CO₂ Capture and Storage

AEP’s New Generation Perspective

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AEP Company Overview

AEP's Generation Fleet
38,388 MW Capacity

Coal/Lignite 67%
Natural Gas/Oil 24%
Nuclear 6%
Pumped Storage/Hydro/Wind 3%

5.1 million customers in 11 states
Industry-leading size and scale of assets:

<table>
<thead>
<tr>
<th>Asset</th>
<th>Size</th>
<th>Industry Rank</th>
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</thead>
<tbody>
<tr>
<td>Domestic Generation</td>
<td>~38,300 MW</td>
<td># 2</td>
</tr>
<tr>
<td>Transmission</td>
<td>~39,000 miles</td>
<td># 1</td>
</tr>
<tr>
<td>Distribution</td>
<td>~208,000 miles</td>
<td># 1</td>
</tr>
</tbody>
</table>
Achieving all targets is aggressive, but potentially feasible.

EIA Base Case 2007

<table>
<thead>
<tr>
<th>Technology</th>
<th>EIA 2007 Reference</th>
<th>Target</th>
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<tbody>
<tr>
<td>Efficiency</td>
<td>Load Growth ~ +1.5%/yr</td>
<td>Load Growth ~ +1.1%/yr</td>
</tr>
<tr>
<td>Renewables</td>
<td>30 GWe by 2030</td>
<td>70 GWe by 2030</td>
</tr>
<tr>
<td>Nuclear Generation</td>
<td>12.5 GWe by 2030</td>
<td>64 GWe by 2030</td>
</tr>
<tr>
<td>Advanced Coal Generation</td>
<td>No Existing Plant Upgrades</td>
<td>150 GWe Plant Upgrades</td>
</tr>
<tr>
<td></td>
<td>40% New Plant Efficiency by 2020–2030</td>
<td>46% New Plant Efficiency by 2020; 49% in 2030</td>
</tr>
<tr>
<td>CCS</td>
<td>None</td>
<td>Widely Deployed After 2020</td>
</tr>
<tr>
<td>PHEV</td>
<td>None</td>
<td>10% of New Vehicle Sales by 2017;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+2%/yr Thereafter</td>
</tr>
<tr>
<td>DER</td>
<td>&lt; 0.1% of Base Load in 2030</td>
<td>5% of Base Load in 2030</td>
</tr>
</tbody>
</table>
AEP’s Long-Term GHG Reduction Portfolio

- Renewables (Biomass Co-firing, Wind)
- Off-System Reductions and Market Credits (forestry, methane, etc.)
- Commercial Solutions of New Generation and Carbon Capture & Storage Technology
- Supply and Demand Side Efficiency

AEP is investing in a portfolio of GHG reduction alternatives
AEP Leadership in Technology: IGCC/USC and Future Gen

**NEW ADVANCED GENERATION**

- **IGCC**—AEP was the first to announce plans to build two 600+ MW IGCC commercial scale facilities in the US in Ohio and West Virginia by the middle of next decade.

- **USC**—AEP will be the first to employ the new generation ultra-supercritical (steam temperatures greater than 1100°F) coal plants in the U.S.—in Arkansas.

- **FUTUREGEN** - First Near Zero Emissions Hydrogen/ Electric (coal-fueled IGCC with CCS)-DOE along with AEP and Alliance members.
Fuels and CO₂ Emission Rates

Note: C/H is the mass ratio of carbon to hydrogen
Efficiency and CO₂ Emission Rates

Increasing Generation Efficiency

- Lignite
- Sub Bituminous
- Bituminous
- Ultra Supercritical (3500psi/1100F/1100F)
- Subcritical (2400psi/1000F/1000F)
Carbon Intensity for Different Systems

**CO₂ Reduction Necessary to Achieve NGCC Emission Levels**

- **US Coal Fleet**
  - H.R. = 7,040
  - CO₂ (lb/kWh) = 62%

- **Nat. Gas Combined Cycle, NGCC**
  - H.R. = 10,980
  - CO₂ (lb/kWh) = 36%

- **Nat. Gas Simple Cycle, NGSC**
  - H.R. = 10,500
  - CO₂ (lb/kWh) = 57%

- **US Coal Fleet Average**
  - H.R. = 8,980
  - CO₂ (lb/kWh) = 54%

- **Ultra Supercritical, USC (Subbituminous)**
  - H.R. = 8,730
  - CO₂ (lb/kWh) = 54%

- **IGCC (Bituminous)**
  - H.R. = 8,730
  - CO₂ (lb/kWh) = 54%

*Note: H.R. = Heat Rate (efficiency). Values represent typical heat rates, used here for illustrative purposes only.*
CO₂ Capture Techniques

Post-Combustion Capture

- AEP is committed to bring carbon capture and storage technologies from the research and pilot stages into large scale commercial application
  - Post-Combustion Capture – **Existing Units**
    - Conventional or Advanced Amines, **Chilled Ammonia**
  - **Key Points**
    - Amine technologies commercially available in other industrial applications
    - Relatively low CO₂ concentration in flue gas – Difficult to capture
    - High parasitic demand – reduced unit output
      - Conventional Amine ~25-30%, Chilled Ammonia target ~10-15%
    - Amines require clean flue gas
Alstom’s Chilled Ammonia Process

