Industry Trends Roundtable

High-Performance Glass and Facades

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PANELISTS

Stephen Selkowitz

Principal
Stephen Selkowitz Consultants

Advisor
Lawrence Berkeley
National Laboratory

Kayla Natividad

Architectural Technical
Service Engineer

Pilkington North America

Andrew Zech

CEO

Alpen High Performance
Products

Jonathan Hafemann

VP Commercialization
& Growth

NEXT Energy Technologies

Challenges and Opportunities in a Carbon-Constrained World

Stephen Selkowitz

Stephen Selkowitz Consultants

Retired: Group Leader, Windows and Envelope Materials

Lawrence Berkeley National Laboratory

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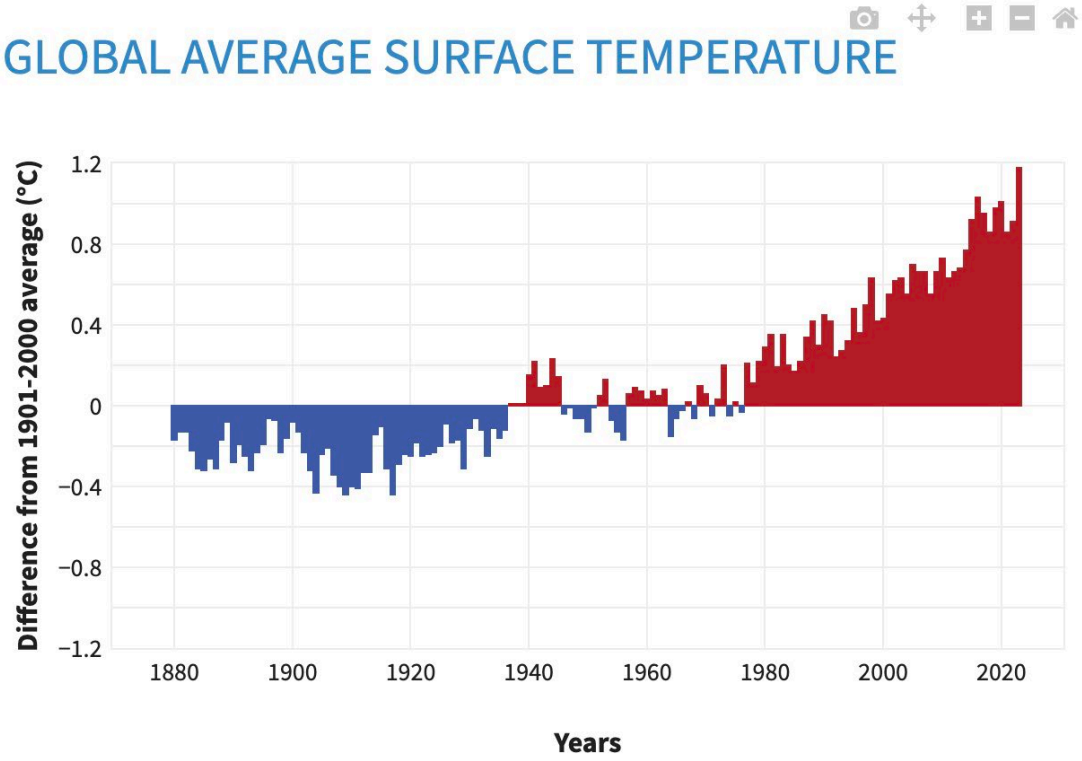
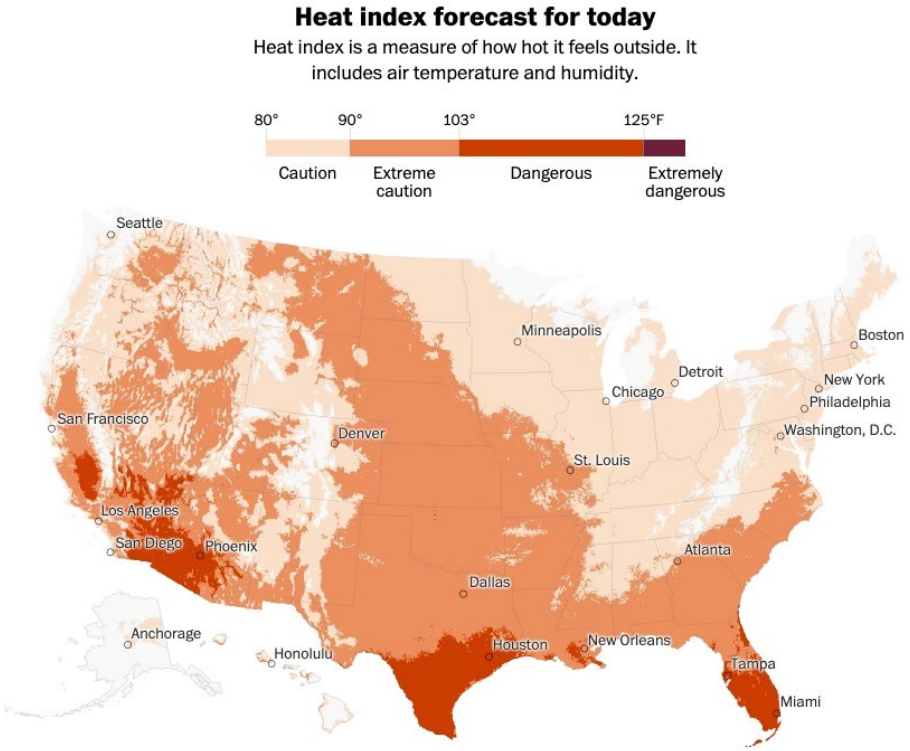
“May You Live in Interesting (HOT) Times…”

- Steady Increase in global temperature
- Phoenix: 100+ days of > 100F Temp.

