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Retrofit, Restore, or Replace

Understanding the whole life carbon of windows

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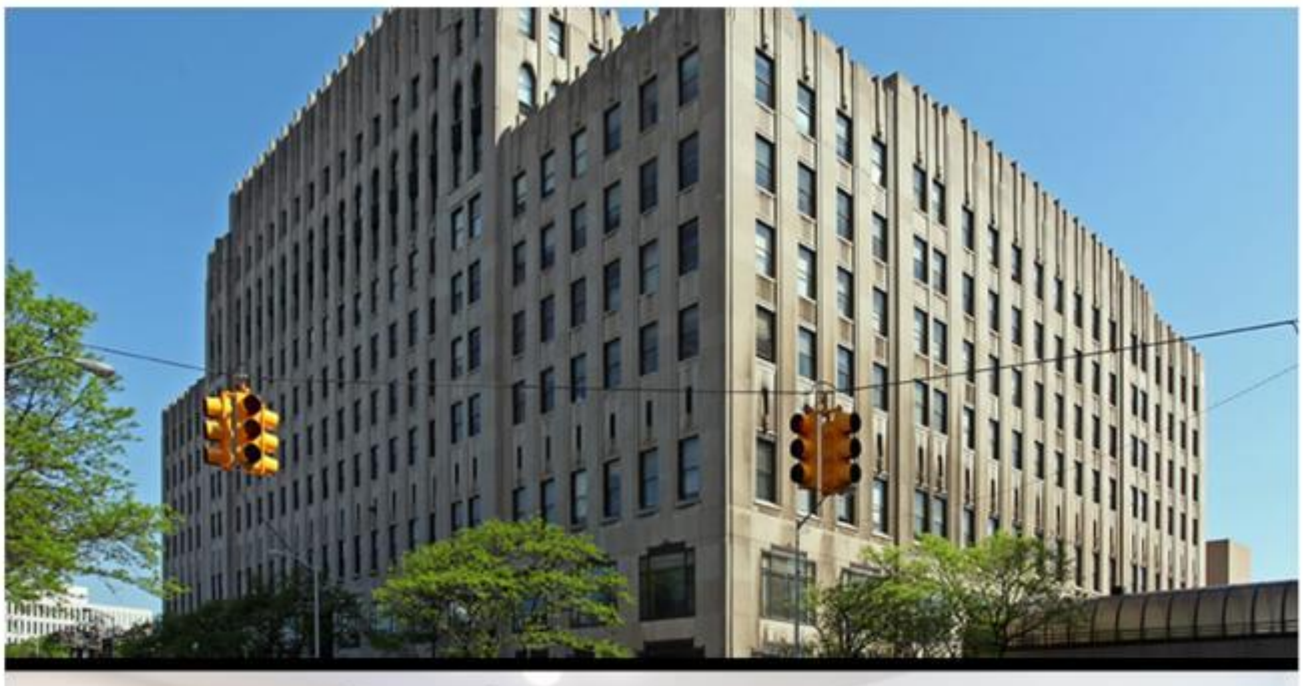
NSG Pilkington



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…

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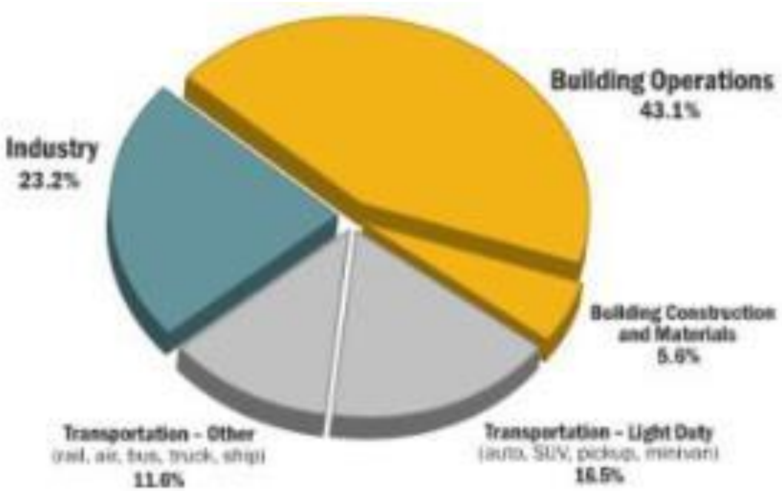
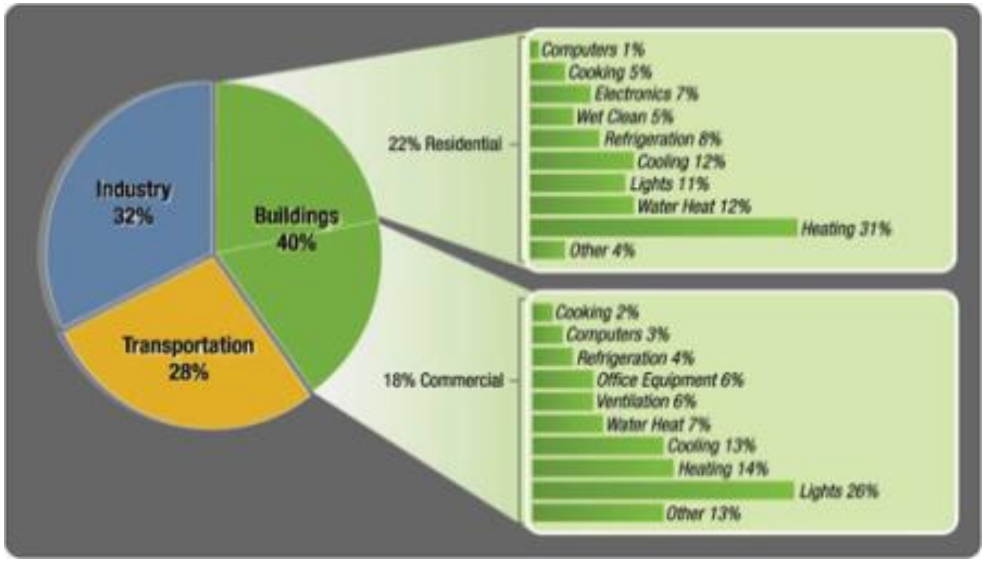


U.S. Energy Consumption by Sector

Source: ©2011 2030 Inc. / Architecture 2030. All Rights Reserved.
Data Source: U.S. Energy Information Administration (2011)



Credit – Architecture 2030, US Energy Information Administration

Buildings use lots of energy…

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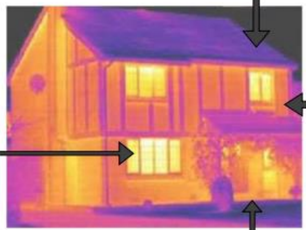
New Build: Windows are falling behind!

IECC 2021	R-60 Ceilings
	R-20 Walls
	R-3.3 Windows

Windows	
Area:	8%
Heat loss:	47%



Roof	
Area:	25%
Heat loss:	9%

Walls	
Area:	42%
Heat loss:	31%

Floor	
Area:	25%
Heat loss:	13%

*Heat loss is defined as the overall average heat transmission of a gross area of the exterior building envelope in BTU/hr at Minneapolis 99% design day conditions.
**Thermal performance is the consolidated layer as calculated in the DOE residential prototype for IECC 2021 climate zone 6A.

