American Electric Power

Utility Perspectives on 21st Century Power Generation

Matt Usher, P.E.
Director – New Technology Development & Policy Support
AEP Generation

Agenda

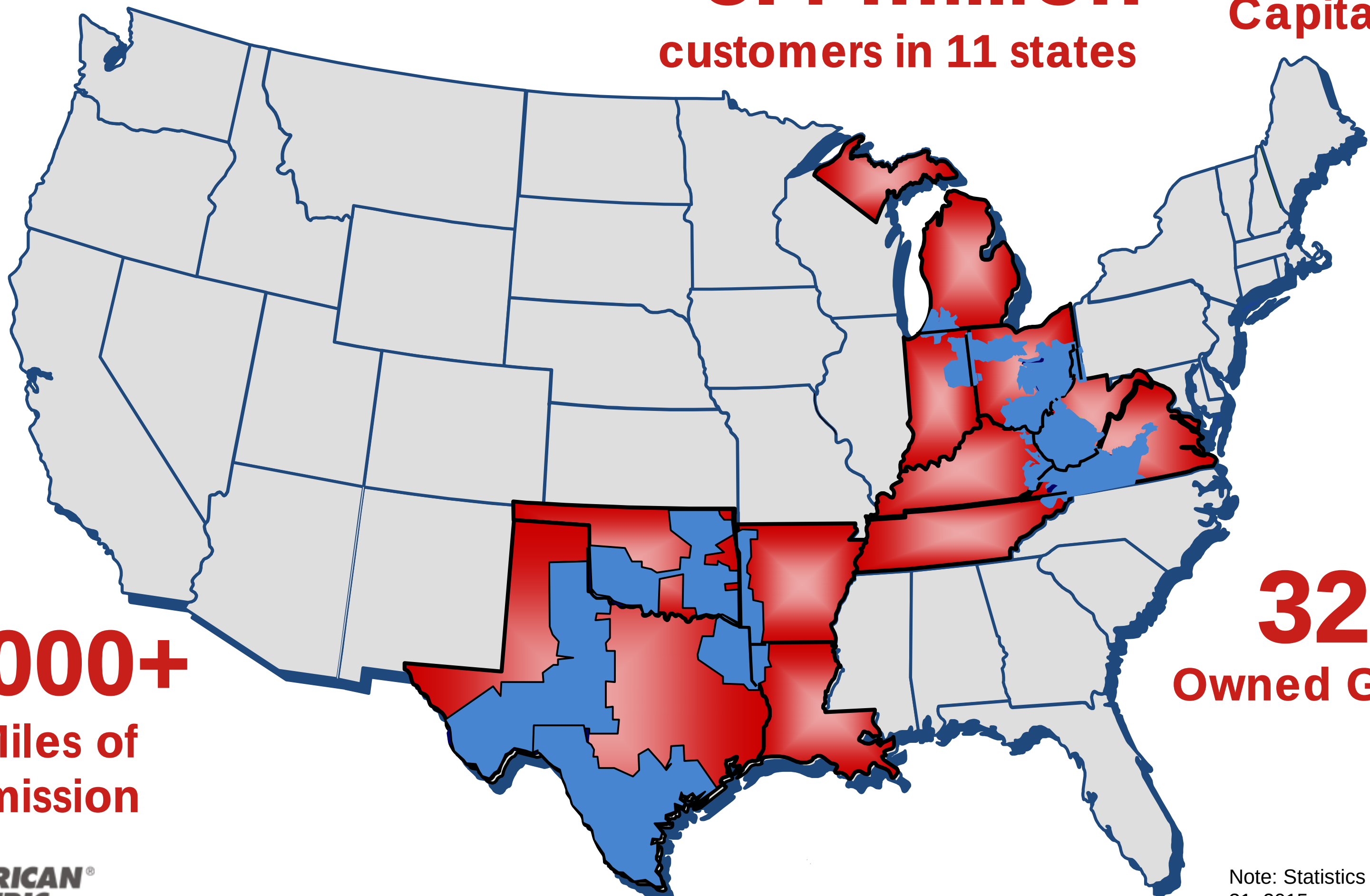
- AEP Overview
- Issues Impacting AEP and the Industry
  - Electricity Generation Outlook and the Utility of the Future
  - Integrated Grid
  - Role of Technology
- Why Supercritical CO_2?
- How Supercritical CO_2?
  - Mechanisms and timing to get SCO2 to commercial scale
  - Challenges to success
  - Facing challenges and overcoming obstacles
- Conclusions