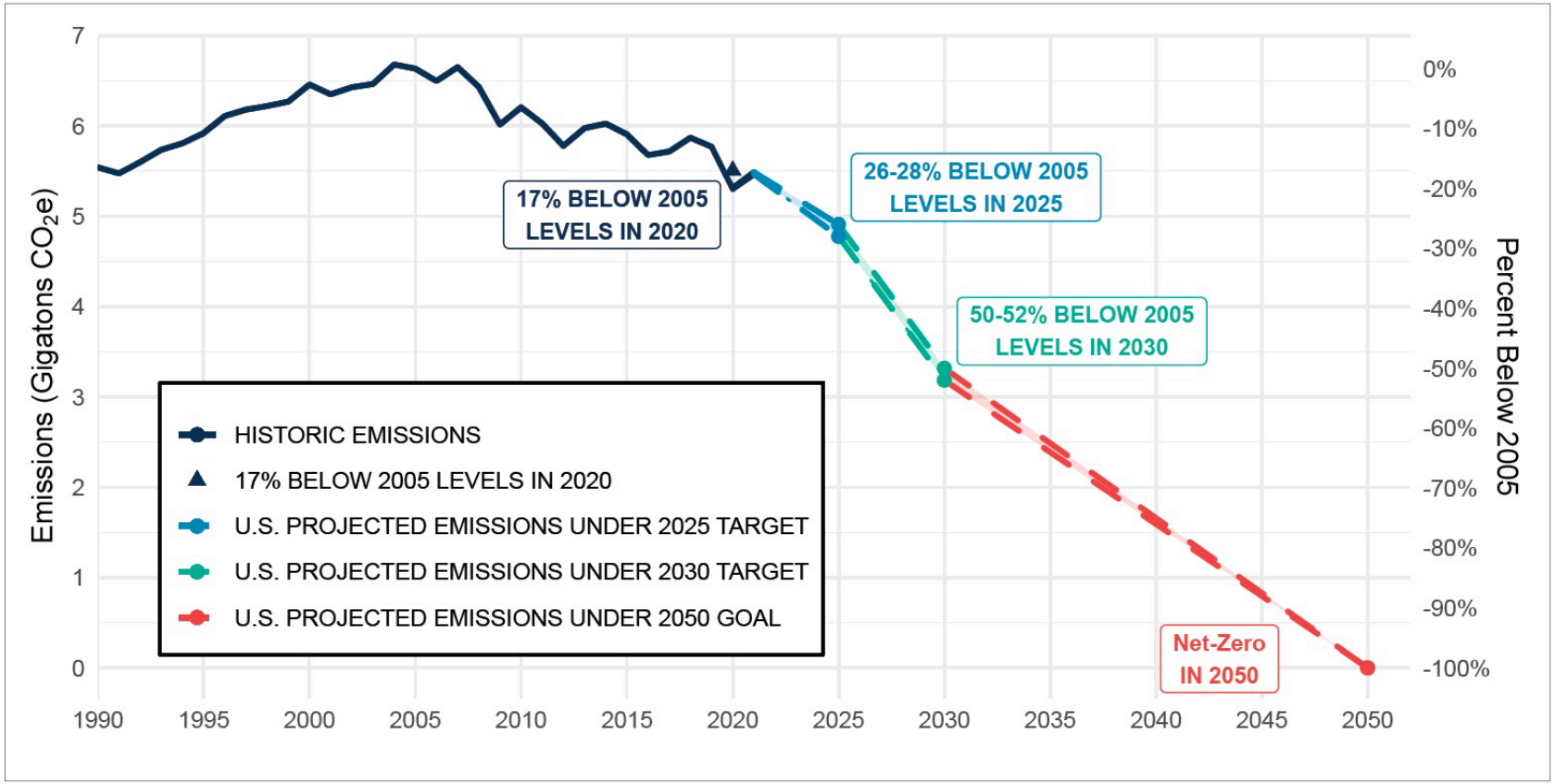


- Local Impacts: Heat Impact
- Dramatic rise in death toll;
- New cooling centers



Source: National Weather Service

Context for Changing Building "Energy/Carbon" Policy: The Long Term U.S. Strategy to Net Zero



Source: US Dept of State, 2021

NGA Message: “Glass Can (help) Save the World”

- Which Glass Solutions?
  - Glass only??.... → Integrated Façade Solutions
  - Building context
- Step 1: Act Quickly - Speed
  - GHG and Climate Change – the clock is ticking…
- Step 2: Maximize impact → Innovation
  - Increase impact per building… max potential
- Step 3: In Order to Have Impact → Deploy at Scale
  - Manufacturing infrastructure?
  - “Affordable” to Owners
    - Low Cost, with system tradeoffs
    - Higher cost but with offsets, e.g. incentives, tax credits…
    - Other financial impacts – Non Energy Benefits, NEBs

What's *Driving* High-Performance Buildings Today?

Energy efficient

Demand responsive

GHG/ Sustainable

Resiliency

Decarbonize

Circularity

Reduce Carbon/Energy Use?

Add Market Value?

