U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

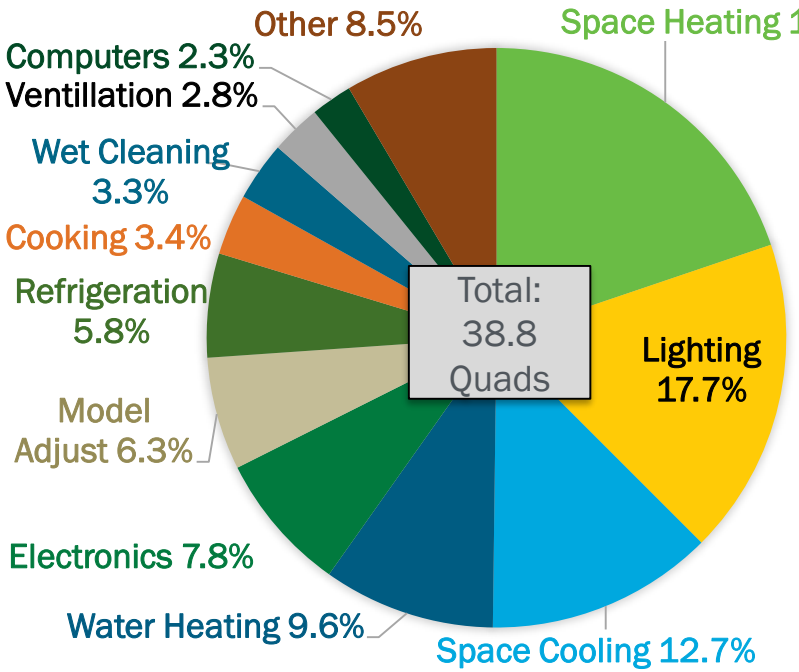
BTO Windows ET R&D and RBI Field Validation Overview for Peer Review

Marc LaFrance

17 & 18 April 2019

U.S. Building's Energy Consumption and Expenditures

Building Energy Use



Envelope & Windows Impact Over 50% of Loads

Building Component	Residential (quads)		Commercial (quads)	
	Heating	Cooling	Heating	Cooling
Roofs	1.00	0.49	0.88	0.05
Walls	1.54	0.34	1.48	-0.03
Foundation	1.17	-0.22	0.79	-0.21
Infiltration	2.26	0.59	1.29	-0.15
Window (conduction)	2.06	0.03	1.60	-0.30
Window (solar heat gain)	-0.66	1.14	-0.97	1.38