American Electric Power Company Overview

$62B
Total Assets

5.4 million
customers in 11 states

$31B
Current Market Capitalization



40,000+
Line Miles of Transmission

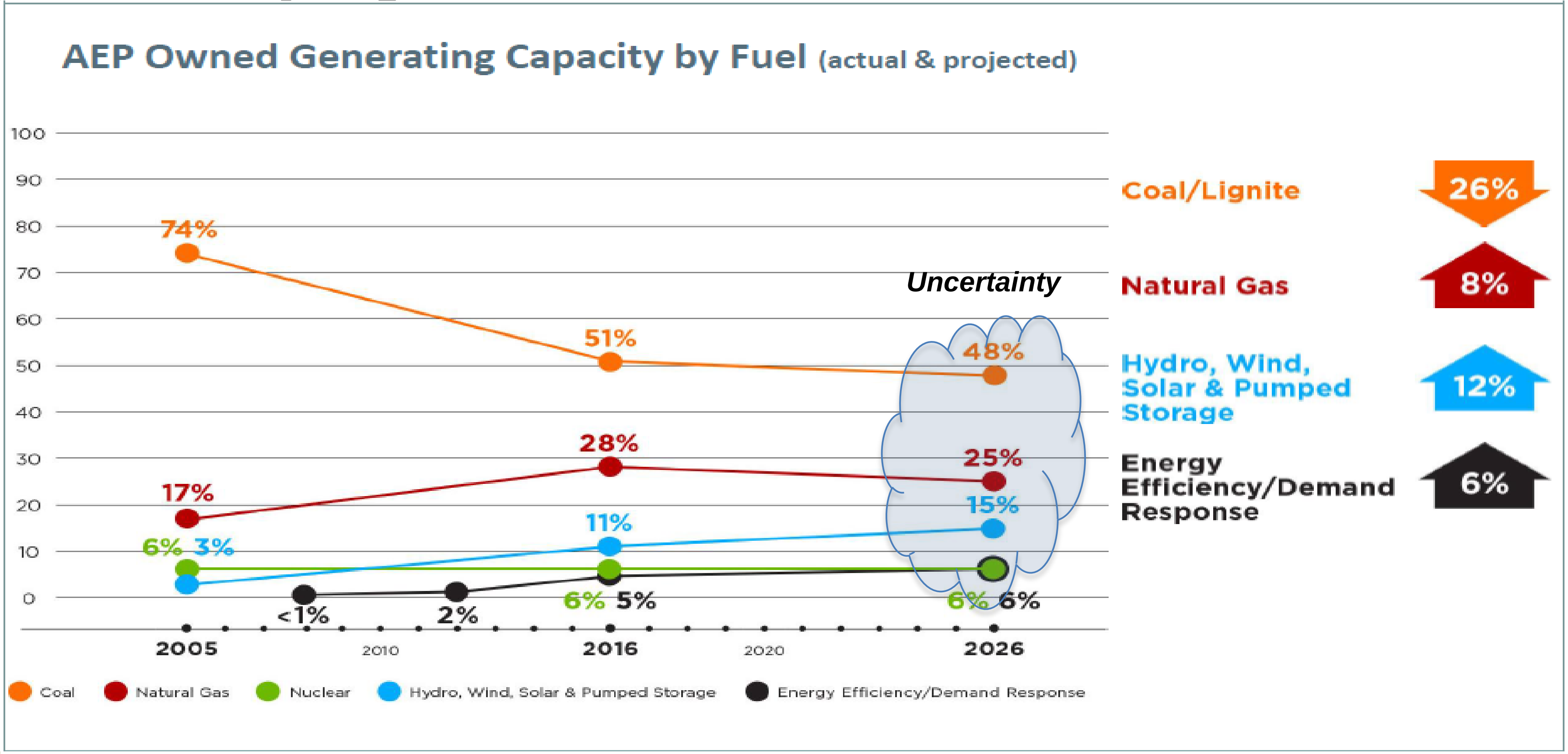
32 GW
Owned Generation

AEP AMERICAN ELECTRIC POWER®

We **power** life's possibilities℠

Note: Statistics as of December 31, 2015, except market capitalization which is as of February 25, 2016

