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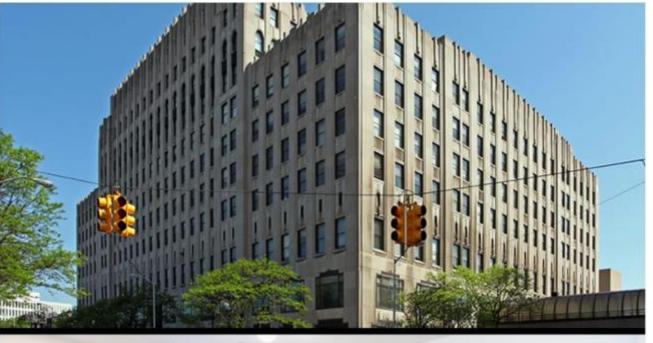


Retrofit, Restore, or Replace Understanding the whole life carbon of windows

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NSG Pilkington







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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

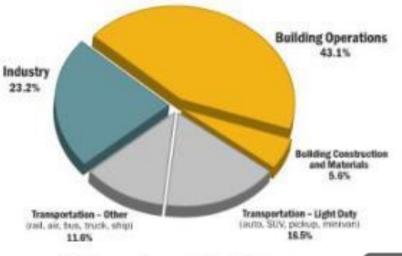
- 1. Compare the energy reduction challenges of **retrofitting versus new construction**
- 2. Identify **emerging technologies** that can help upgrade existing buildings and significantly reduce carbon usage.
- 3. Analyze how the embodied carbon and operational carbon from case studies can be applied 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.



<u>Agenda</u>

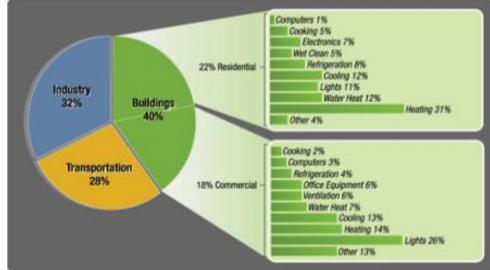
- Building consumption and window impact
- Window overview performance, design, and current state
- Baseline expectations
- Albert Kahn building case study review
- Triple bottom line project management
- Albert Kahn building energy and carbon impact
- Emerging technologies

Buildings use lots of energy...



U.S. Energy Consumption by Sector

Source: 62(011, 2030 mc / Anthecture 2030 All Pights Reserved Data Source: U.S. Energy Information Administration (2011)

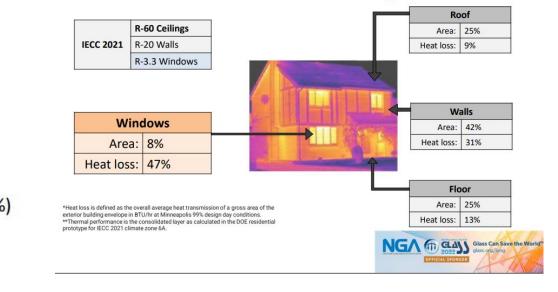


Credit – Architecture 2030, US Energy Information Administration GROUP

Buildings use lots of energy...



New Build: Windows are falling behind!



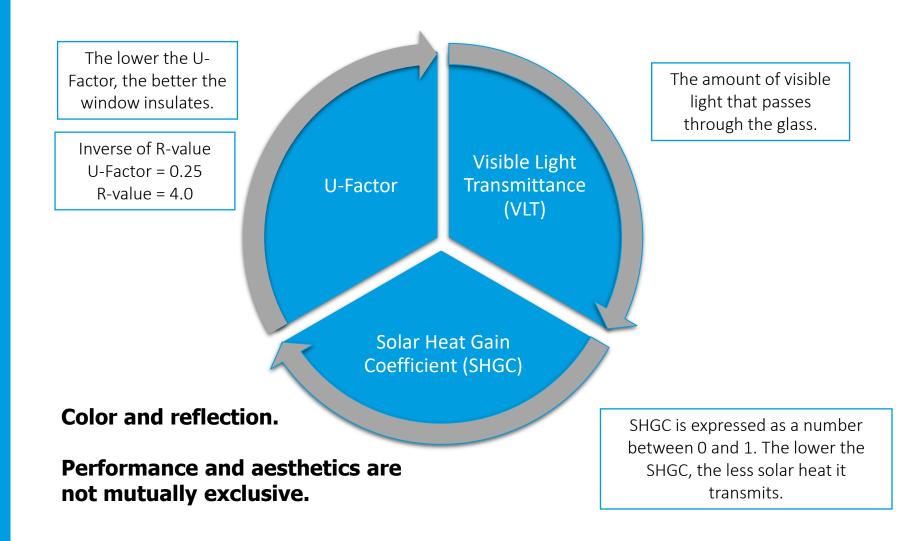
48 million Single-Pane Homes (41%) *2015 RECS