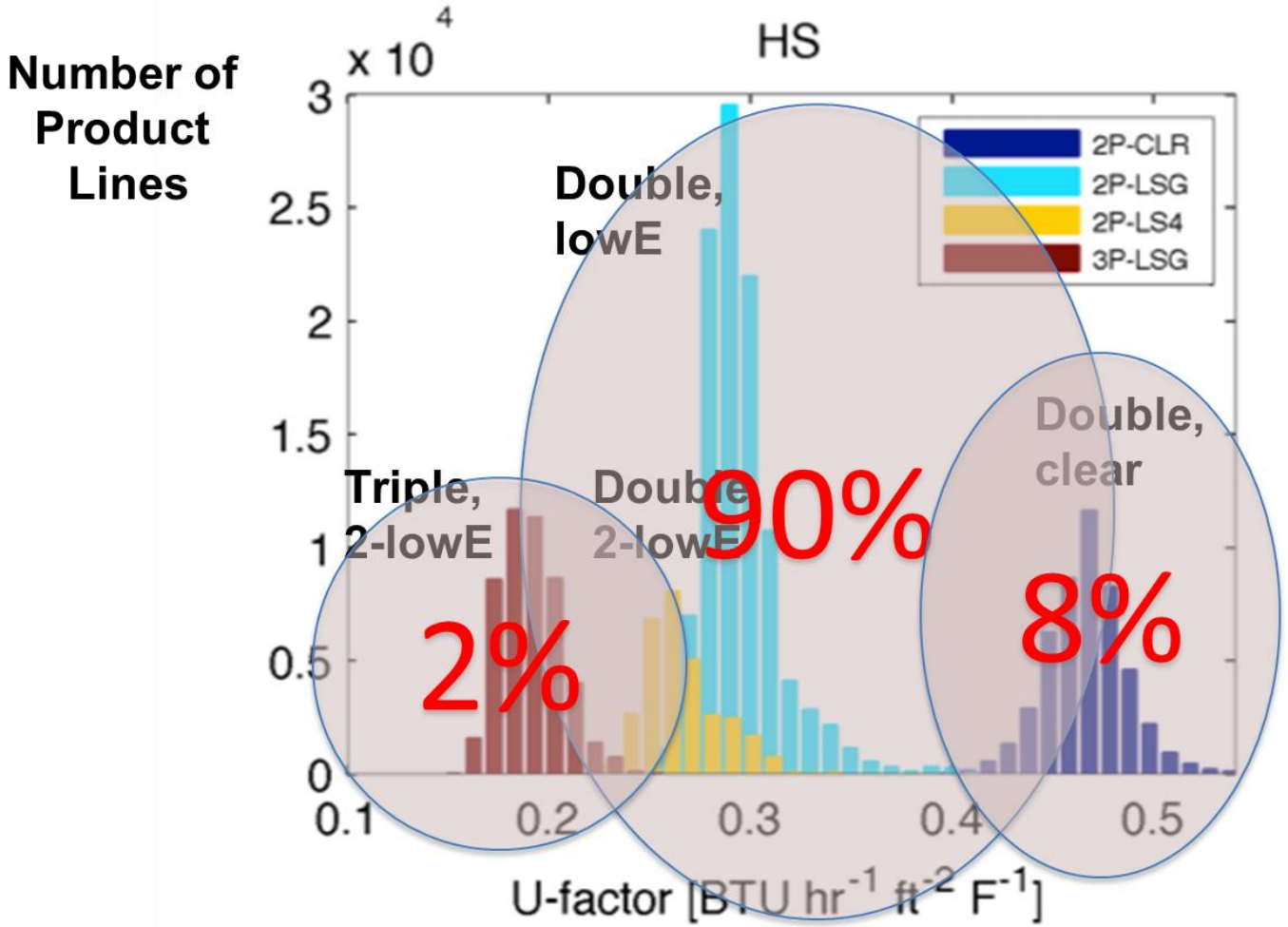
Buildings Natural Gas Use: 60% of U.S. total