Diversifying our Fuel Portfolio

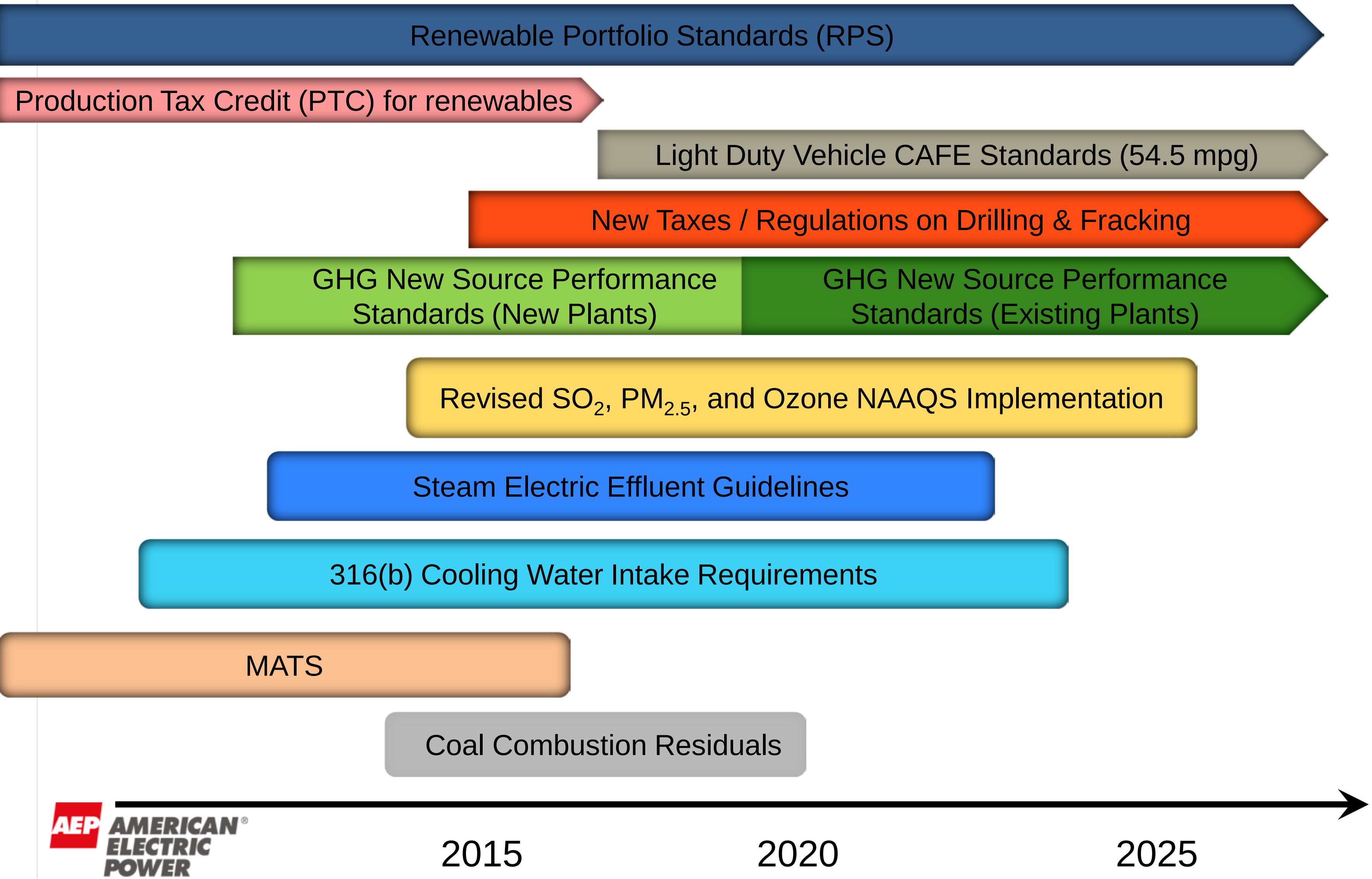


- 7,000+ MW of generation retiring by mid-2016
- Some planned coal to natural gas conversions and/or repower considerations
- No new fossil generation planned between now and 2020
- Utility Scale Solar PV under construction in Indiana (4 sites, 2.5-5MW each, ~16MW total by 2017)

