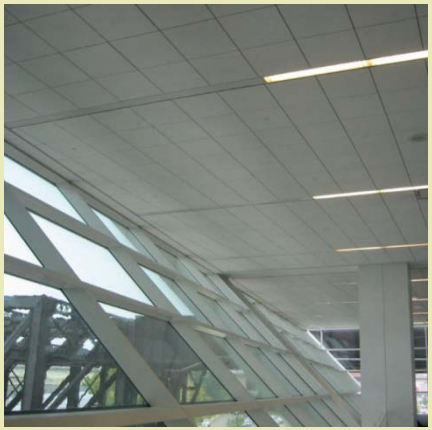

How the Classic Materials Science Stool is being changed by the Sustainability Stool

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Materials + Sustainability: an Outline

- Background
- Existing models for materials and sustainability
- Example of a sustainable building and materials used
- Examples of materials that have been changed by the sustainable building movement
- Issues for manufacturers
- What does the Materials Science community need to do?
- A new model for sustainable materials

What is the impact of the sustainable building movement on the world of Materials Science?

Sustainability

What is driving the Sustainability movement?

Impact of buildings on the environment:

30-40% of all energy used

30% of CO_2 emissions

40% of all raw materials consumed

40% of non-residential waste is construction-related

But, this is something we can address!

Sustainable Buildings Standards + Materials

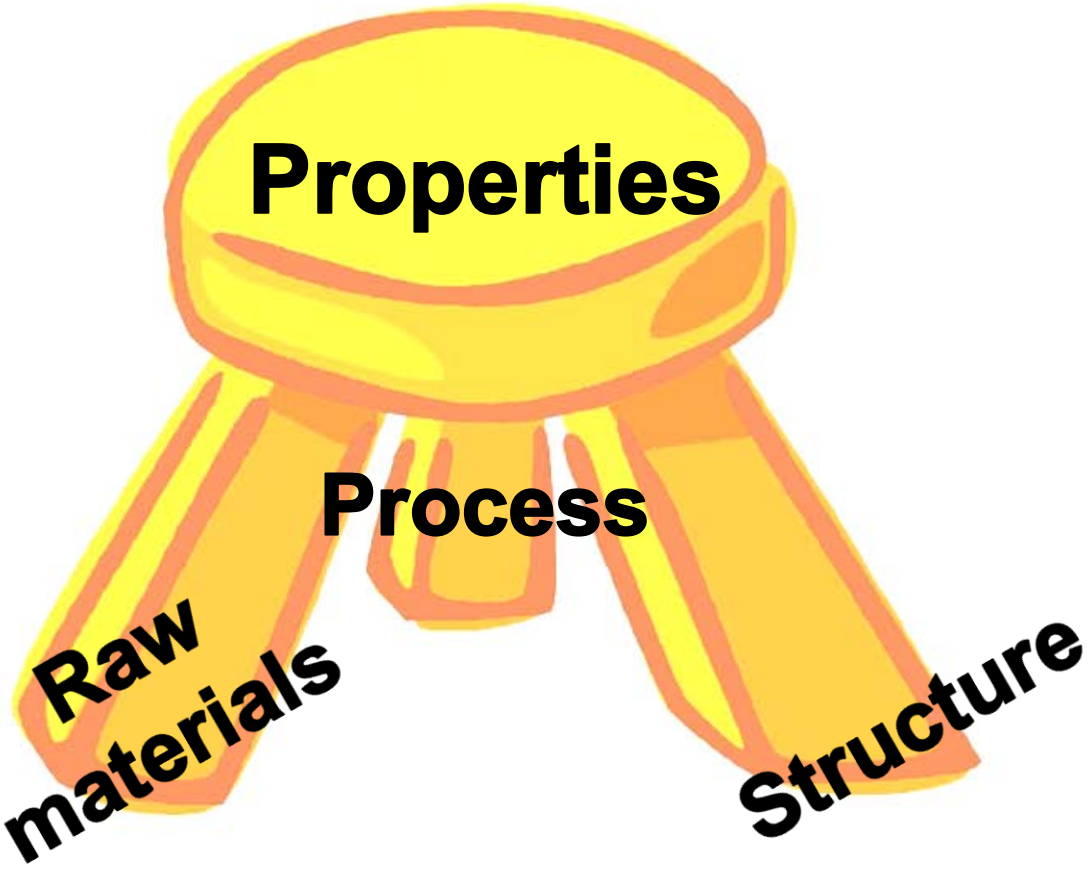
- Sustainable building standards are being established all over the world
- Influence all aspects, including:
  - Site location
  - Resource usage in construction and use
  - **Material content**
- The requirements for materials are changing
- Often, materials experts were not included in the change-making process!
- We react.
- We should be proactive.

