Challenges and Opportunities for Low-Carbon Buildings

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U.S. Energy Consumption by Sector (Historic / Projected)

Source: ©2010 2030, Inc. / Architecture 2030. All Rights Reserved.
Data Source: U.S. Energy Information Administration.
Performance-based design
Integrated systems approach
Energy literate consumers

Hundreds of sensors
Operable windows
Function drives form
What is the “gas mileage” of a building?
Engineers often are asked to optimize poor designs.
Which can lead to catastrophe.
If covered in photovoltaics, this would provide only ~20% of the required energy for the John Hancock Tower
(Source: L. Glicksman)

*We must focus on the demand side*
Cost of Carbon Reductions

Cost of Carbon Reductions

MOST COST EFFECTIVE ARE LESS THAN ~$20/tCO₂e

Buildings offer cost-effective CO"2"e reductions

Economics of Office Buildings

Over typical lifetime of 30 years

- Construction: $1
- Operation: $5
- Salaries: $200
Challenges

• Improved tools for the conceptual design stage to overcome gulf between professions

• Life-cycle metrics for designers, policy makers, and public

• Lack of R&D in a conservative industry
Current Structural Tools

**Architectural Design**
- Computational design tools are widespread
- Emphasis on generative ability
- Lack legitimate performance evaluation

**Structural Analysis**
- Computational analysis tools are widespread
- Emphasis on sophisticated performance predictions
- Not useful in conceptual design
We have analysis tools, but we need more design tools
Some conceptual design tools under development

• Energy
  – MIT Design Advisor
• Structure
  – Optimally directed
  – Interactive
• Integrated systems
  – DIVA
Metrics for designers and policy makers

• Greater literacy needed on environmental impacts of buildings

• We have focused on global warming potential (CO$_2$e)

• Life Cycle Assessment (LCA) provides a rigorous approach for quantifying emissions
The story of a can of Coke....

“In England, consumers discard 84% of all cans, which means that the overall rate of aluminum waste, after counting production losses, is 88%. The United States still gets three fifths of its aluminum from virgin ore, at twenty times the energy intensity of recycled aluminum, and throws away enough aluminum to replace its entire commercial aircraft fleet every three months.”

(Natural Capitalism)
Why Life Cycle Assessment (LCA)?

- LCA quantifies environmental impacts
- Gives direction on areas for reductions
- Must look up and down the supply chain
Growing Use of Raw Materials

Life Cycle Assessment (LCA) of Buildings

Pre-use phase
- Extraction
- Manufacturing
- Transportation
- Concrete
- Steel
- Insulation
- Glass

Use phase
- Heating
- Cooling
- Lighting
- Fans
- Plug loads
- Maintenance
- Energy Mix

End of life
- Disposal
- Recycling
- Reuse
- Transportation
Total 60-year emissions for single-family houses

Source: Concrete Sustainability Hub @ MIT
Motivations for LCA work

Growing demand for quantifying performance of structures

*2030 Challenge* calls for carbon reductions of:
- 60% in 2010 (of average carbon emissions for building type)
- 70% in 2015
- 80% in 2020
- 90% in 2025
- Carbon-neutral in 2030
Motivations for LCA work

1) Growing demand for improved quantification of green building

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- 60% in 2010 (of carbon emissions)
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Source: Sasaki Associates
Opportunities

• Conceptual design tools are in their infancy

• Design education can bridge gaps between engineering and architecture

• Industry, government, academic partnerships can overcome poor history of R&D in construction industry
DESIGN STRATEGIES
The largest energy reductions can be achieved through design.

TECHNOLOGIES AND SYSTEMS
Including on-site renewable energy systems.

OFF-SITE RENEWABLE ENERGY
20% maximum.

Source: Architecture2030
Net-Zero: Richardsville School, KY

- Reduce demand to 30 kBtu/sf/yr
- Generate energy on site with PVs
- Many integrated technologies
Net-Zero: NREL RSF, Golden, CO

- Reduce demand to 35 kBtu/sf/yr
- Generate energy on site with PVs
South Africa National Parks asked for a new visitor’s center with:

- local materials and local labor
- passive energy strategies
- poverty relief program
Mapungubwe Visitor’s Centre
Peter Rich, Architect
Henry Fagan, Engineer
Mapungubwe Visitor’s Centre
Peter Rich, Architect
Henry Fagan, Engineer
Integrated design team developed low-cost soil-cement structural shells
Mapungubwe Visitor’s Centre
Peter Rich Architects

World Architecture Festival
Building of the Year, 2009

Earth Awards Finalist, 2010
Measuring, managing, and reducing carbon emissions will be the norm

Cost-effective carbon reductions will transform the built environment

LCA provides rigorous benchmarking of life-cycle building performance

New conceptual design tools and software are sorely needed
Thank you

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Mapungubwe Visitor’s Centre
Peter Rich Architects