U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Windows and Opaque Envelope R&D Opportunities Report Update

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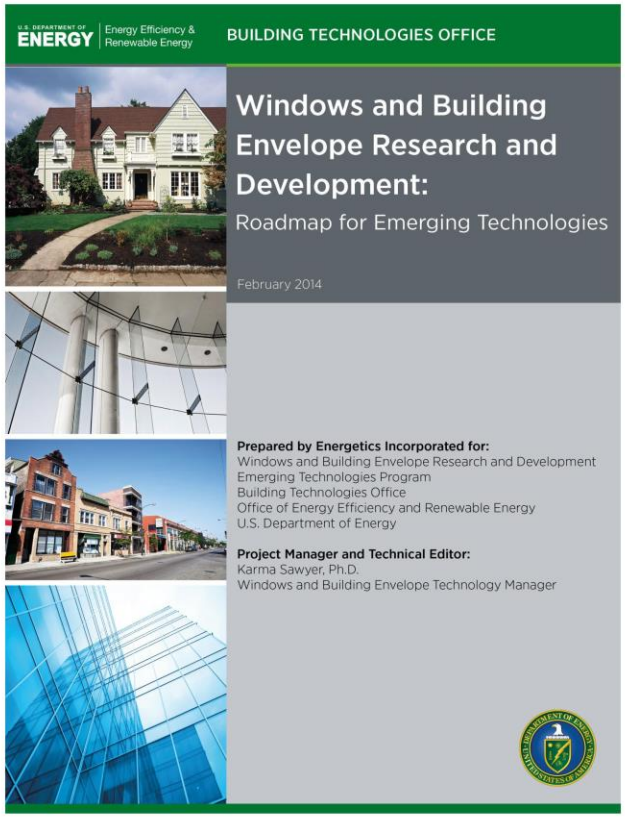
Previous Envelope R&D Reports

- 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



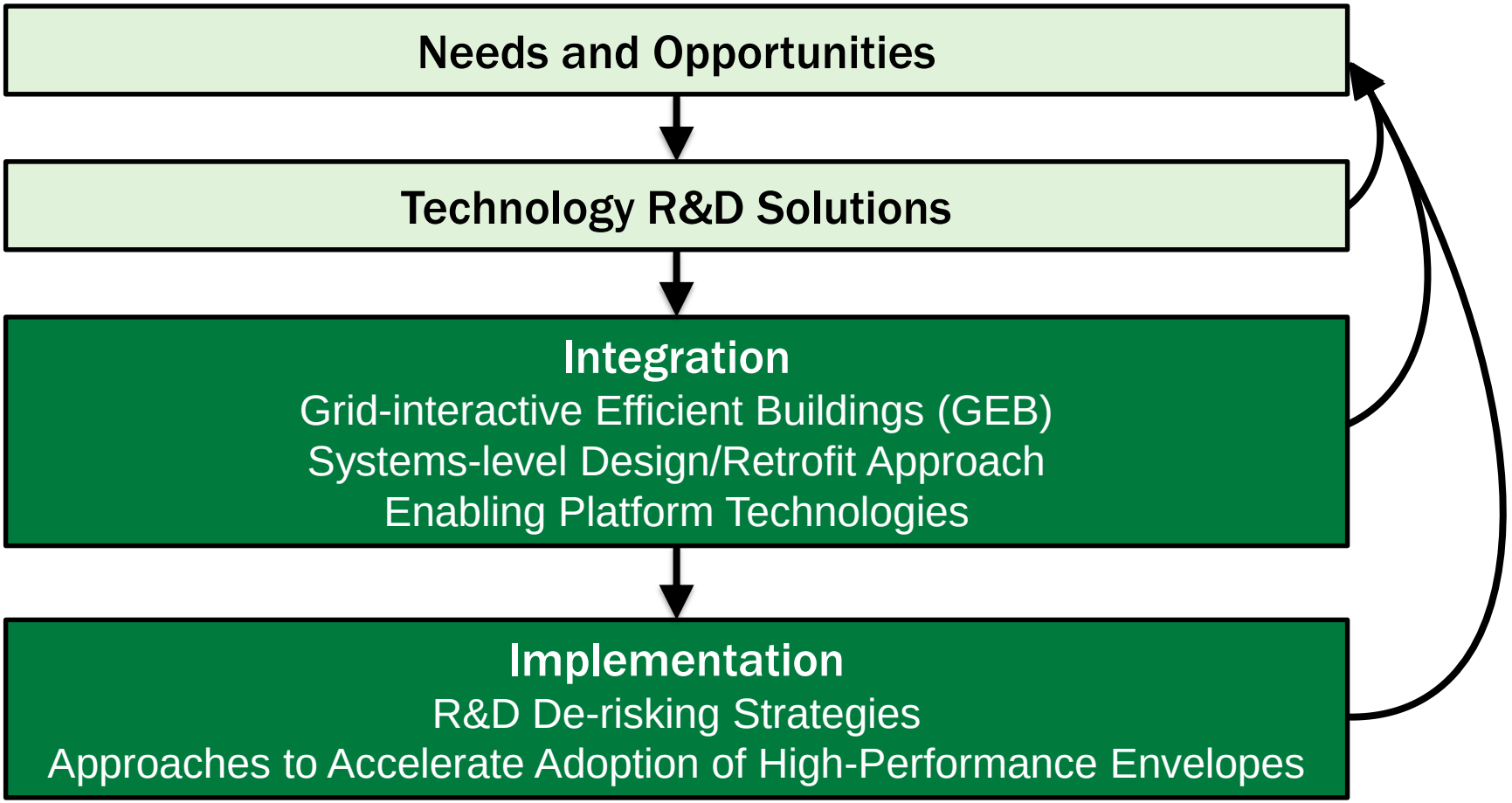
Process for R&D Opportunities Report Revision

