Topics Related to Sustainable Design

Donald Fournier
Chair, Building Research Council
University of Illinois at Urbana Champaign
Engineers and Sustainability

- Engineers have a leading role in planning, designing, building, and ensuring a sustainable future.
- Engineers provide the bridge between science and society.
- Engineers must actively promote and participate in multidisciplinary teams with other professionals, such as architects, ecologists, economists, and sociologists, to effectively address the issues and challenges of sustainable development.
The Sustainability Nexus

Energy

Water ↔ Climate
Issues in Sustainability

• The Energy Connection
• The Climate Connection
• The Water Connection
• Adapting to a Changing World
The Energy Connection
US Energy Projection (Quads)

Total Energy up 14% by 2035

- Renewables (excluding Hydro)
- Hydro Power
- Natural gas
- Liquid fuels
- Coal
- Nuclear

Source: Annual Energy Outlook 2010
In 2008 prices hit the wall. Now they have recovered some.
International Energy Agency 2009 Assessment of Oil

Actual Production
2004 – 80.9 Mb/day
2005 – 82.5 Mb/day
2006 – 82.5 Mb/day
2007 – 82.4 Mb/day
2008 – 83.3 Mb/day
2009 – 82.1 Mb/day
2010 – 83.8 Mb/day
Source: USDOE 2010
Illinois Natural Gas Prices

Source: DOE/EIA September 2010

2010 prices 6 months
Natural Gas – A Fracking Mess

• Roughly 90 percent of the 450,000 gas wells in the U.S. use hydraulic fracturing.
• The new gas play is not without risks.
• About 4 million of gallons of water and thousands of pounds of chemicals are pumped into the well under intense pressure to fracture the rock and release the gas.
• NY State has a moratorium on fracking.
• USEPA re-examining the health risks with study due out in 2012.

Photo © Heather Rousseau / Circle of Blue
The Bottom Line

- The step change in fossil energy prices was driven by structural changes in the world economy that produced rapidly increasing demand at the same time rising costs of production.
- We are still very much dependent on imported oil and domestic coal for much of our energy resources.
- These two dependencies are problematic for a sustainable future – both economically and environmentally.
The Climate Connection
$\text{CO}_2, \text{CH}_4$ and estimated global temperature (Antarctic $\Delta T/2$ in ice core era)
$0 = 1880-1899$ mean.

The Midwest GHG Reduction Accord

Main recommendations (May 2010):
- We would prefer a federal system of cap and trade (American Power Act of 2010).
- GHG Reduction targets (2005 baseline):
  - 20% by 2020
  - 80% by 2050
- Cap & Trade Program Sectors and Fuels:
  - Electricity generation and imports to the region.
  - Industrial combustion sources.
  - Residential, Commercial, and Industrial Building fuels.
  - Transportation fuels.
  - Biofuels and small electrical generators exempt.
Climate Change is Here

- There is already enough CO2 in the atmosphere to continue the warming trend for several hundred years.
- We must reverse our emission trends starting now or face the worst of the expectations.
- Acting now is much cheaper than acting later.
- Yes, it will cost and it will require some changes in lifestyle, but we can get half way there with a positive return on investment.
The Water Connection
Water Issues

- Only 2.5% of the world's water supply is not salty and two-thirds of that is in the form of icecaps or glaciers.
- Countries around the world are diligently developing new water supplies and conservation measures.
- The US will experience significant fresh water problems in the future.
- Historical sources are shifting due to climate change and depletion of ground water sources.
Historical Usage in US

The graph shows the historical usage of water in the US from 1950 to 2005. The x-axis represents the years, and the y-axis represents withdrawals in billion gallons per day. The bars indicate groundwater, surface water, and total usage. The pink line represents population growth. The trend indicates an increase in water usage and population over the years.
US Water by Usage Category

The chart shows the water withdrawals in billion gallons per day by usage category from 1950 to 2005. The categories include public supply, rural domestic and livestock, irrigation, thermoelectric power, and other. The total withdrawals are also indicated, showing a trend over the years.
Rainfall Change in the US
Intensity of Water Withdrawals 2005

Source: www.USGS.gov
### Consumptive Water Use for Electricity

For Illinois – 1.05 Gallons/kWh – 152 Billion Gallons

<table>
<thead>
<tr>
<th>Power Provider</th>
<th>Gallons Evaporated per kWh at Thermoelectric Plants</th>
<th>Gallons Evaporated per kWh at Hydroelectric Plants</th>
<th>Weighted Gallons Evaporated per kWh of Site Energy</th>
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<tbody>
<tr>
<td>Western Interconnect</td>
<td>0.38 (1.4 L)</td>
<td>12.4 (47.0 L)</td>
<td>4.42 (16.7 L)</td>
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<td>Eastern Interconnect</td>
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<td>Texas Interconnect</td>
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<td>0.0 (0.0 L)</td>
<td>0.43 (1.6 L)</td>
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<tr>
<td>U.S. Aggregate</td>
<td>0.47 (1.8 L)</td>
<td>18.0 (68.0 L)</td>
<td>2.00 (7.6 L)</td>
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Adapting to a Changing World
Adapting to Change

