Exploring the Role of Advanced Nuclear in Future Energy Markets
Economic Drivers, Barriers, and Impacts in the U.S.

John Bistline, Ph.D.
Senior Technical Leader

Enabling Advanced Reactors Symposium
March 8, 2018
Key Drivers of the Future Role of Advanced Nuclear Power

- **Capital costs:** Capital cost “sweet spots” for new nuclear depend critically on the costs of other technologies and on markets (e.g., natural gas prices)

- **Energy and environmental policies:** Policy and market environments drive advanced nuclear deployment as much as cost targets

- **Revenue streams:** Extent of deployment depends jointly on changes in costs and benefits/value of different technologies at the margin

- **Regional factors:** Key regional differences (e.g., gas pipelines, renewable resources, existing asset mix, transmission) make the economic competitiveness of advanced nuclear vary across the U.S.

The future of nuclear deployment is a complex function of these drivers
### Analysis Approach and Scenario Matrix

<table>
<thead>
<tr>
<th>Market and Policy Sensitivities</th>
<th>Technology Sensitivities (Nuclear Capital Cost Scenarios: $/kW in 2030)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reference Natural Gas Prices</strong></td>
<td>$5,000</td>
</tr>
<tr>
<td>Electric Sector CO₂ Policy</td>
<td>$15/t-CO₂ Tax @ 5%</td>
</tr>
<tr>
<td></td>
<td>95% Cap</td>
</tr>
<tr>
<td>Additional Revenue Streams</td>
<td>$5/MWh</td>
</tr>
<tr>
<td></td>
<td>$15/MWh</td>
</tr>
<tr>
<td>RPS with New Nuclear</td>
<td>50% by 2050, No Trading</td>
</tr>
<tr>
<td></td>
<td>50% by 2050, Trading</td>
</tr>
<tr>
<td><strong>High Natural Gas Prices</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Low Natural Gas Prices</strong></td>
<td></td>
</tr>
</tbody>
</table>

- Advanced nuclear capital cost sensitivities vary after 2030 ($/kW)
- Natural gas price trajectories based on EIA’s *Annual Energy Outlook*
- Additional revenue streams → Proxy for PTC, sales of primary heat, or other products
- Expanded RPS: New nuclear considered an eligible resource; requirements expanded to all regions and stringency increased over time (30% by 2030 through 50% by 2050); sensitivity to national REC trading
US-REGEN: EPRI’s In-House Electric Sector and Economy Model

U.S. Regional Economy, GHG, and Energy

Capacity Expansion Economic Model, Long Horizon to 2050

Customizable State/Regional Resolution for Policy and Regulatory Analysis

Innovative Algorithm to Capture Wind, Solar, and Load Correlations in a Long-Horizon Model

For more information, see our website at http://eea.epri.com
Evolution of the Electric Sector Absent Further CO₂ Policy

Reference Policies, Reference Gas Prices, $5,000/kW Nuclear

Observations

• Expiring PTC and ITC accelerate wind and solar investments

• Absent additional policies, new builds are mostly gas, wind, and solar (some existing nuclear and coal capacity remains unless gas prices are lower)

• New nuclear is not “in the money,” but Vogtle is included
Lower Capital Costs Encourage Advanced Nuclear Investment

Reference Policies, Reference Gas Prices
Advanced Nuclear Deployment

Observations

- Capital cost “sweet spots” for advanced nuclear depend critically on the costs of other technologies and markets

- Without policy and assuming reference gas prices, levels below $4,000/kW would be required to be competitive

- With strong policy support, additions depend jointly on technology “value” and costs

- Caveats: Time profile of investment, regional impacts, and sensitivity to natural gas prices
Future Nuclear Capacity Additions across Scenarios

- Reference
- High
- Low

Gas Prices
- $15/t-CO₂
- 95% Cap

CO₂ Policy
- $5/MWh
- $15/MWh

Revenue
- No Trade
- Trading

Expanded RPS
- $2,000/kW Nuclear
- $3,000/kW
- $4,000/kW
- $5,000/kW
Advanced Nuclear Economics Report Now Available

- Published on March 6, 2018
- Report is free and publicly available at epri.com, including a standalone Executive Summary
- Contains additional sensitivities, figures, and detailed assumptions

