American Electric Power
Utility Perspectives on 21st Century Power Generation

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Agenda

• AEP Overview

• Issues Impacting AEP and the Industry
  • Electricity Generation Outlook and the Utility of the Future
  • Integrated Grid
  • Role of Technology

• Why Supercritical CO₂?

• How Supercritical CO₂?
  • Mechanisms and timing to get SCO2 to commercial scale
  • Challenges to success
  • Facing challenges and overcoming obstacles

• Conclusions
American Electric Power Company Overview

$62B
Total Assets

$31B
Current Market Capitalization

5.4 million customers in 11 states

32 GW Owned Generation

40,000+
Line Miles of Transmission

Note: Statistics as of December 31, 2015, except market capitalization which is as of February 25, 2016.
Diversifying our Fuel Portfolio

- 7,000+ MW of generation retiring by mid-2016
- Some planned coal to natural gas conversions and/or repower considerations
- No new fossil generation planned between now and 2020
- Utility Scale Solar PV under construction in Indiana (4 sites, 2.5-5MW each, ~16MW total by 2017)
Environmental/Regulatory Signposts & Milestones

- Renewable Portfolio Standards (RPS)
- Production Tax Credit (PTC) for renewables
- Light Duty Vehicle CAFE Standards (54.5 mpg)
- New Taxes / Regulations on Drilling & Fracking
- GHG New Source Performance Standards (New Plants)
- GHG New Source Performance Standards (Existing Plants)
- Revised SO₂, PM₂.₅, and Ozone NAAQS Implementation
- Steam Electric Effluent Guidelines
- 316(b) Cooling Water Intake Requirements
- MATS
- Coal Combustion Residuals

Timeline:
- 2015
- 2020
- 2025
Traditional Vs. Integrated Grid

- Centralized generation sources feed transmission/distribution network
- Electricity flows “one-way” from centralized generators to consumers
- Mature regulatory rate structure and market infrastructure

- Greater integration of entire electric system
- Distributed generation: supports localized demand along with central generation and supplies excess generation to grid (“two-way” flow)
- Energy efficiency and demand response program can augment and/or offset “steel-in-the-ground” generation capacity
- Requires innovative rate design and cost transparency at the retail level
What Might the Future Look Like?

**Visible Trends Today**
- Ever-tightening environmental regulations for new & existing sources
- Increased shale gas recovery
- Renewable Portfolio Standards
- Reduced Federal fossil energy R&D budgets
- Federal & state renewable subsidies
- Aging fossil & nuclear fleet

**2040 Electricity Generation by Fuel**

2040 Electricity Generation by Fuel (EIA AEO2015 Ref. Case)

- Coal 34%
- Natural Gas 31%
- Nuclear 16%
- Renewables 18%
- Oil & Other 1%
On the Minds of Utilities

What is the greatest obstacle to the evolution of your utility’s business model?

- Existing regulatory model: 35%
- Integration of emerging technologies: 21%
- Internal resistance to change: 20%
- Cost of stranded assets: 11%
- Stakeholder consensus: 10%
- Nothing – my utility’s business does not need to evolve: 3%

The Role of Technology

Develop and deploy new generation technology, systems and equipment to support the integrated grid of the future.

Improve the efficiency, reliability, flexibility & maintainability of the existing generating fleet.

Explore opportunities “Behind the Meter” to improve overall grid efficiency and maximize customer benefits.

Options / Solutions / Satisfaction

Data / Feedback / Preferences

NGCC
Large-scale Wind & Solar PV
Innovative Power Cycles
Clean Fossil (CCUS)
Advanced Nuclear

Community Solar PV
Energy Storage
Microgrids

Recip Engines & Aero Turbines
Combined Heat & Power
Hybrid Technologies
Fuel Cells

Meter

Rooftop PV
Energy Storage
“Smart” Home
21st Century Technologies

• Distributed Generation & Renewables

• Virtual Power Plants and Microgrids

• Bulk Energy Storage

• Advanced Nuclear

• Advanced Fossil Combustion / Thermal Energy Conversion Technologies

• IGCC & Post-Combustion CO$_2$ Capture

• Advanced Cycles (e.g. ScCO$_2$ direct & indirect, Inorganic Rankine, etc.)
Why Supercritical CO$_2$?
Efficiency

• 50-60% of conventional steam power cycle losses occur in the transfer of high temperature combustion heat to low(er) temperature steam.