- **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**

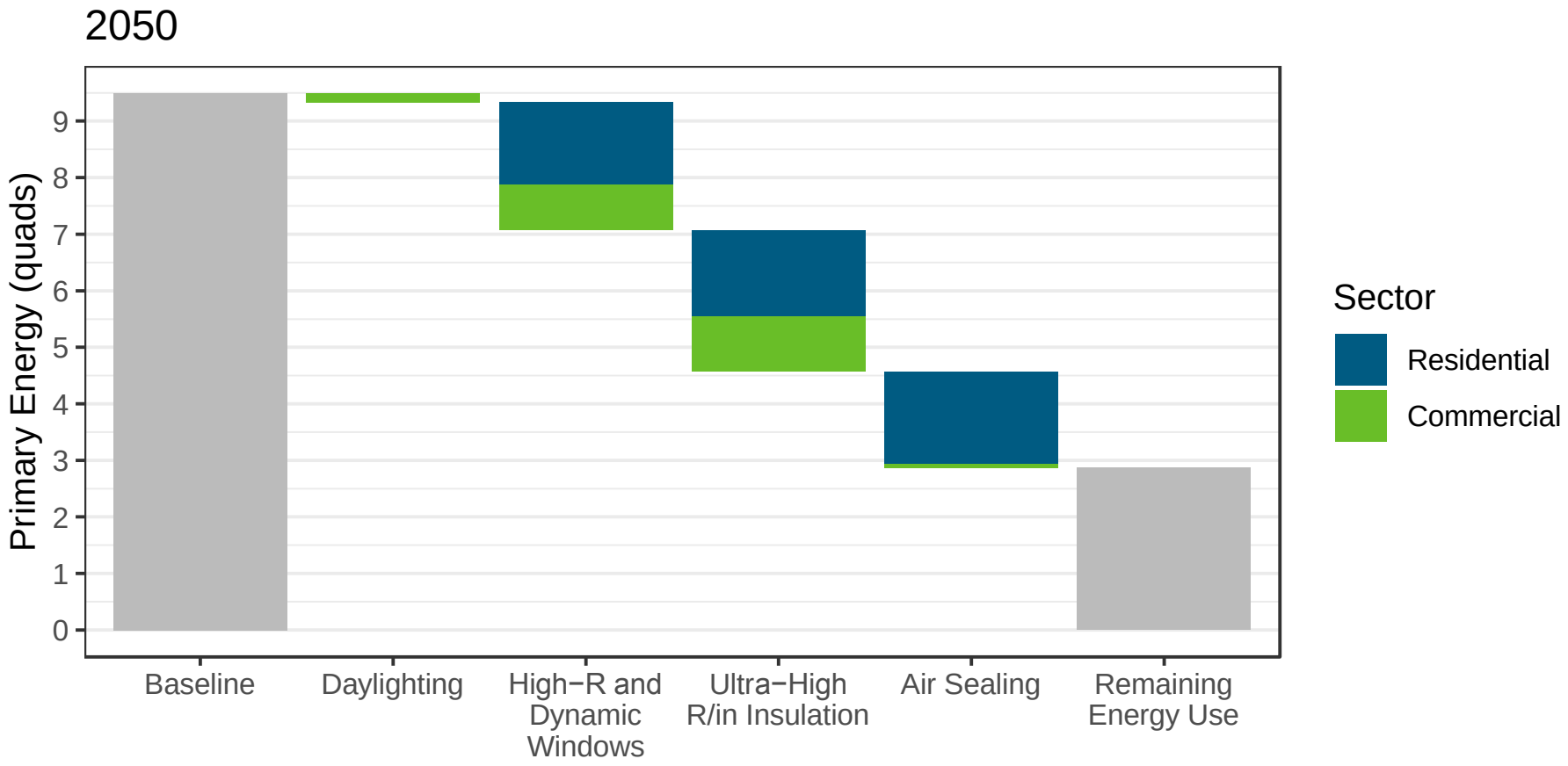
Keys in Approach to Current R&D Report

- Increased detail regarding technical needs and gaps relative to current state-of-practice/state-of-the-art
- Explicit linkages between current needs/gaps, R&D areas, energy savings potential, and enabling strategies
- Increased detail regarding R&D technical areas
- Additional forward-looking R&D objectives
- Longer time horizon for targets
- More expansive treatment of enabling and cross-cutting R&D

Structure of R&D Opportunities Report



Overview of Energy Savings from Targets



Competed savings shown (overlapping savings removed), Technical Potential scenario

Cross-cutting Need – Envelope Retrofit Adoption

- **Addressing envelope retrofit market acceptance**
  - Minimize disruption to building occupants
  - Minimize on-site labor
  - Simplify and streamline interface/detail work
  - Fault-tolerant installation features/characteristics
  - Expand value proposition beyond energy savings

Needs/Opportunities (Opaque Envelope)