AEP AMERICAN ELECTRIC POWER®

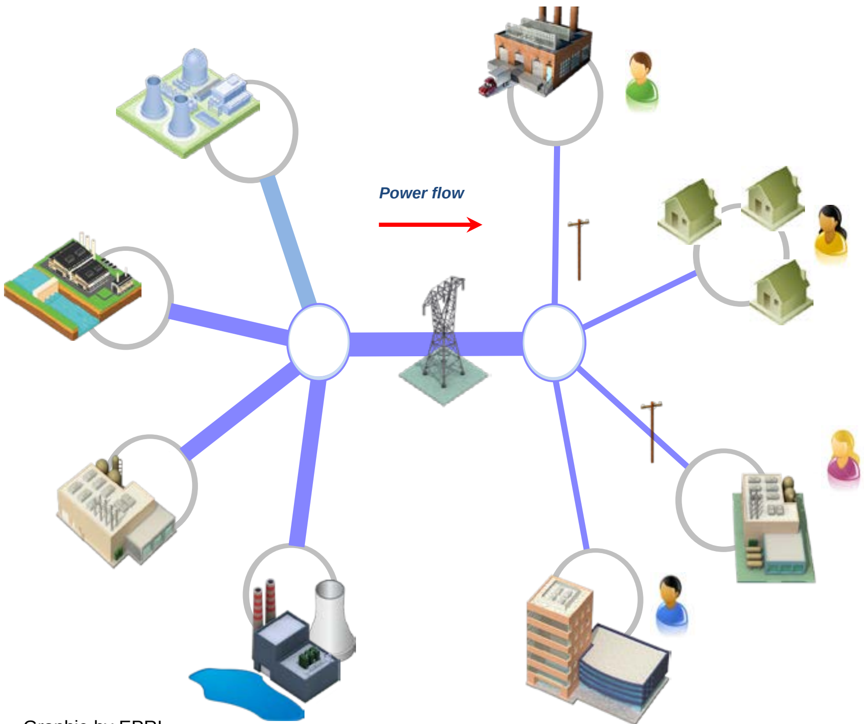
We power life's possibilities℠

Environmental/Regulatory Signposts & Milestones

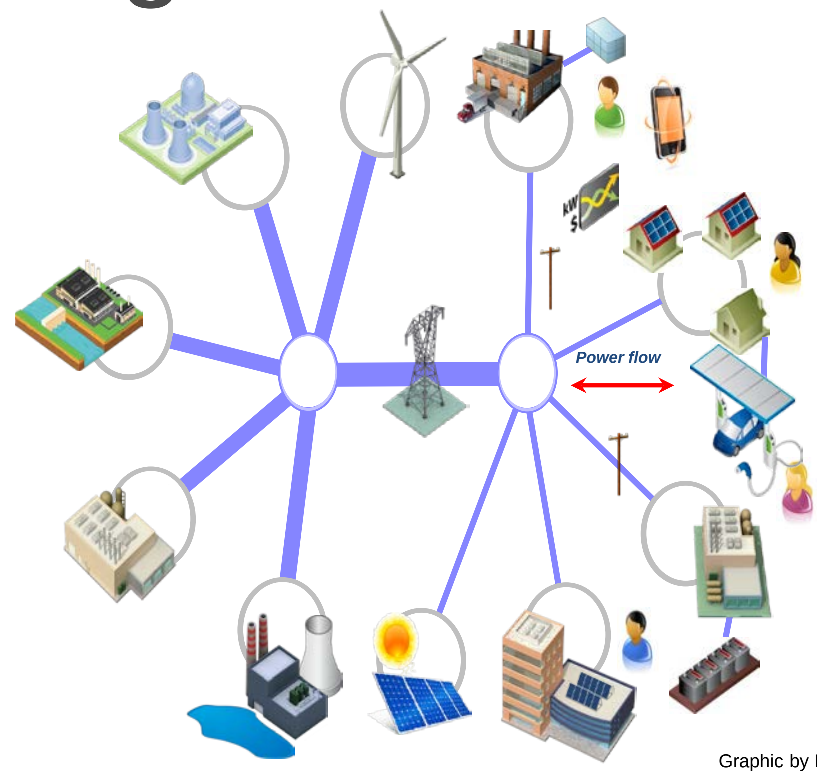


