CHANGING WHAT'S POSSIBLE

Technologies for Transforming Building Materials into Carbon Sinks

Marina Sofos, Ph.D.

Program Director @ ARPA-E

ARPA-E Carbon Negative Building Materials Workshop - Day 2

March 25, 2021

Day 1 Recap – Themes in What We Heard from You

- Performance Advantage
- Durability and Service Life
- Multifunctional Materials
- Transparency
- Uncertainty

Day 1 Recap – Some Ways We're Thinking Now…

- **Categorization:**
  - Flooring assembly that meets specific structural requirements over a given span
  - Materials that meet both structural and insulating property requirements
  - Enabling multifunctionality

- **Metrics:**
  - Emphasize reproducibility over final deliverable size

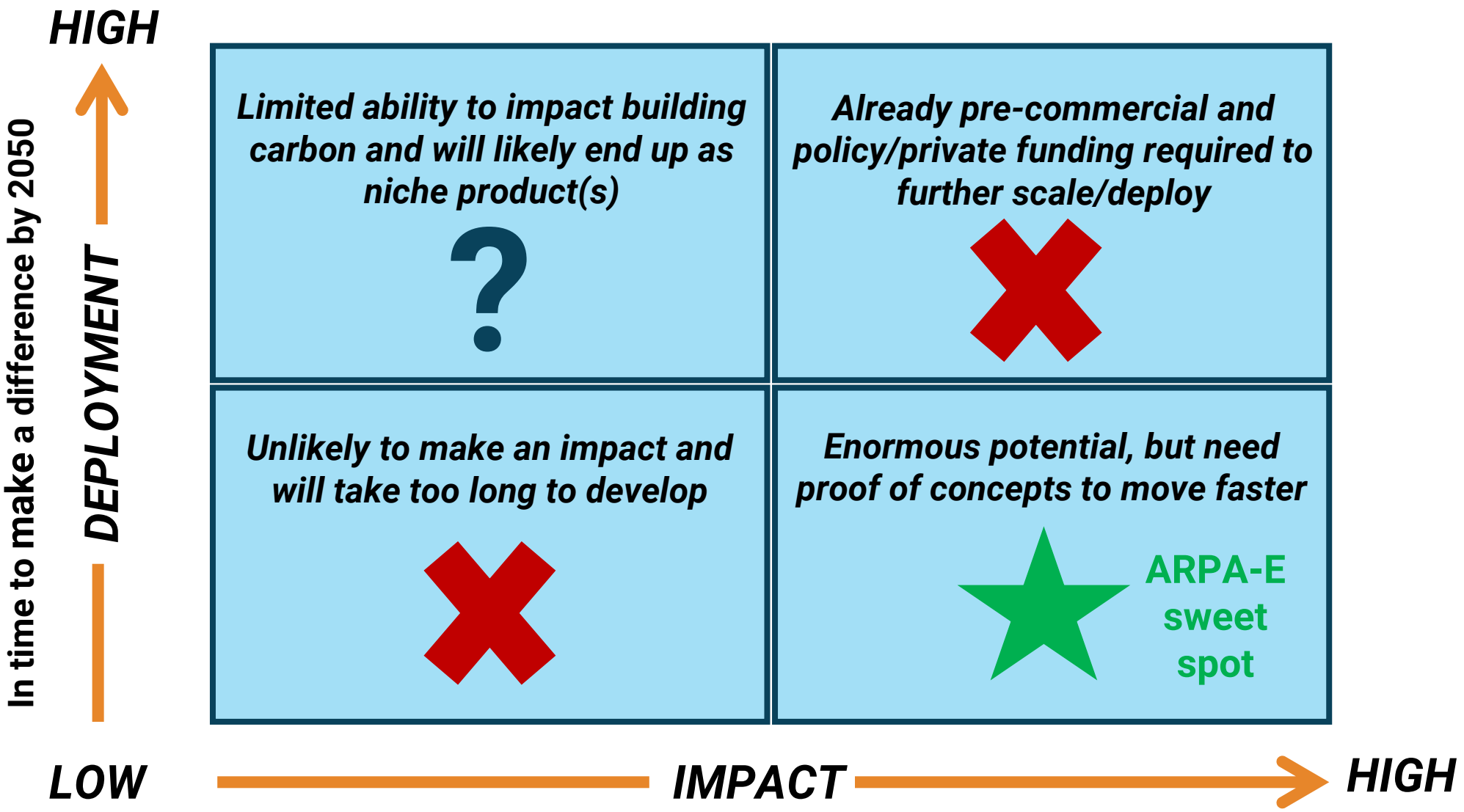
- **LCA:**
  - Achieve performance first and then quantify LCA
  - BUT the LCA then needs to cover the full life, not just A1-A3