Needs/Opportunities

Thermal energy management

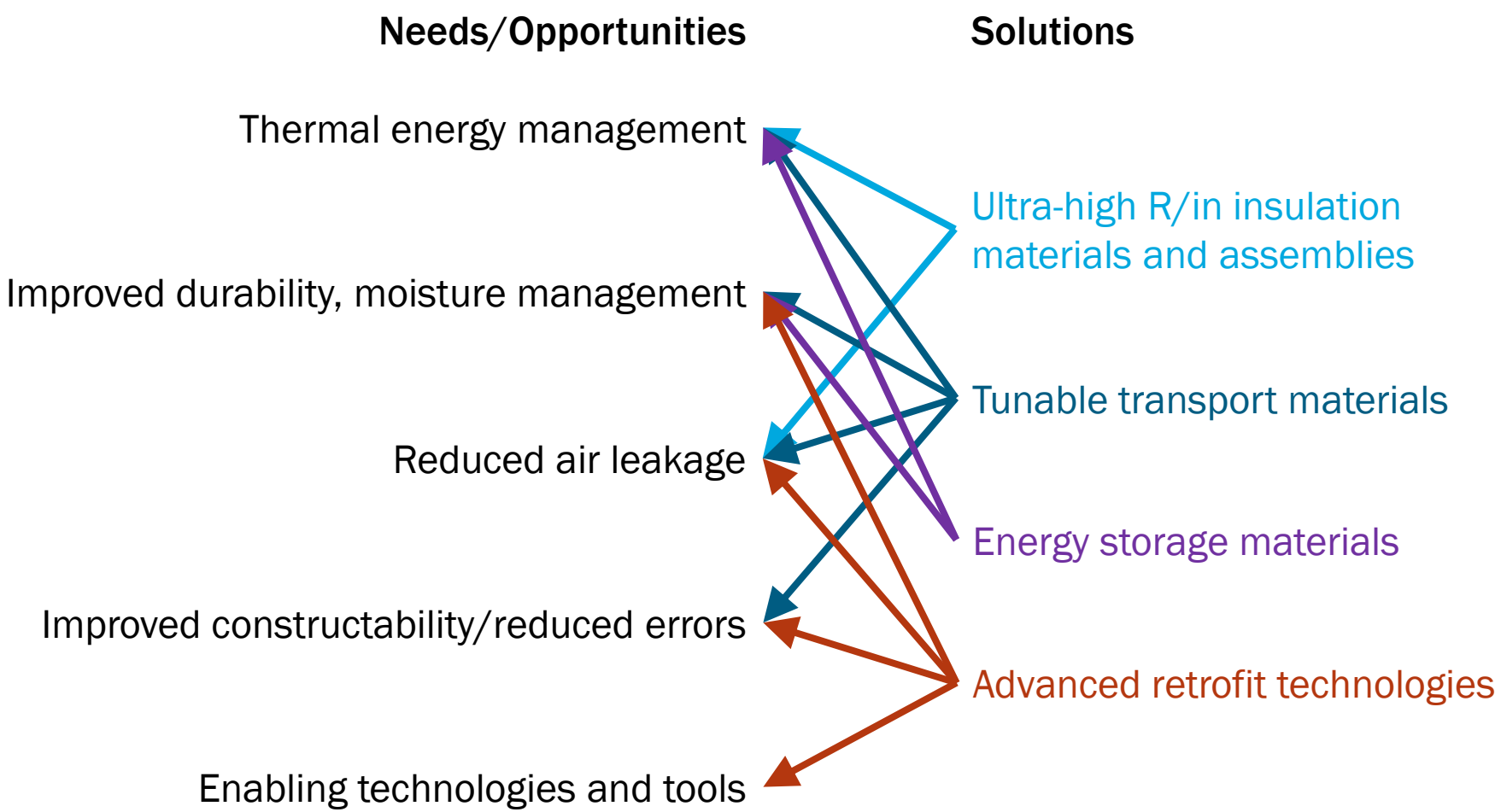
Improved durability, moisture management

Reduced air leakage