AEP AMERICAN ELECTRIC POWER

Traditional Vs. Integrated Grid



Graphic by EPRI



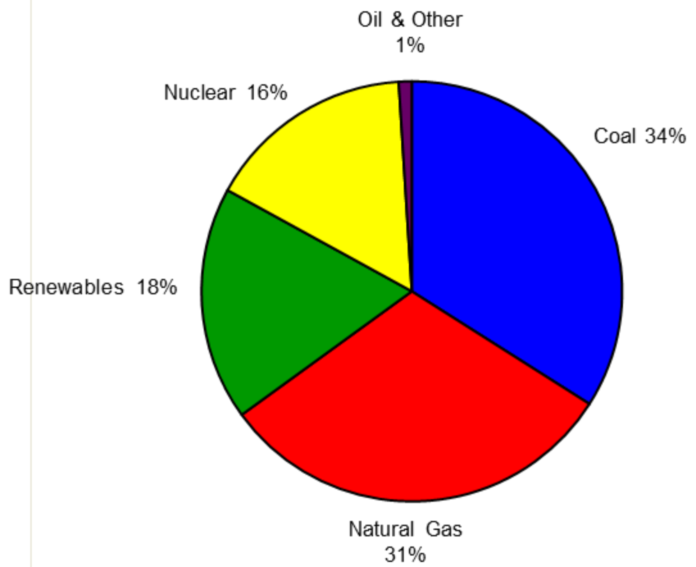
Graphic by EPRI

- 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?