Economics/Cost

Comfort

IAQ

Natural daylight

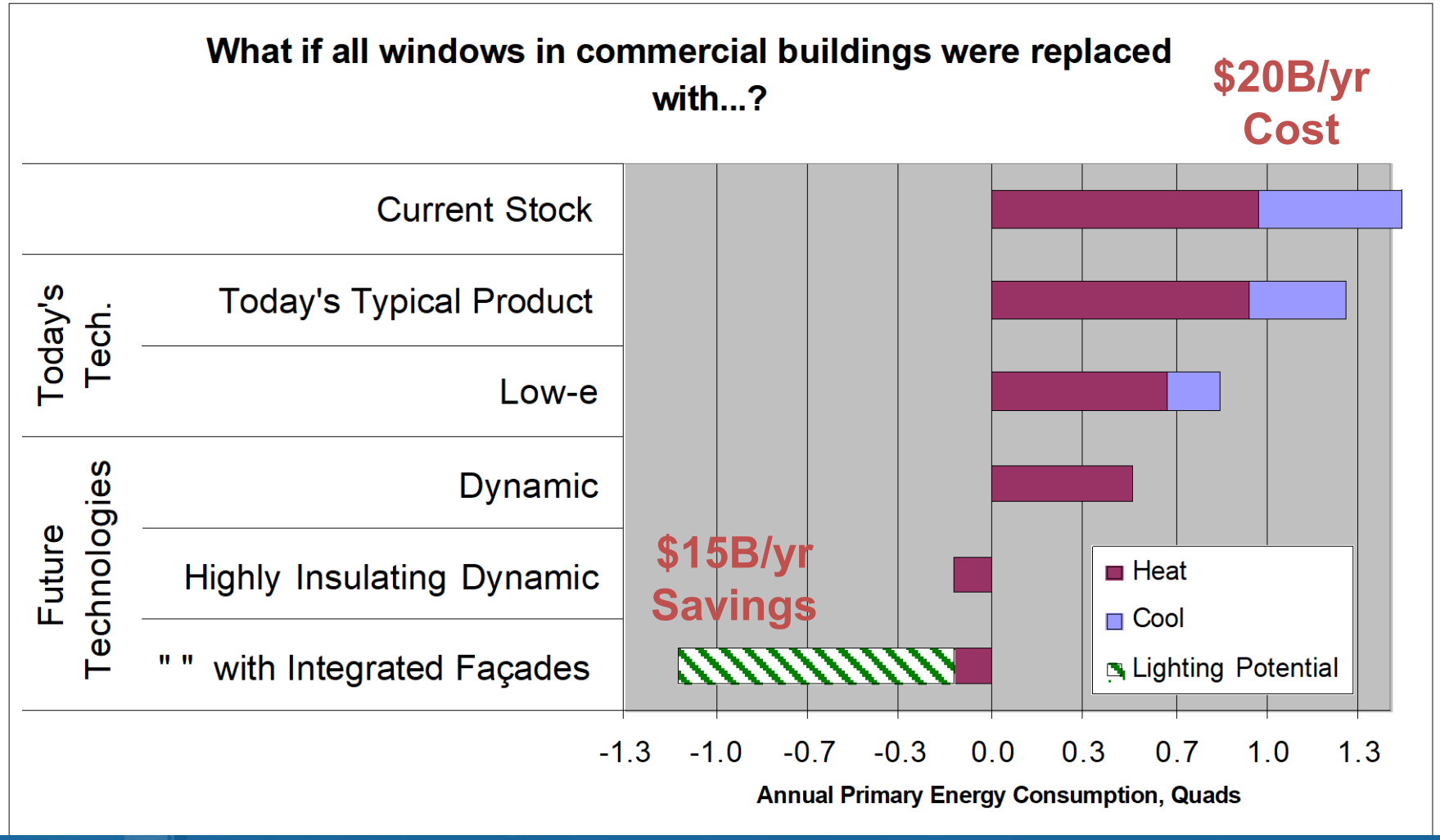
Outdoor views

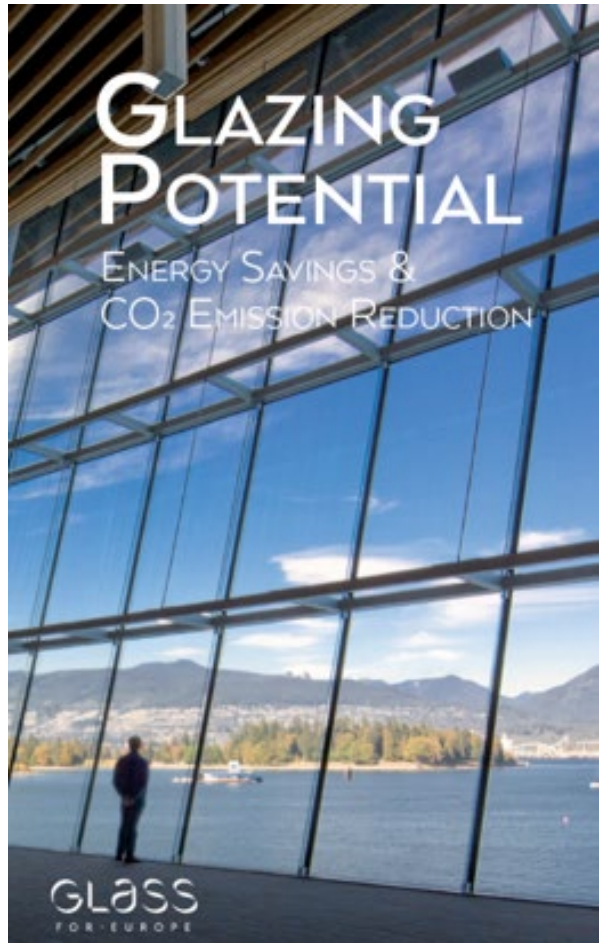
Health + well-being

Productivity

U.S. Commercial Building Window Energy Use

Converting a $20B/yr cost to a $15B/yr Net Surplus



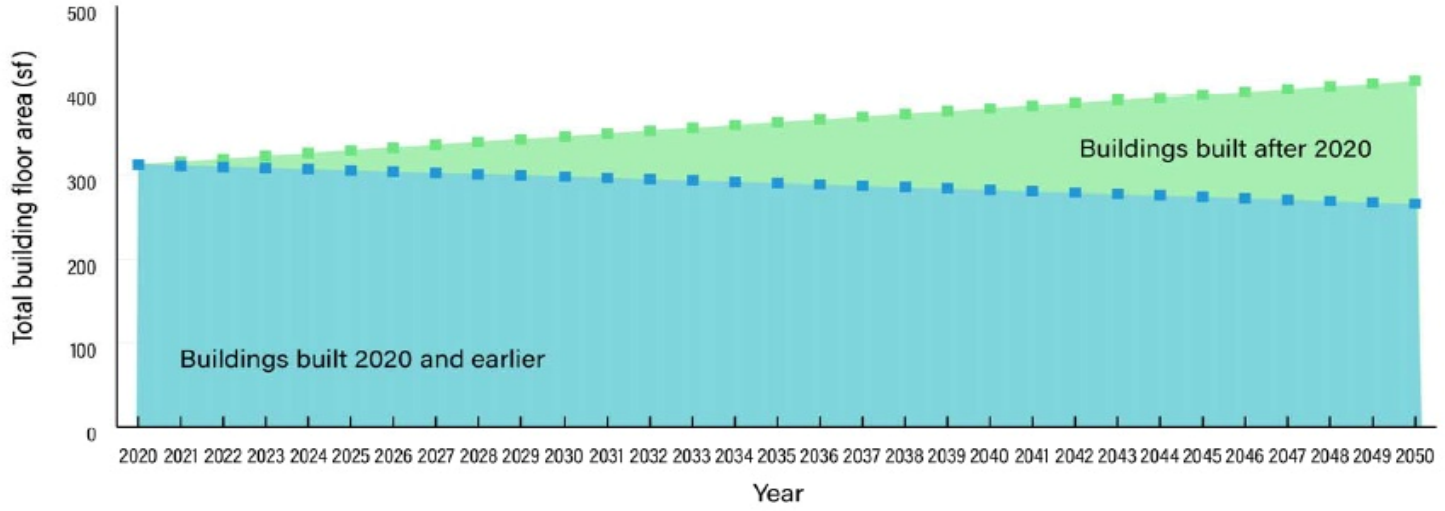


EU Glazing Energy Study

Existing Building Performance Drives Energy/Carbon Impacts:

Must Address Existing Building Stock to Reach Goals