Improved constructability/reduced errors

Enabling technologies and tools

Solutions (Opaque Envelope)



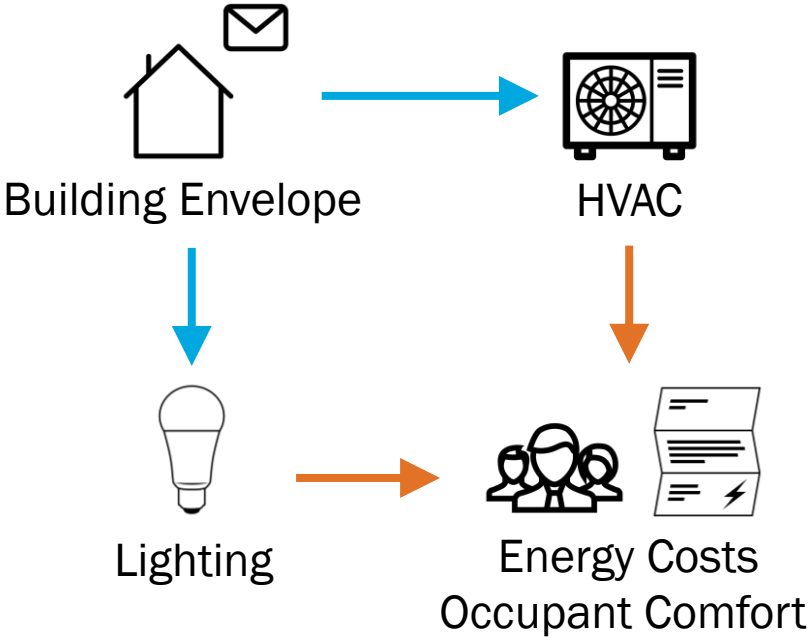
R&D Presentations (Opaque Envelope)

