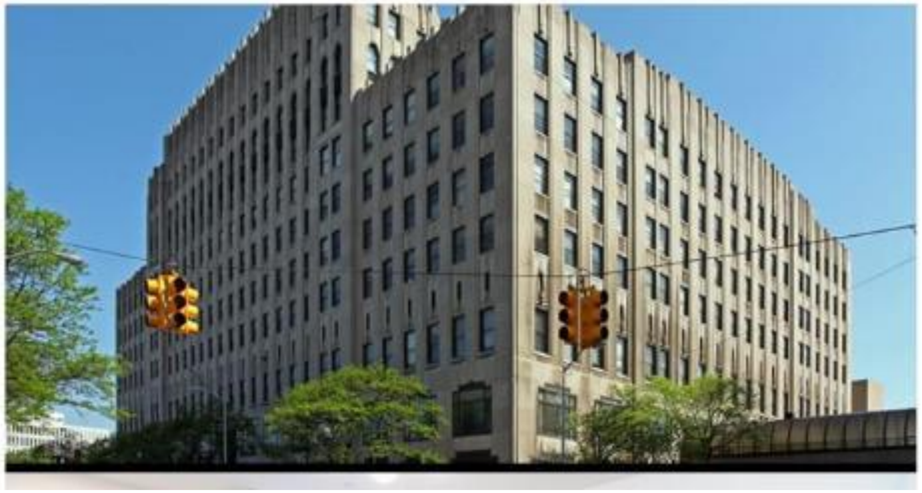


Albert Kahn office building – Detroit

Allen Architectural Metals Inc.

- 1931
- 11 story
- 320,000 ft^2 building, 17,500 ft^2 glazing area
- Bronze, double-hung windows, monolithic ¼" glass

The Kahn




156- AIR VIEW OF GENERAL MOTORS FISHER BLDG. AND ART CENTER BLDG., DETROIT, MICH.
1566
HistoricDetroit.org


HABS No. MI-310-1


ALBERT KAHN BUILDING

Allen
Architectural Metals Inc.



Allen
Architectural Metals

North Equities Group / Lutz Real Estate

Allen
Architectural Metals Inc.

