BUILDINGENERGY BOSTON

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

Kyle Sword (NSG Pilkington) Katherine Allen-Lezak (Allen Architectural Metals)

Curated by Michael Simons (Abode)

Northeast Sustainable Energy Association (NESEA) February 28, 2022





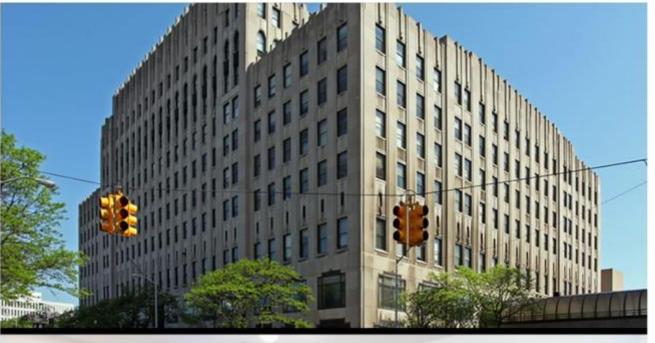
Retrofit, Restore, or Replace

Understanding the whole life carbon of windows

Kate Allen-Lezak – President – Allen Architectural Metals

Kyle Sword - Manager Business Development

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.

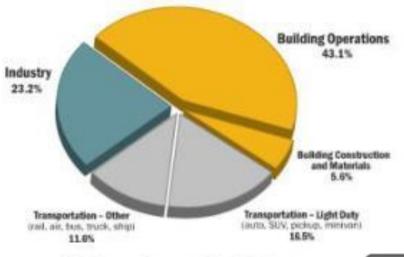
Learning Objectives

- 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.

<u>Agenda</u>

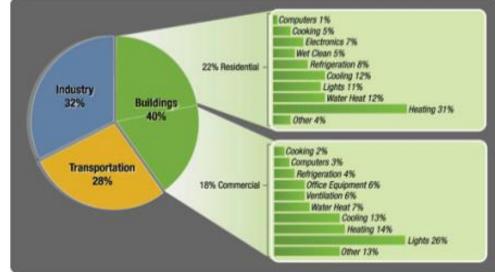
- Building consumption and window impact
- Window overview performance, design, and current state
- Baseline expectations
- Albert Kahn building case study review
- Triple bottom line project management
- Albert Kahn building energy and carbon impact
- Emerging technologies

Buildings use lots of energy...



U.S. Energy Consumption by Sector

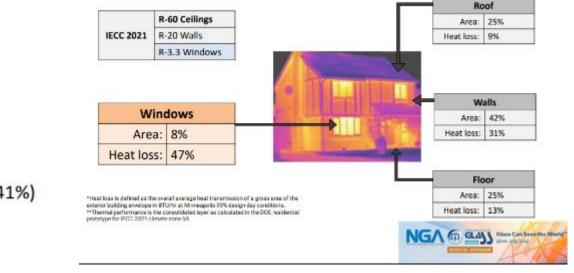
Source: 62(011, 2030 mc / Anthecture 2030 All Pights Reserved Deta Source: U.S. Energy Information Administration (2011)

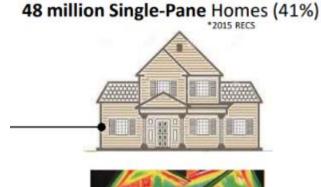


Credit – Architecture 2030, US Energy Information Administration

Windows are huge opportunity...

New Build: Windows are falling behind!