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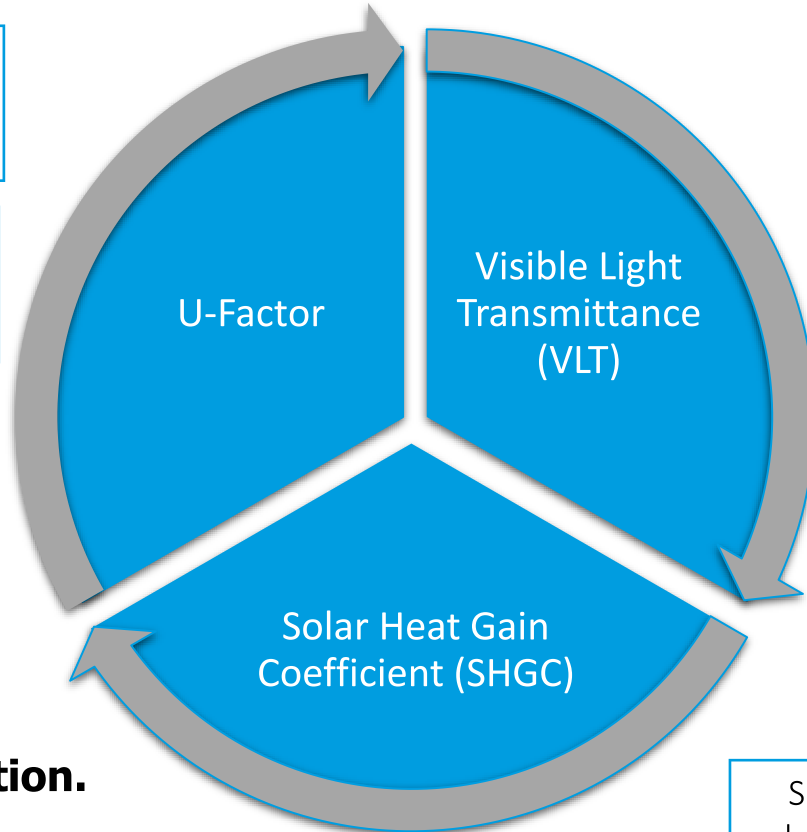
48 million Single-Pane Homes (41%)
*2015 RECS

Credit – Steve Selkowitz, LBNL

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.

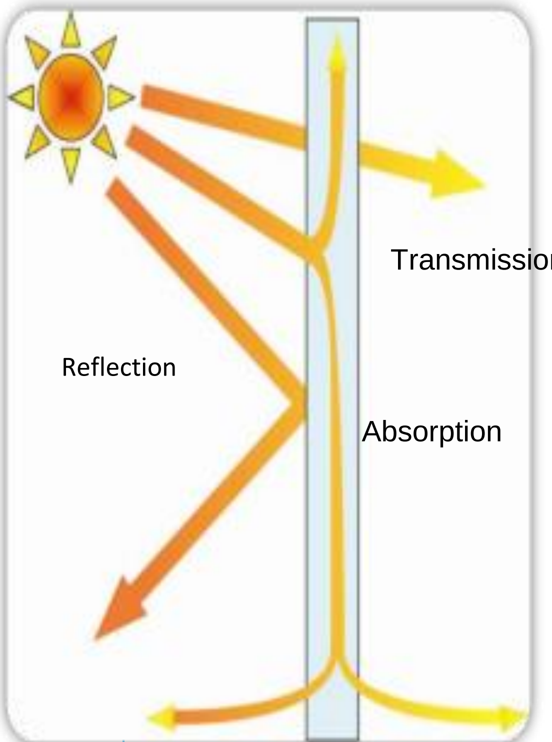
SHGC is expressed as a number between 0 and 1. The lower the SHGC, the less solar heat it transmits.

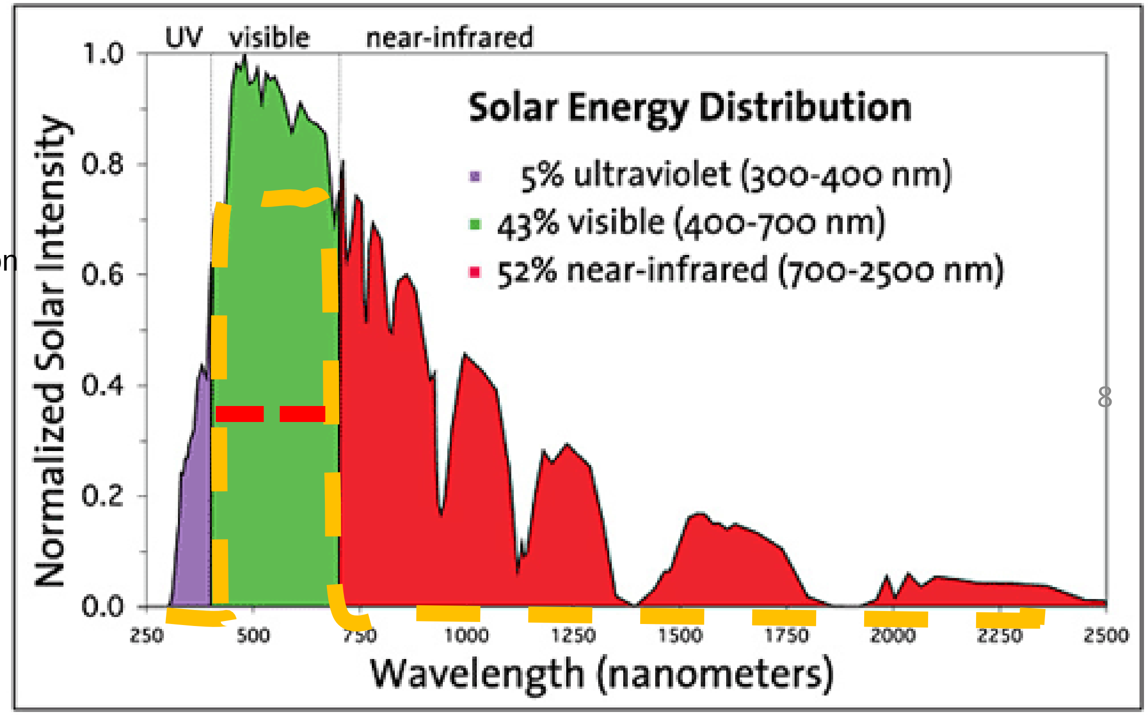
Color and reflection.

Performance and aesthetics are not mutually exclusive.