Monday	Ultra-high R/in insulation materials and assemblies	*Models for Low Thermal Conductivity Materials (12:00 PM)*
		Metrology for Super-insulating Materials (1:30 PM)
		Closed-cell Vacuum Insulation (2:00 PM)
		Inventwood (2:45 PM)
		Self-Healing VIPs (3:15 PM)
		Ultralow Thermal Conductivity Material (4:15 PM)
		Robust Super Insulation (4:45 PM)
		R-12/in PIR-based Super Insulation (5:15 PM)
Tuesday	Tunable transport materials	Active Insulation Systems (11:30 AM)
		Dynamic Photonic Metamaterial (4:15 PM)
		Adaptive Weather Resistant Barrier (4:45 PM)
	Energy storage materials	Low-cost Composite PCM (12:00 PM)
		Solid State Tunable Thermal Storage and Switches (2:45 PM)
	Daylighting (Windows)	Stationary Concentrator Daylighting System (5:15 PM)

Opaque Envelope Metrics and Targets

	Building Sector	Performance	Installed Price	Primary Energy Savings (quads)	
				2030	2050
Wall Insulation	Residential	20 R-value/in	0.37 $/ft^2 wall area	1.16	1.04
	Commercial		1.54	0.82	0.70
Roof Insulation	Commercial	2x ASHRAE 90.1 2016	0.34 $/ft^2 roof area	0.41	0.34
Foundation Insulation	Residential	15 R-value/in	0.42 $/ft^2 footprint	0.62	0.50
Multifunctional Materials	Residential	25% Envelope energy savings	0.21 $/ft^2 envelope	0.68	0.42
	Commercial		0.33	0.40	0.24
Air Sealing Remediation	Residential (New)	1 ACH50	0.48 $/ft^2 wall area	0.29	0.50
	Residential (Existing)		0.61	1.55	1.15
	Commercial (New)	0.2 CFM75/ft^2	0.37	0.10	0.37
	Commercial (Existing)		0.80	0.38	0.18