Buildings Electricity Use: 75% of U.S. total

U.S. Building Energy Bill: $380 billion per year

Market Snapshot – Residential Example

Source: EPA ENERGYSTAR analysis, Horiz. sliding windows

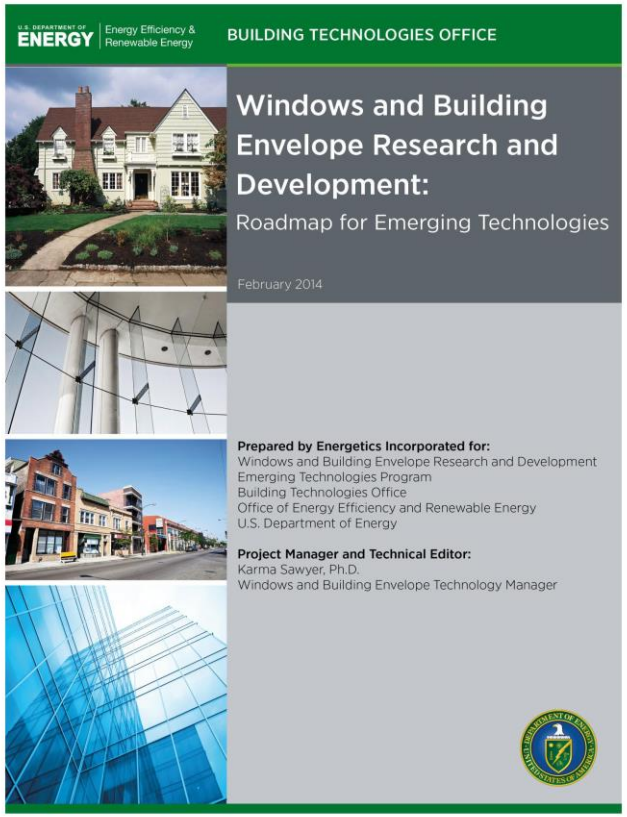


Current Roadmap Goals/Targets – Being Updated

Technology	2025 Installed Cost Premium Target	2025 Performance Target
	Highest Priority R&D Area	
R-10 Windows	Residential: ≤ \$6/ft^2 Commercial: ≤ \$3/ft^2 over typical 2010 windows	• Residential: R-10, V_T > 0.6 • Commercial: R-7, V_T > 0.4 • Comparable weight and thickness to currently installed base
	High Priority R&D Areas	
Dynamic Windows	Windows: ≤ \$8/ft^2 Window Films: ≤ \$2/ft^2 over a standard IGU	• ΔSHGC > 0.4 • V_T bleached state > 0.6 (residential) and > 0.4 (commercial)
Visible light redirection (commercial)	≤ \$5/ft^2 over standard window or shade including lighting and controls costs	50% reduction in lighting energy use over a 50-ft floor plate

Roadmap History

- 2001 — First BTO Windows and Opaque Envelope Roadmaps
- 2002–2012 — Workshops to prioritize technology development
- 2014 — Current BTO Windows and Opaque Envelope R&D Roadmap
- Related Roadmaps
  - 2015 — Building America Technology-to-Market Roadmaps
  - 2013 — IEA Envelope Roadmap



BTO Developing an Updated Windows and Opaque Envelope R&D Roadmap

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BUILDING TECHNOLOGIES OFFICE

Windows and Building Envelope Research and Development:

Roadmap for Emerging Technologies

February 2014

long-term air infiltration and structural requirements in order to gain a high-performance window label.

- **Window construction cost reductions –** Cost reductions are needed for the overall assembly of triple-glazed units with a thin glass middle layer, krypton gas fill[22], and multiple low-E coatings. Cost savings will likely come from manufacturing advances that enable automated, high-throughput product manufacturing and installation while still being able to produce custom sizes required in diverse building applications.
- **Amenability to retrofits –** Highly insulating windows must be developed at reduced or at least comparable thickness and weight to the currently installed window base so that they are amenable for commercial and residential building retrofit applications. A bulky/heavy window is also more costly to transport.
- **Simplified window installation –** Window installation is currently labor intensive, expensive, and variable. In order to enable mass-scale and possibly automated retrofits, window installation must be simplified to be "snap-in" or "dummy-proof." Effectively, the entire window system, including all components and insulation, must be easily installed with the "snap-in" capability.

BTO internal analysis shows that if the R&D roadmap cost and performance targets are achieved, the payback period would be reduced from 12 to 5.3 years and 66 to 8 years for the residential and commercial sectors, respectively. BTO projections show that energy savings from highly insulating windows would become even more substantial beyond 2030 as the installed base of windows turns over. Windows are generally a once-in-a-lifetime purchase, and as such the diffusion of new window technologies into the market will take longer than other energy-efficiency technologies.

Figure 14. R-5 window, schematic diagram (left) and commercial product (right) (images courtesy of Alcoa/TRACO)

Figure 15 (with corresponding data shown in Table 8) shows the results of an economic sensitivity analysis for highly thermally insulating residential windows, considering the projected impacts of high ($18/ft^2), medium ($12/ft^2) and low ($6/ft^2) installed cost premiums. The payback period is more heavily dependent on the installed cost of the window than on the R-value. For example, the payback of R-10 windows decreases by a factor of 3 when reducing the installed cost premium from $18/ft^2 to $6/ft^2.

[22] Due to its higher molecular mass, krypton is a more effective insulator than argon ($k \propto \frac{c_v}{\sigma^2}\sqrt{\frac{T}{MW}}$ where k = thermal conductivity, c_v = constant volume specific heat capacity of gas, σ = molecular radius, T = temperature and MW = molar mass of gas). The thermal conductivity of krypton is 0.0053 Btu/ft ·°F·hr, while the thermal conductivity of argon is 0.0093 Btu/ft ·°F·hr.