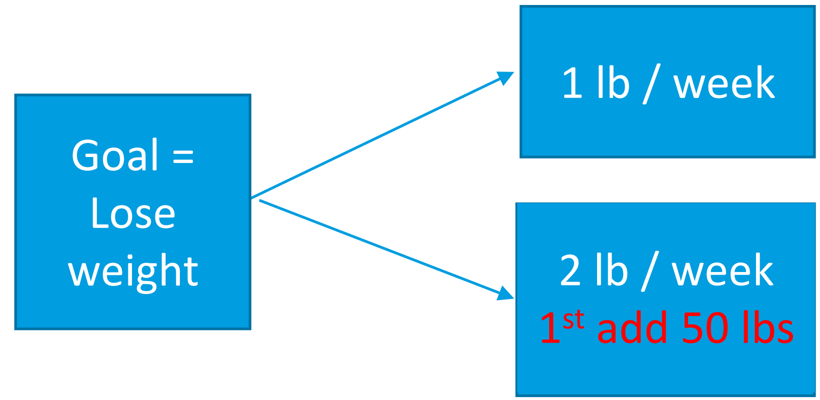



Energy and carbon impact

Counting Carb(on)s – 40% buildings

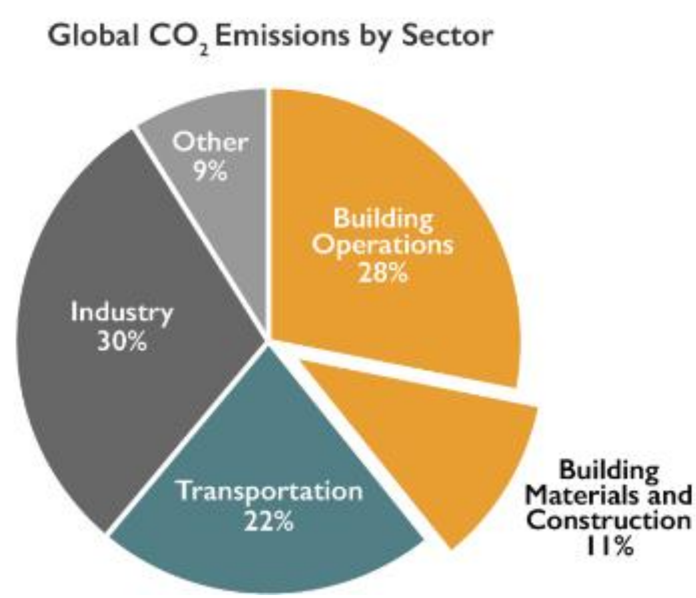
Operational Carbon

- Carbon emissions from use of energy to heat and power a building



Embodied Carbon

- Carbon emissions from manufacturing, production, and transportation of building materials

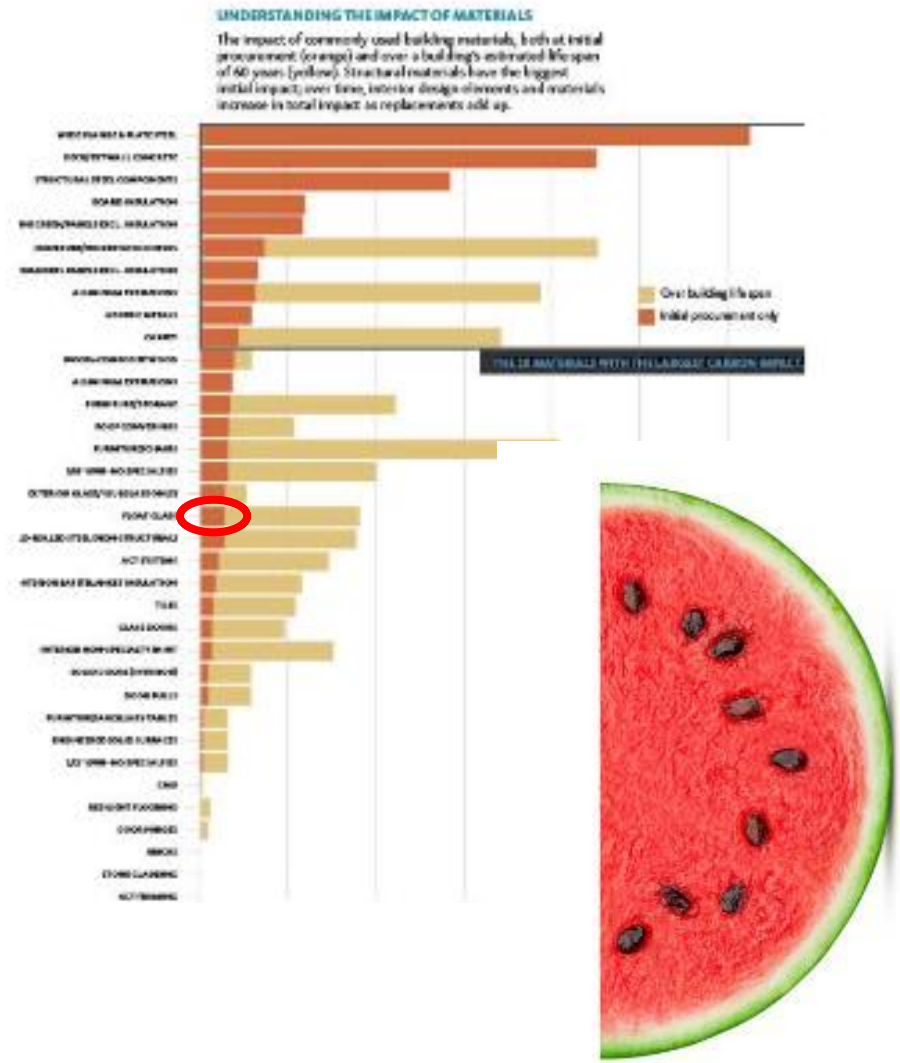


- **Goal** – reduce overall carbon impact / usage

Embodied - Glass and window impact

- Glass – skin of building
  - Structural elements - majority

- Improve operation performance with minimal embodied impact
  - Right size glass
  - Better gas
  - Longer life
  - Buy local
  - Design strategy