• A very effective way to mitigate CO₂ emissions from fossil-fueled power generation is to never burn the carbon in the first place.
  • Past: Supercritical and Ultra-supercritical steam generation
  • Present: Natural gas combined cycle (NGCC)
  • Future: Advanced NGCC
    Advanced Ultra-supercritical steam generation
    Supercritical CO₂ power cycles
Opportunities

• **Near term: Start small**
  - Near term benefits may exist in size range of 10-50 MW
  - Benefits scaling, constructability, cost
  - Qualification of design, materials, equipment
  - Understand performance for optimal scalability and advanced cycles

• **Mid-Term: Grow in proportion to technical capabilities**
  - Larger plants – Higher MW outputs 50-100MW
  - Reduce risk associated with operating conditions, materials, maintenance
  - Further explore opportunities to improve cost, reliability, and technology gaps through cycle innovation.

• **Long-Term: Technology for Transformational Solutions**
  - Demonstrated to support/enhance advanced ultra-supercritical steam cycles and/or advanced fossil combustion technologies (e.g. oxy-fuel, chemical looping, etc.)
How Supercritical CO$_2$?
DE-FOA-0001457

• **Nominal 10 MWe Supercritical CO₂ Pilot**
  - Includes design, development and fabrication of **ALL** necessary components

• **Demonstrate potential for thermodynamic cycle efficiency > 50%**

• **Demonstrate operability of turbine at 700 °C turbine inlet temp**
  - Infrastructure, equipment and components must also support

• **Limited to Recompression Closed Brayton Cycle (RCBC)**
  - Must be capable of reconfiguration to future system/cycle upgrades, new cycles and new components

• **Capability to monitor, measure and support test campaigns to assess critical component degradation mechanisms necessary to support cost effective designs**

• **Schedule (72 Months):**
  - Site Selection and Detailed Design (12-18 mo)
  - Fabrication & Construction (30-36 mo)
  - Operation & Testing (24 mo)
Challenges

• **Design Integration**
  • Site Selection / Heat source identification
  • Balance of Plant integration
  • Grid/customer interconnection

• **Materials**
  • Thermal fatigue and stress resistance at 700 °C temps and higher
  • Few if any materials in long term use and exposure to these temps
  • ASME code case development and approval takes time/data/operating experience
  • Impacts piping, valves, components, instrumentation
  • Corrosion/oxidation impacts

• **Fabrication / Manufacturing / Constructability**
  • Lead time, cost, supply chain
  • Manufacturing techniques and necessary innovations to improve
  • Modularity vs. field erected (weld-ability, availability of skilled labor, etc.)

• **Operability and Maintainability**
  • Startups/shutdowns, steady-state and transient operation
  • Isolation of equipment/components for maintenance
  • Operator training
Facing Challenges & Overcoming Obstacles

- **Collaboration – Collaboration – Collaboration**
  - Consortia, partnerships, industry/utility advisory committees
    - *More is better – build on existing and ongoing expertise*
    - *Early engagement*
  - One provider or technology will not corner the Supercritical CO$_2$ market

- Similar collaborative models that work
  - *DOE National Carbon Capture Center*
  - *Advanced Ultra-supercritical Consortium ComTest Program*
  - *Water Research Center at Southern Research Institute*
Conclusions

• The energy landscape is changing rapidly

• Utility business models are changing to meet the current demands of the customer

• Utilities cannot lose sight of strategy for the future

• Technology is key to unlock near- and long-term solutions

• Challenges and obstacles to achieving an acceptable level of risk

• Collaboration and Open Communication will drive successful outcome
Thank You