Performance basics

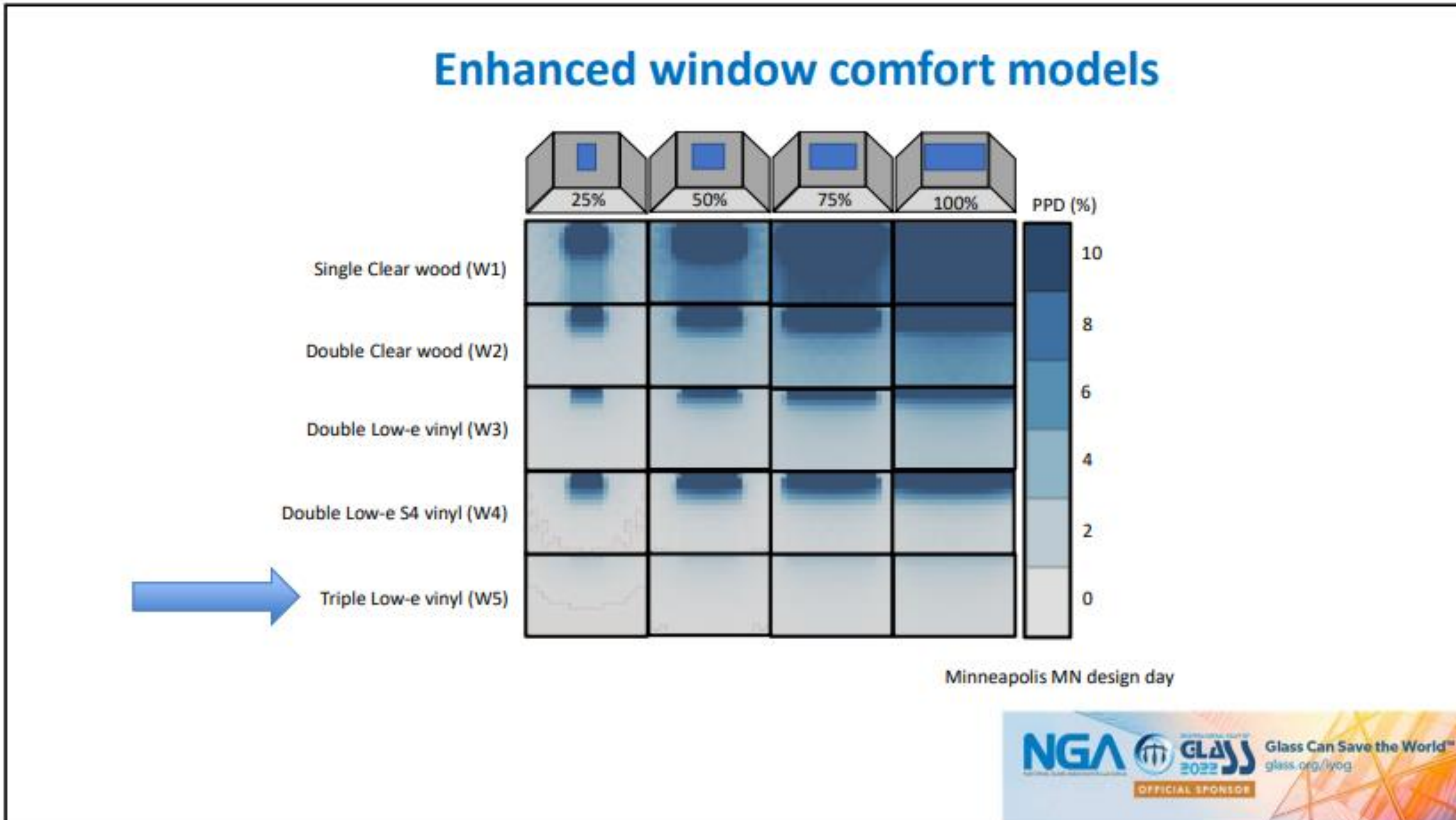
- Think of coatings in two primary functions
  - Filter - Solar energy, light transmission, reflection, etc.
  - Insulator - Manage re-radiation of absorbed energy (both from sun and from room)
- Potential concerns with color and aesthetics.






& Seafood

Thermal comfort



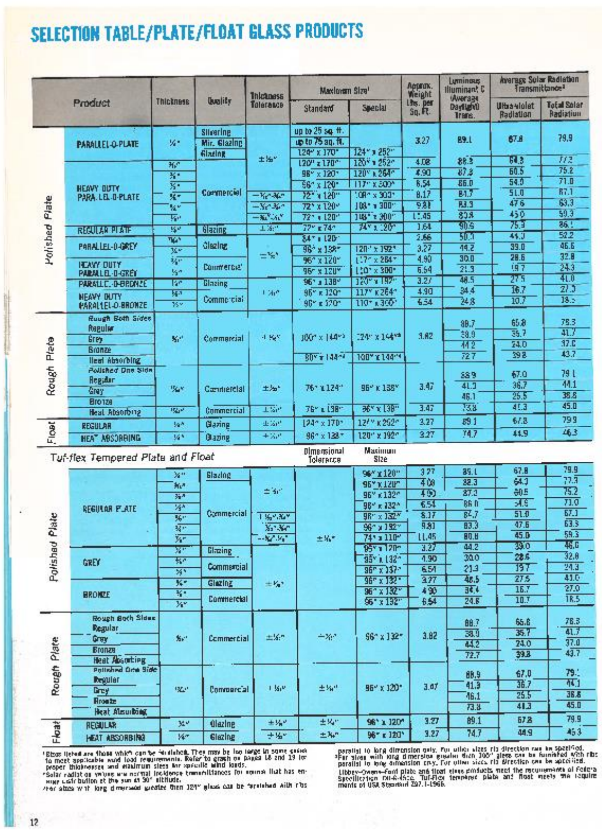
Credit – Steve Selkowitz, Robert Hart, LBNL

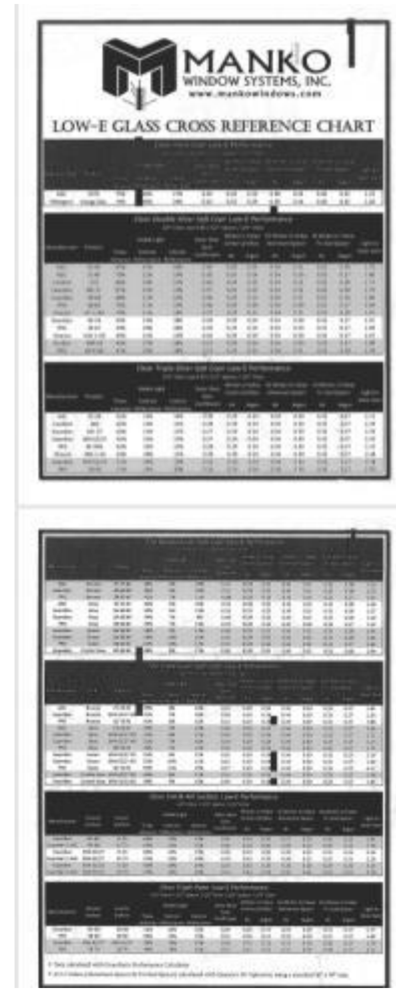
How did we get here?

