Electric Power Sustainability Challenges

Equity
Economics / Resource Use
Environment

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Electric Power: ~ 40% of U.S. Energy Use

Net Primary Resource Consumption ~97 Quads

Source: Production and end-use data from Energy Information Administration, Annual Energy Review 2002.
*Net fossil-fuel electrical imports.
**Biomass/other includes wood, waste, alcohol, geothermal, solar, and wind.
Electric Energy System

Fuel → Transport → Processing → Products, Distribution, End-Use

(mining, drilling, harvesting, solar collecting, …)
(combustion, gasification, photovoltaics, fission, …)

Supply Options
- Coal
- Nuclear
- Natural Gas / LNG
- Unconventional oil & gas
- Renewables

Infrastructure
- Central processing vs distributed generation
- Electricity grid design – real-time analysis & control

Processing
- Central processing vs distributed
- Improved efficiency
- Near-zero emission
- Technology / Cost

Energy Use / Rejected Energy
- Reduce consumption
- Improve end-use efficiency
- Technology / Cost

What are the choices – What ‘handles’ to turn?

Trade-offs are a reality in future energy choices

Equity/Affordability - Health/Safety - Environment - Resources
Sustainability?

- Affordable – low cost
- Safe, Clean
- Domestic, Long-term Availability
- Natural resource stability (e.g. climate, water)
- Timely Transition
- Minimum use to achieve ‘quality of life’

What sustainability guidelines will meet present and future needs?

- Prudent use of all forms of capital (e.g. human, human created, nature’s, cultural)
- Decisions for common good
Electric Power Generation Challenges

- Electricity - central to societal needs
- Natural gas ~ 43% of current generation capacity – resource availability, price, and optimal use are concerns
- Coal – available, domestic – environmental concerns
- Nuclear option driven by spent nuclear fuel storage
- Renewables driven by cost and availability
- ~ 40% of U.S. CO₂ emissions
AEO 2006 Reference Case
Gas Price: $5.60 to $6.41/10^6 Btu

What are the uncertainties with this forecast?
What are the options?
Forecast Drivers

• Natural gas and coal price assumptions
• Natural gas resource availability
• Nuclear ‘health’ assumptions
• Environmental concerns
• No GHG regulations
• High cost of alternatives – lowest COE
• End-use demand tied to GDP
Coal Capacity Additions
History and Forecast

Are we prepared to realize this projected growth?
What are the options?
Electric Power Sector
Carbon Dioxide Emissions

Is this an acceptable risk?
What is the cost/benefit?
Nuclear Plant Capacity

What replaces nuclear capacity?
What is coal plant life extension?

What are the trade-offs?
## Sustainability Indicators

<table>
<thead>
<tr>
<th>Objective</th>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality of Life / Social Health</td>
<td>• Equity (share of population with electricity)</td>
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<tr>
<td></td>
<td>• Health (e.g. safety, deaths)</td>
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<tr>
<td>(Sustainable future meeting basic needs of all people; life worthwhile)</td>
<td></td>
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</tbody>
</table>

### Graphs

- **Single Family Home Avg Sq. Ft.**
  - Residential Electric Energy Use
  - Residential Electricity Sales

- **Quads**
### Sustainability Indicators

#### Objective
- **Economics** (utilize resources to achieve quality of life)

#### Indicator
- Affordable / price
- Resource productivity (kWhr/GDP)
- Resource Use (resource availability/production; conversion efficiency; use/capita)
- Security (import dependency)

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**Graph:**
- **kWhr/GDP**
- **Years:** 1950 to 2010
- **KWhr/GDP Values:**
  - 1950: 0.2
  - 1960: 0.25
  - 1970: 0.3
  - 1980: 0.35
  - 1990: 0.4
  - 2000: 0.35
  - 2010: 0.3
### Sustainability Indicators

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<tr>
<td>Environmental (Minimize impact on achieving quality of life)</td>
<td>• GHG emissions (per capita; per GDP)</td>
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<td></td>
<td>• Air emissions (e.g. S, NOx, Hg)</td>
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<td></td>
<td>• Water use / quality</td>
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<td>• Solid waste management</td>
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<td>• Land use / quality</td>
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<td>• Biodiversity</td>
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**Freshwater Use**

346 billion gal/day

![Freshwater Use Chart](chart.png)
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<th>Quality of Life</th>
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<th>Environment</th>
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<tbody>
<tr>
<td>Coal</td>
<td>Health</td>
<td></td>
<td>GHG</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Land Use</td>
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<td></td>
<td></td>
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<td>Water</td>
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<td>Gas</td>
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<tr>
<td></td>
<td></td>
<td>Resource Use</td>
<td></td>
</tr>
<tr>
<td>Unconventional Gas</td>
<td>Health</td>
<td>(Resource Use)</td>
<td>GHG</td>
</tr>
<tr>
<td>Gas</td>
<td></td>
<td></td>
<td>Land Use</td>
</tr>
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<td></td>
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<td></td>
<td>Water</td>
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<tr>
<td>Nuclear</td>
<td>Health</td>
<td>Resource Use</td>
<td>Rad-Waste</td>
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<tr>
<td>Solar</td>
<td></td>
<td>Affordable</td>
<td>(Land Use)</td>
</tr>
<tr>
<td>Wind</td>
<td>Equity</td>
<td>Resource Use</td>
<td>Land Use</td>
</tr>
<tr>
<td>Biomass</td>
<td>Equity</td>
<td>Resource Use</td>
<td>Land Use</td>
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![Solar panels](image1.png)

![Wind turbines](image2.png)

![Biomass energy](image3.png)

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From Science to Solutions
Concerns

• 2.7 billion people live on less than $4/day and cannot access electricity, clean water or sanitation

• Knowledge of energy use and resource issues is increasing and is a force in resource development and use

• Demand growth is escalating

Status quo is not sustainable – politically, economically, environmentally
Reflections

• The boundaries are porous – sustainability is an international challenge

• Complicated trade-offs – no single ‘piece of the puzzle’ sustainable – requires systems view

• Solution is not at the limits: independence, no water use, no land use, no carbon emissions

• Solvable problem

• Need technology creativity and social creativity

• Chemical engineers can inform energy policy and technology policy

• Chemical engineers are an integral part of the solution