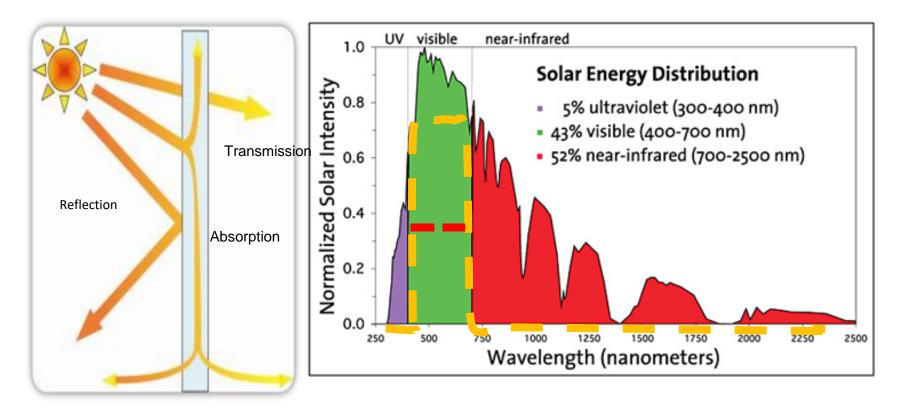




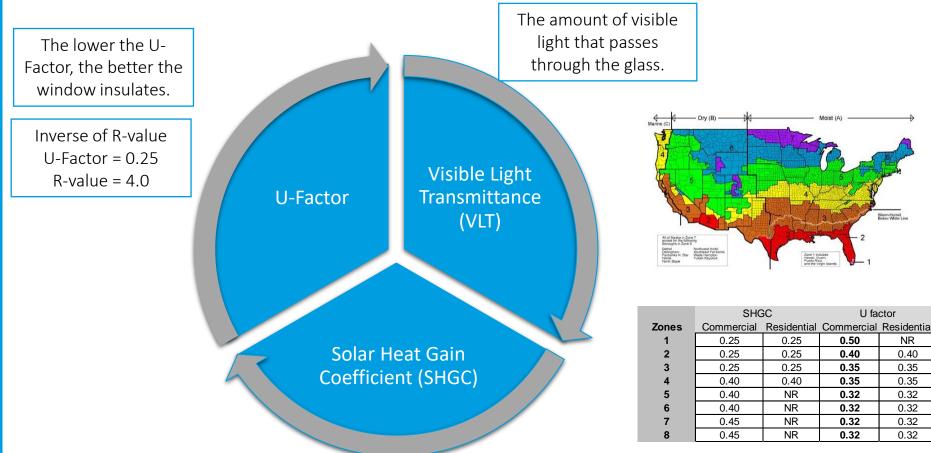
Credit – Steve Selkowitz, LBNL

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



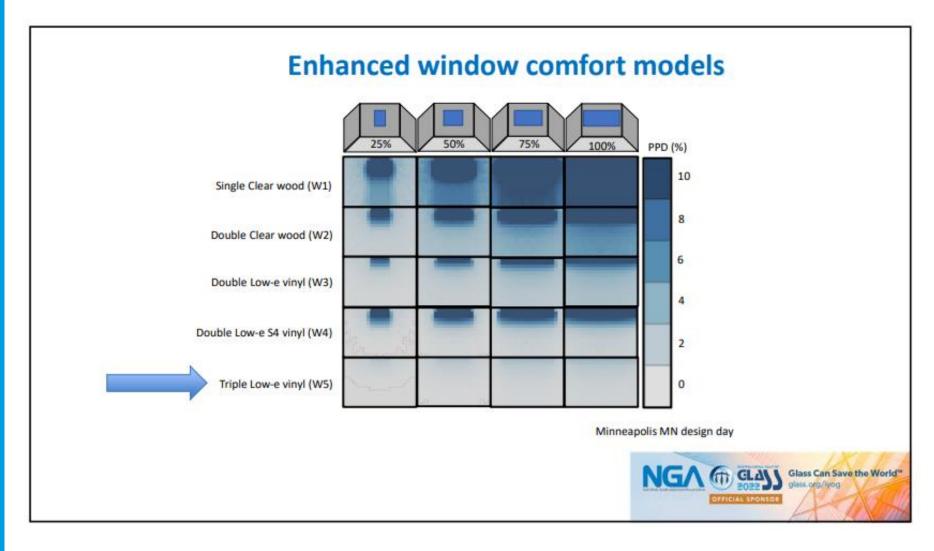
Color and reflection.

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.



Thermal comfort



Credit – Steve Selkowitz, Robert Hart, LBNL

How did we get here?