Glass complexity

1970

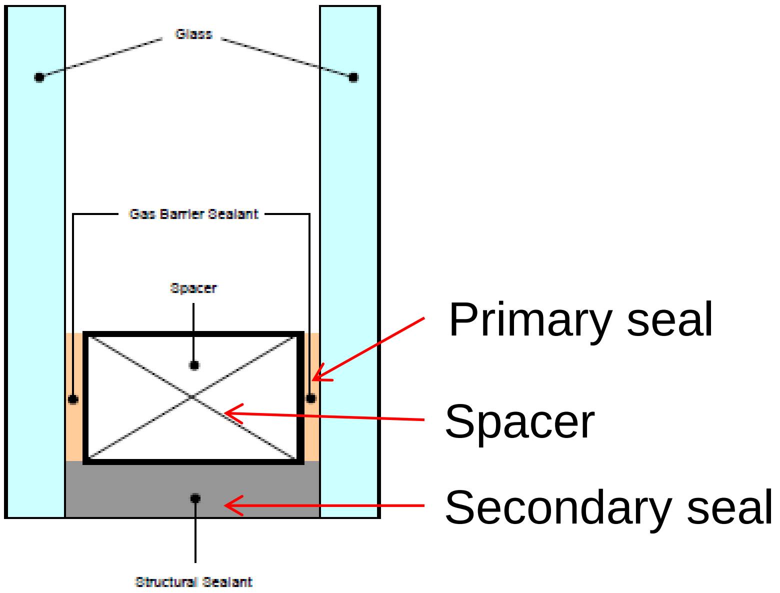
Today

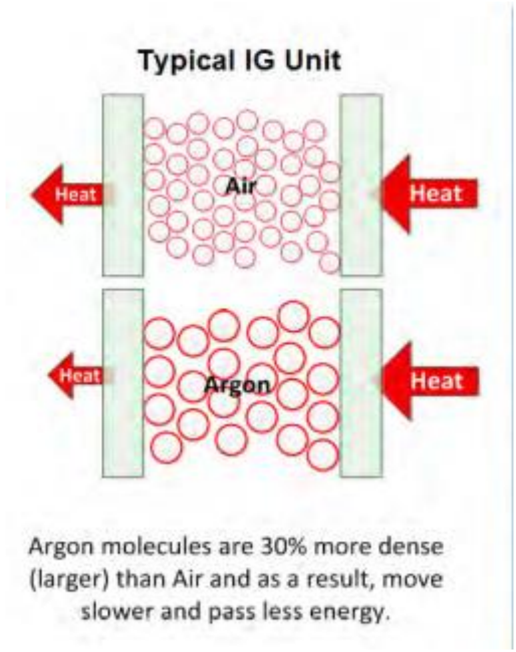




IG construction

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

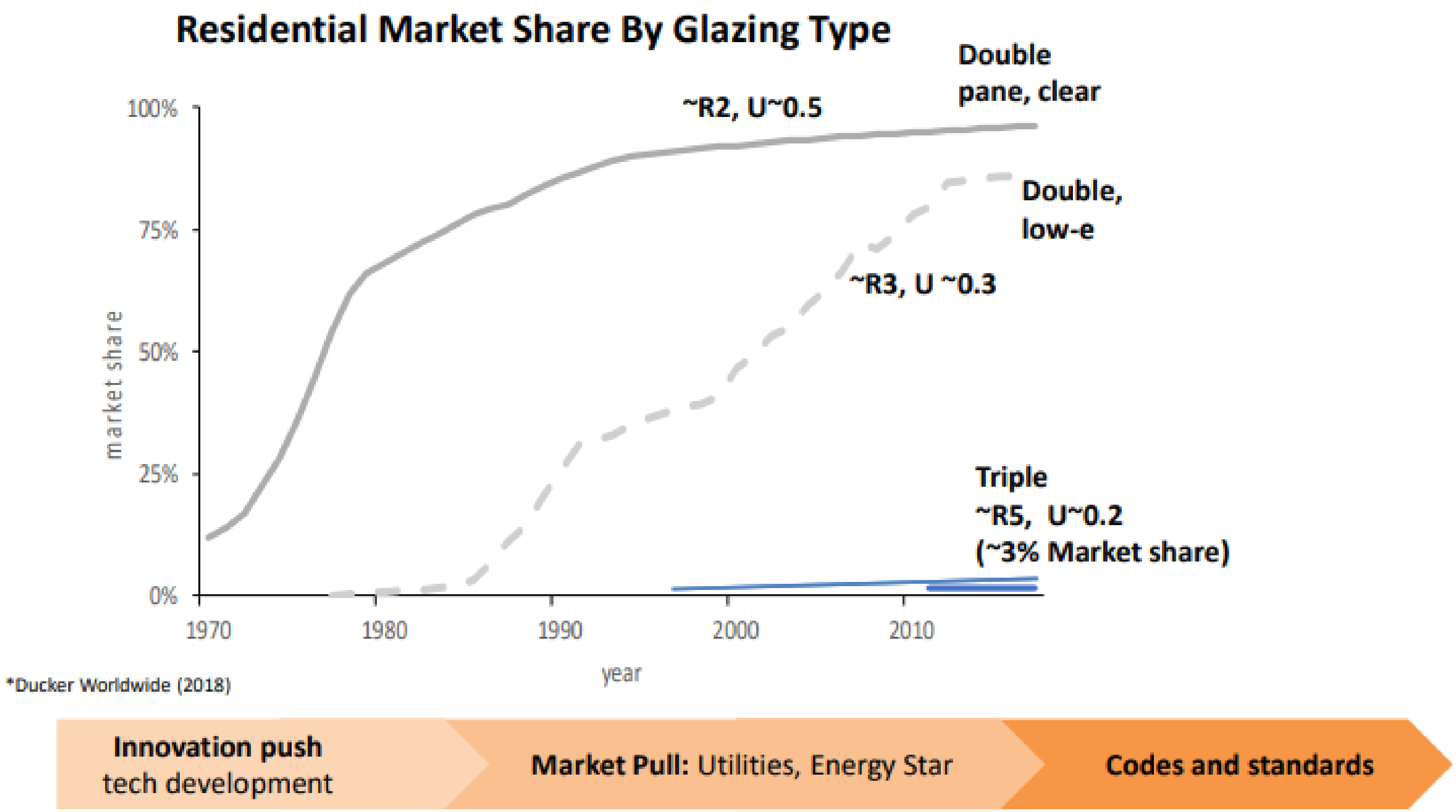




- Potential concerns with seal failure, moisture, aesthetics

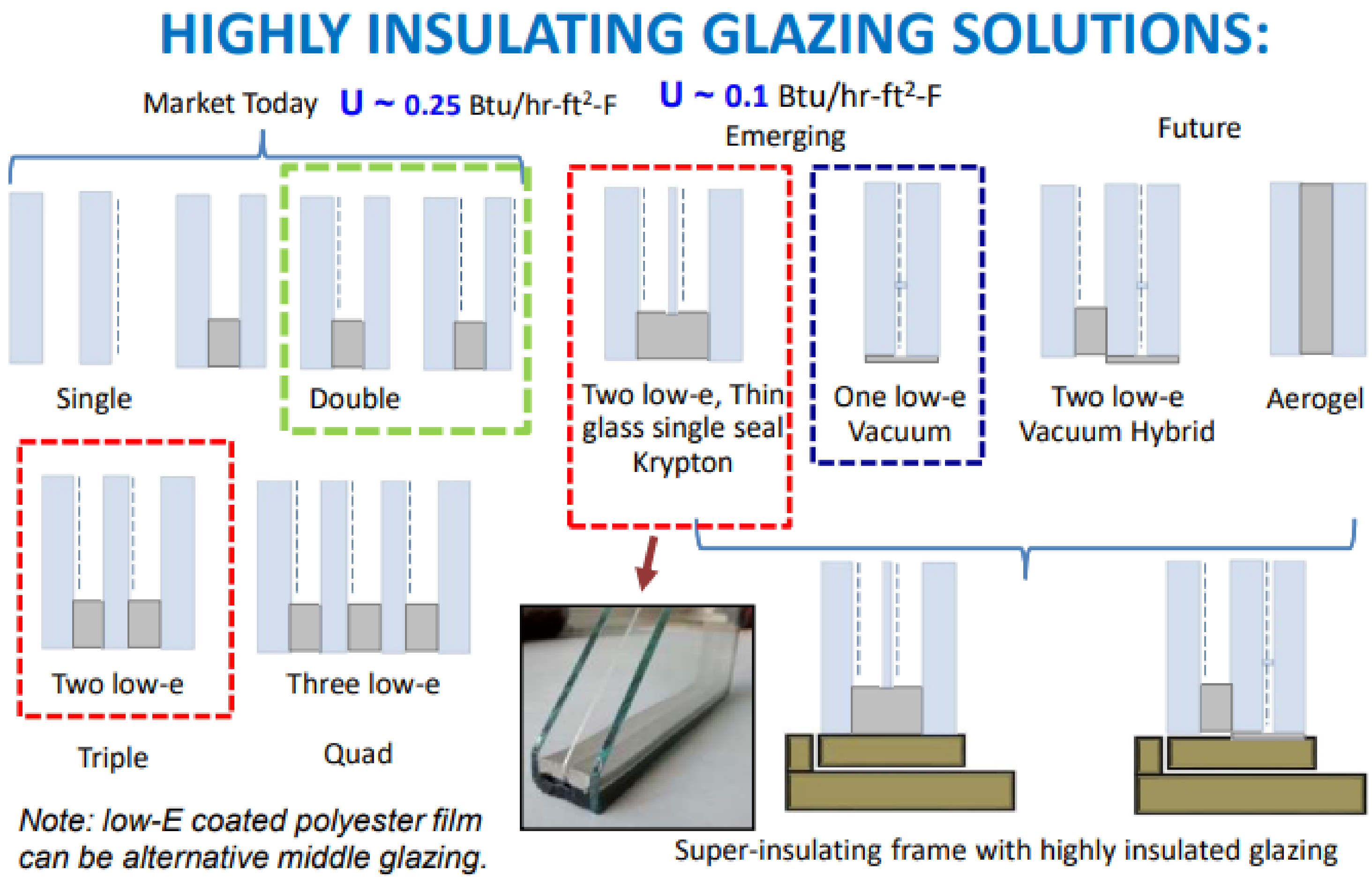
Market status

Markets Evolve Slowly…How to Accelerate?