Integration – Systems-level Design Approach



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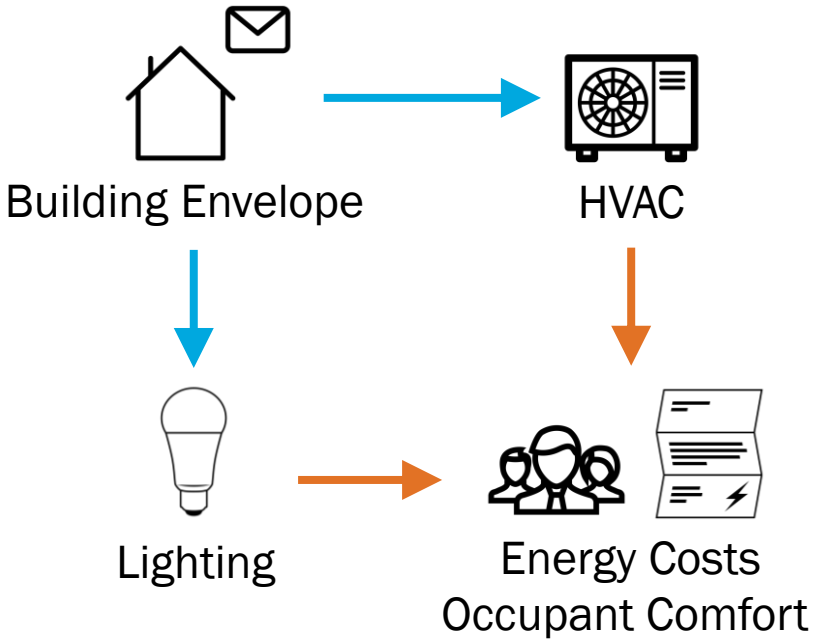
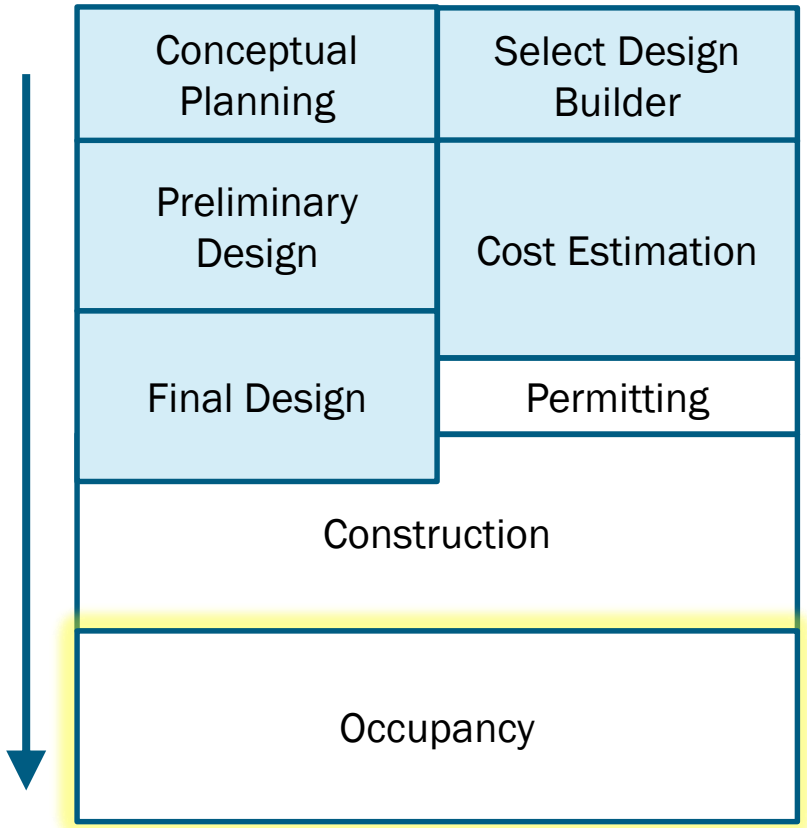
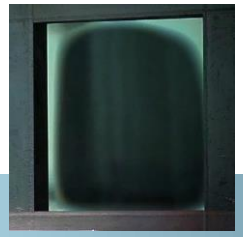




Integration – GEB Potential for the Envelope

- **Buildings can provide services to grid operators**
  - Reduce peak electricity demand
  - Help integrate variable renewables
  - Provide storage capacity
  - Balance supply and demand at multiple scales
- **Building envelopes can be part of a GEB strategy**
- **GEB can increase the value of envelope upgrades**