New and Existing Buildings as Share of Building Floor Area (Residential + Commercial)



Source: ACEEE calculations based on data in EIA AEO 2020.

2020 2050

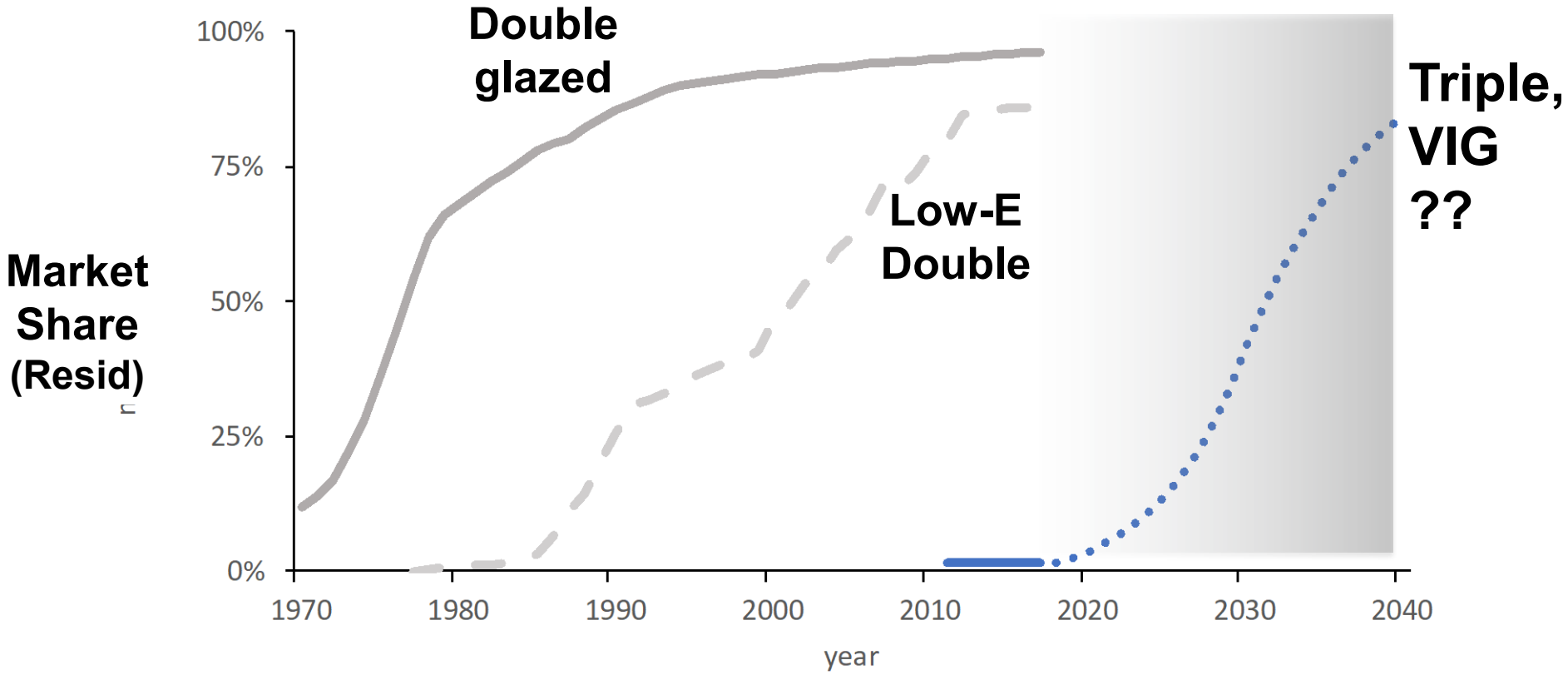
To Reach 2050 Carbon "Aggressive Goals" in Brattle/LBNL Study:

Commercial:
1.5 Billion sq ft glass/yr. → 43 B sq ft by 2050

Residential:
4M homes/yr. → 1.2 B sq ft/yr 30 B sq ft by 2050

(x 2 or 3 VIG, Triple,…)