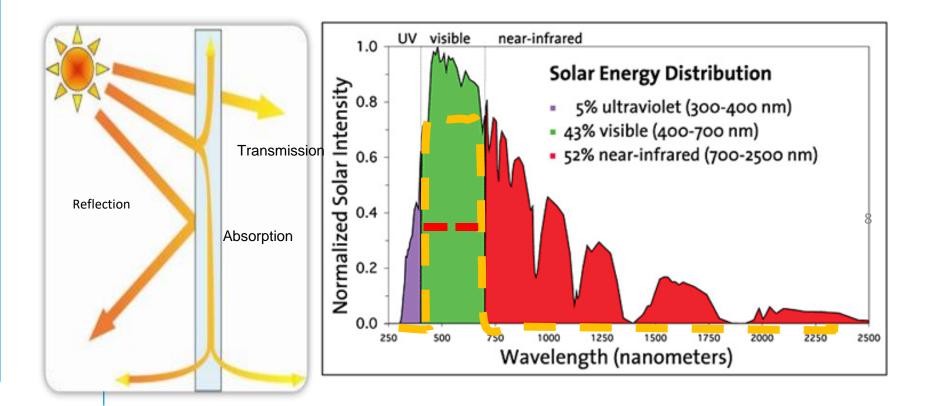
Window performance measurements



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Performance basics

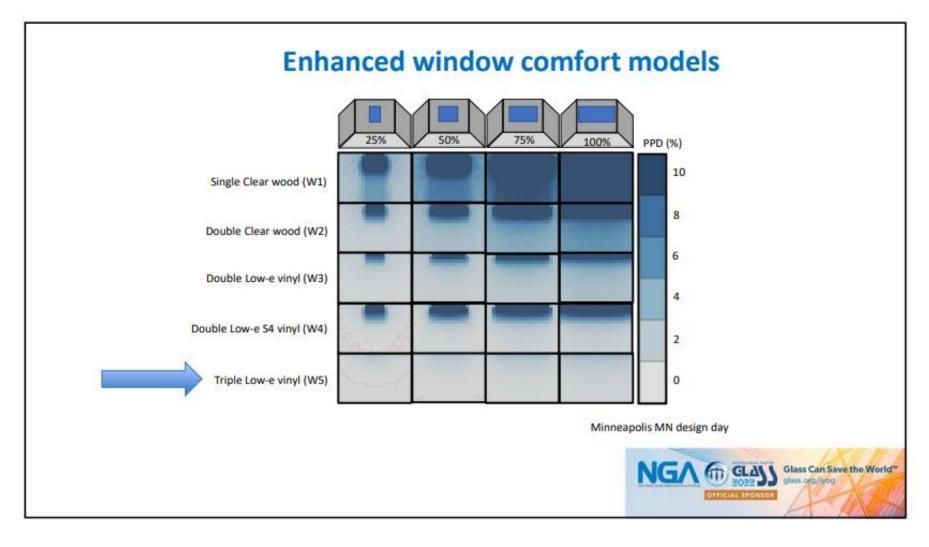
- Think of coatings in two primary functions
 - Filter Solar energy, light transmission, reflection, etc.
 - Insulator Manage re-radiation of absorbed energy (both from sun and from room)
- Potential concerns with color and aesthetics.





Thermal comfort





Credit – Steve Selkowitz, Robert Hart, LBNL



How did we get here?