- **Markets & Drivers:**
  - Institutional buildings may be good first market
  - Can't have equivalent replacements: products must be better than incumbent

Updates to Materials Metrics

	Revised
Categorization	• Building Elements • Assemblies: Flooring, Walls, etc. • Performance / Purpose (ex. Structural) ***Multiple Options***
Performance Metrics	1. Min 200% carbon storage (LCA A1-A3) (100% for cementitious materials) 2. Durability testing – accelerated aging / wear 3. Code-based standard performance 4. Fire safety rating 5. Health / toxicity assessment (in service and production) 6. Cradle-to-grave LCA *Optional:* region-based testing included (ex. meet seismic performance for CA)
Sample Requirements	• Large enough samples for required test specimen count per test • Samples made on different days to test performance repeatability

Framework for Materials Under Consideration



Maximum potential to impact embodied/stored carbon @ scale

Today's Objectives

- Evaluate proposed **material categories** based on ARPA-E framework (i.e. likelihood of deployment vs. potential impact)
- Prioritize greatest **technical challenges** within a selected category
- Identify any **critical technologies/pathways** that are missing

Truly Neutral Concrete

- **Problem:** Concrete is the biggest contributor to CO_2 emissions in the built environment.
- **Opportunity:** With the high volume of concrete, a carbon storing alternative would be impactful.
- **Question:** Where could ARPA-E funding have a meaningful impact?
  - Synthetic aggregates? Biological routes? Something else?

Photo: Pascal Meier, Unsplash

Mass Timber on the Rise

nature sustainability

PERSPECTIVE

https://doi.org/10.1038/s41893-019-0462-4

Buildings as a global carbon sink

Galina Churkina[1,2*], Alan Organschi[3,4], Christopher P. O. Reyer[2], Andrew Ruff[3], Kira Vinke[2], Zhu Liu[5], Barbara K. Reck[1], T. E. Graedel[1] and Hans Joachim Schellnhuber[2]

- **Opportunity:** Mass timber is at the heart of thinking about buildings as a carbon sink.

- **Questions:**
  - Are technical advances needed in mass timber?
  - Where else are innovations in forestry products emerging?

Other Uses for Agriculture Residues

- **Opportunity:** From Chris Magwood: using just the straw waste in the country would offset all transportation emissions

- **Questions:**
  - Building materials and techniques using agricultural residues exist but are seldom implemented. What are the barriers?
  - How can we merge the carbon benefits of using agricultural residues with the convenience and comfort of modern materials?


Photo: Neringa, Unsplash

New Uses for Carbon

- **Problems:**
  - Long-term carbon storage is needed.
  - Methane pyrolysis may result in large amounts of solid carbon.

- **Opportunity:** Emerging technologies in carbon materials from greenhouse gasses could produce high carbon density storage.

- **Questions:** Can these materials be produced cheaply enough to find application in building materials?

Resins, Adhesives, and Matrix: the Connecting Thread

- **Problem:** Making materials from many of these sources require high-emissions resins, adhesives, or matrix.

- **Opportunity:** Focused effort in this area could benefit many different classes of materials.