Can we **Repeat** the **Market Adoption** Success of double low-e → Triple or VIG, but Faster



SPEED + SCALE

50% by 2050

Innovation push
tech development

Market Pull
Utilities
Energy Star

Codes and standards

Technical Vision for Glass/Façade Energy Impacts

Net Loss -> Neutral/"Net Zero" -> "Net Positive"

"Double glazing – Triple Low-E Glazing – VIG – Double Envelope Façade"

Dynamic Façade, Smart Glass, PV

Energy → grid impact, peak demand, carbon

Business Vision for "Net Zero" Glass/Façade

New Business Opportunities: Retrofit

More Value Added Product Sales

Design Freedom → WWR → Building Codes

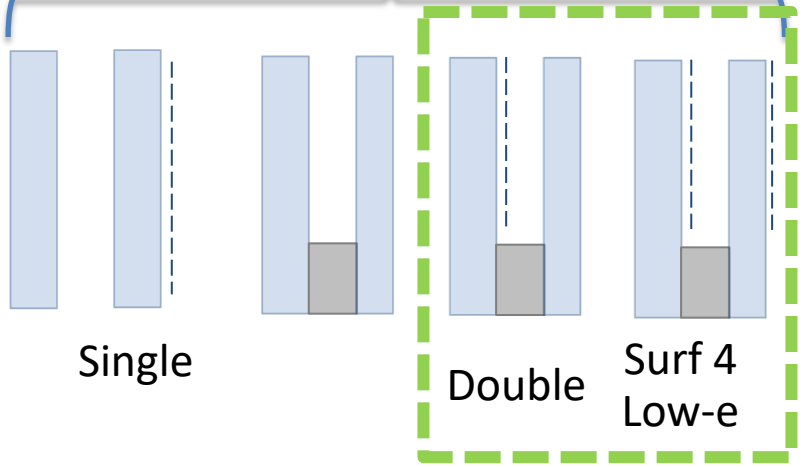
Occupant Benefits: View, Comfort, Health