Glass complexity

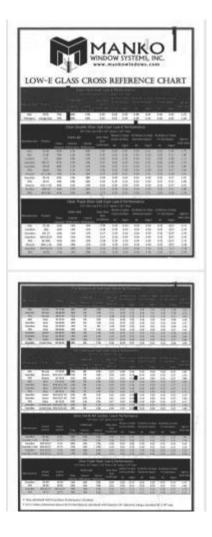
Today

1970

SELECTION TABLE/PLATE/FLOAT GLASS PRODUCTS

		Thickness	Quality	Thickness Telerauce	Mastourn Size		Approx. Weight	Luminous Illuminant C	Average Solar Radiation Transmittonce ²	
	Product				Standard	Special	Lins. per Sq. Ft.	UAwersaye Daytightu Trans.	Ultua violet Radiation	Total Sola Radiation
	PARALLEL-O-PLATE	%*	Silvering Mir, Glazing	±%*	up to 25 sq. #. up to 75 aq. ft.		3.27	B9.1	67.8	79.9
			Gizzing Commerciel		124" x 170"	124" > 252"		88.3	583	1/2
- 1	HEANY OUTY PARA. LCL-D-PLATE	96°			120" x 170"	120" 1 252"	4.08	87.3	50.5	75.2
		×.			98" × 120" 56" × 120"	120° k 264° 117° x 300°	8.54	86.0	54.0	71.0
		- *			22" 1 120"	1081 x 3031	8.17	B1.7	51.0	87.1
뷺		-12-		-30.40	72" x 120"	108* 1 300*	981	R3.3	476	63.3
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	REGULAR PLATE	15.0	6lazing	1.25-*	77" x 74"	74 1 20	1.64	90.5	75.3	86.1 52.2
de la		744*	Clazing		\$4* I L2D		2.66	50.1	44.J 39.0	46.6
i i i i	PARALLEL-D-GREY	36-	CURCINE	-141	96" x 138"	120.1 × 192.1	3.27	14.2	28.5	32.8
ĩ,	HEAVY DUTY	3%**	Commercise'		96° x 120°	[17" x 264"	4.90	21.3	197	24.3
	PARALEL-D-GREY	350	and the second second	100	96" x 120" 96" x 138"	120" × 300" 120" × 197"	3.2/	48.5	275	41.0
	PARALLC. D-BRONZE	140 34-3	Glazing	1.262	95" x 120"	117" x 264"	4.90	34.4	16.7	21.3
	MEANY OUTY MARAL1EL-D-BRONZE	16.4	Commorcial	1.0	90" x 170"	110" + 300"	6.54	24.8	10.7	18.5
-	Rough Both Sides	0.	-	1 897			3.82	89.7	65.8	75.3
	Grey	5.º	Commarcial		100° × 144°3	24" x 144**		38.9	35.7	41.7
Rough Plate	Bronze			a second		and the second second		44.2	24.0	17.C 43.7
0.	lies Absorbing				BOY # 144**	1007 1 144-14	L .	72.7	7.9.8	43.6
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PO	Regidar	1964	Constituted					41.3	36.7	44.1
œ	Brotze	- M.	Gaennerenan					45.1	25.5	36.8
	Heat Atoorbing	1540	Commercial	Line	76" L 138"	36" x 138"	3.47	13.8	41.3	45.0
*	REGULAR	194	Glazing	di Sant	124" × 170"	12/* x 262*	3.27	89.1	67.8	799
Float	HEAT ABSORBING	14*	Gazing	+32	96" x 128*	120" × 192"	3.27	74.7	41.9	46.3
-	flex Tempered Pl	the and l	Inat		Dimensional Tolerance	Maximun Size	-			
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		ד	Blacing			96* x 120** 95* x 120**	408	323	64.3	72.3
	REGULAR PLATE		Commercial	2.50		96° x 132°	400	87.3	0.5	75.2
		144		1.55°.86° X5°.86° 		96" x 132"	6.54	1 85.8	3.kc	71.0
ų,		16				98" x 132"	8.17	82.7	51.0	67.1
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B		24.		± <i>V</i> A1		95× = 120*	3.27	44.2	39.0	32.8
12	GREY	150	Commercia			35" 1 132"	4.90	21.3	197	24.3
2		24.5	A Louise transmission			36" x 137" 96" x 132"	327	48.5	27.5	41.0
	BRONZE	<u>K</u> *	Glazing			36" x 132"	+ 490	34.4	15.7	27.0
		34	Commercia			96° x 192"	6.54	24.8	10.7	18.5
-	Rough Both Side		Commercia	al ±16:"	-%*	\$6* x 132*				
	Regular							88.7	65.6	76.
	Gray	8.						38.0	35.7	41.3
4								44.2	39.8	43.3
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tough Plate	Eronze Heat Absorbing Polished Gree Sile Degular	ke - 112/	Commercia	1 150	±%"	96" x 120"	3.07	41.3	36.7	79.
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Rough	Bronze Heat Absorbing Politika Cone Sid Regular Groy Ricetz Heat Absorbing			1 1 360 ±360	±%**	96° x 120°		41.9 46.1 73.8 89.1	36.7 25.5 41.3 67.8	46 38.4 45.1 79.1
Float Rough Plate	Bronze Heat Aksorbing Polished One Sie Prguler Groy Rroeze	962	Commercia Olazing Glazing				3.27	41.9 46.1 73.8 89.1	36.7 25.5 41.3	