Together...Shaping the Future of Electricity

John Bistline
Senior Technical Leader
650-855-8517
jbistline@epri.com
EPRI’s US-REGEN: Modeling the Future Today

- State-of-the-art computable general equilibrium (CGE) model of the U.S. economy with enhanced regional detail
- Includes detailed focus on the energy sector and electricity system
- Regional breakdown captures variability in generation mix, resources, and demand
- Tool to support scenario planning
- Incorporates EPRI’s proprietary datasets related to expected costs and performance of electric generation technologies and environmental controls
- Developed and maintained by EPRI staff
US-REGEN Assumed Capital Cost Trajectories

Ranges indicate regional variation

Source: 2016 Integrated Generation Options Report (3002011806)
Reference ("Business-as-Usual") Scenario Assumptions

- Reference load growth and fuel prices per EIA’s 2017 Annual Energy Outlook
- No forced retirements for existing coal units; retirement for economic reasons possible for any unit
  - Follows AEO assumptions
  - 60–80 year lifetimes for existing nuclear units (license extension assumptions based on EPRI Nuclear input)
- Upper bounds on near-term transmission expansion
- Technology costs per EPRI Generation Options report
  - Solar and wind costs updated more regularly
  - Integration costs and value erosion for variable renewables captured endogenously
- Includes on-the-books policies like state RPSs, RGGI, California’s AB 32
  - Fleet database as of December 2016, plus announced retirements
  - No additional environmental regulatory costs are included
  - December 2015 updates of PTC and ITC
Stringent power sector cap aligns with the (former) Climate Action Plan’s “80-by-50” economy-wide target
Observations: Advanced Nuclear Deployment

- **Non-electricity revenues** and the policy environment drive advanced nuclear deployment as much as cost targets

- **Additional revenue streams** (e.g., production tax credit, primary heat sales) provide greater investment certainty than other forms of regulatory support
  - CO₂ tax or cap offer predictable ways to value emissions benefits of nuclear, but their technology-neutral structures also helps other low-carbon technologies as well (e.g., wind, solar, CCS)
  - Expanded RPS with new nuclear offers an additional revenue stream, but there is uncertainty associated with REC markets
Regional Outputs: 2050 Generation
Reference Policies, High Gas Prices, $5,000/kW Nuclear Costs

Total 2050 U.S. Market for New Nuclear = 860 TWh
Higher Gas Prices Impact Investments and Dispatch

Reference Policies, High Gas Prices, $5,000/kW

Observations

- New wind and solar are more competitive with high gas prices (even more than with lower renewables costs)
- New nuclear is economic in some regions without additional policy
  - Even with higher capital costs
  - Especially in the South and East where gas prices are high and wind resources are lower quality
Even a CO₂ Price May Not Be Enough with Low Gas Prices

95% Cap by 2050, $5,000/kW Nuclear
Regional Capacity Factors of New Nuclear Vary by Scenario

$2,000/kW Nuclear

Observations

- Low short-run marginal costs lead to high capacity factors for most new nuclear plants.
- Scenarios (and regions) with high variable renewable deployment require flexible operations.
- Regional variation is significant, largely due to percentage of renewables on the grid.

<table>
<thead>
<tr>
<th>Reference Gas Prices</th>
<th>High Gas Prices</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Policy</td>
<td>95% Cap</td>
</tr>
<tr>
<td>No Policy</td>
<td>95% Cap</td>
</tr>
</tbody>
</table>
2050 Generation under Alternate RPS Policies

“Expanded RPS” = new nuclear is eligible; targets reach 50% by 2050

Takeaways

• Regulatory approaches to climate policy differ from market-based approaches in technology-specific impacts (e.g., coal retirements)

• Uncertainty associated with relying on REC markets
  - Exposure to external forces? Increased stringency required
  - Liquidity/depth? Cheap wind could flood market and depress prices
  - Volatility? Trading assumptions and market expectations matter
Bibliography

- Bistline and Blanford (2016), More Than One Arrow in the Quiver: Why “100% Renewables” Misses the Mark, *PNAS*, 113(28):E3988.
- Blanford, Merrick, Bistline, Young (2018), Simulating Annual Variation in Load, Wind, and Solar by Representative Hour Selection, *The Energy Journal*

For more information, see our website at [http://eea.epri.com](http://eea.epri.com)