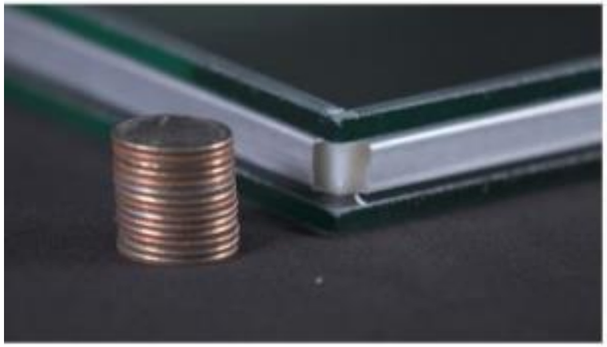
Credit – Gensler

The Kahn

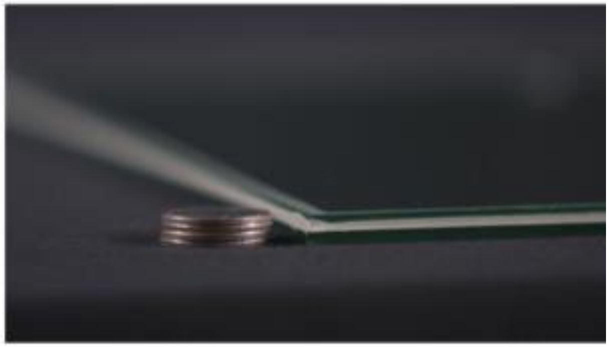
Existing building – ¼″ monolithic (reference)

1. Storm windows (steel)
2. Storm windows (Aluminum)
3. VIG re-glaze
4. Replacement Aluminum windows

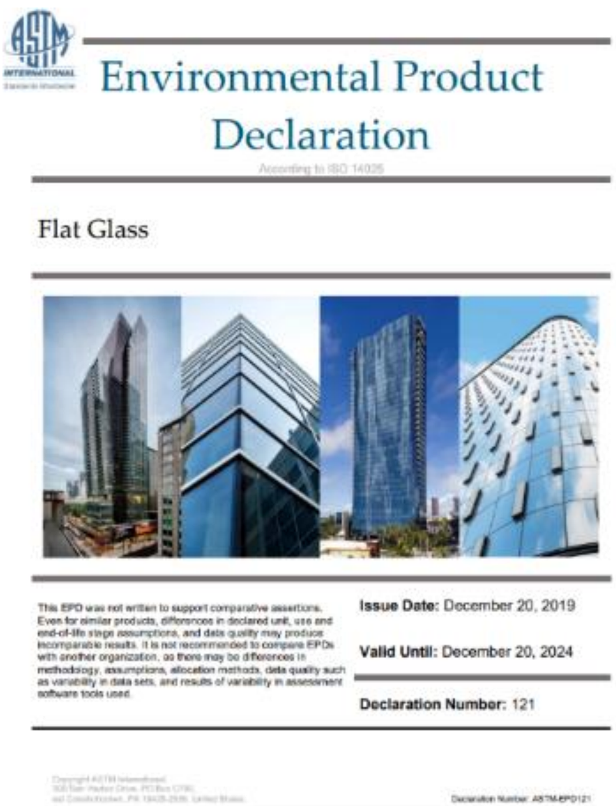
Typical IGU – 1” Thick



VIG – ¼” Thick



DOE reference building



Environmental Product Declaration

According to ISO 14025

Flat Glass

This EPD was not written to support comparative assertions. Even for similar products, differences in declared unit, use and end-of-life stage assumptions, and data quality may produce incomparable results. It is not recommended to compare EPDs with another organization, as there may be differences in methodology, assumptions, allocation methods, data quality such as variability in data sets, and results of variability in assessment software tools used.