Glass complexity

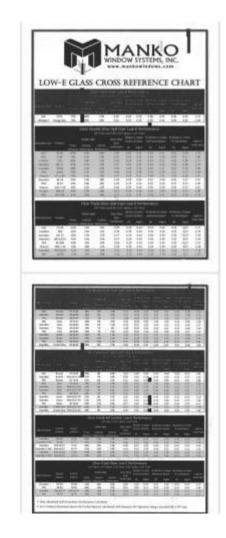
1970

SELECTION TABLE/PLATE/FLOAT GLASS PRODUCTS

VARALLEL-O-PLATE	Thickness %* %* %* %* %* %* %* %* %* %*	Quality Strearing Mir. Glazing Glazing Commercial	<u> </u>	Standard up to 25 sq. #. up to 75 sq. ft. 124" x 170" 120" x 170" 98" x 120" 56" x 120"	Special 124* > 252* 120* > 252*	Approx. Weight Lins. per Sq. Ft. 327	Average Daylight	Ultraviolet	-
IEANY DUTY MRA.LEL-D-PLATE REGULAR PLATE PARALLEL-D-GREY NTAVY DUTY	100 100 100 100 100 100 100 100 100 100	Mir, Glazing Glazing Commerciel		up to 75 sq. ft. 129" x 170" 120" z 170" 96" x 120" 56" x 120"	124" > 252"	3.27	Average Daylighti Trans.	Radiation	Total Sola Radiation
IEANY DUTY MRA.LEL-D-PLATE REGULAR PLATE PARALLEL-D-GREY NTAVY DUTY	100 100 100 100 100 100 100 100 100 100	Gizzing Commerciel		124" x 170" 120" x 170" 98" x 120" 56" x 120"	124" > 252"	3.27			20.0
PARA LEL O-PLATE RECULAR PLATE PARALLEL-D-CREY	* * * * * * * * *	Commercial		120" x 170" 96" x 120" 56" x 120"	124 1 252	128 S 122 S 1	89.L	67.8	79.9
PARA LEL O-PLATE RECULAR PLATE PARALLEL-D-CREY	* * * * * * * * *			98* x 120* 56* x 120*		4.08	88.3	64.3	112
PARA LEL O-PLATE RECULAR PLATE PARALLEL-D-CREY				-021 x "82	120" x 264"	4.90	87.3	50.5	75.2
PARA LEL O-PLATE RECULAR PLATE PARALLEL-D-CREY					117" x 500"	8,54	86.0	54.0	71.0
PARALLEL-D-GREY	1400 1500			72" + 120"	108* x 303*	8.17	B1.7	51.0	87.1
PARALLEL-D-GREY	150	and the second second		72° x 120°	108. 1 300.	981	R3.3	476	63.3 59.3
PARALLEL-D-GREY			-Na ^v -Sa ^v	72" + 120"	145° x 300" 74° x 300"	1.45	80.8	753	86.1
REAVY DUTY		Glazing	T.W.	84* 1 120	14. 1.20	2.56	50.3	44.J	52.2
		34" Cliszing 34" Counterpat' 55" Counterpat'	=%*	96" x 138"	120' x 192*	3.27	19.2	39.0	46.6
				96" x 120"	[17" x 264*	4.90	30.0	28.5	32.8
PARALEL-D-GREY	50			95" x 120"	1:0" × 300*	6.54	21.3	(97	24.3
PARALLE D-BRDNZE	120	Glazing		96" a 138"	150 A 185.	3.2/	48.5	275	2/.0
NEAVY BUTY	M-1	Commercial	1.264	95* x 120*	117" x 264"	4.90	24.8	10.7	18.2
MARALLEL-O-BROWZE	N.~	Contraction of the second		90° s 170°	110* x 300*	8.34	2+15	40.7	10.0
Rough Both Sides		Communial		L INTE V LLAPS			39.7	65.8	75.3
			4.857		274" x 144**	3.62	38.9	35.7	41.7
	a.	- on marchan	10000				44.2	24.0	17.C
liest Absorbing				80Y x 144**	100*1144***		727	298	43.7
Polithed Das Side				19 19 19 19 19 19 19 19 19 19 19 19 19 1	1		19.0	67.0	791
	1.000	Caminercial	±/w*	76° x 124°	96° x 135°	3.47			44.1
	26.						45.1	25.5	36.8
	1940	Commercial	THE	76" . 138"	36" x 138"	3.47	73.8	41.3	45.0
			de Saint	124" × 170"	12/ × 252*	3.27	891	67.8	799
			+32	96" x 128*	120" × 192"	3.27	74.7	41.9	46.3
			-						
a sampanua Fia				Dimensional	Maximum				
				Olmensional Tolerence	Size	1.12	95.1	62.8	1 29.9
12 C	×"	Black			Size 96* x 128**	3 77	85.1 32.3	67.8 64.3	79.9
			±'60'		Size 96* x120** 95* x120*	377 408 490	85.1 82.3 87.2	64.J 805	77.3
DECIMAN IF ATF		Blackog	±'60'		Size 96* x 128**	409 400 6.54	88.3 87.3 86.0	64.3 805 34.5	77.3
REGULAR PLATE	24** #6* 24* 25*		1 1/2 " . 34"		Size 96* x120** 96* x122** 96* x132** 96* x132** 96* x132** 96* x132**	408 400 654 8.17	82.3 87.1 86.0 84.7	64.3 805 54.9 51.0	77.3 75.2 71.0 67.1
REGULAR PLATE	21 - 22 - 22 - 22 - 22 - 22 - 22 - 22 -	Blackog	1.96° A4*	Toleranze	Size 96*x120** 96*x122* 96*x132* 96*x132* 96*x132* 96*x132* 96*x132*	408 400 6.54 8.17 8.81	88.0 87.2 86.0 87.7 85.7 83.3	64.J 80.5 34.5 51.0 47.5	77.3 75.2 71.0 67.1 63.3
REGULAR PLATE	21 - 22 - 22 - 22 - 22 - 22 - 22 - 22 -	<u>Blacing</u> Commercial	1 1/2 " . 34"		Size 96*x120* 96*x122* 96*x132* 96*x132* 96*x132* 96*x132* 96*x132* 74*x132*	408 499 654 8,17 9,81 11,45	88.0 87.3 86.0 87.7 85.7 83.3 80.8	64.J 80.5 34.5 51.0 47.5 45.0	77.3 75.2 71.0 67.1 63.3 59.3
	N= Ha N= N= N= N= N= N=	Blackog	1.96° A4*	Toleranze	Size 96* ± 120* 96* ± 122* 96* ± 132* 96* ± 132* 96* ± 132* 96* ± 132* 74* ± 110* 95* ± 120*	4 09 4 90 6 54 8 17 9 81 11 45 3 27	88.0 87.3 88.0 84.7 83.3 80.8 44.2	64.J 805 34.5 51.0 47.5 45.0 3910	77.3 75.2 71.0 67.1 63.5 59.3 46.0
REGULAR PLATE	3" #1" 31" 31" 31" 31" 31" 31" 31" 31" 31"	<u>Blacing</u> Commercial	1.96° A4*	Toleranze	Size 96*x120* 96*x120* 96*x132* 96*x132* 96*x132* 96*x132* 96*x132* 96*x132* 95*x132* 95*x132*	4 08 4 09 6.54 8.17 9.81 11.45 3.27 4.90	88.3 87.3 88.8 87.7 83.3 80.8 80.8 44.2 30.0	64.J ÷0.5 ×1.5 51.0 47.5 45.0 3910 28.5	77.3 75.2 71.0 67.1 63.3 59.3 46.0 32.8
	31" #14" #14" #14" #14" #14" #14" #14" #1	Gamercial Commercial Glazing Commercial	1 %****** ******* -*****	Toleranze	Size 96*x120* 96*x122* 96*x132* 96*x132* 96*x132* 74*x110* 95*x132* 74*x110* 95*x132* 96*x132*	4 09 4 90 6 54 8 17 9 81 11 45 3 27	82.3 87.3 86.0 87.7 83.3 80.8 44.2 30.0 21.4 45.5	64.J 605 51.0 47.6 45.0 3910 28.6 197 27.5	77.3 75.2 73.0 67.1 63.3 59.3 46.0 32.8 24.3 41.0
GREY	31" 16.4 1	Graning Commercial Dirating Commercial Glazing	1.96° AL* X1° Me	Toleranze	Size Size S5*x120* 95*x120* 95*x132* 95*x132* 95*x132* 95*x132* 95*x132* 95*x132* 95*x132* 95*x132* 95*x132* 95*x132*	408 409 654 8,17 9,81 11,45 3,27 4,90 6,54 4,90 4,90	28.3 88.0 87.3 88.0 87.7 83.3 80.8 44.2 30.0 21.3 46.5 36.4	64.1 60.5 50.5 51.0 47.5 45.8 3300 28.6 1977 27.5 16.7	77.3 75.2 71.0 67.1 63.3 59.3 46.0 32.8 24.3 41.0 27.0
	31" #14" #14" #14" #14" #14" #14" #14" #1	Gamercial Commercial Glazing Commercial	1 %****** ******* -*****	Toleranze	Size 96*x120* 95*x120* 95*x132* 96*x132* 96*x132* 96*x132* 96*x132* 95*x12* 95*x132* 95*x132*	408 499 6.54 8.17 9.81 11.45 3.27 4.90 6.54 3.27 4.90 6.54 3.27	82.3 87.3 86.0 87.7 83.3 80.8 44.2 30.0 21.4 45.5	64.J 605 51.0 47.6 45.0 3910 28.6 197 27.5	77.3
GREY	3" 10" 10" 10" 10" 10" 10" 10" 10" 10" 10	Graning Commercial Dirating Commercial Glazing	1 %****** ******* -*****	Toleranze	Size Size S5*x120* 95*x120* 95*x132* 95*x132* 95*x132* 95*x132* 95*x132* 95*x132* 95*x132* 95*x132* 95*x132* 95*x132*	408 409 654 8,17 9,81 11,45 3,27 4,90 6,54 4,90 4,90	22.3 85.0 84.7 83.3 80.8 44.2 32.0 21.4 45.5 34.4 24.8	64.1 805 34.5 47.5 45.8 3300 28.6 1977 27.5 16.7 10.7	77.3 75.2 73.0 67.1 63.3 59.3 46.0 32.4 24.3 41.0 27.0 18.3
GREY	200 200 200 200 200 200 200 200 200 200	Graning Commercial Dirating Commercial Glazing	1 55.0 AL	±Na*	Size 56* x120* 55* x120* 55* x120* 55* x122* 56* x132* 56* x132* 56* x132* 56* x132* 56* x132* 56* x132* 56* x132* 56* x132* 56* x132*	4 08 4 09 6 54 8 .17 8 .81 11.45 3.27 4.30 6.54 4.30 6.54	22.3 87.3 86.0 87.7 83.3 80.8 44.2 21.3 44.2 21.4 24.8 33.4 24.8 88.7	64.1 60.5 34.5 51.0 45.0 28.6 1977 27.5 16.7 10.7 65.6	77.3 75.2 71.0 67.1 63.3 59.3 46.0 32.6 24.3 41.0 27.0 1R.5 78.5