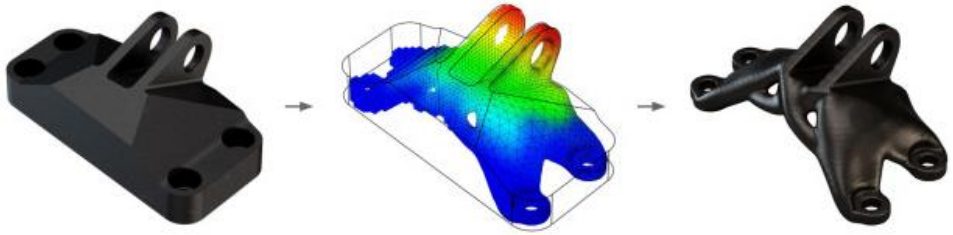


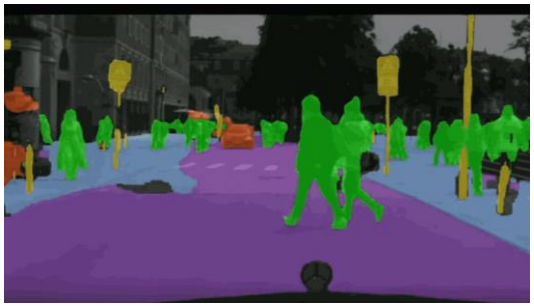
Passive
Static

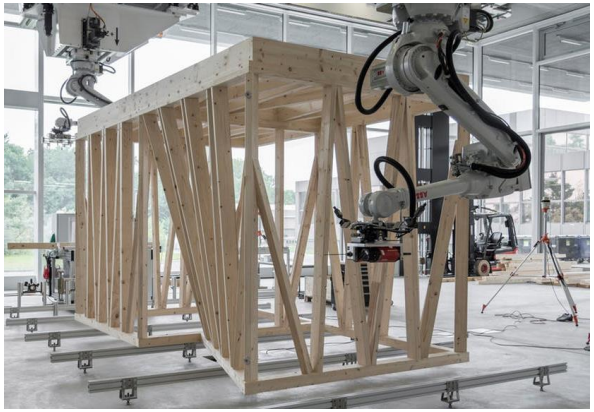
Active
Dynamic

Integration – Enabling Platform Technologies

- Advanced manufacturing
- Mobile diagnostic platforms (i.e., UAVs)
- Machine learning and related methods; topology optimization







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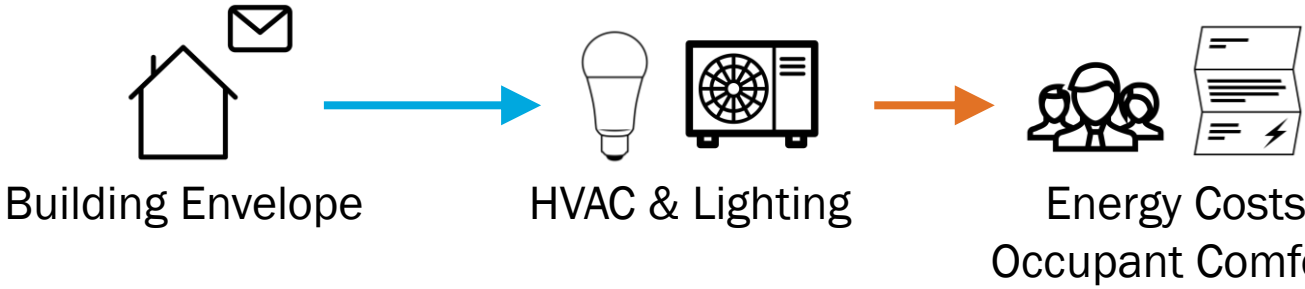
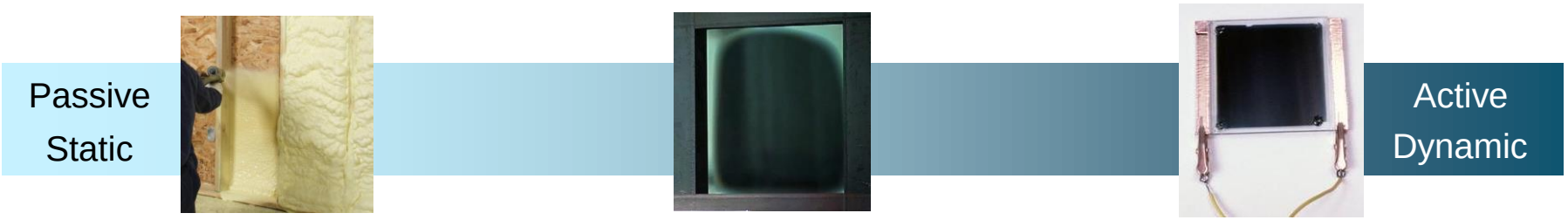
Backup

Integration — Cross-cutting Solutions

- Systems-level design and retrofit approach



- Grid services from the building envelope



- Enabling platform technologies