Future Role of Natural Gas Fired Power Generation with CCS

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EPRI Overview

Mission

• Assure long-term availability of affordable, reliable, and environmentally responsible electricity through research, development and demonstration.

Key Facts

• 450+ participants in more than 30 countries

• EPRI members generate approximately 90% of the electricity in the United States

• ~$380M/year funding; international funding ~25%

• Non-profit 501(c)(3), independent, collaborative R&D institution
Power Sector Policy Drivers

• CO₂ emissions reduction

• Existing limits (e.g. SOₓ, NOₓ, Hg, thermal pollution)

• Water availability

• Environmental impact of renewables (e.g. avian, bats)

• Policy-driven technology choices (e.g. renewables)
Power Sector Technical Drivers

- Meet demand
- Maintain reliability
- Minimize cost
- Recognize long lead times for technology deployment.
- Hedge technology risks
Natural Gas in the Power Sector

• Electric sector gas consumption
  – 2012: electric sector gas consumption ~36% of all US consumption
  – 2014 EIA AEO projection for 2040: electric sector gas consumption ~34% of total

• Growth in NG consumption in electric sector
  – 2011-2012: increased 22%
  – 2014 EIA AEO: projects 8% growth in electric sector gas consumption (2012-2040)

• Generation share
  – 2011: 21% of total generation
  – 2011-2012: 24% increase
  – 2012: 27% of total generation (196 TWh)
  – 2040: 31% of total generation
Natural Gas - Strengths

• Low NG prices make CTCCs attractive
  – breakpoint with coal regionally dependent, but generally in $4-$6/mmBtu range

• Reduced fossil plant emissions, including CO₂

• More operational flexibility compared to coal units.

• Smaller capital outlay for new capacity, can be constructed more quickly, lower water requirements compared to coal/nuclear
  – Often favored by PUCs

• Delays need to invest in more expensive options (e.g. coal, nuclear)
  – Gives lead time to develop more advanced technologies for other generation technologies.
Natural Gas – Challenges

• Dynamic combustion control
  – Balancing efficient operations w/emissions control
  – Harder if cycling

• CTCC cycling/HRSG reliability
  – Renewable portfolio standards + increasing role of demand response, end-use efficiency => increased cycling of CTCCs => performance, reliability issues
  – Heat Recovery Steam Generators (HRSGs) particularly important, problematic

• Assurance of supply, pricing
  – Potential growth of opposition to fracking.
  – Pipeline infrastructure expansion.
  – Pipeline operations and fluctuating power sector demand.

• Hedging against future high NG prices, price volatility, availability
  – Substantially increased demand for natural gas from the power sector could significantly drive prices up.
  – ~55% of electricity production costs for CTCCs = fuel cost => financial exposure in generation portfolio.
Trending Toward Higher Efficiency, Flexibility

*Improved Metallurgy, Coatings, Cooling, Aerodynamics, Size*

*Efficiency versus Temperature*

- Majority of existing units

*Combined Cycle Efficiency, % vs. Turbine Rotor Inlet Temperature, °F*

- D/E Class
- F and FA Class
- G and H Class

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R&D Focus Areas
Improved Efficiency, Flexibility, and Durability

• Fuel Flexibility
  – LNG and Natural Gas Variability
  – Lower NO\textsubscript{x} and CO Emissions/Combustion Dynamics

• Operational Flexibility
  – Fast Startup and Shutdown
  – Frequent Cycling (Many Starts Per Year)
  – Part Load Efficiency and Low Load Emissions
  – Load Following and Frequency Control

• System/Component Durability
  – Preventive Maintenance
  – Repair and Replacement Costs
  – Forced/Unscheduled Maintenance, Catastrophic Failures
R&D Focus – CTCC + CCS

• Evaluate the performance and cost impact of applying post-combustion capture (PCC) to today’s NGCC

• Cases considered:
  – Reference 556-MWe (Net) base NGCC plant
  – Retrofit post combustion plant to base plant
  – New build NGCC plant designed with capture
  – New build NGCC plant designed with capture + exhaust gas recycle (EGR).

• PCC technology = advanced amine solvent (Aker Clean Carbon)

• Conclusions
  – Retrofitting is more expensive than integrated design.
  – Key sensitivities
    • Engineering, procurement & construction (EPC) contingency
    • Unit capacity factor
    • Overall levelized cost of electricity more sensitive to fuel cost than to avoided CO₂ cost
Total Plant Costs
NGCC with and without CO₂ Capture

- New NGCC plant (No Capture)
- NGCC Plant (Retrofitted with PCC)
- New Build NGCC Plant (Designed with PCC + EGR)
- New Build NGCC (Designed With PCC)

<table>
<thead>
<tr>
<th>Description</th>
<th>Total Plant Cost ($/kW (2011$))</th>
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<tbody>
<tr>
<td>New NGCC plant (No Capture)</td>
<td>780</td>
</tr>
<tr>
<td>NGCC Plant (Retrofitted with PCC)</td>
<td>1736</td>
</tr>
<tr>
<td>New Build NGCC Plant (Designed with PCC + EGR)</td>
<td>1586</td>
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<tr>
<td>New Build NGCC (Designed With PCC)</td>
<td>1676</td>
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</tbody>
</table>
556-MWe (Net) NGCC Base Plant with PCC and Exhaust Gas Recycle
### Overview from Electricity Sector Perspective

<table>
<thead>
<tr>
<th>Environmental Policies</th>
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<tbody>
<tr>
<td>- CO₂ policy</td>
<td>- long-term problem</td>
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<tr>
<td>- RPS/RES</td>
<td>- good (backup); bad (competes)</td>
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<tr>
<td>- Ash</td>
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<tr>
<td>- Env. impacts/renewables</td>
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<td>- Water impacts</td>
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<td>- HAPS</td>
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<td>- Shale gas/hydro-fracking</td>
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<td>- potential environmental issues</td>
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<tr>
<td>Hedge technology risk</td>
<td>- good (diversity); bad (too much)</td>
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<td>Capital cost/long development lead times</td>
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<tr>
<td>Long-term demand growth</td>
<td>- expensive bulk energy</td>
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<td>Load curve/capacity needs</td>
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<td>Grid reliability</td>
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<td>Minimizing electricity costs</td>
<td>- long term price volatility</td>
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Key Takeaways

• NG is a key part of electricity sector, but drivers are diverse, creating both pros and cons for NG
• Cycling will become a larger issue with renewables, DG, end-use load mgmt. and efficiency.
• NGCC technology improving in efficiency, flexibility
• R&D issues associated with long-term reliability, maintainability.
• CCS for NGCC likely to be necessary in future.
• Diversified generation technology portfolio provides reliability, economic efficiency, operational flexibility, hedge against uncertainty in gas supply and cost.
Together…Shaping the Future of Electricity