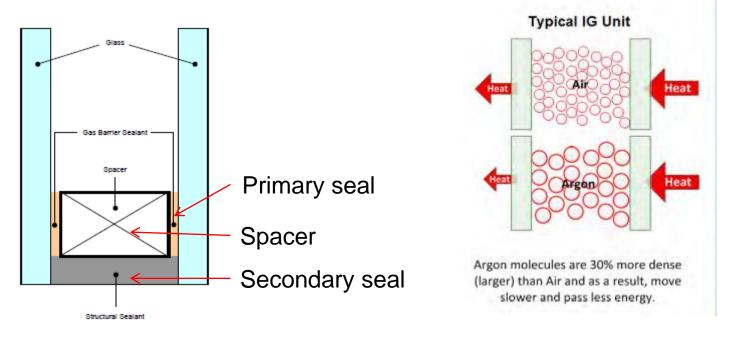




IG construction



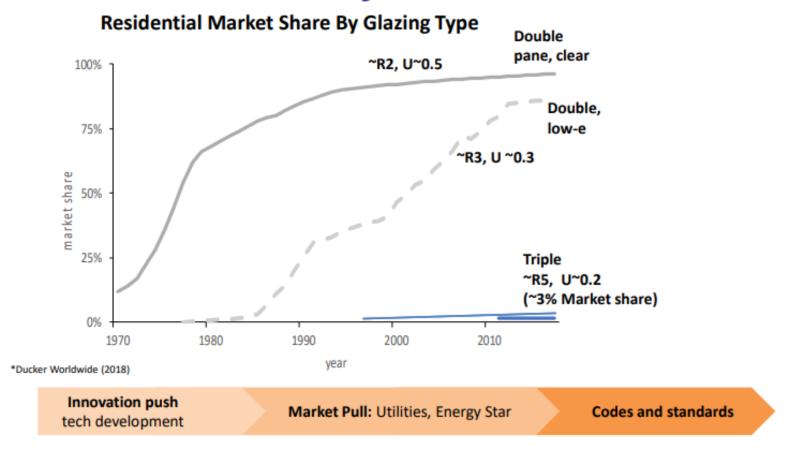
- More than one piece of glass (double glaze, triple glaze)
- Different types of seals used
- Variety of gases to fill space
 - Impacts convection, conduction



• Potential concerns with seal failure, moisture, aesthetics



Markets Evolve Slowly...How to Accelerate?

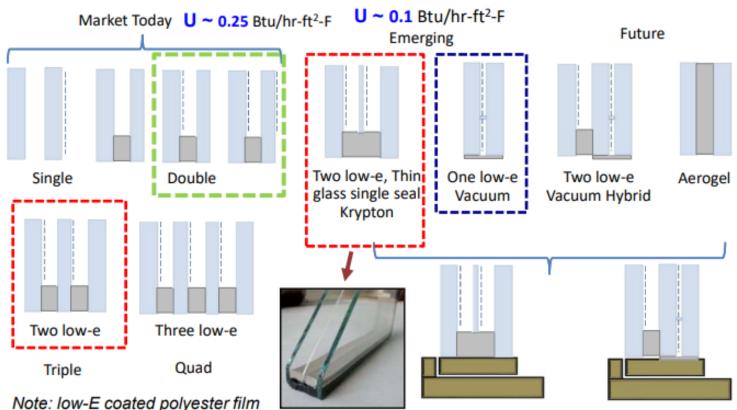


Credit – Steve Selkowitz, LBNL

Higher performance available



HIGHLY INSULATING GLAZING SOLUTIONS:

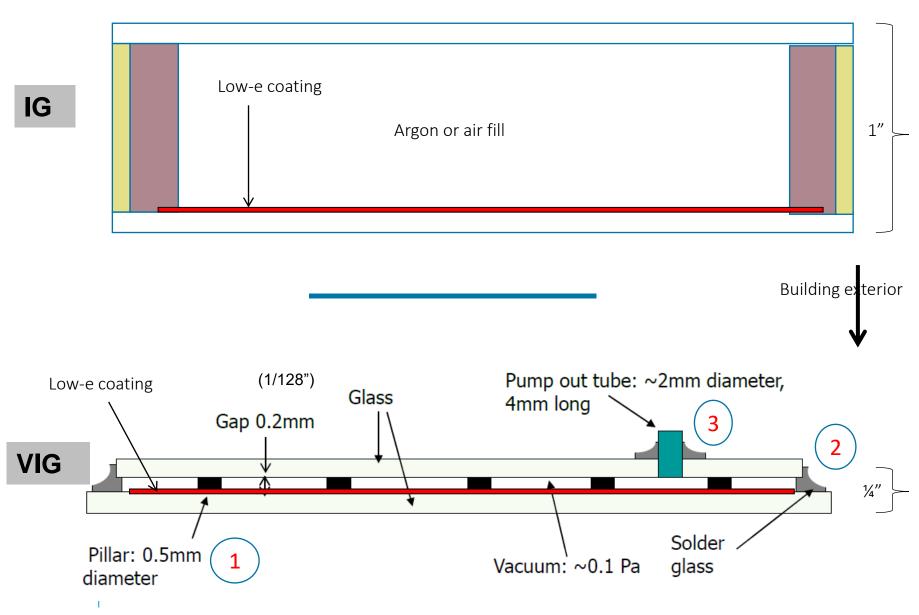


Super-insulating frame with highly insulated glazing

Credit – Steve Selkowitz, LBNL

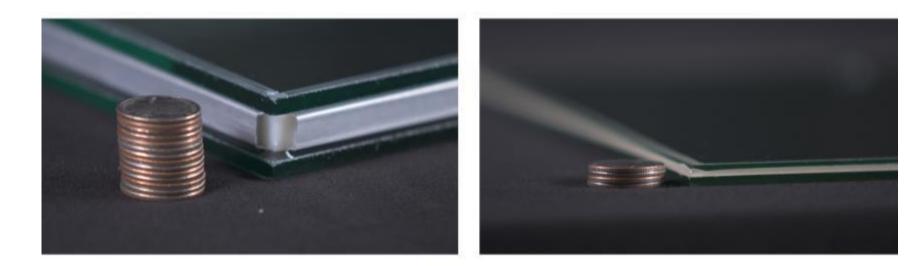
can be alternative middle glazing.

IG versus VIG construction



IG versus VIG construction







Albert Kahn office building – Detroit

- 1931
- 11 story
- 320,000 ft² building, 17,500 ft² glazing area
- Bronze, double-hung windows, monolithic ¼" glass