• We must adapt to new climatic realities:
  ▪ Hydrology – large rainfalls and droughts.
  ▪ Much higher heat index.
• The energy system must radically change by 2050:
  ▪ Building loads and energy efficiency.
  ▪ Low carbon sources – renewables and nuclear power.
  ▪ Carbon capture and sequestration.
New Climate Realities

• Higher rainfalls and more droughts:
  ▫ Need to control for much higher run-off and flooding.
  ▫ Need to provide for more storage to get through droughts.
  ▫ Need to design for more fire resistance in the built environment.
  ▫ Greater evaporation from surface waters.
  ▫ Depletion of groundwater sources.
A Hotter World

• Much higher heat indices and a hotter world:
  ▫ Need to be better prepared for dealing with heat emergencies.
  ▫ Need to consider rising sea levels in coastal design.
Illinois’ Climate Migrates South

Changes in average summer “heat index”—a measure of how hot it actually feels based on a specific combination of temperature and humidity—could strongly affect Midwesterners’ quality of life in the future. For example, the red outlines track what summers in Illinois could feel like over the course of the century under the higher-emissions scenario; the yellow outlines track what summers could feel like under the lower-emissions scenario.
A Hotter World

- Much higher heat indices and a hotter world:
  - Need to be better prepared for dealing with heat emergencies.
  - Need to consider rising sea levels in coastal design.
Energy Futures

• Over 80 per cent of the world's primary energy supply is currently derived from fossil fuels.

• Concerns around energy availability and security, climate change, and price volatility and inflation are driving the search for cheaper and more environmentally friendly alternatives.

• We must be greatly more energy efficient and move to more benign energy sources.
Opportunity for Change

• Each year in the United States, we tear down approximately 1.75 billion square feet of buildings, renovate 5 billion square feet, and build new another 5 billion square feet.
• During the next 30 years, some 50 billion square feet will be torn down, some 150 billion will be renovated, and another 150 billion will be built new.
• By 2040, three-quarters of the built environment will be either new or renovated.

EE…A powerful lever in the greenhouse gas debate

“The most dramatic reductions in greenhouse gas emissions will come from energy efficiency and conservation”

Dr. Steven Chu
US Secretary of Energy

Energy Efficiency

• The cost of saving energy is going down while the price of has been energy is going up. Current low prices are temporary.
• Efficiency is the cleanest, cheapest, safest, and most secure source energy we have.
• These savings from energy efficiency to date have not yet come close to tapping the full potential of another 25-30%.
ASHRAE Vision 2020

• Providing tools by 2020 to enable the building community to produce market-viable NZEBs by 2030.

• NZEB means the building produces as much energy as it uses when measured at the site.
ASHRAE Path to Net Zero Energy

Energy Use Targets

For Code-Intended Standards

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<th>Year</th>
<th>Target (kbtu/square foot/year)</th>
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<tr>
<td>2010</td>
<td>36</td>
</tr>
<tr>
<td>2013</td>
<td>30</td>
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<td>2028</td>
<td>5</td>
</tr>
<tr>
<td>2031</td>
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</table>

Targets in kbtu/square foot/year
What is renewable energy?

- Energy which comes from sources that are regenerative and virtually inexhaustible
- Several types available, including:
  - Wind
  - Solar Photovoltaic and Thermal
  - Biomass (Plant materials)
  - Hydrokinetic (Hydroelectric, Run of River, Wave, Tidal)
  - Geothermal (Heat from the ground)
US Renewable Energy 2009

US Energy Consumption Growth Rates 2008-2009:
Solar/PV grew 12.6%
Wind grew 29%, cap grew 40% -- 10 GW
Biofuels grew 29%
Coal fell 11%
Natural Gas fell 2.1%
Petroleum fell 4%
Electricity fell 4.2%
Renewable Energy Available Now

Source: UNDP, Johansson et al., IEA

Energy Flow (exajoules per year)

- Solar: >1600
- World Energy Use: 477
- Wind: 600
- Geothermal: 500
- Biomass: >250
- Hydro-power: 50
- Ocean: <1
What the future must look like:

Renewable energy
Some Sobering Thoughts

The transition to new renewable energy sources is unavoidable, but there are some issues to consider:

- Scale of the shift.
- Energy density (Btu/lb).
- Power density (Watts/ft^2).
- Intermittency.
- Geographical Distribution.

### Energy Density

- Coal: 12-15 kBTu/lb
- Petroleum: 19 kBTu/lb
- Natural Gas: 22 kBTu/lb
- Biomass: 8-9 kBTu/lb
- Nuclear: 35 BBtu/lb

### Power Density

- Fossil: 10 to 100 W/ft^2
- Biomass: <0.1 W/ft^2
- PV: 2 W/ft^2
- Hydro: <1 W/ft^2
- Wind: 22 W/ft^2
- Nuclear: 12-50 W/ft^2
Putting it Together

- We have entered interesting times.
- Moving to a more sustainable future is an imperative.
- New buildings and utility system designs have to be profoundly more energy and water efficient.
- This is not going to go away.
- We must deal with the nexus between energy, water, and climate.
- Your careers and work will focus on sustainability – it will be a major goal of everything you design or build.
This lecture can be found at www.sedac.org

Don Fournier
Contact: don@sedac.org
265-0681