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



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

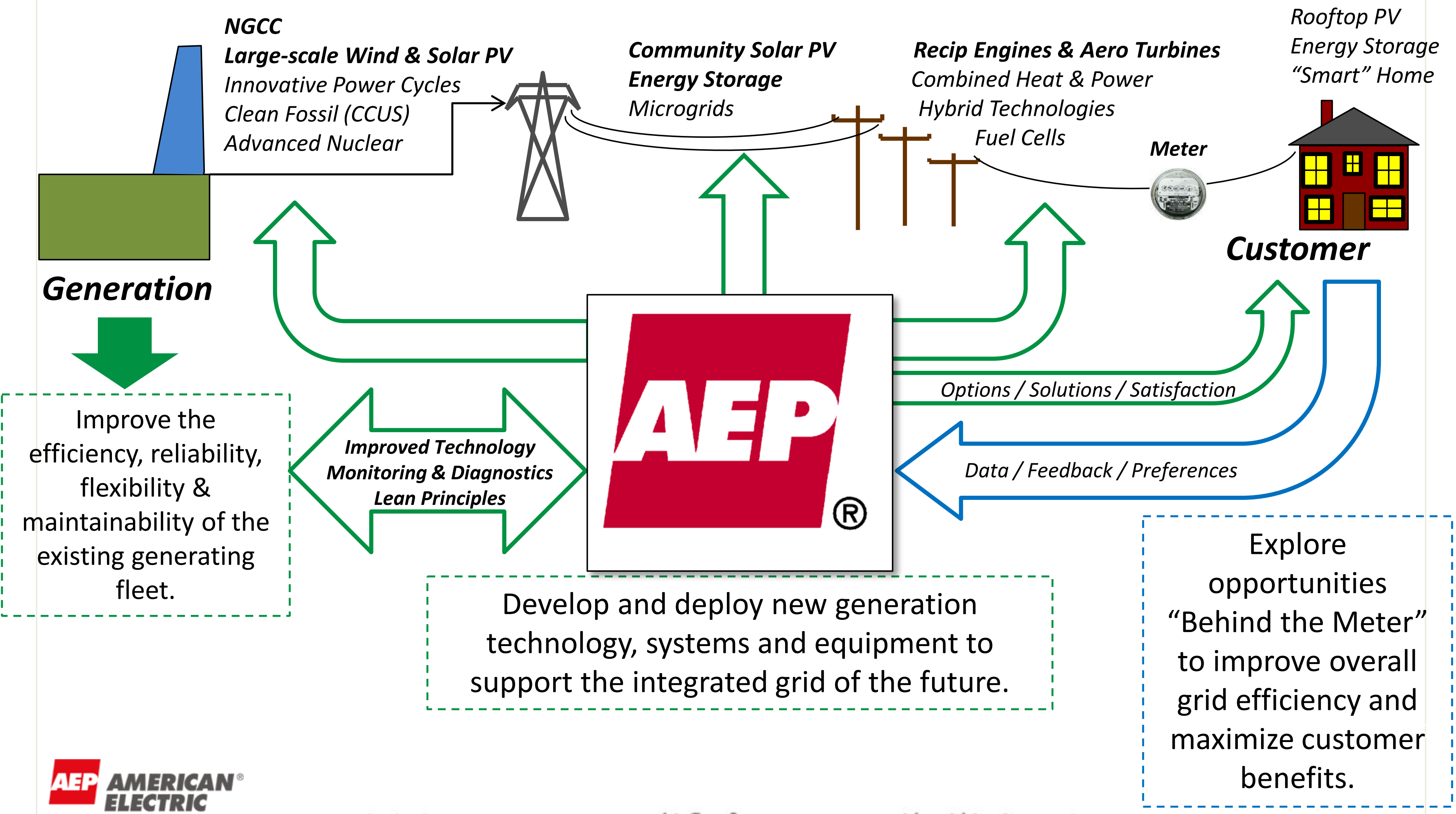
2040 Electricity Generation by Fuel

AMERICAN ELECTRIC POWER

On the Minds of Utilities

Source: Utility Dive – 2016 State of the Electric Utility Survey

The Role of Technology



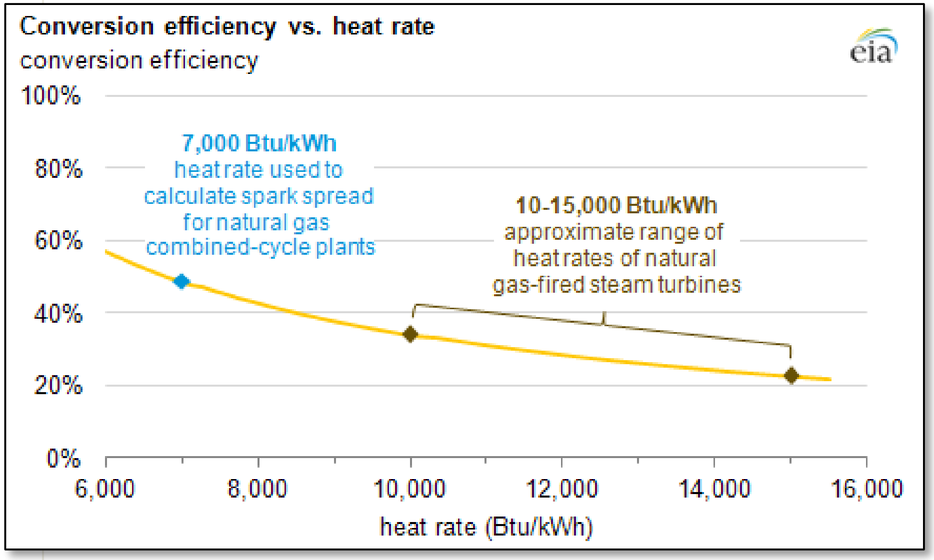
21st Century Technologies

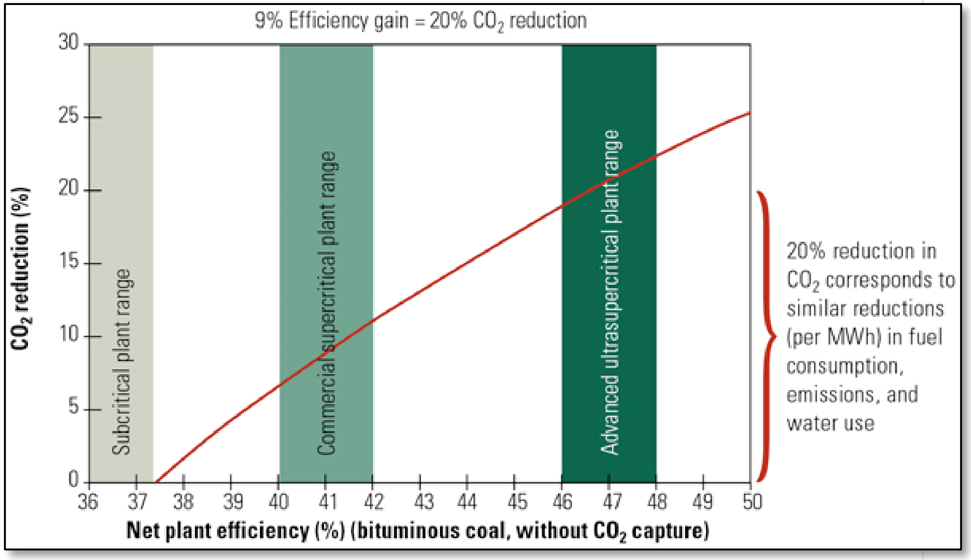
- *Distributed Generation & Renewables* ✓
- *Virtual Power Plants and Microgrids* ✓
- *Bulk Energy Storage* ✓
- *Advanced Nuclear* ?
- *Advanced Fossil Combustion / Thermal Energy Conversion Technologies* ✓
- *IGCC & Post-Combustion CO_2 Capture* ?
- *Advanced Cycles (e.g. ScCO_2 direct & indirect, Inorganic 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.





Power Magazine May 2011

- A very effective way to mitigate CO_2 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 CO_2 power cycles

Opportunities

- ***<u>Near term: Start small</u>***
  - *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*

- ***<u>Mid-Term: Grow in proportion to technical capabilities</u>***
  - *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.*

- ***<u>Long-Term: Technology for Transformational Solutions</u>***
  - *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 CO_2 Pilot*
  - *Includes design, development and fabrication of <u>ALL</u> necessary components*
- *Demonstrate potential for thermodynamic cycle efficiency > 50%*
- *Demonstrate operability of turbine at 700 ^{o}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

- *<u>Design Integration</u>*
  - *Site Selection / Heat source identification*
  - *Balance of Plant integration*
  - *Grid/customer interconnection*
- *<u>Materials</u>*
  - Thermal fatigue and stress resistance at 700 ^oC 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
- *<u>Fabrication / Manufacturing / Constructability</u>*
  - *Lead time, cost, supply chain*
  - *Manufacturing techniques and necessary innovations to improve*
  - *Modularity vs. field erected (weld-ability, availability of skilled labor, etc.)*
- *<u>Operability and Maintainability</u>*
  - *Startups/shutdowns, steady-state and transient operation*
  - *Isolation of equipment/components for maintenance*
  - *Operator training*

Facing Challenges & Overcoming Obstacles

- *Collaboration – Collaboration – Collaboration*
  - Consortiums, 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