- **Questions:**
  - What is already being done?
  - Where are new solutions most needed?

Photo: Santonii, Unsplash

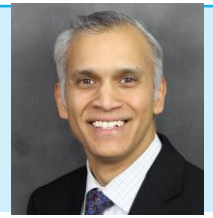
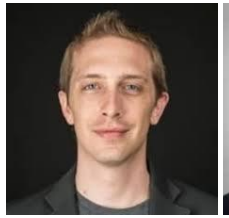
Polymers

- **Problem:** Polymers have become ubiquitous in buildings and are almost exclusively petroleum derived.
- **Opportunity:** Increasing awareness and demand for better products.
- **Questions:**
  - Is there a less toxic alternative to PVC?
  - Can bioderived and recycled products compete?


Photo: Jason Krieger, FreeImages


Photo: Eric McLean, Unsplash

Day 2 Agenda

12:00 – 12:20 PM	**Day 1 Summary and Day 2 Objectives** *Marina Sofos, ARPA-E*
12:20 – 12:30 PM	**Introduction to ARPA-E Tech-to-Market** *Madhav Acharya, ARPA-E* 
12:30 – 1:30 PM	**Products to Market Panel** *Moderator: Josh Agenbroad, Rocky Mountain Institute* *Ryan Spies, Saint-Gobain* *Jerry Uhland, CalPlant* *Michael Dosier, bioMASON* *Kaustubh Pandya, Brick & Mortar Ventures*     
1:30 – 1:40 PM	**Break**
1:40 – 2:00 PM	**Uses of Agricultural and Forestry Products in Thermosetting Polymers** *Dean Webster, North Dakota State University* 
2:00 – 2:20 PM	**Lignin-Based Carbon Materials – Potential High Value and High Volume Applications** *Zhiyong Cai, USDA Forest Products Laboratory* 

Day 2 Agenda (cont.)

2:20 – 2:40 PM	**Mycotecture: shaping the built environment with mycelium** *Christopher Maurer, redhouse*	
2:40 – 3:00 PM	**Reduce and Recapture CO2: Sustainable Approach for Macro- and Nano-Scale Carbon in Building Materials** *Anna Douglas, SkyNano* *Hicham Ghossein, Endeavor Composites*	 
3:00 – 3:15 PM	**Break**	
3:15 – 4:30 PM	**Breakout Sessions Day 2**	
4:30 – 5:00 PM	**Report out and Closing Remarks** *Marina Sofos, ARPA-E*	

Today's Breakouts

Other Materials

Facilitator: Doug Wicks

Notetaker: Kalena Stovall

Moderator: Christina Chang

Wood/Purpose Grown Materials

Facilitator: Marc von Keitz

Notetaker: Dave Lee

Moderator: Emily Yedinak

Carbon Materials

Facilitator: Scott Litzelman

Notetaker: Rose Cox-Galhotra

Moderator: Ian Robinson

Agricultural Residues

Facilitator: Dave Babson

Notetaker: Laura Demetrion

Moderator: Elizabeth Schoenfelt-Troein

Concrete/Concrete Replacements

Facilitator: Joe King

Notetaker: Kate Pitman

Moderator: Grace Ryan

More opportunities to engage with us

- ***RFI just issued (closing on April 21 @ 5 pm ET), share with your networks!***

https://arpa-e-foa.energy.gov/

- ***For ideas not covered here, check out OPEN FOA***

https://arpa-e.energy.gov/open-2021

- ***Virtual ARPA-E Summit May 24-27, 2021***

https://www.arpae-summit.com/Home

- ***Subscribe to the ARPA-E Newsletter***

https://arpa-e.energy.gov/news-and-media/newsletter

“We shape our buildings;
thereafter, our buildings shape us.”

-Winston Churchill

THANK YOU!

Marina Sofos, Madhav Acharya
Advanced Research Projects Agency-Energy

Kate Pitman, Kalena Stovall
Booz Allen Hamilton

CHANGING WHAT'S POSSIBLE