Increased Real Estate Market Value

Technology: Highly Insulating Glazing Options

U ~ 0.25 Btu/hr-ft^2-F

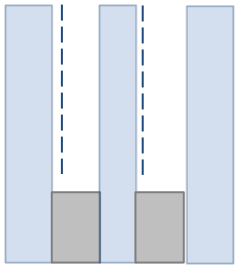
90% Market Today



Single

Double

Surf 4 Low-e



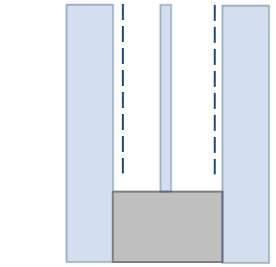
Two low-e Triple

U ~/< 0.1 Btu/hr-ft^2-F

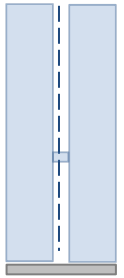
Emerging

Thin Glass

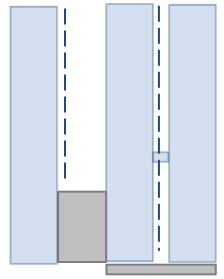
VIG



Two low-e, Thin glass, one spacer **Triple**

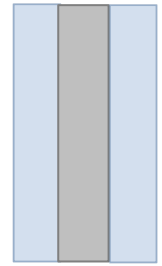


One low-e Vacuum, Prime/**retro**

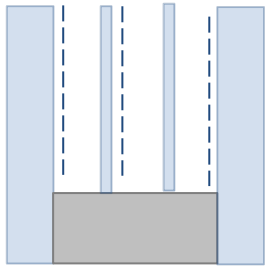


Two low-e Vacuum Hybrid

Future

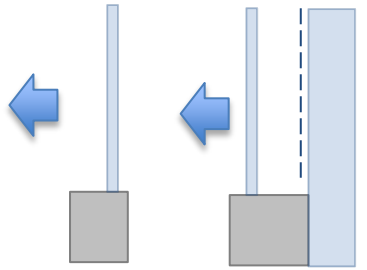


Aerogel

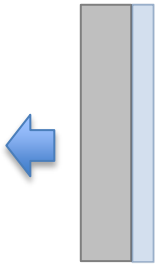


Three low-e **Quad**

Retrofit, Renovation



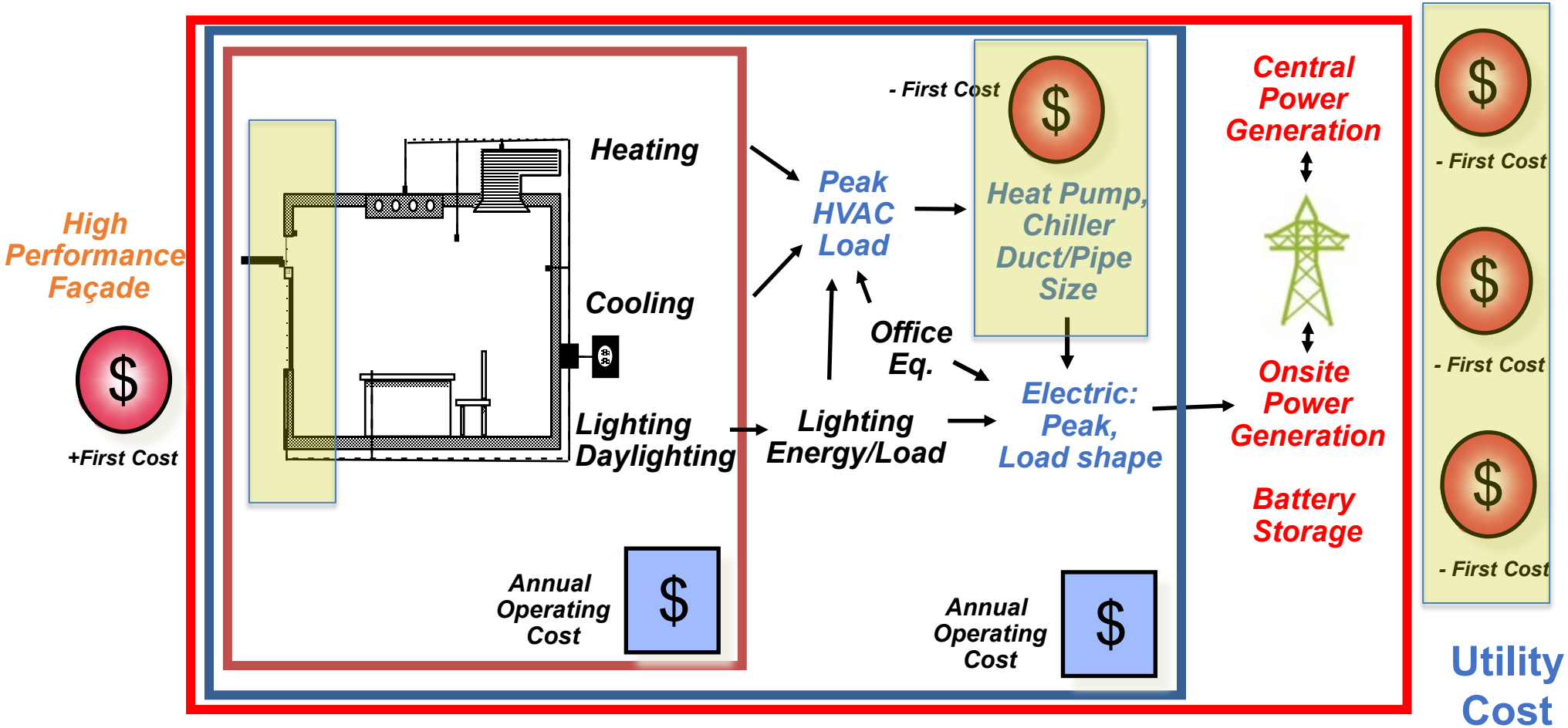
Single, Double "Secondary Glazings"



Aerogel, **Retrofit**

Glass/Façade vs. Total Building Systems Costs

Improved Façade → Lower HVAC System Cost → Lower Grid Cost



Building Cost Tradeoffs

Utility Cost Tradeoffs

Cost Tradeoff: Glazing vs Perimeter Heating

Triple Glazing Value Proposition:

Decrease perimeter **HVAC cost**
(pays for the glass cost?)

Reduce overall building **cost**
Condensation resistance
Comfort
Resilience
Peak heating and cooling
Stable load

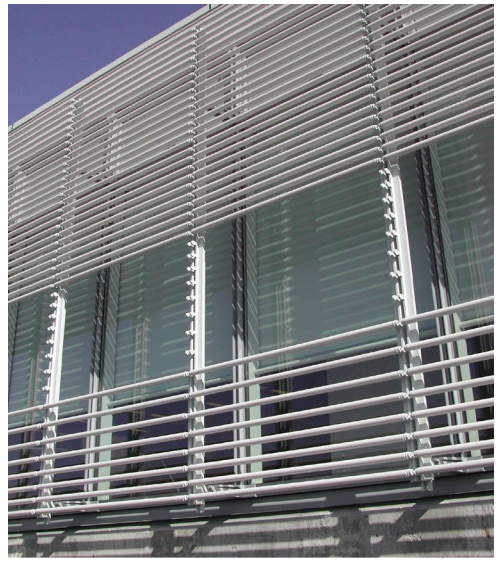
	Cost/ft2 Window
Upgrade Double to Triple Pane	$5.47
Add Perimeter Heat to Double	$53.20

*image credit and cost data: Chris Mackey at Payette Architects

How Do We Build Owner Confidence to Invest in these Systems Integration Challenges?

Validated Simulation/Modeling Tools

WINDOW, THERM, EnergyPlus



“De-risk” design, cost, operations

Mockups: Beyond air/water/structural

Demonstration Projects: DOE, GSA,…

“Field test” in new and existing, occupied buildings

Barriers to Better Facades

Source: Prieto JFDEv5#1

Most Expensive Building Element?

People!

Energy: $4/sf

Productivity: $400/sf

Energy Use, Carbon

vs

Occupant performance, salary, comfort, health, satisfaction, …

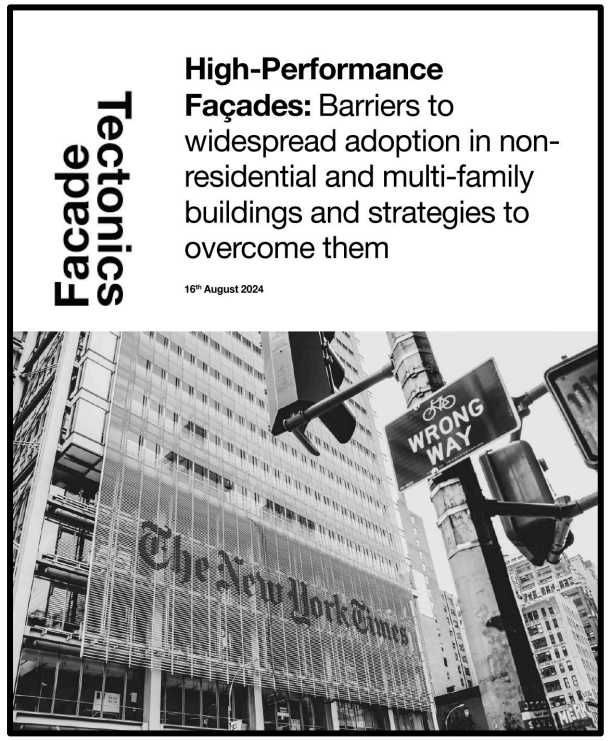
Transforming Markets for Advanced Glazings/Facades

Engage and Advocate for Better Glazing, Better Windows

- Identify and promote Best Practice
  - **Commercial Secondary Windows (CSW) are a key program element**

PAWS
PARTNERSHIP FOR ADVANCED WINDOW SOLUTIONS

https://www.PAWS.energy



"Accelerating the Adoption of High Performance Fenestration/Façade Solutions in Commercial Buildings"

Assess Barriers to Adoption

- Building type, Climate, Ownership models…

Recommendations to DOE: new concepts, best practice for market facing initiatives, R&D needs, decision-support tools, public policy,… immediate and longer term action

https://www.facadetectonics.org/

How Can the Glass/Facade Industry Deliver Innovative Solutions for New and Existing Buildings, Rapidly, At Scale?