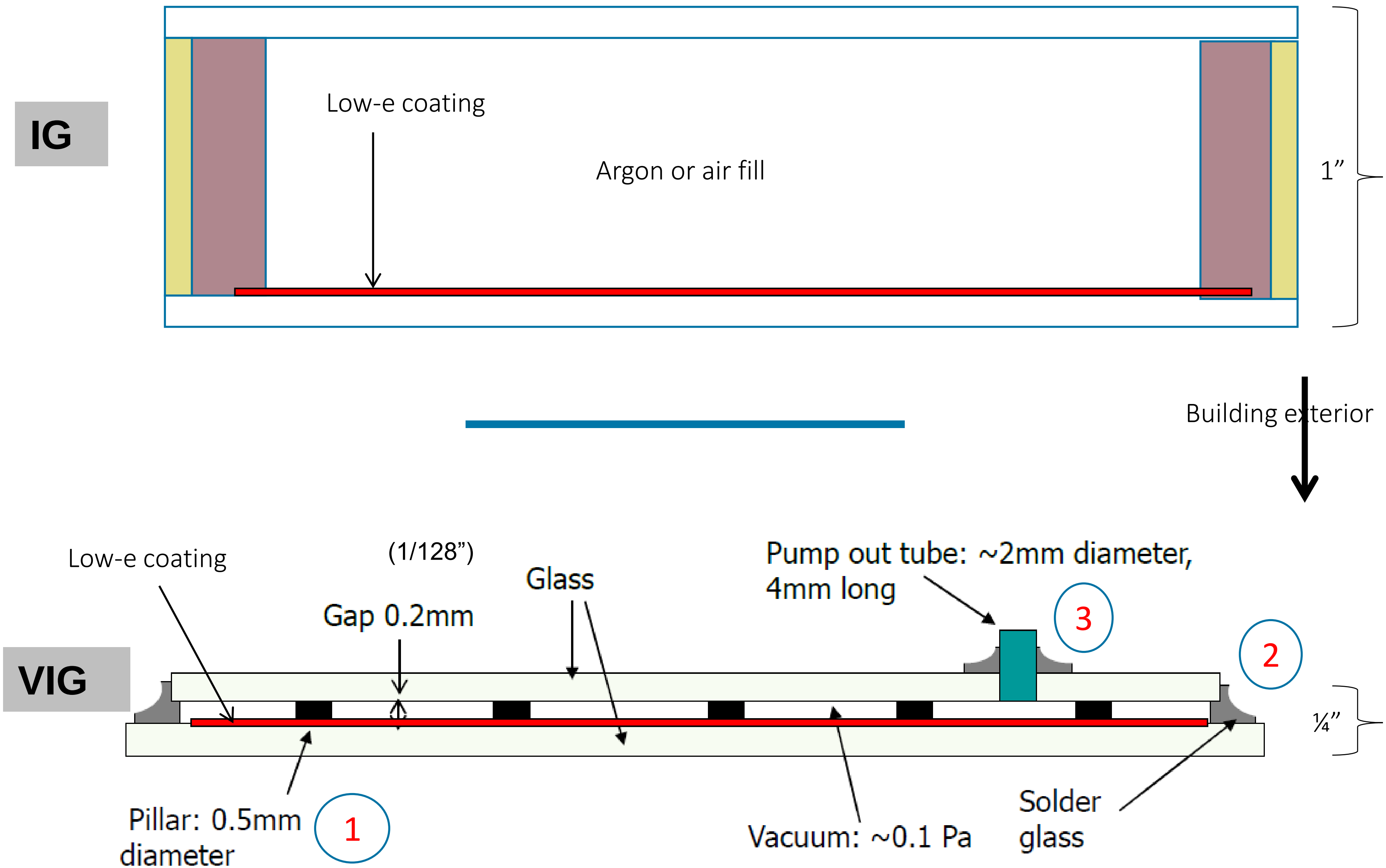
Credit – Steve Selkowitz, LBNL

Higher performance available

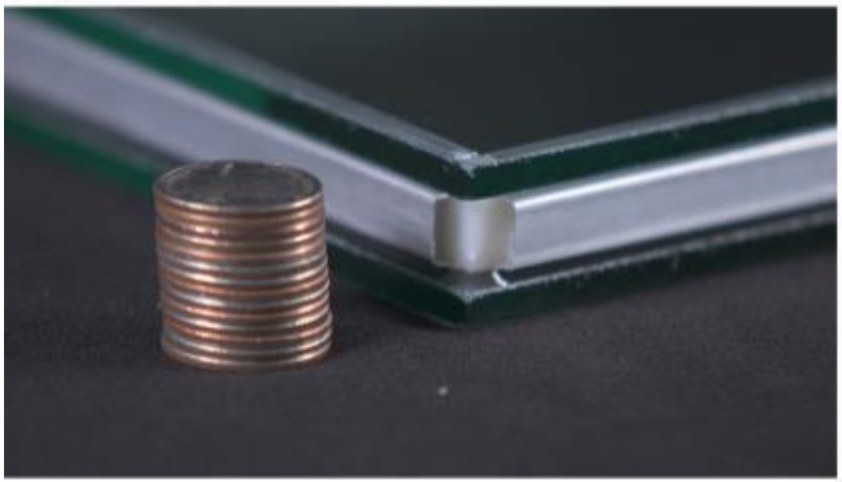


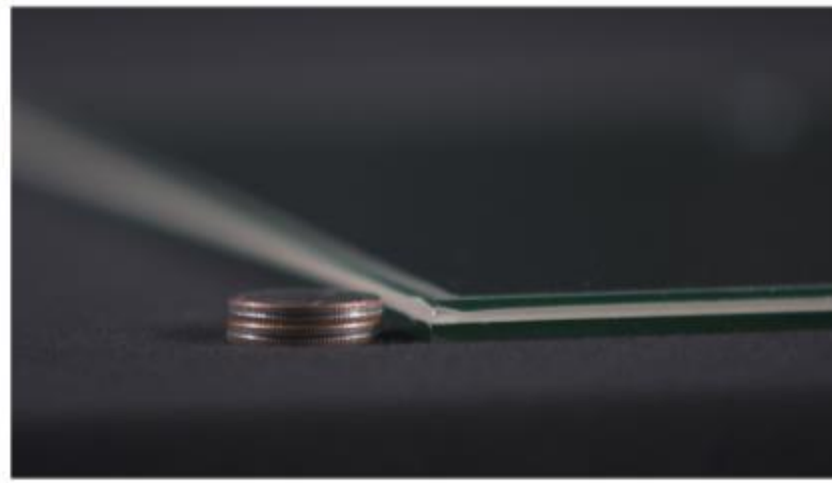
Credit – Steve Selkowitz, LBNL

IG versus VIG construction



IG versus VIG construction

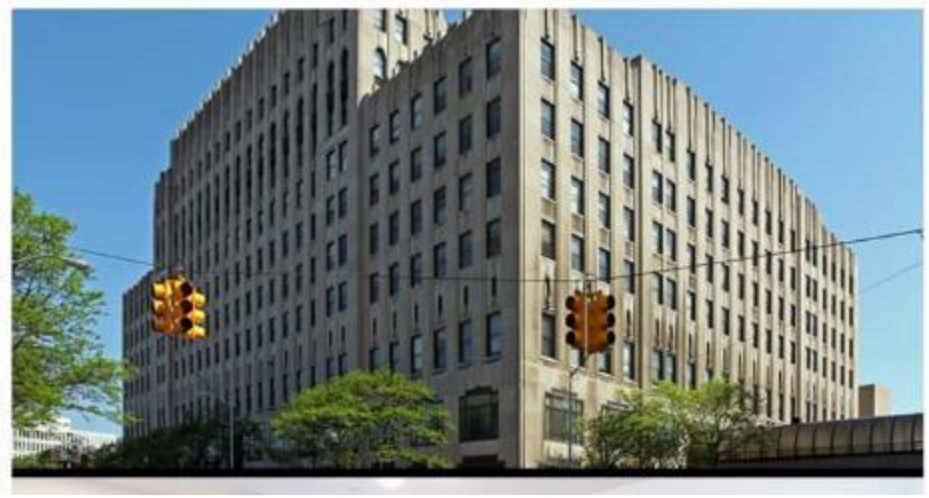




Albert Kahn office building – Detroit

- 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