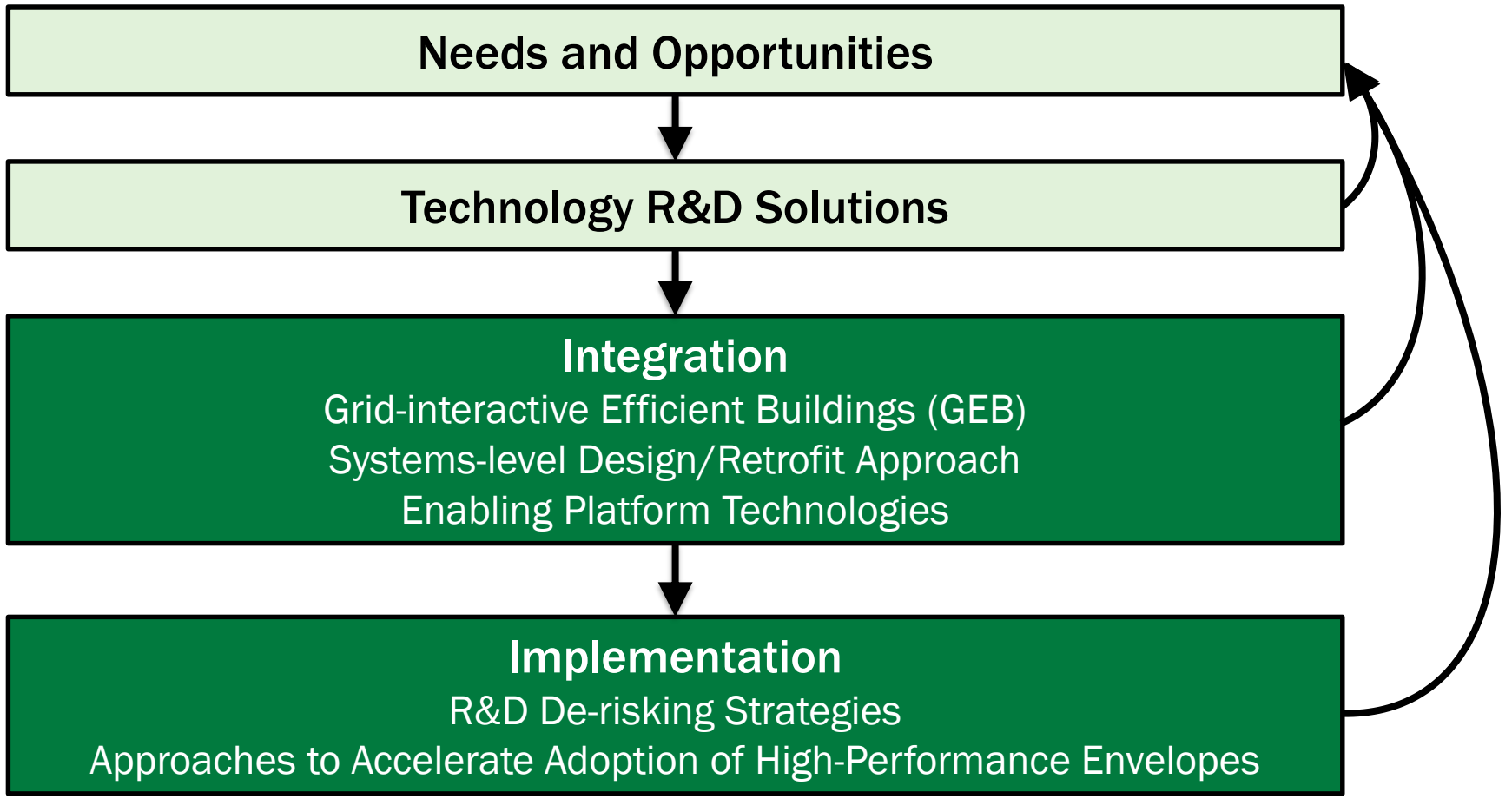
R&D Roadmap For Emerging Window And Building Envelope Technologies 20

