The Electricity Technology Challenge

Surface Transportation Board
Rail Energy Transportation Advisory Committee
Washington, DC
December 1, 2009

Henry A. “Hank” Courtright
Senior Vice President
Defining the Electricity Technology Challenge

- **De-carbonize the electricity infrastructure**

- **Provide reliable, affordable, and environmentally responsible electricity to consumers**

*Two Key Metrics: CO₂ Emissions and Cost of Electricity*
The CO₂ Challenge

Assumed Economy-wide CO₂ Reduction Target

Historical Emissions

Remainder of U.S. Economy

U.S. Electric Sector

2005 = 5982 mmT CO₂
2012 = 3% below 2005 (5803 mmT CO₂)
2020 = 17% below 2005 (4965 mmT CO₂)
2030 = 42% below 2005 (3470 mmT CO₂)
2050 = 83% below 2005 (1017 mmT CO₂)

83% Reduction in CO₂ emissions from 2005

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The Cost Challenge

U.S. Retail Price of Electricity

Flat real electricity prices for past 40 years... what about the next 40 years?
The Technology Challenge

Wholesale Electricity Cost (2007 cents/kWh)

Emissions Intensity (metric tons CO₂/MWh)

Cost of Electricity

2007

U.S. Average

De-Carbonization

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Understanding the Technology Challenge

Insights Provided by Two Different Analytical Models

• Bottoms-up “Prism” Technology Analysis
  • Uses Energy Information Administration’s (EIA) Annual Energy Outlook as the base case
  • Estimates CO₂ reduction impacts relative to the base case if more aggressive technology targets could be met

• Tops-down “MERGE” Economic Analysis
  • Optimization model of economic activity and energy use
  • Inputs: Energy supply technologies and costs for electric generation and non-electric energy
  • Constraints: Carbon policy and energy resource availability
  • Output: Economy-wide impacts of carbon policy
U. S. Electric Sector CO₂ Emissions
41% reduction in 2030 from 2005 level is technically feasible using a full portfolio of electric sector technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>EIA Base Case</th>
<th>EPRI Prism Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td>Load Growth ~ +0.95%/yr</td>
<td>8% Additional Consumption Reduction by 2030</td>
</tr>
<tr>
<td>T&amp;D Efficiency</td>
<td>None</td>
<td>20% Reduction in T&amp;D Losses by 2030</td>
</tr>
<tr>
<td>Renewables</td>
<td>60 GWe by 2030</td>
<td>135 GWe by 2030 (15% of generation)</td>
</tr>
<tr>
<td>Nuclear</td>
<td>12.5 GWe New Build by 2030</td>
<td>No Retirements; 10 GWe New Build by 2020; 64 GWe New Build by 2030</td>
</tr>
<tr>
<td>Fossil Efficiency</td>
<td>40% New Coal, 54% New NGCCs by 2030</td>
<td>+3% Efficiency for 75 GWe Existing Fleet 49% New Coal; 70% New NGCCs by 2030</td>
</tr>
<tr>
<td>CCS</td>
<td>None</td>
<td>90% Capture for New Coal + NGCC After 2020 Retrofits for 60 GWe Existing Fleet</td>
</tr>
</tbody>
</table>
2009 Prism – PEV and Electro-Technologies

Low-carbon generation enables electrification and CO₂ reductions in other sectors of economy

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</table>
| Electric Transportation | None             | PHEVs by 2010  
40% New Vehicle Share by 2025  
3x Current Non-Road Use by 2030 |
| Electro-technologies | None             | Replace ~4.5% Direct Fossil Use by 2030           |
Generation by Fuel Source in 2030

What if we LIMIT the Generation PORTFOLIO?