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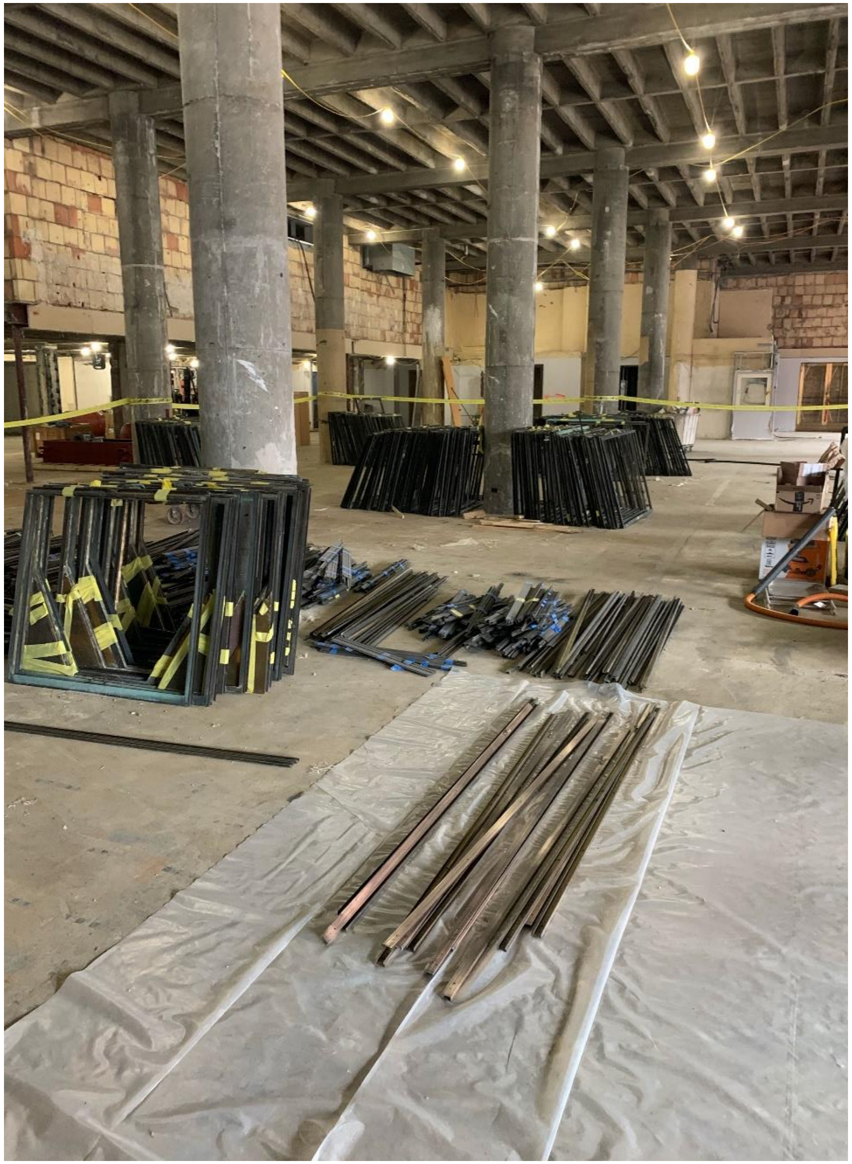


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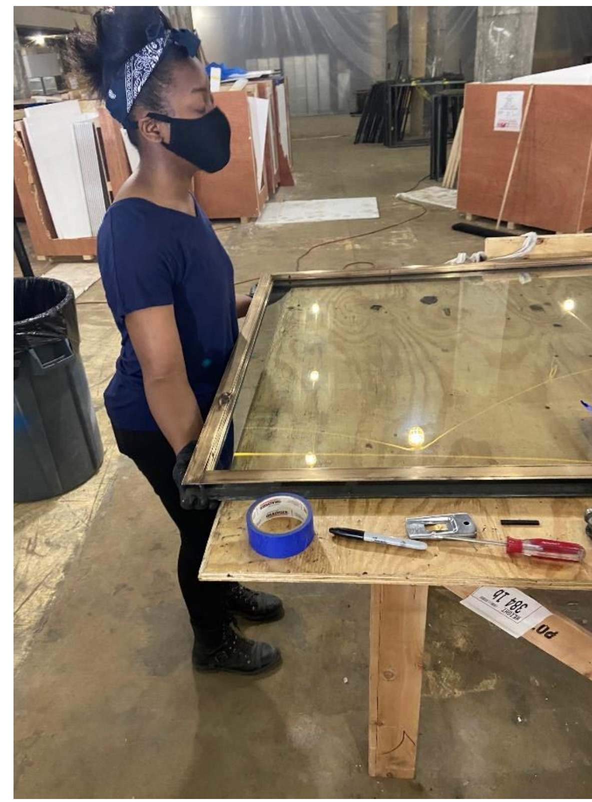

North Equities Group / Lutz Real Estate


Energy and carbon impact

Counting Carb(on)s – 40% buildings

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Operational Carbon

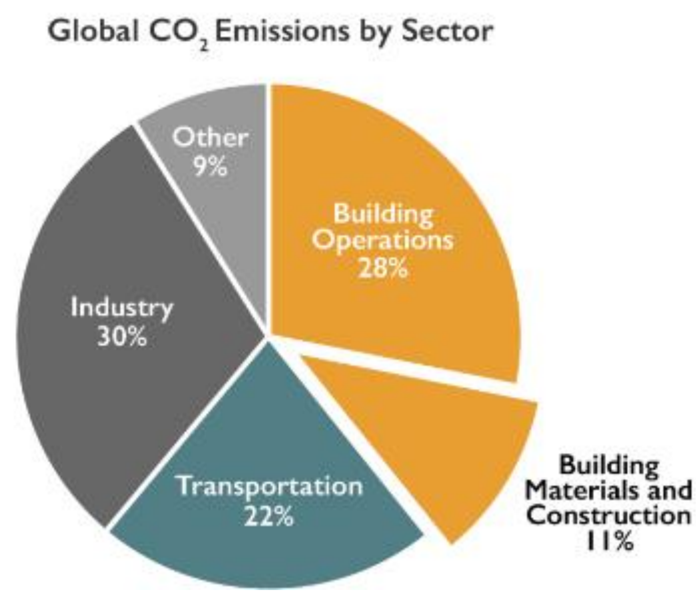
- Carbon emissions from use of energy to heat and power a building