GREY BRONZE Rough Both Sides Rogular Gray	3" 10" 10" 10" 10" 10" 10" 10" 10" 10" 10	Graning Commercial Dirating Commercial Glazing	1 55, 7 50 ° 35 ° 50 ° 30 ° 30 °	Toleranze	Size Size S5*x120* 95*x120* 95*x132* 95*x132* 95*x132* 95*x132* 95*x132* 95*x132* 95*x132* 95*x132* 95*x132* 95*x132*	408 409 654 8,17 9,81 11,45 3,27 4,90 6,54 4,90 4,90	22.3 87.3 86.0 82.7 83.3 80.8 44.2 32.0 21.3 46.5 36.4 24.8 88.7 38.9	64.3 605 51.0 47.6 45.6 39.0 28.5 19.7 27.5 16.7 10.7 65.6 35.7	77.3 75.2 73.0 67.1 633 59.3 59.3 59.3 59.3 59.3 59.3 59.3 59
GREY BRONZE Rough Both Sides Regular Groy Bronze	200 200 200 200 200 200 200 200 200 200	Slading Commercial Dissing Commercial Glazing Commercial	1 55, 7 50 ° 35 ° 50 ° 30 ° 30 °	±Na*	Size 56* x120* 55* x120* 55* x120* 55* x122* 56* x132* 56* x132* 56* x132* 56* x132* 56* x132* 56* x132* 56* x132* 56* x132* 56* x132*	4 08 4 09 6 54 8 .17 8 .81 11.45 3.27 4.30 6.54 4.30 6.54	22.3 87.3 85.0 87.7 83.3 80.8 44.2 30.0 21.3 44.5 32.4 24.8 86.7 38.9 44.2 44.2 44.5 32.4 24.8 86.7 38.9 44.2	64.1 64.1 60.5 51.0 47.5 45.9 39.0 22.5 19.7 10.7 66.6 35.7 24.0	77.3 75.2 71.0 67.1 67.1 67.3 58.3 58.3 46.0 22.6 24.3 45.0 27.5 27.5 27.5 27.5 27.5 27.5 27.5 27.5
GREY BRONCE Rough Both Sleve Begular Gray Efonza Hont Acambian	200 201 201 201 201 201 201 201 201 201	Slading Commercial Dissing Commercial Glazing Commercial	1 55, 7 50 ° 35 ° 50 ° 30 ° 30 °	±Na*	Size 56* x120* 55* x120* 55* x120* 55* x122* 56* x132* 56* x132* 56* x132* 56* x132* 56* x132* 56* x132* 56* x132* 56* x132* 56* x132*	4 08 4 09 6 54 8 .17 8 .81 11.45 3.27 4.30 6.54 4.30 6.54	22.3 87.2 88.0 87.7 83.3 80.8 44.2 21.3 46.5 21.3 35.4 24.8 88.7 35.9 88.7 35.9 44.2 72.7	64.3 34.5 51.0 37.5 45.9 39.0 225.5 16.7 10.7 65.6 39.8 39.0 27.5 16.7 27.5 16.7 27.5 16.7 27.5 16.7 27.5 16.7 27.5 16.7 27.5 16.7 27.5 16.7 27.5 16.7 27.5 16.7 27.5 16.7 27.5	77.3 75.2 71.0 653.3 583.3 583.3 583.3 583.3 583.3 583.3 583.3 583.3 583.3 584.3 784.4 775.2 775
GREY BRONZE Bogular Gray Bronze Bronz	200 201 201 201 201 201 201 201 201 201	Slading Commercial Dissing Commercial Glazing Commercial	1 55, 7 50 ° 35 ° 50 ° 30 ° 30 °	<u>Toleranze</u> ± %* + 36*	Size Size Si x 120" Si x 132" Si x 132"	4 08 4 09 6 54 6 54 5 87 11.45 3.27 4.30 6.54 3.82 3.82	22.3 37.3 85.8 84.7 85.8 85.7 85.3 85.7 83.3 84.4 24.2 30.0 21.3 84.5 35.4 24.8 88.7 35.0 44.2 24.8 88.7 35.0 44.2 24.8 88.7 35.0 44.2 24.8 88.8 88.8 88.8 80.7 80.8 80.8 80.8 80.7 80.8 80.8 80.8 80.7 80.8 80.7 80.8 80.7 80.8 80.7 80.8 80.7 80.8 80.7 80.8 80.8 80.7 80.8	64.3 60.5 51.0 67.5 67.5 67.5 7	77.3 75.2 77.0 67.3 63.3 59.3 59.3 46.0 92.6 92.6 92.6 92.6 92.6 92.6 92.6 92.6
GREY BRONCE Rough Both Sleve Begular Gray Efonza Hont Acambian	200 201 201 201 201 201 201 201 201 201	Slading Commercial Dissing Commercial Glazing Commercial	1 35° 30° Xi 36° Xi 3° ±%*	±Na*	Size 56* x120* 55* x120* 55* x120* 55* x122* 56* x132* 56* x132* 56* x132* 56* x132* 56* x132* 56* x132* 56* x132* 56* x132* 56* x132*	4 08 4 09 6 54 8 .17 8 .81 11.45 3.27 4.30 6.54 4.30 6.54	823 87.0 88.0 87.7 83.3 80.0 44.2 380.0 21.3 44.2 384.5 384.5 384.5 384.5 384.7 72.7 72.7 72.7 72.7 88.9 41.9	64.3 60.5 71.5 60.5 60.5 71.5 71.5 72.5 7	77.3 75.2 71.0 87.1 63.3 59.3 59.3 48.6 32.6 32.6 32.6 32.6 32.6 32.6 32.6 32
GREY BRONZE Begular Grey Bronze Peter Adopting Peter Adopting Degular Grey Bronze Bronze	30" 50" 50" 50" 50" 50" 50" 50" 50" 50"	Blacing Opmmercial Bitting Commercial Glazing Commercial Commercial	1 35° 30° Xi 36° Xi 3° ±%*	<u>Toleranze</u> ± %* + 36*	Size Size Si x 120" Si x 132" Si x 132"	4 08 4 09 6 54 6 54 5 87 11.45 3.27 4.30 6.54 3.82 3.82	823 873 888 827 833 808 442 320 213 465 344 248 867 380 442 727 887 887 887 887 887 887 887 887 88	¢13 ¢05 315 315 45.0 330 2265 157 16.7 10.7 10.7 330 330 275 45.0 330 26.6 330 330 357 275 38.7 39.8 67.0 39.8 67.0 30.7 30	77.3 75.2 73.0 87.1 85.3 59.3 59.3 59.3 59.3 59.3 59.3 59.3 5
GREY BROWZE BROWZE Bronze Bronze Heat Advanting Popularia Case Side Popularia Case Side Popularia Case Side Popularia Carry Riseatz Heat Attaunibing	34" 54" 54" 54" 54" 54" 54" 54" 5	Blackog Gommercial Dissing Commercial Giazing Commercial Commercial	1 <u>15</u> -25 ² <u>X1-36</u> ² <u>56</u> -55 ² ±56 ²	Tolerance ± %* ± %** ± %**	Site Set 2120" Set 74.120" Set 74.120"	4 08 4 09 4 09 5 07 7 881 11,45 11,45 11,45 4 30 6 59 4 30 6 59 3.82 3.82	823 87.3 85.6 84.6 82.7 83.3 80.8 80.8 44.2 21.3 44.5 34.4 24.8 24.8 88.9 44.2 44.2 24.8 93.3 44.2 24.8 24.8 88.7 38.9 41.3 41.3 73.8 73.8	64.3 005 34.5 51.0 45.5 45.5 22.6 137.7 10.7 66.4 39.2 67.0 39.2 67.0 38.7 25.5 44.3	77.3 75.2 73.0 67.1 63.3 46.0 24.3 45.0 27.0 75.2 73.0 67.1 34.0 27.0 75.2 76.3 37.1 37.1 37.1 37.1 37.1 37.1 37.1 37
GREY BRONZE Begular Grey Bronze Peter Adopting Peter Adopting Degular Grey Bronze Bronze	30" 50" 50" 50" 50" 50" 50" 50" 50" 50"	Blacing Opmmercial Bitting Commercial Glazing Commercial Commercial	1 35° 30° Xi 36° Xi 3° ±%*	<u>Toleranze</u> ± %* + 36*	Size Size Si x 120" Si x 132" Si x 132"	4 08 4 09 6 54 6 54 5 87 11.45 3.27 4.30 6.54 3.82 3.82	823 873 888 827 833 808 442 320 213 465 344 248 867 380 442 727 887 887 887 887 887 887 887 887 88	¢13 ¢05 315 315 45.0 330 2265 157 16.7 10.7 10.7 330 330 275 45.0 330 26.6 330 330 36.7 275 45.0 330 36.7 27.5 37	77.3 75.2 73.0 87.1 85.3 59.3 59.3 59.3 59.3 59.3 59.3 59.3 5
	Rough Both Sides Asgular Srey Sronze Heat Absorbing	Rough Rom Sider Regular Broy Bionze Hear Moto/Mrz Acuther Dan Sider Bregdar Bearta Bionze Hear Moto/Sing Hear M	Madi (L-1 dammer 1) Maugh 1 can Screen Begular Bring Bronze Bronz	MARTIELO MARTES TO- Marting Band States Topp Sto	Modellic Jointon 10° 90° 100° Modellic Jointon 100° 100° 100° 100° More Jointon 100° 100° 100° 100° 100° More Jointon 100°	Modellicol Salariza The See Color The Ages Modellicol Salariza See Communical The Color The See Color Modellicol Salariza See Color The See Color The See Color See Color The Communical The Color The See Color See Color The Communical The Color The Color See Color See Color The Color The Color See Color See Color The Color The Color	Stand Display No. Stand Display No. Commonial Stand Display No. Commonial Stand Display No. Display	MARTILED All OLD The Spir Log Control Martiled Schwarz	MARTILED ABMORTS The SP CLUP Life Aggle Control Barge Band Level B