Sustainability + Materials

Move towards being Proactive:

- Review the existing models
- Find & address the gaps

The Classic Materials Science Stool



The Sustainability Stool

How do these 2 stools intersect and interact?

Sustainability Issues in the Materials Stool

Raw Materials	Process	Structure	Properties
Recycled content	How much energy needed to produce?	Optimized at micro level?	Generates or stores energy
Recyclable materials	How much water needed to produce?	Optimized at macro level?	Reduces energy use in buildings
Toxins	How much waste?	Designed for disassembly?	Strength
Emissions	Toxic by-products	How many components?	Durable
Source of materials: from the rain forest?	Worker safety	Macrostructures that use compatible materials?	Enhances indoor environment
Bio-based			**Life safety**

Materials Issues in the Sustainability Stool

Economic	Social	Environmental	Sustainability
Cost of process	Worker safety	Reduces use of natural resources	Life cycle assessment
Cost of raw materials	Positive health benefits	Impact of transportation	Durable
Viability of product in market place	Local manufacture	Impact of obtaining of raw materials	Lowers carbon footprint
Increases productivity	Increases productivity	Non-polluting	Increases quality of indoor environment
Cost of end-of-life	No toxins used or produced	End-of-life issues	Decreases energy usage
Use of regional materials	Responsible labor	Reduces green house gasses	
Reduces operational costs		No toxins	

Sustainability Issues Commonly Addressed

Economic	Social	Environmental	Sustainability
Cost of process	**Worker safety**	**Reduces use of natural resources**	Life cycle assessment
Cost of raw materials	Positive health benefits	Impact of transportation	**Durable**
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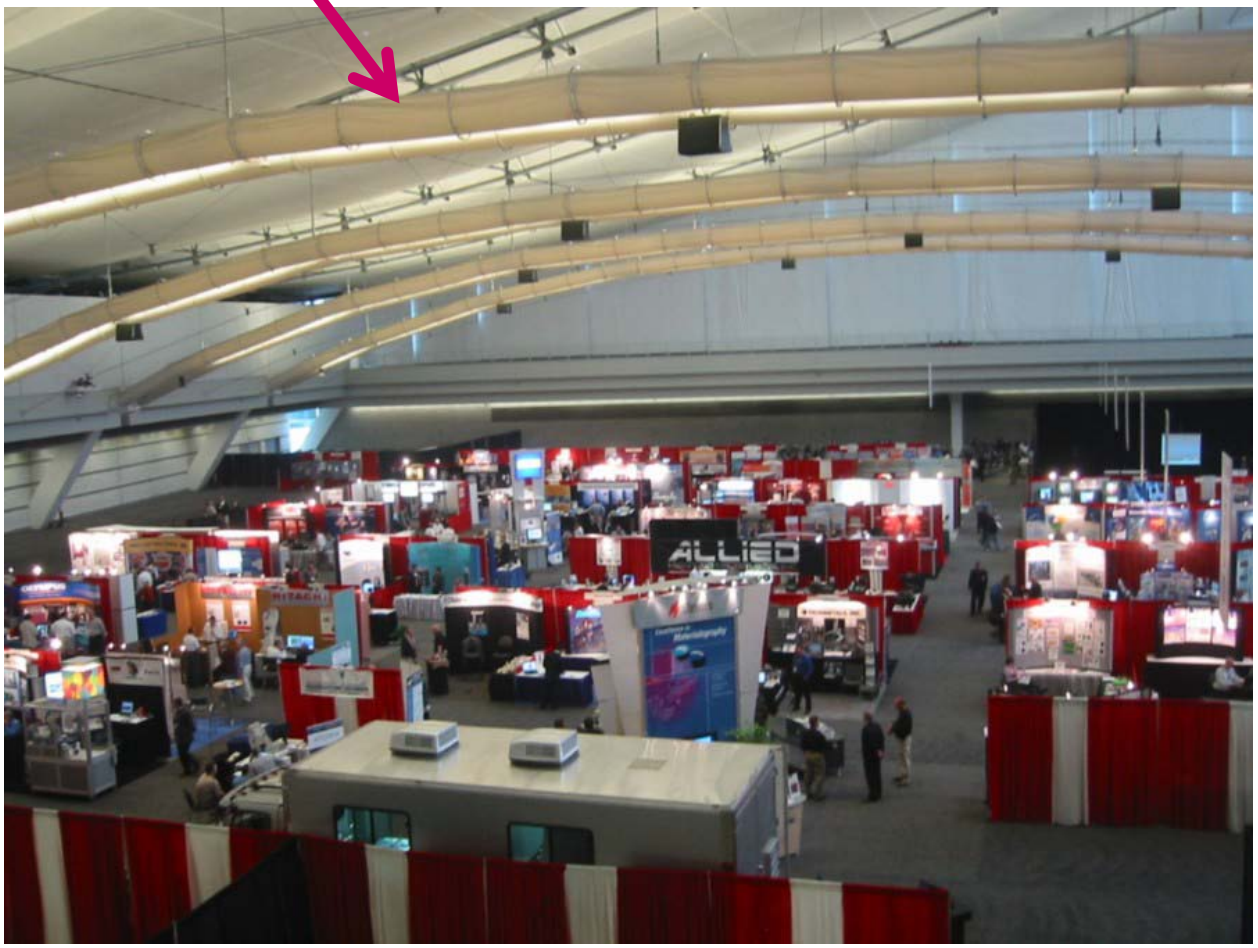
Example: Sustainable Building