Goal = Lose weight → 1 lb / week

Goal = Lose weight → 2 lb / week, 1st add 50 lbs

Embodied Carbon

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

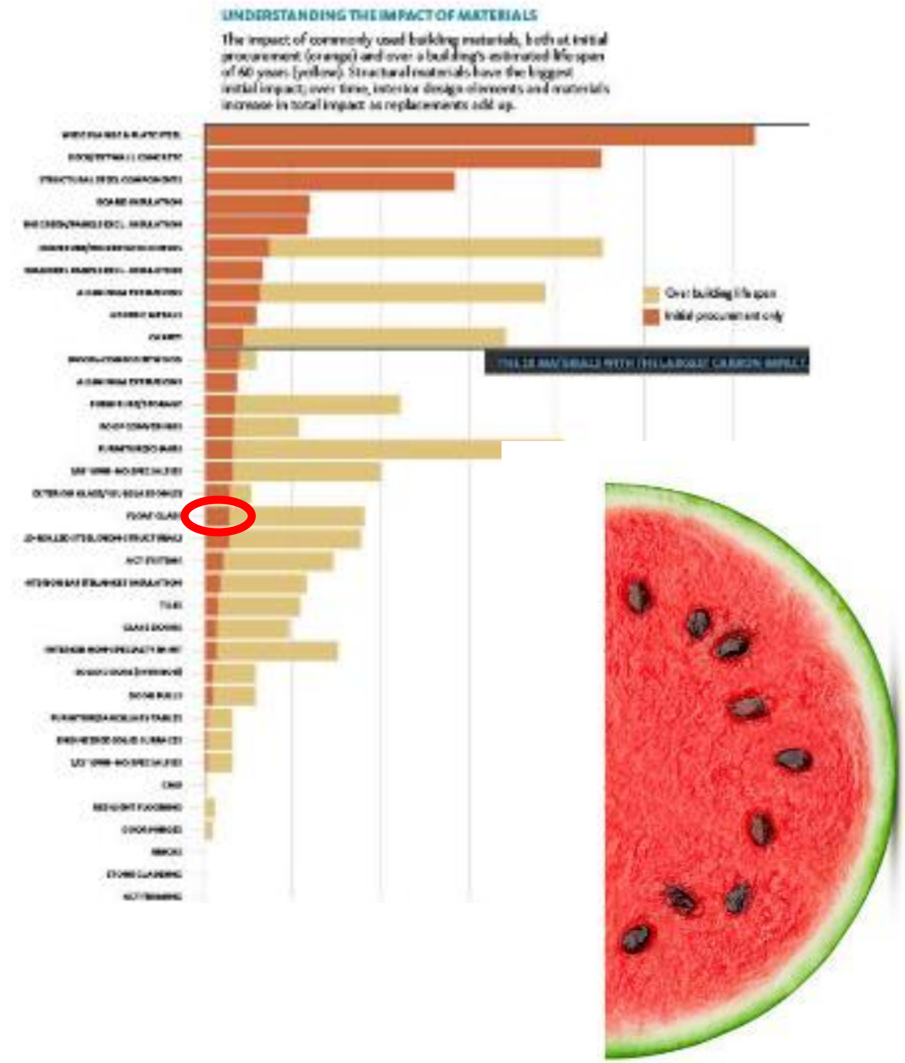


- **Goal** – reduce overall carbon impact / usage

Embodied - Glass and window impact

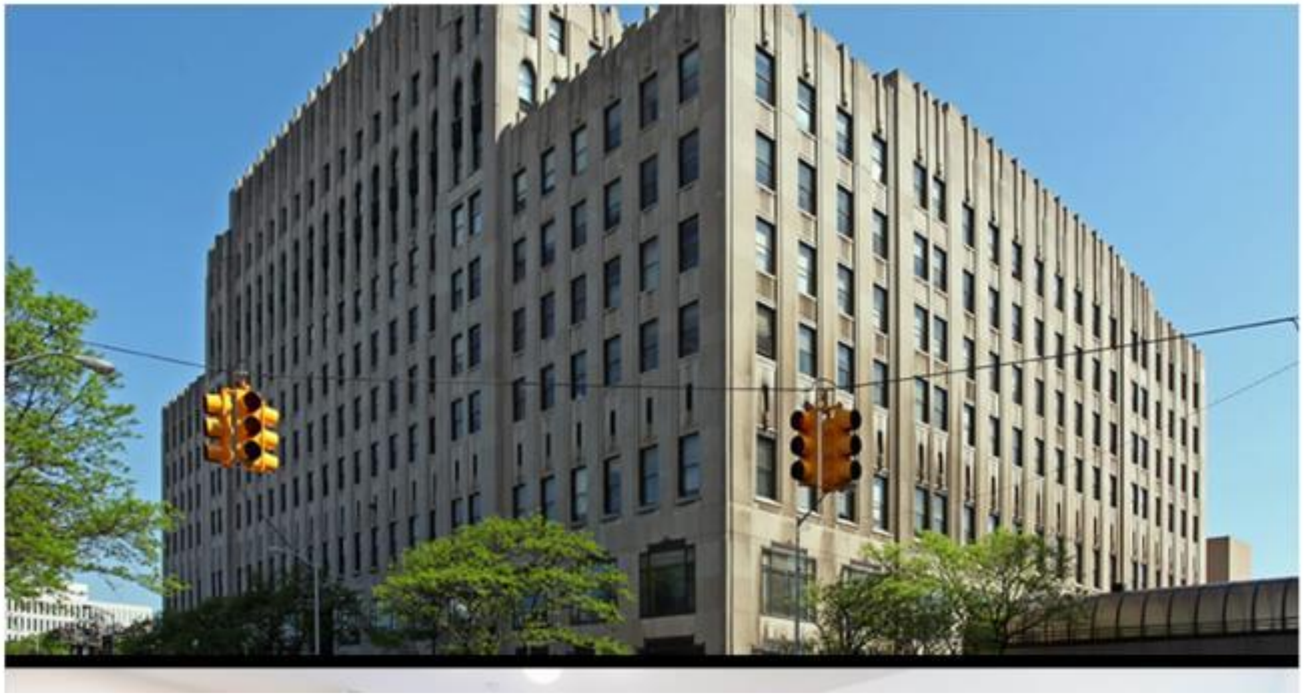
- Glass – skin of building
  - Structural elements - majority

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



Credit – Gensler

Albert Kahn office building – Detroit



The Kahn

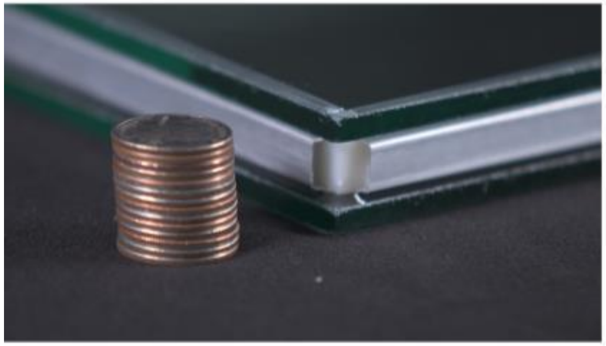
- 1931
- 11 story
- 320,000 ft^2 building, 17,500 ft^2 glazing area
- 700 bronze, double-hung windows, monolithic ¼″ glass

The Kahn

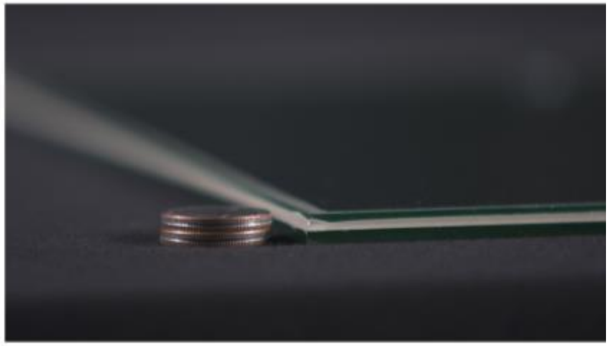
Existing building – ¼″ monolithic (reference)