Define Market Advantages; Minimize Added Cost or Risk

Glass/Façade Technology, Building Integration, Smarter Design offers:

- Manufacturers → New Business Opportunities
- Architects → Design freedom and flexibility
- Occupants → Better comfort, view, acoustics…
- Owners → Higher Value Properties
- Society → Reduce carbon emissions

Vacuum Insulating Glass (VIG)

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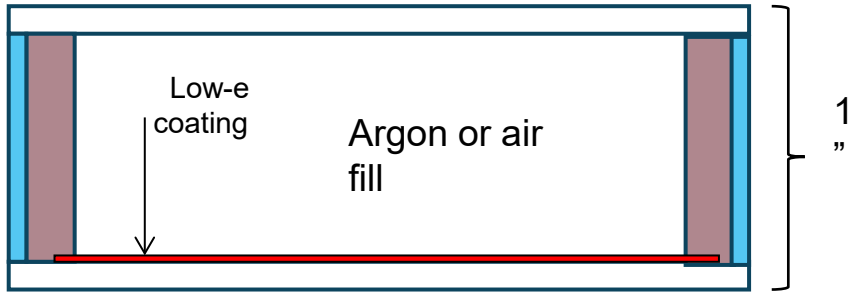
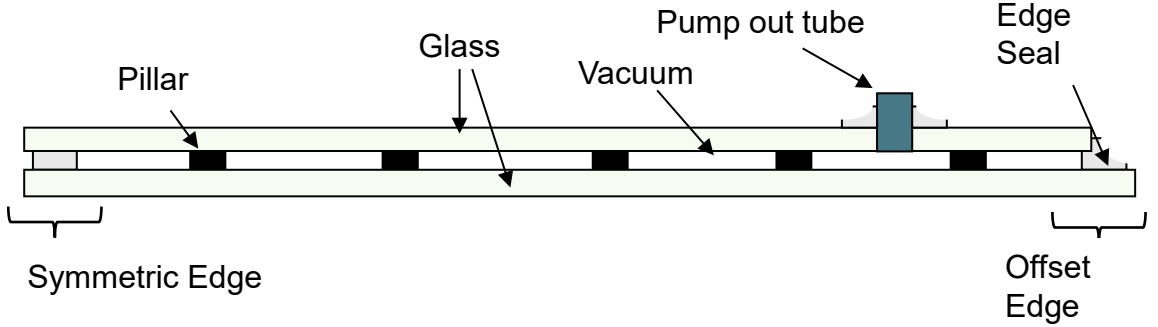
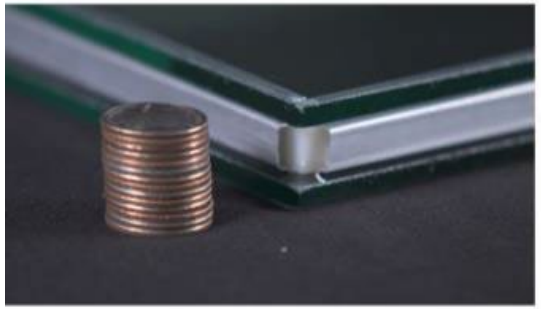
VIG Profile

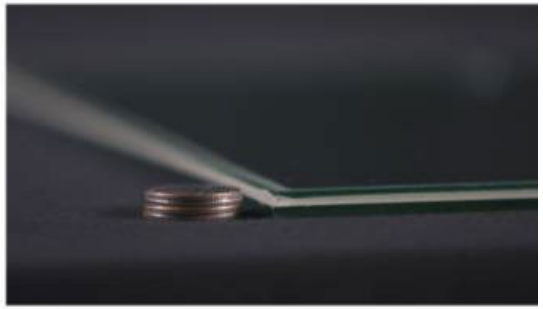
Typical Design

- Glass separated by a 0.2mm gap
- Partial vacuum between two pieces of glass
- Micro-spacer array separates the two pieces of glass
- Evacuation tube
- Hermetic seal along perimeter









Key Benefits

- dIGU/tIGU performance
  - Occupant comfort
  - Carbon payback
- Thin profile
  - Fits in existing monolithic sash
  - Lightweight
- Improved acoustic performance
  - dGU STC
- Options
  - VIG (AN-FT), Laminated VIG, Hybrid VIG
- Commercially available for ~25 years

Thin Triple/Quad IGU's & Lightweight Secondary Glazing

Technology Profile

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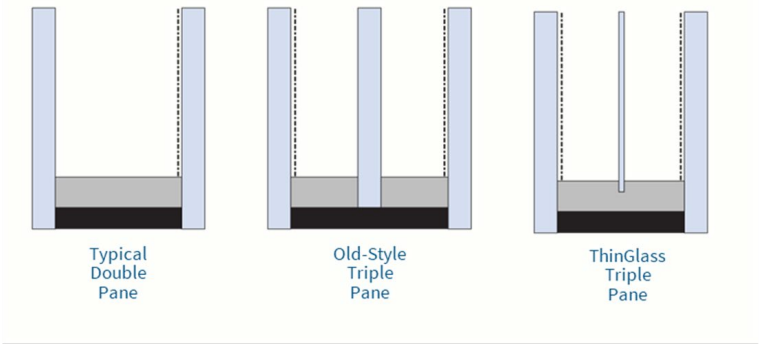
Thin **Triple/Quad IGU's**



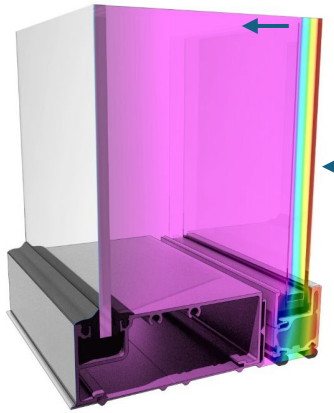
What Are Thin Glass IGU's?