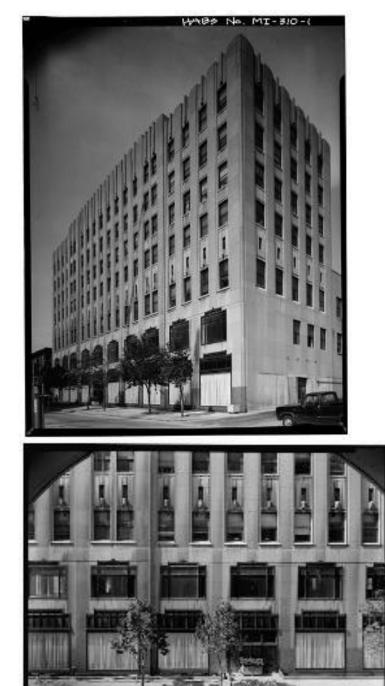


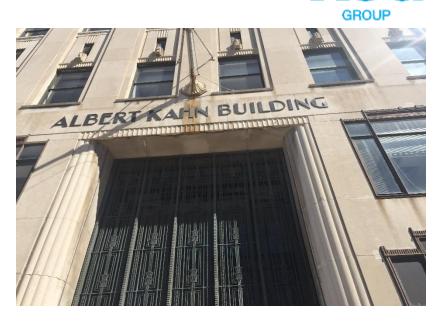
The Kahn



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





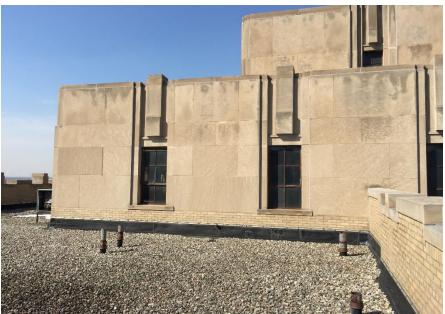






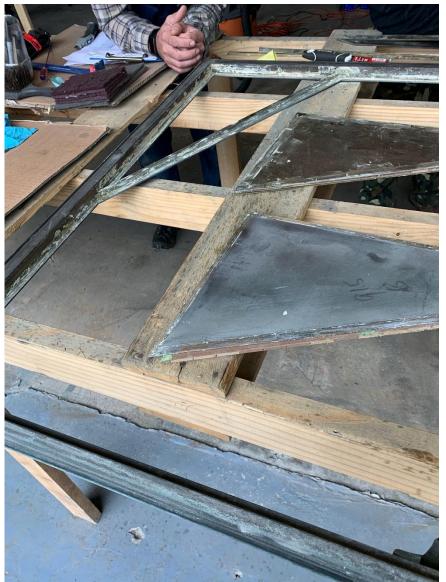


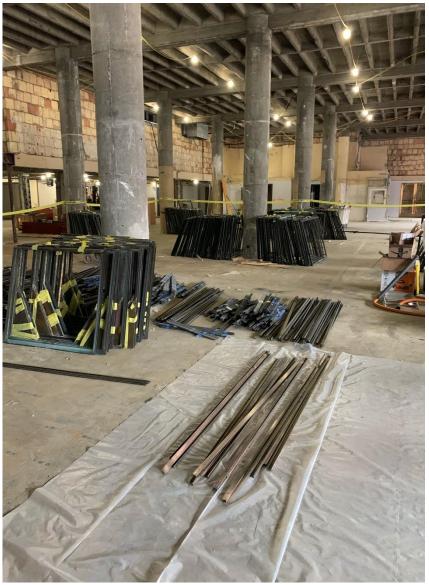




Allen Architectural Metals ...







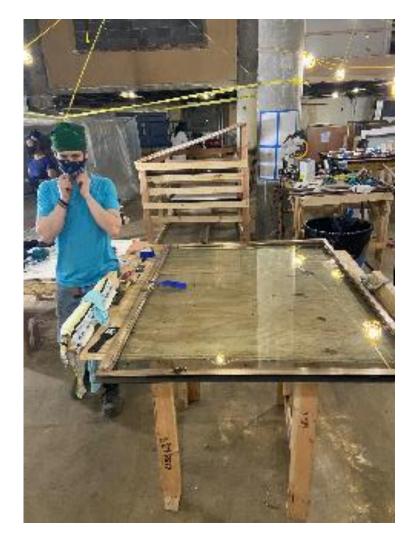
























North Equities Group / Lutz Real Estate















Energy and carbon impact

Counting Carb_(on)s – 40% buildings

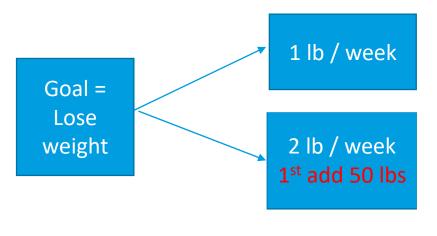
Operational Carbon

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

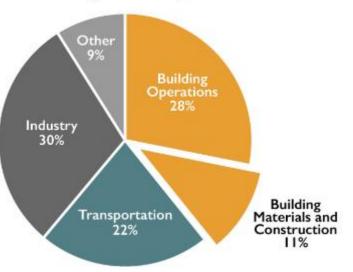
Embodied Carbon

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

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



Global CO₂ Emissions by Sector





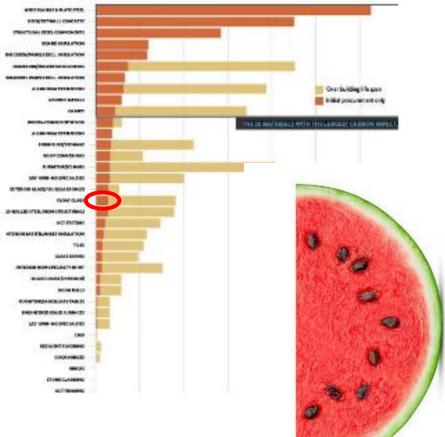


Embodied - Glass and window impact

- 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

UNDERSTANDING THE IMPACT OF MATERIALS

The impact of commonly used building metantish, both at initial procumenter (or ange) and over a building's estimated life span of 60 years. [policy], Structural materials have fire largest initial impact; over time, interior design elements and materials increase in analympact; are replacements odd up.