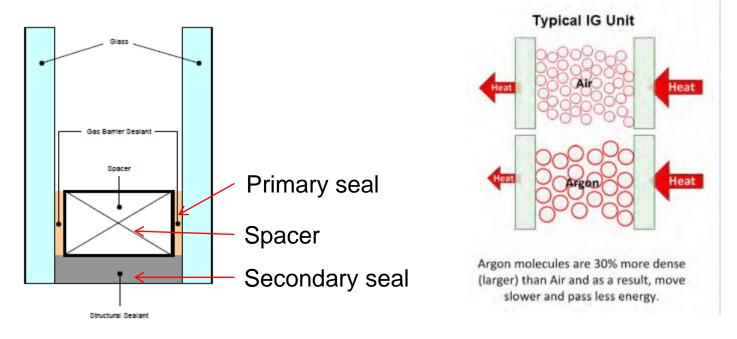


Today



IG construction

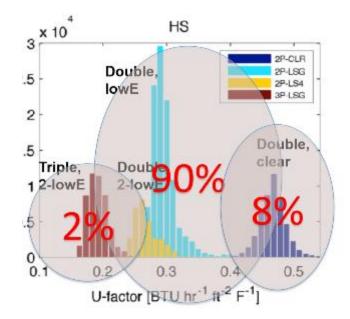
- More than one piece of glass (double glaze, triple glaze)
- Different types of seals used
- Variety of gases to fill space
 - Impacts convection, conduction