Issue Date: December 20, 2019

Valid Until: December 20, 2024

Declaration Number: 121

Declaration Number: ASTM-EPD121

Software:

- Energy Plus
- DOE Commercial reference buildings

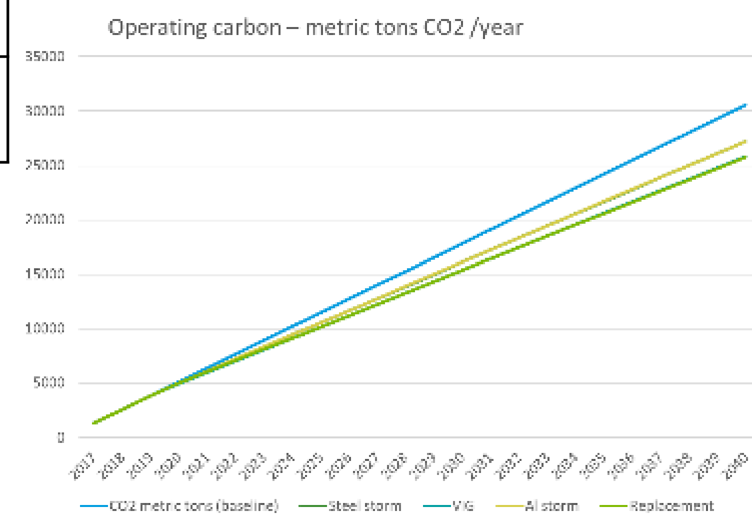
Building

- Existing building pre-1980
- Climate Zone - ne 5a – Chicago, IL
- Large office (498,558 ft2 – 12 floor)
- mixed humid

DOE reference building

	Reglazing with VIG	Interior Storm with Steel Frame	Interior Storm with Aluminium Frame	Aluminium replacement windows
Total Embodied Carbon (tonnes CO_2E)	25	33	43	73
Operating Carbon Annual Savings (tonnes CO_2E)	-226	-161	-161	-233
Total Y1 Carbon Impact (tonnes CO_2E)	-201	-126	-114	-160
Embodied Carbon Debt Payback (months)	1	3	3	4
Breakeven point – years payback embodied carbon				11

Current operating carbon (metric tons CO2 eq)	931



Key learnings

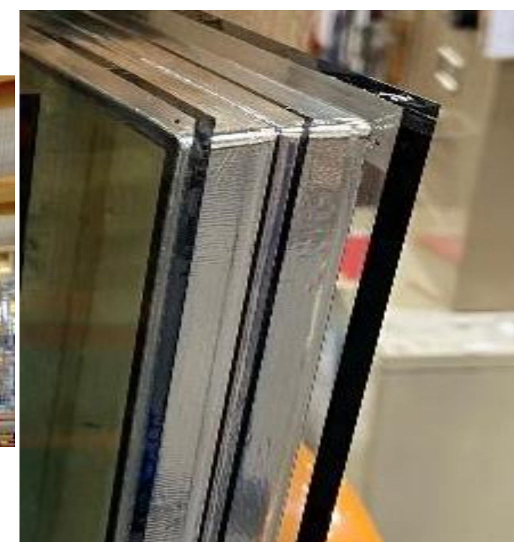
1. Building re-use / upgrades
2. Embodied material choices matter
3. Time-based carbon – save now

Emerging technology









Triple glazing – Juice worth the squeeze?