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

Typical IGU – 1” Thick



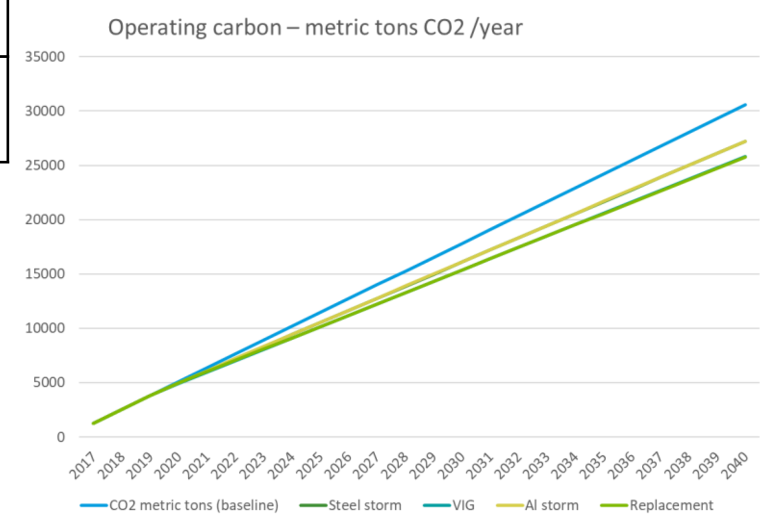
VIG – ¼” Thick



DOE reference building

	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

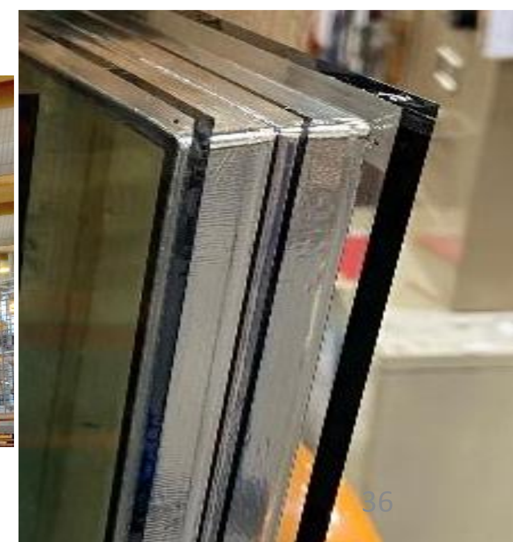
Current operating carbon (metric tons CO2 eq)	1273



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?

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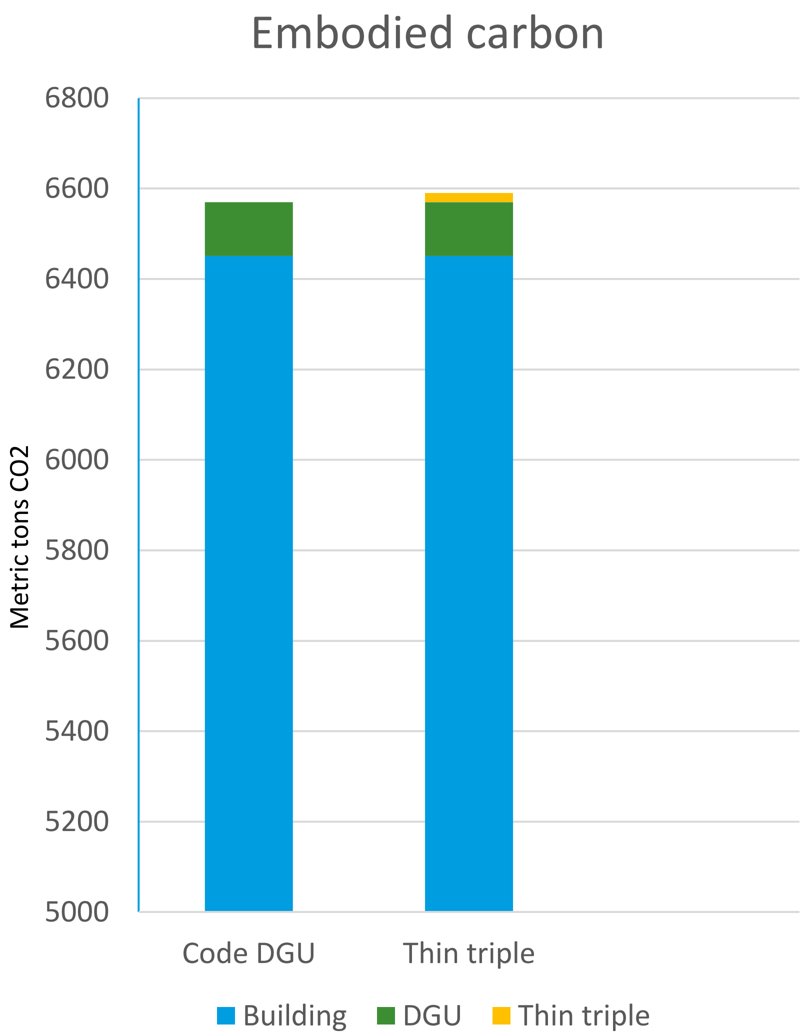
Table 1: RESIDENTIAL ANALYSIS (all windows in model home)

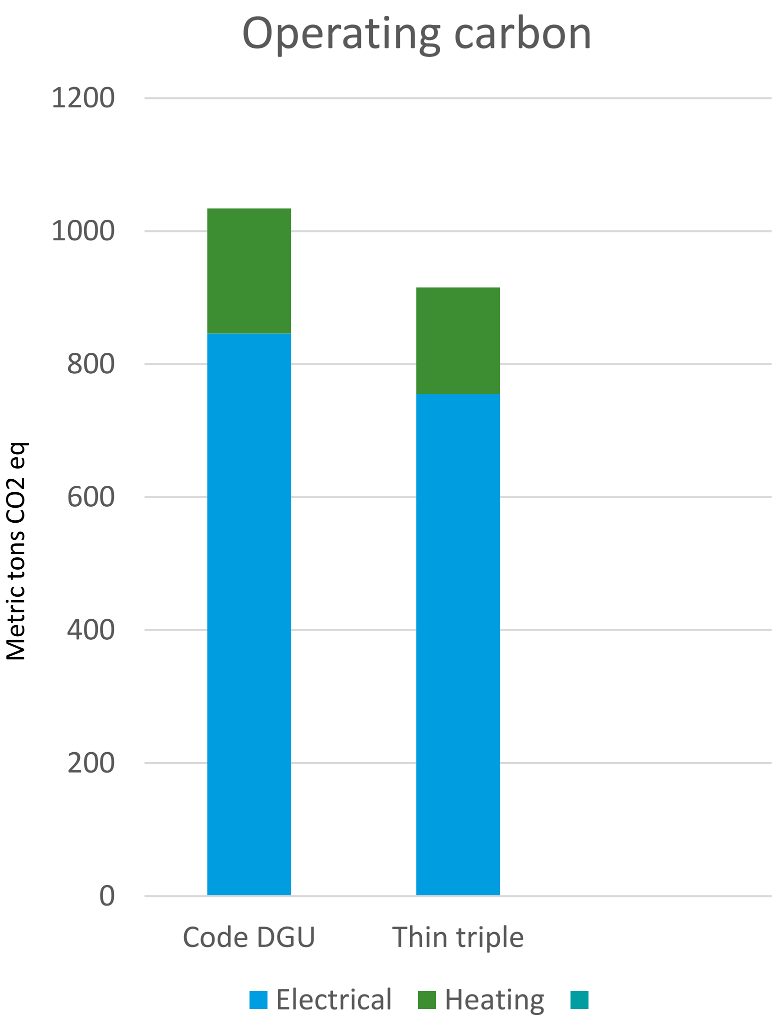
Embodied Energy		
Embodied primary energy of flat glass	2.16E+04 MJ/MT	
Total window area in analysis home	356 ft^2	
Middle lite thickness	**2.2 mm**	**1.1 mm**
Mass of 3rd lite (total for home)	184 kg	92 kg
Embodied energy of 3^{rd} lite (total for home)	3.98 GJ	1.99 GJ
Energy Savings – ENERGY STAR 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	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





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1. Building re-use / upgrades
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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

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