• Potential concerns with seal failure, moisture, aesthetics

Upgrade v. replace



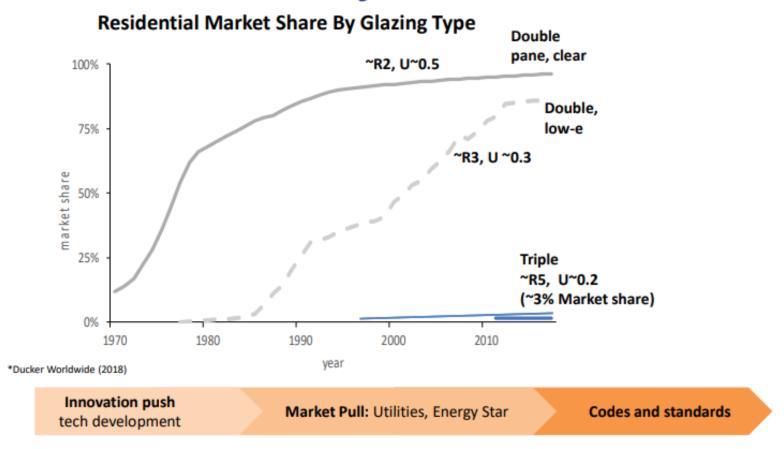


Secondary glazing U-factor = $1.0 \rightarrow (<0.5 \text{ to } 0.35)$ SHGC = $0.8 \rightarrow (<0.70-0.65)$

Credit – Steve Selkowitz, LBNL, Kimber Degling - Innerglass

Market status

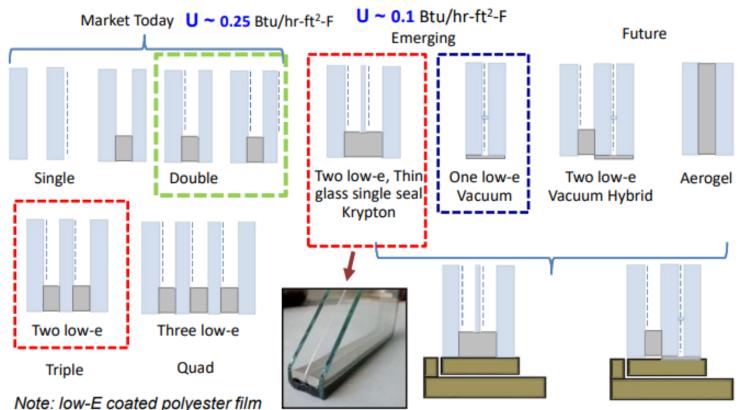
Markets Evolve Slowly...How to Accelerate?



Credit – Steve Selkowitz, LBNL

Higher performance available

HIGHLY INSULATING GLAZING SOLUTIONS:

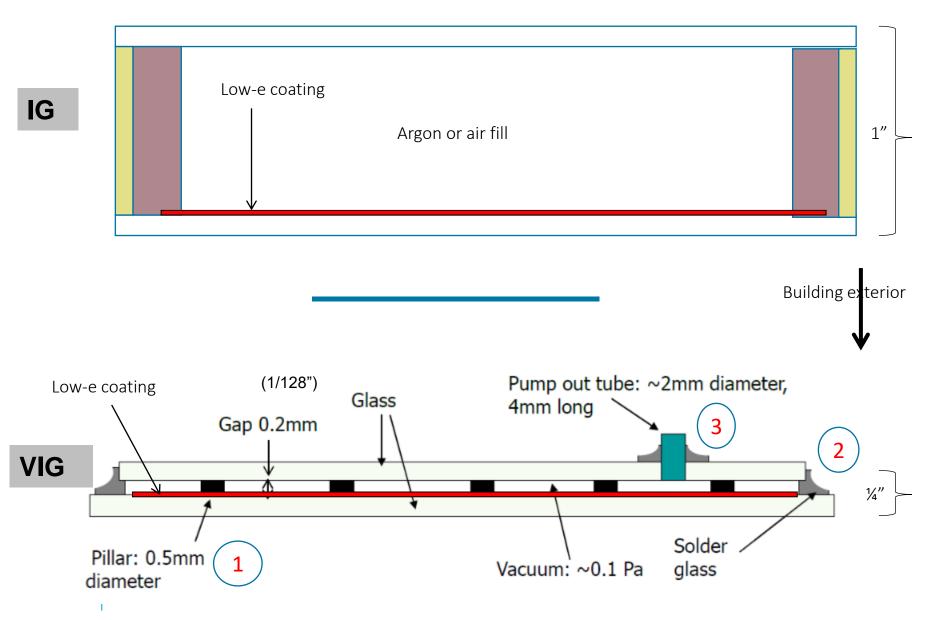


Super-insulating frame with highly insulated glazing

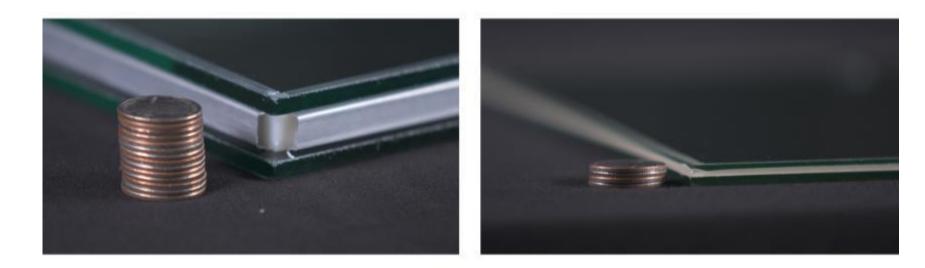
Credit – Steve Selkowitz, LBNL

can be alternative middle glazing.