- BTO uses roadmaps to guide strategy for R&D programs, criteria used in FOA
- R&D early stage research but programs should lead to commercialized energy efficient technologies
- Core window objectives expected to stay fundamentally the same, cost effective highly insulating dynamic windows along with daylighting
- Recent Roadmap Meeting Summary – https://energy.gov/eere/buildings/downloads/windows-envelope-rd-opportunities-workshop

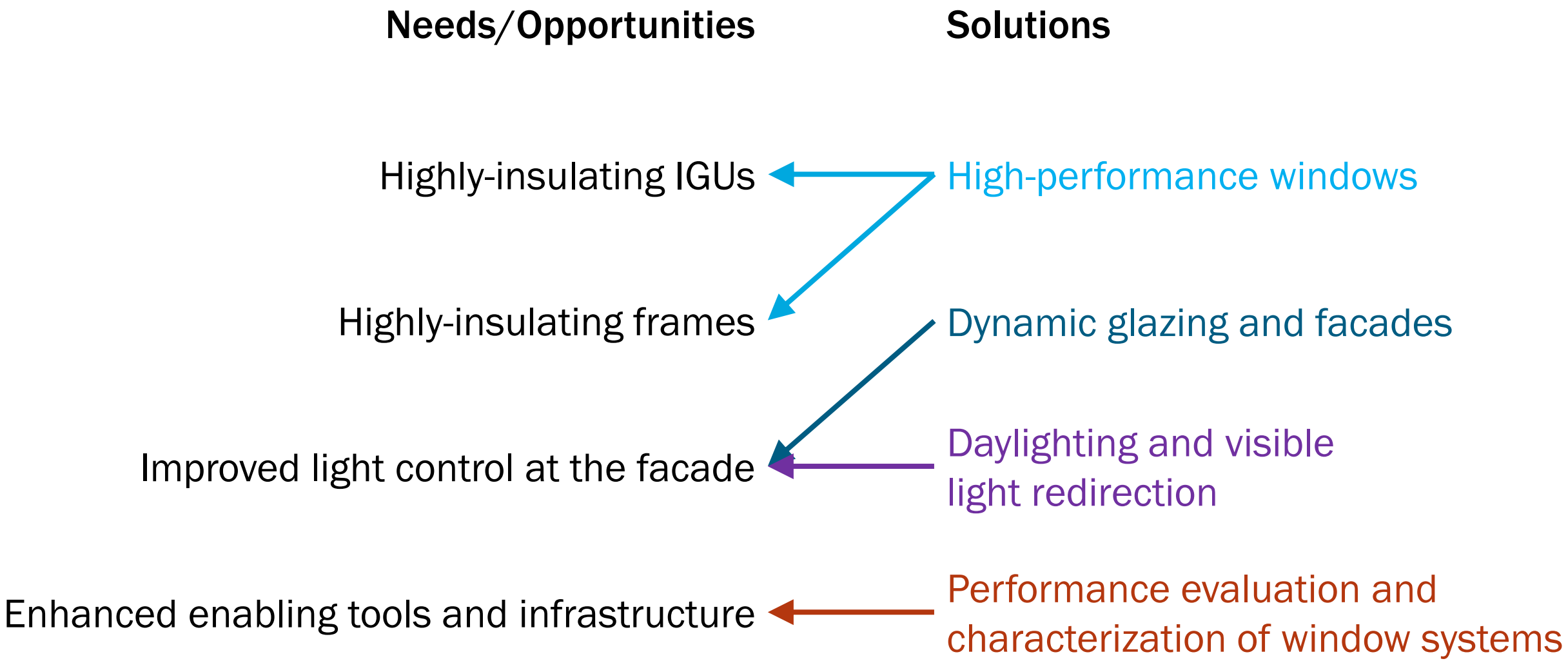
Process for Roadmap Revision

- **Obtained input from wide range of stakeholders**
  - Buildings XIII Conference, Clearwater, FL — December 2016
  - Georgia Tech Workshop — February 2017
  - Chicago Workshop — June 2017
- **Working with LBNL, ORNL, and NREL on key sections**