When it was built, the David Lawrence Convention Center was considered to be one of the most sustainable buildings in the country

“Sustainable” materials used in this building

Material	Sustainability Attribute
Steel	Recycled content: 60-85% recycled is common
Concrete	Thermal mass, recycle content, local materials
Glass	Skylights, glass walls, low e glass: reduced electrical needs for lighting, enhanced productivity
Cotton ducts for HVAC	Novel structure, reduced weight, bio-based
“Reflective” interior materials	Ceilings and walls: “harvest” the natural light – passively reduces energy consumption
Low-reflectivity stainless steel roof	Reduced heat load
Low or no VOC paints, carpets, adhesives and sealants	Reduces emissions inside building, improving indoor environment
50% of materials were made within 500 miles	Reduces impact due to transportation & supports local economy
Polylactic acid flatware	Biodegradable, daily use factor; requires composting plan

“Sustainable” duct work



Daylight harvesting

“Sustainable” materials used in this building

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Materials Impacted by Sustainability Requirements

- Plywood
- Concrete with Fly ash

Two materials strongly influenced by sustainability issues

Plywood: Eliminating Toxic Chemicals

- Until recently, urea formaldehyde was the binder system for interior grade plywood, medium density fiber board (MDF) and similar products.
- Urea formaldehyde emits formaldehyde gas.
- Formaldehyde is a known carcinogen.
- Concerns over rising formaldehyde levels in homes led to voluntary standards and legislation that set limits on emission levels.

Plywood: Eliminating Toxic Chemicals

- Massive shift in the industry
  - Urea formaldehyde replaced by phenol formaldehyde, and later by protein based binders (such as soy flour)
- Urea formaldehyde is banned by most of the sustainable building standards.
- Federal legislation is expected

Requirements for internal air quality changed an entire industry

Concrete: Environmental Impact due to Fly Ash

- If 1 ton fly ash replaces Portland Cement in Concrete:
  - CO_2 reduction is 0.8 tons (1 car not driven for 2 months)
  - Uses 100 gallons less water
  - Uses 1 ton less virgin raw material
  - 1 ton material diverted from landfill
  - Reduces cost by 50%
  - Creates a product that is more resistant to acid, sulfates, etc., and is stronger and less permeable.
- Fly ash use is encouraged by USGBC, EPA and others
  - Use in concrete increased 21% from 2001 to 2005; the EPA hopes to increase that another 24% by 2011.
- Concerns over health issues: potential toxins

Is there an incentive to investigate alternatives?

What other issues face manufacturers?

- Social issues
- Details of various sustainability guidelines
- Lack of data for LCA’s
- Lack of support from materials science community in addressing standards

Social Issues and Raw Materials

- Cobalt being used in batteries ($LiCoO_2$):
  - Largest supply is in the Congo (50%) and Zambia
  - The Congo is recovering from a brutal civil war
  - Control of cobalt supplies was a key issue in the civil war in DR Congo
  - The demand for cobalt is expected to continue to grow
  - Is this a stable source?

Where are the raw materials coming from?

Issues with Sustainability Standards

Not all recycled content is considered equally:

- USGBC's LEED™ rating system weights post-consumer (PC) recycle content twice as heavily as post-industrial (PI) recycle content:

LEED recycle content = 100% PC + 50% PI

  - Concrete with 15% fly ash has 7.5% recycled content
  - Drywall made with 100% synthetic $CaSO_4 \bullet 2H_2O$ has a 50% recycle content
- PC streams can be problematic: contaminants, consistency, composition; Add additional costs

Manufacturers may favor some raw material sources for products destined for LEED-rated projects

Recycled content issues

Not all recycled content is OK: toxicity

- Some groups don't want any heavy metals in plastics
- There are some sustainability standards that require minimum recycle content in plastic products
  - Most plastic bottles contain small amounts of heavy metal stabilizers (Cd, Sb)
  - Difficult to have both high recycle content and no heavy metals in plastic products (carpets, lumber, etc.)