IG versus VIG construction



IG versus VIG construction



Albert Kahn office building – Detroit



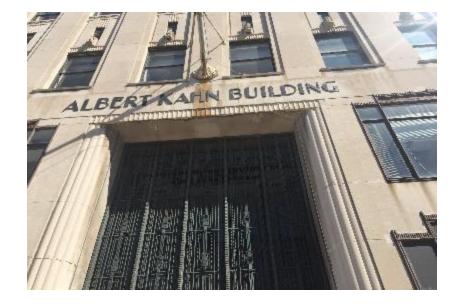
- 1931
- 11 story
- 320,000 ft² building, 17,500 ft² glazing area
- Bronze, double-hung windows, monolithic ¼" glass





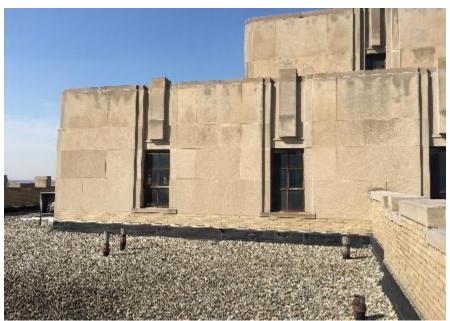








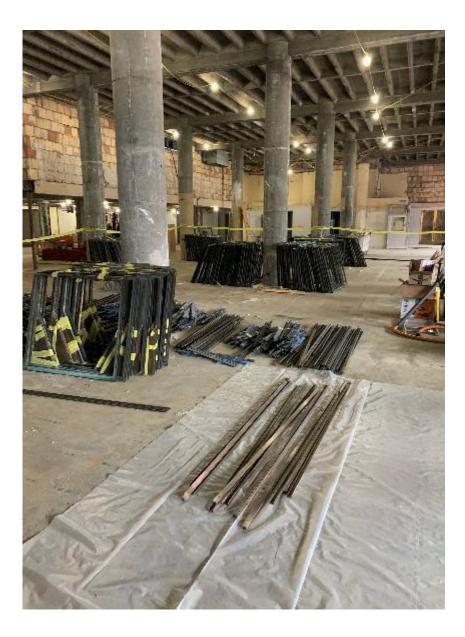
















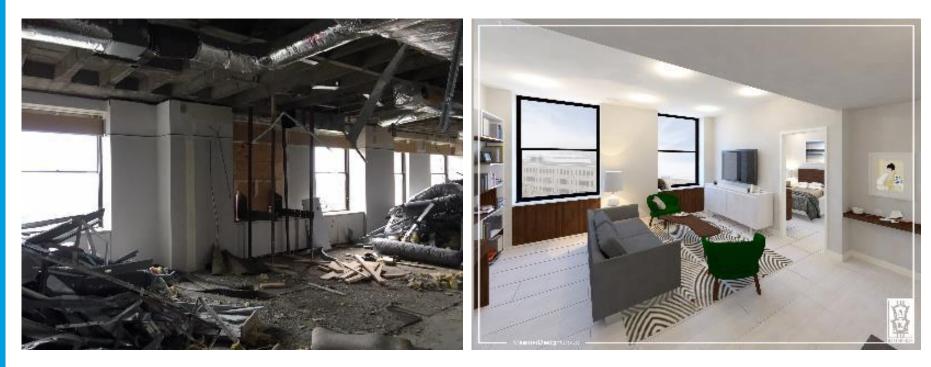




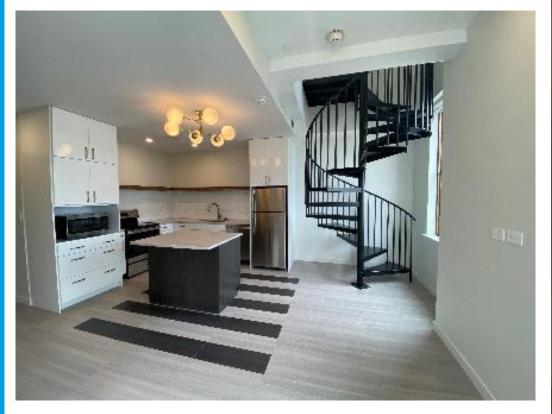








North Equities Group / Lutz Real Estate















Energy and carbon impact

Counting Carb_(on)s – 40% buildings

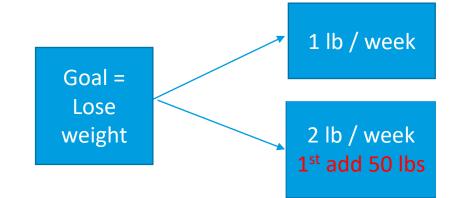
Operational Carbon

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

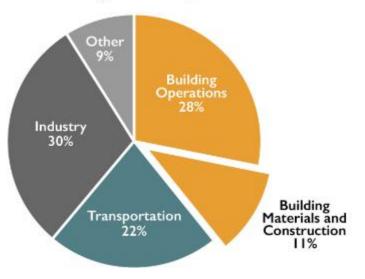
Embodied Carbon

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

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



Global CO2 Emissions by Sector

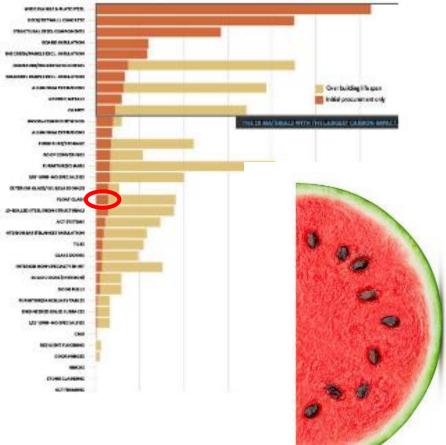


Embodied - Glass and window impact

- 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

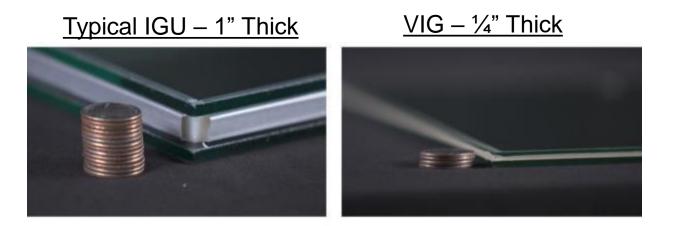
The impact of commonly used building metantich, both at initial procumment (or ange) and over a building's estimated life span of 60 years (policie). Structural materials have the higgest initial impact, over time, interior design elements and materialis increase in total impact as replacements all up.