Structure of Roadmap



Solutions (Windows)



Window Metrics and Targets by Technology (DRAFT ROADMAP)

	Building Sector	Performance		Installed Price Premium		Primary Energy Savings (quads)	
						2030	2050
Highly Insulating Windows	Residential	13	R-value	2.9	$/ft^2 window area	1.28	1.07
	Commercial	10		8.5		0.93	0.72
Dynamic Windows	Residential	0.05/0.65	SHGC (active/inactive)	2.9	$/ft^2 window area	1.35	1.5
	Commercial			15		1.56	1.64
Daylighting	Commercial	40%	Lighting energy savings	13	$/ft^2 window area	0.26	0.17

Significant Success

- **Overwhelming majority of windows and glazing systems are designed using DOE/LBNL software tools that are based on comprehensive science**
- **Major progress/contribution to development and/or market adoption of many products: low-e spectrally selective, low-e film, low-e storms, low conductive thermal frames, dynamic glass, high volume factory conventional triple pane, integrated highly insulated and dynamic**
- **Recent project completions:**
  - **LBNL/Pella automated residential shades** -consumer acceptance deemed much higher priority than optimized energy savings
  - **Arconic R7 windows with low conductive frames** -fundamental new approach to thermal break with bonding vs mechanical attachment
  - **WCMA development of the Attachment Energy Rating Council (AERC)** -now rating and labeling residential attachment products

ET Projects Underway or Soon to Start

- LBNL core window energy performance lab and NREL enabling core window durability lab, Merit Review/Lab Call FY18, peer reviewed today
- University of Colorado (formerly Stanford) reversible metal plating dynamic windows, FOA FY17, peer reviewed today
- V-Glass low cost annealed VIG, SBIR Phase II, FY18, peer reviewed today
- Ashwin Ushas - Electrochromic Auto-Darkening Windows (TM – S. Mumme), peer reviewed today
- ORNL vacuum glazing, Lab Call, FY18/19, too early for peer review
- NREL thermochromic PV coatings, Lab Call, FY18/19 too early for peer review
- ANL thermochromic, BENFIT FY18, selected, yet to be awarded
- Polyceed/NREL, electrochromic, BENEFIT FY18, selected, yet to be awarded
- University of Maryland, BENEFIT FY18, selected, yet to be awarded

RBI Window Field Validation Projects

- PNNL highly insulating windows (thin triple), Lab Call FY18/19, early but peer reviewed tomorrow to help coordinate and assess plan moving forward rather than results
- LBNL with PNNL and ORNL window attachments, Lab Call FY18/19, early but peer reviewed tomorrow to help coordinate and assess plan moving forward rather than results
- LBNL with ORNL wall/window panels, Lab Call FY18/19, early but peer reviewed tomorrow to help coordinate and assess plan moving forward rather than results

Peer Review - Evaluation Criteria and Weighting

This year we will have 3 set of scored criteria

Project Criteria

- Approach (30%)
- Impact (20%)
- Progress (15%)
- Collaboration and Coordination (20%)
- Remaining Project Work (15%)

Portfolio (Partnerships)

- Scope (30%)
- Impact (40%)
- Collaboration, Coordination, and Integration (30%)

Portfolio (Data, Modeling, and Controls)

- Scope (30%)
- Impact (30%)
- Collaboration, Coordination, and Integration (20%)
- Communication and Stakeholder Engagement (10%)
- Metrics (10%)

Peer Reviewers

- Do the best you can applying the generic criteria to the large varying project scopes
- Comments are most useful, can provide key bullets to reduce writing time

Thank You for Your Service!!

Contact Information

P Marc LaFrance, CEM
Advanced Technology and Energy Policy Manager
US Department of Energy
1000 Independence Ave, SW
Washington, DC 20585-0121
marc.lafrance@ee.doe.gov
202-586-4972
Cell 240-474-2177