- IGU with one (triple) or two (quad) non-structural thin glass center lites (0.5-1.3mm)
- Weight/thickness of dual pane with thermal properties of triple/quad pane (up to R-15 COG)
- Fully customizable to meet OA, coating, tempering, lamination, bird glass, etc. needs up to 60 sq ft.

Why Do They Matter?

- Compatible w/ most existing North American window designs and glazing standards
- Achieve Energy Star 7.0 and stretch code standards with **no design changes** in most windows
- Enable R8-10+ full frame in higher performing windows
- **Available at scale today** with automated production, 2MM+ square feet in the field

Lightweight **Secondary Glazing**



With thin-glass 2ndary glazing system (1lb/ft2), full frame **u = 0.27**

Existing, single-pane aluminum window (full frame **u = 1.12**)

What Is Lightweight Secondary Glazing?

- Thin glass unit (single pane or IGU) in thin, insulated frame
- Interior installation inside or proud (preferred) to existing frame
- Typical installation = 5-10 minutes
- Improves comfort, sound attenuation, thermal performance, glare. Invisible in most installs (no impact to sight lines).

Why Does It Matter?

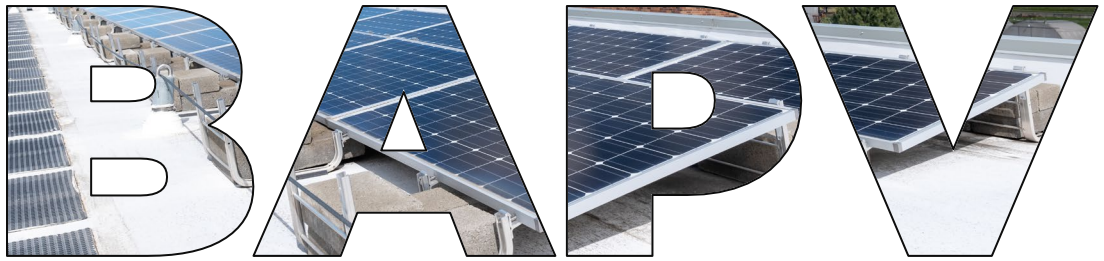
- Changes the math on window projects (<5-year payback)
  - 50% of the material cost vs. window replacement
  - 10-20% of the installation cost vs. window replacement
  - Greatly reduced installation risk/burden (tenants, penetrations)
- 80% of 2050's buildings already exist. Acute need!
  - Addresses greatest "energy hog" buildings + preserves historical gems with comfort/aesthetic issues
  - Light weight (1-3lbs/ft) facilitates fast, versatile installs; reduces structural engineering constraints

UNDERSTANDING EMERGING

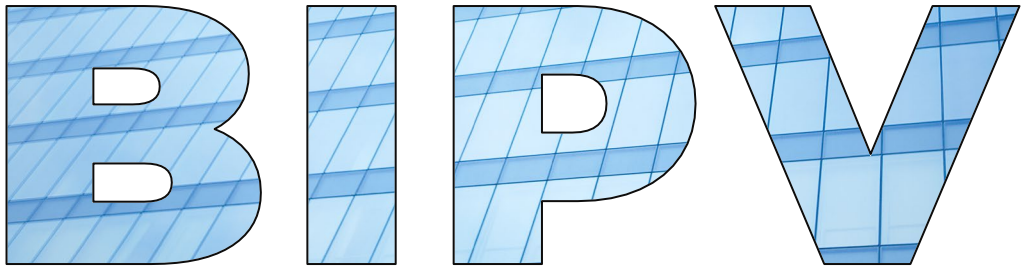
Building Integrated PhotoVoltaics (BIPV)

BLUEPRINT
FOR COLLABORATION

GLASSBUILD MAINSTAGE
KAY BAILEY HUTCHISON CONVENTION CENTER
DALLAS, TX



- Conventional PV modules directly attached to the building using additional mounting structure
- No direct effect on the building structure and function



- Specialized PV modules integrated into the building structure
- Integral component of the building providing both electricity generation and building functionality

Tech Integrators vs. Developers

- Integrators use existing solar technology (Si Wafer, CdTel, Amorphous Si, CIGS)
- They control the form factor
- Manage the certifications and integration systems for connecting into the building
- No ability to develop the underlying solar technology
- Limited applications

- Developers control the technology and manufacturing
- Organic PV (OPV)
  - Small molecule
  - Polymer
  - Solution Processed
  - Vapor Deposition
- Tunable, transparent, scalable, channel friendly
- Wide range of applications

MARKET DRIVERS

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CHALLENGES to MAIN STREAM ADOPTION

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PLAYBOOK >
What's Next?

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Questions or Comments?

Stephen Selkowitz

Principal
Stephen Selkowitz Consultants

Advisor
Lawrence Berkeley
National Laboratory

Kayla Natividad

Architectural Technical
Service Engineer

Pilkington North America

Andrew Zech

CEO

Alpen High Performance
Products

Jonathan Hafemann

VP Commercialization
& Growth

NEXT Energy Technologies

Share Your Thoughts!