Post-Combustion Capture

Flue Gas
Low CO₂, Low Sulfur

Flue Gas
High CO₂, Low Sulfur

CO₂ Absorber

Final Wash

Stack

Concentrated CO₂

CO₂ to Compression

CO₂ Geologic Storage by AEP/Battelle

Lean (CO₂) Reagent

Rich (CO₂) Reagent

FGD

Booster Compressor

Flue Gas Chiller

Regenerator
Chilled Ammonia Technology Program

Project Validation
- 20 MWₑ (megawatts electric) scale (a scale up of Alstom/EPRI 5 MWₜ (megawatts thermal) field pilot, under construction at WE Energies)
- ~100,000 tonnes CO₂ per year
- In operation 2Q 2009
- Approximate total cost $80 – $100M
- Using Alstom “Chilled Ammonia” Technology
- Located at the AEP Mountaineer Plant in WV
- CO₂ for geologic storage

2009 Commercial Operation
Phase 1
1300 MW Mountaineer Plant (WV)
MOU (Alstom)
CO₂ (Battelle)
Chilled Ammonia

Commercial Scale Retrofit
- ~ 200 MWₑ scale (megawatt electric)
- ~1.5MM tonnes CO₂ per year
- In operation 2012
- Approx. capital $250 – $300M (CO₂ capture & compression)
- Approx. O&M cost $12M per year
- Energy penalty ~ 35 – 50 MW steam, 25 – 30 MW for CO₂ compression
- Retrofit NOx Controls and FGD Required: ~$225 – $300M (required for CO₂ capture equipment)
- Located at AEP’s Northeastern Plant Unit 3 or 4 in Oklahoma
- CO₂ for Enhanced Oil Recovery (EOR) or geologic storage

Phase 1 will capture and sequester 100,000 metric tons of CO₂/year

2012 Commercial Operation
Phase 2
450 MW Northeastern Plant (OK)
MOU (Alstom)
CO₂
Chilled Ammonia
EOR

Phase 2 will capture and sequester 1.5 Million metric tons CO₂/year
CO₂ injectivity in the Mountaineer Area

CO₂ injection should also be possible in shallower sandstone and carbonate layers in the region.

Rose Run Sandstone (~7800 feet) is a regional candidate zone in Appalachian Basin.

A high permeability zone called the “B zone” within Copper Ridge Dolomite has been identified as a new injection zone in the region.

Mount Simon Sandstone/Basal Sand - the most prominent reservoir in most of the Midwest but not desirable beneath Mountaineer site.
Sedimentary Rocks
A Microscopic View

Permeability much less than 0.01 mD
Shale with Extremely Low Permeability Forms Good Caprock

Permeability 10 – 100 mD
Sandstone with Medium Permeability Forms Good Host Reservoir Medium Cost

Permeability 100 – 1,000 mD
Sandstone with High Permeability Forms Excellent Host Reservoir at Low Cost
Enhanced Oil Recover (EOR)
CO₂ Capture Techniques

Oxy Coal Firing

- Modified-Combustion Capture – Oxy Coal Firing
  - *Key Points*
    - Technology not yet proven at commercial scale
    - Creates stream of high CO₂ concentration
    - High parasitic demand, >25%
  - Demonstration Scale
    - 10 MWe scale
    - Teamed with B&W at its Alliance Research Center and several other utilities
    - Demo completion 4Q 2007
  - Commercial Scale
    - Retrofit on existing AEP sub-critical unit (several available)
    - 150 – 230 MWe scale retrofit
    - 4,000 – 5,000 tons CO₂ per day
    - Feasibility study in progress
CO₂ Capture Techniques

Pre-Combustion Capture

• Pre-Combustion Capture
  • IGCC with Water-Gas Shift – FutureGen Design
  • *Key Points*
    • Most of the processes commercially available in other industrial applications
      • Have never been integrated
    • Turbine modified for H₂-based fuel, which has not yet been proven at commercial scale
    • Creates stream of very high CO₂ concentration
    • Parasitic demand (~20%) for CO₂ capture - lower than amine or oxy-coal options
FutureGen’s Water-Gas Shift Process
Pre-Combustion Capture

Diagram showing the process of Air Separation, Gasifier, Gas Clean-Up, CO₂ Separation, Deep Saline Formation, Electricity Generation, and transportation/refinery applications.
Examples of Relative GHG Mitigation Costs for Power Sector

- Carbon Capture with Geologic Sequestration
- Other renewable, advanced geothermal and/or solar
- Carbon Capture for Enhanced Oil Recovery
- New Biomass Generation
- Dispatch of additional gas vs. inefficient coal
- Biomass Co-firing
- Biological Sequestration (e.g. Forestry)
- New Wind
- Energy Efficiency
- Methane Offsets

$/ton CO$_2$e

- $0
- $40+

Nuclear?
Questions?

Thank you for listening