Albert Kahn office building – Detroit





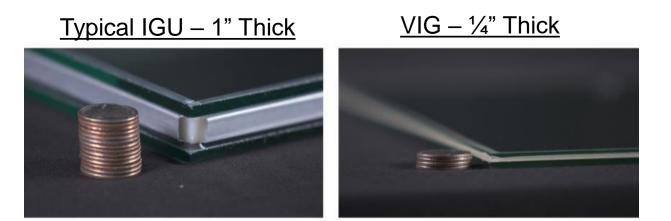
The Kahn

- 1931
- 11 story
- 320,000 ft² building, 17,500 ft² glazing area
- 700 bronze, double-hung windows, monolithic 1/4" glass



Existing building $-\frac{1}{4}''$ monolithic (reference)

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



DOE reference building



	Reglazing	Interior	Interior	Aluminium		
	with VIG	Storm with	Storm with	replacement	Current operating c	arbon
		Steel Frame	Aluminium	windows	(metric tons CO2 ec	
			Frame		(incare tone cozy	
Total Embodied Carbon (tonnes CO ₂ E)	25	33	43	73		
Operating Carbon Annual Savings (tonnes CO ₂ E)	-226	-161	-161	-233		
Total Y1 Carbon Impact (tonnes CO ₂ E)	-201	-126	-114	-160		
Embodied Carbon Debt Payback (months)	1	3	3	<mark>4</mark>	Operating carbon – met	ric tons CO2 /year
Breakeven point – years payback embodied carbon				<mark>11</mark>	35000 30000 25000	
					20000	
					15000	
					10000	
					5000	

0

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Key learnings



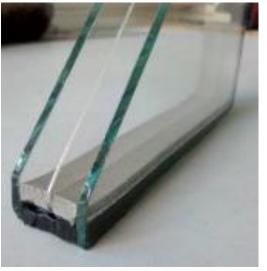
- 1. Building re-use / upgrades
- 2. Embodied material choices matter
- 3. Time-based carbon save now

Emerging technology













Triple glazing – Juice worth the squeeze?



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

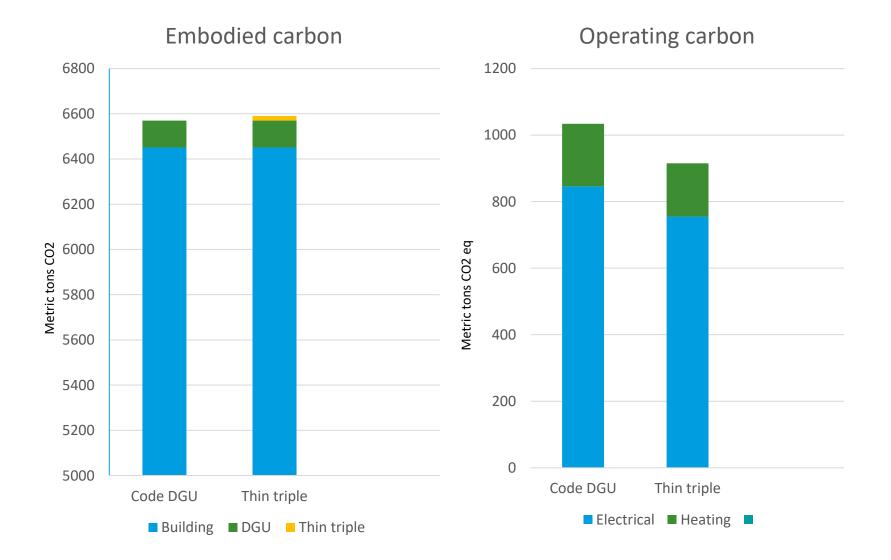
Embodied Energy				
Embodied primary energy of flat glass	2.16E+04	2.16E+04 MJ/MT		
Total window area in analysis home	356	356 ft ²		
Middle lite thickness	2.2 mm	1.1 mm		
Mass of 3rd lite (total for home)	184 kg	92 kg		
Embodied energy of 3 rd lite (total for home)	3.98 GJ	1.99 GJ		
Energy Savings –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

Carbon impacts





2/23/2022

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
- Design low embodied impact / high return operating savings
- 7. Emerging technology -> better windows

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
- Design low embodied impact / high return operating savings
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References



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2/24/2022



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