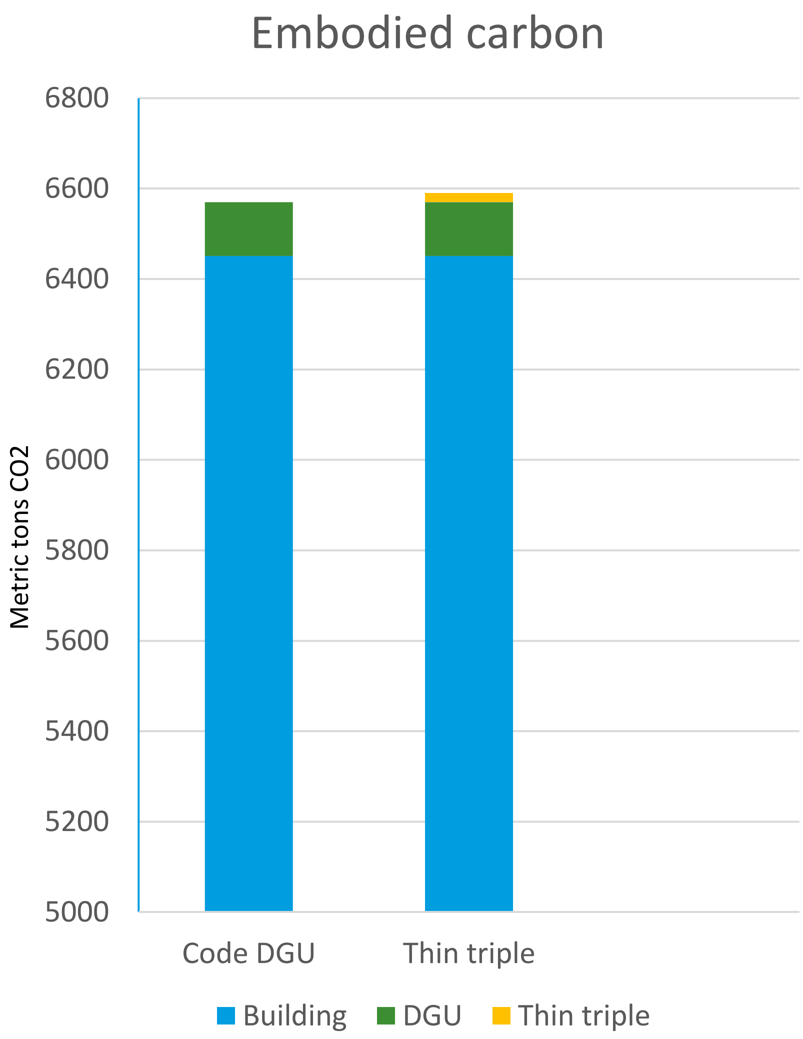
Table 1: RESIDENTIAL ANALYSIS (all windows in model home)