Prism → 60% no- or low-carbon electricity by 2030

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Technology Portfolios

• Limited Portfolio
  No CO₂ capture and storage (CCS)
  Nuclear generation does not expand
  No plug-in electric vehicles (PEV’s)

• Full Portfolio
  Coal and Gas CCS available
  Accelerated end-use efficiency
  PEV’s can expand
  Nuclear production can expand
MERGE Economic Model

- Optimization Model of Economic Activity and Energy Use through 2050
  - Maximize Economic Wealth

- Inputs
  - Energy Supply Technologies and Costs for Electric Generation and Non-Electric Energy

- Constraints
  - Greenhouse Gas Control Scenarios
  - Energy Resources

- Outputs
  - Economy-wide Impact of Carbon Policy
MERGE U.S. Electric Generation Mix

Aggressive Energy Efficiency Needed with Either Portfolio

Limited Portfolio

Full Portfolio

Generation Mix

Demand Reduction

Demand Reduction

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Insights – Renewables

Limited Portfolio

Full Portfolio

> 20% Renewables by 2030 with Either Portfolio
> 50% Renewables by 2050 with Limited Portfolio
Insights – Nuclear and CCS

Limited

Full Portfolio

Gas Expands Rapidly 2010-2020 if Uncertainty Exists Regarding Availability of New Nuclear and CCS post 2020
2030 Generation Mix

Remarkably different futures...and only 20 years away!

Limited Portfolio

Full Portfolio

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2050 Generation Mix

**Totally different futures in 2050**

Limited Portfolio

- Solar
- Gas
- Biomass
- Wind
- Hydro
- Nuclear

Full Portfolio

- Coal + CCS
- Biomass
- Wind
- Hydro
- Nuclear
- Gas
MERGE CO₂ Price Results

> $50/MT CO₂ by 2020 for either portfolio

$/metric ton CO₂ (2007$)

2020 2030 2040 2050

Limited Portfolio

Full Portfolio
MERGE Wholesale Electricity Cost Results

2007 U.S. Average Wholesale Electricity Cost

$/Mwh (2007$)

<table>
<thead>
<tr>
<th>Year</th>
<th>Limited Portfolio</th>
<th>Full Portfolio</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>$60</td>
<td>$80</td>
</tr>
<tr>
<td>2030</td>
<td>$80</td>
<td>$100</td>
</tr>
<tr>
<td>2040</td>
<td>$100</td>
<td>$120</td>
</tr>
<tr>
<td>2050</td>
<td>$120</td>
<td>$140</td>
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2050

2007 U.S. Average Wholesale Electricity Cost
MERGE De-carbonization Results

MERGE Projections 2020-2050

Cost of Electricity

Wholesale Electricity Cost (2007 cents/kWh)

Emissions Intensity (metric tons CO₂/MWh)

De-Carbonization
MERGE De-carbonization Results

High Cost to meet 2050 Reduction Target with >80% Generation Mix Gas and Renewables
Meeting the Challenge

Wholesale Electricity Cost (2007 cents/kWh)

Emissions Intensity (metric tons CO₂/MWh)

MERGE Projections 2020-2050

Limited Portfolio

Full Portfolio

RD&D and Deployment Challenge

Innovation Challenge

De-Carbonization

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Electricity policy and technology actions over the next decade will to a great extent shape the electricity future of 2050
Industry / EPRI
Demonstration Projects

Carbon Capture and Storage
Alstom / We-Energies / EPRI
Chilled Ammonia Pilot

Achievements:
- High CO₂ removal ~90%
- High purity CO₂ ~99%
- Low ammonia emissions
- Energy use as predicted

Declared Success!!!
Pilot Concluded
PC with CCS: AEP/Alstom

• ~20 MW capture module at AEP’s Mountaineer plant. CO2 injection into on-site storage wells

• Mountaineer started capturing CO$_2$ on Sept 1 and injecting CO$_2$ on Oct 1

• Formal dedication October 30

• Several years of planned operation & testing
PC with CCS: Southern/MHI

• ~25 MW capture module at Southern Company’s Plant Barry (Alabama)
• MHI KS-1 advanced amine process
• Injection and storage test conducted by DOE “SECARB” regional partnership with EPRI technical leadership

Status

• Site characterization under way
• Start-up scheduled for 1Q 2011
Progress to date

- Initial testing of 0.5 tons $O_2$/day with over 600 days of cumulative operation
- Initial testing of 1.0 ton $O_2$/day modules planned this year
- Engineering & design completed for 150 tons $O_2$/day test unit