Understand the requirements of the end-user & standards writing organization

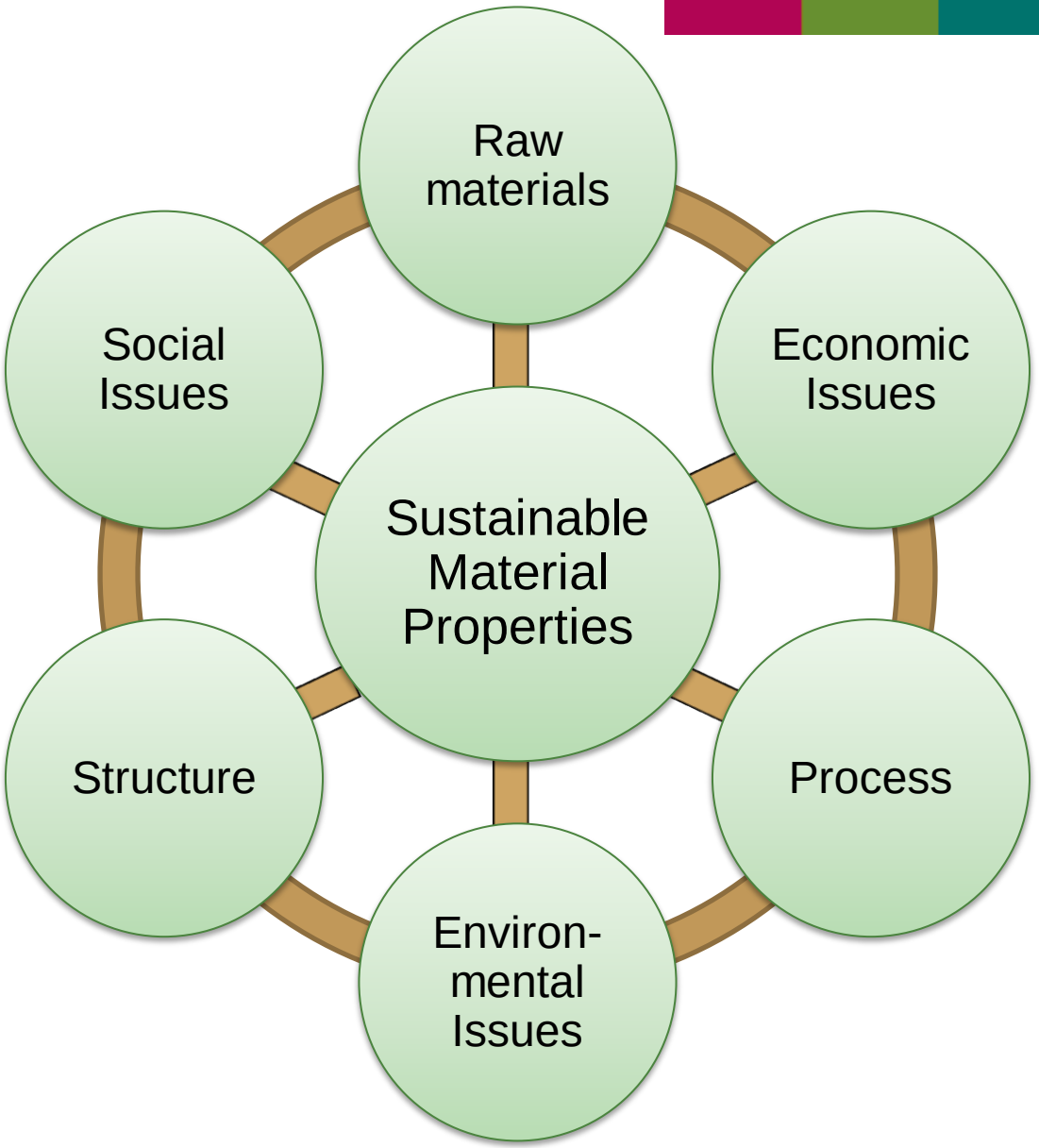
What else is needed from the Mat Sci Community?

- Take a holistic view of materials and processes
- Be aware of the sources and impacts of raw materials
- We need good data for the service life of materials
  - Critical for developing valid Life Cycle Assessments
  - The old durability tests are not sufficient (NIST)
  - These should be done by Materials Scientists
- Get involved in the creation of Sustainability standards so that they are based on good materials science.
  - In NA, all standards are open and consensus driven

We need to get involved! We need to lead!

New Model for Sustainable Materials

We need to embrace a new model that simultaneously optimizes materials and sustainability properties so that we can create technologically sound, environmentally benign materials



Thank you!

- A paper has been submitted to the Ceramic Transactions Conference Proceeding.

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Discussion