The Kahn

Existing building – ¼" monolithic (reference)

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



DOE reference building



Flat Glass



This EPO use not written to support comparative essentions. Even for existing rotoxids, difference in indicated usil, use and end-d-Hit steps resourciptons, and data quality may produce lemma status. It is not recommended to compare EPOs with another organization, as there may be differences in methodology, assumptions, advances 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

201 New Party Drive PC Res (200), and Consideration. PR 13425-2476. Large Bosic

Decenation Number A81M-8PD12

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

Energy Plus

ZNCC

tally,

KNOW

YOUR

EC3

IMPACT

DOE reference building

	Dista 1			
	Reglazing	Interior	Interior	Aluminium
	with VIG	Storm with Steel Frame	Storm with Aluminium	replacement windows
		SteerFrame	Frame	windows
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 mpact (tonnes CO ₂ E)	-201	-126	-114	-160
Embodied Carbon Debt Payback (months)	1	3	3	<mark>4</mark>
Breakeven point – years payback embodied carbon				11

Key learnings

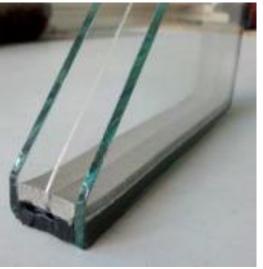
- 1. Building re-use / upgrades
- 2. Embodied material choices matter
- 3. Time-based carbon save now

Emerging technology













Triple glazing – Juice worth the squeeze?

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

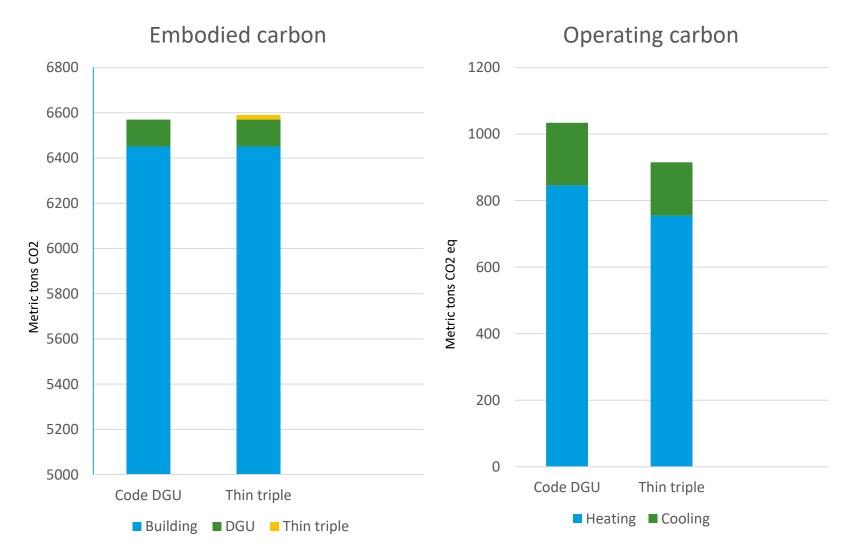
Embodied Energy						
Embodied primary energy of flat glass	2.16E+04 MJ/MT					
Total window area in analysis home	356 ft ²					
Middle lite thickness	2.2 mm	1.1 mm				
Mass of 3rd lite (total for home)	184 kg	92 kg				
Embodied energy of 3 rd lite (total for home)	3.98 GJ	1.99 GJ				
Energy Savings – ENERGY STAR Northern Zone						
Code baseline - U lowered from 0.30 to 0.22 Btu/hr 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	iJ/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



 $U_{glass} \simeq 0.6 W/m^2-K$



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.officience.educe.org/downloads/.id/tetracritectWordow.pdf https://www.officience.educe.org/content/_title-readers at new home; page we surrainery https://literary.cett.org/content/2015_initiation_initiation_initiation_attraction_attraction_initiatio



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

References

- <u>https://www.dbusiness.com/daily-news/renovation-of-historic-albert-kahn-building-in-detroit-into-apartment-community-complete/</u>
- <u>https://www.energy.gov/eere/buildings/commercial-reference-buildings</u>
- <u>https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-</u> <u>calculations-and-references</u>
- <u>https://www.convert-measurement-</u> units.com/convert+Million+BTU+to+Gigajoule.php
- <u>https://www.dkhardware.com/bronze-universal-sash-storm-window-frame-bs1brz-product-4943.html</u>
- <u>https://www.aisc.org/why-steel/resources/leed-v4/</u>
- <u>https://www.nrel.gov/docs/fy13osti/55219.pdf</u>
- <u>https://adfs.nsg.com/adfs/ls/wia</u>
- <u>https://www.engineeringtoolbox.com/density-solids-d_1265.html</u>
- <u>Flat Glass Environmental Product Declaration</u> <u>https://www.glass.org/sites/default.files.2019-12/NGA_EPD_2019_12_16.signed.pdf</u>
- <u>Northwest Energy Efficiency Alliance (NEEA) | Thin Triple Pane...</u> -<u>https://neea.org/resources/thin-triple-pane-windows-a-market-transformation-strategy-for-affordable-r5-windows</u>

References

- <u>https://finance-commerce.com/welcome-ad/?retUrl=/2019/06/the-carbon-footprint-of-modern-construction-is-huge/</u>
- <u>https://www.energy.gov/eere/buildings/commercial-reference-buildings</u>
- <u>https://issuu.com/intelligentpublications/docs/igs_spring2021.hi-</u> res_singles/s/12041237
- <u>https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-</u> <u>calculations-and-references</u>
- <u>https://gbdmagazine.com/building-materials-and-climate-change/</u>
- <u>https://beta.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle</u>
- <u>https://mailchi.mp/thekraemeredge/kdg-historic-project-spotlight-the-albert-kahn-building?e=81c7f13bd3</u>
- https://doi.10.1016.j.buildenv.2015.09.018
- <u>https://buildingtransparency-live-87c7ea3ad4714-809eeaa.divio-</u> <u>media.com/filer_public/64/46/644653b8-eeda-45db-b6a2-8576e1606257/wc_am-jll-</u> <u>interfacebasecamppdf.pdf</u>
- <u>Triple Glazing and Embodied Energy: Yes, the Juice is Worth the Squeeze | National</u> <u>Glass Association</u> – Tom Culp, January 18, 2022, www.glass.org



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