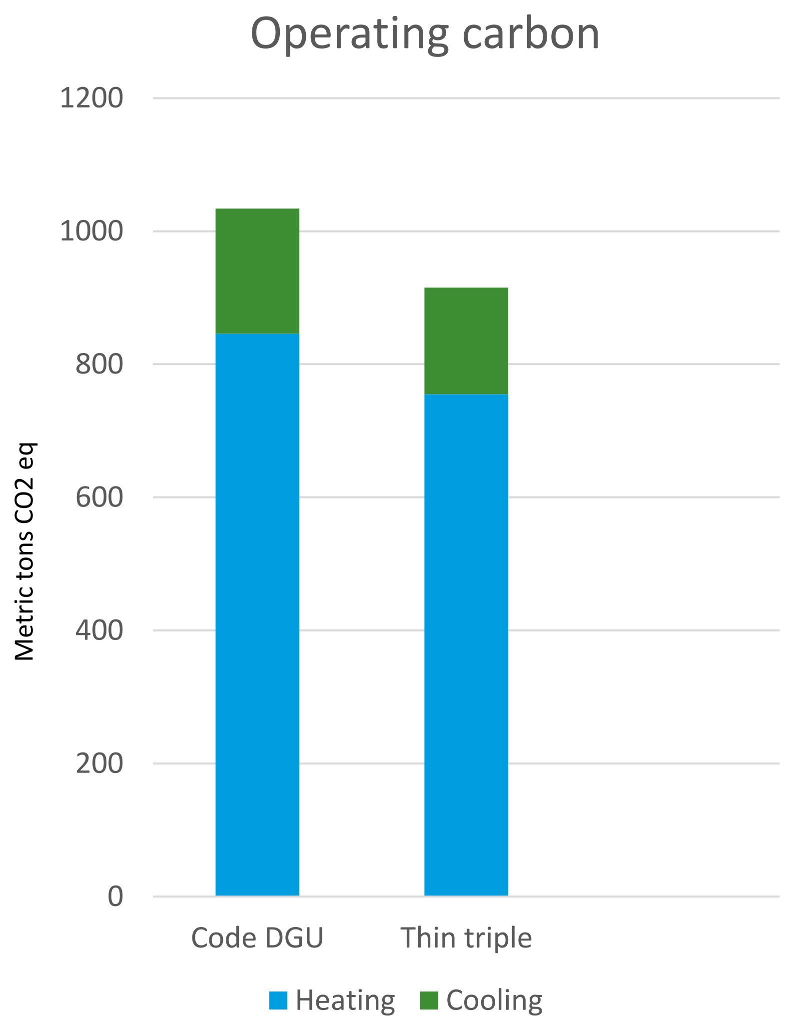
Embodied Energy		
Embodied primary energy of flat glass	2.16E+04 MJ/MT	
Total window area in analysis home	356 ft^2	
Middle lite thickness	**2.2 mm**	**1.1 mm**
Mass of 3rd lite (total for home)	184 kg	92 kg
Embodied energy of 3rd lite (total for home)	3.98 GJ	1.99 GJ
Energy Savings – ENERGY STAR Northern Zone		
Code baseline - U lowered from 0.30 to 0.22 Btu/hr ft^2 F, SHGC kept constant at 0.30		
Site energy savings	6.59 GJ/yr	
Source energy savings	6.97 GJ/yr	
Embodied energy payback period	**6.8 months**	**3.4 months**
ENERGY STAR v6 baseline - U lowered from 0.27 to 0.22 Btu/hr ft^2 F, SHGC constant at 0.30		
Site energy savings	4.04 GJ/yr	
Source energy savings	4.27 GJ/yr	
Embodied energy payback period	**11.2 months**	**5.6 months**

MJ/MT = megajoule per metric ton. GJ = gigajoule.
Assumed site-to-source conversion factor: 1.1 for gas, 3.0 for electricity

Credit – Tom Culp, Birch Point Consulting, LLC

Carbon impacts





Incentives, manufacturing

U_{glass} ~ 0.6 W/m²-K

Credit – Alpen HPP

PAWS
PARTNERSHIP FOR ADVANCED WINDOW SOLUTIONS

Utility Incentives for Better Windows

- Programs throughout the country
  - CEE and EWC compile lists
  - Better than ENERGY STAR and Energy Star Most Efficient programs are growing
    - PG&E, CA New Construction
    - EVERSOURCE, CT Retrofit
    - Minnesota Power, New Construction
    - Energy Trust, OR Retrofit
    - Others?

https://www.efficientwindows.org/downloads/UtilityIncentivesWindows.pdf
https://library.cee1.org/content/2018-residential-new-homes-program-summary/
https://library.cee1.org/content/2018-residential-windows-program-summary/

Key learnings

1. Building re-use / upgrades
2. Embodied material choices matter
3. Time-based carbon – save now
4. Material reuse
5. Operating carbon – Offsets, reduce
6. Design – low embodied impact / high return operating savings
7. Emerging technology –> better windows

References

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- https://www.energy.gov/eere/buildings/commercial-reference-buildings
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- https://adfs.nsg.com/adfs/ls/wia
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