LUCID CATALYST

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PRESS RELEASE FOR IMMEDIATE ISSUE: TUESDAY 14 JULY 2020

LARGE MARKETS FOR ADVANCED REACTORS THAT COST LESS THAN $3,000/KW, NEW STUDY FINDS

A new study by LucidCatalyst for the ARPA-E MEITNER program is the first to derive the highest allowable capital cost for advanced reactors across four of the major power markets in the United States in 2034.

Advanced reactors that cost less than $3,000/kW will be attractive investments, and create the most value for plant owners, the study finds.

By modeling high penetrations of renewables in the mid-2030s, following National Renewable Energy Laboratory (NREL) scenarios, the study shows how advanced reactors can complement wind and solar. Together, these technologies drive down costs, reduce emissions, and improve performance in future U.S. electricity grids. In each of the markets modeled, the addition of advanced reactors lowered the overall system cost.

Eric Ingersoll, Managing Director, LucidCatalyst:

"Delivering plants for less than $3,000/kW requires meaningful cost reduction in all systems and components, and all aspects of the plant delivery process. Key strategies include reuse of designs, high productivity manufacturing, and separation of the nuclear safety case from the balance of plant."

"Advanced reactors can supply clean dispatchable power without raising the overall cost of electricity. This conclusion should motivate ISO operators, public utility commissioners, policymakers, utilities, and other stakeholders to investigate the role that these products could play in the grids of the future. And in particular to continue and increase their support for acceleration of advanced reactor commercialization efforts. This study should also motivate organizations responsible for national and international energy modeling to include flexible, advanced nuclear with thermal energy storage in their projections for future energy systems."

Rachel Slaybaugh, Director of the ARPA-E MEITNER Program:

"Advanced reactor developers are at various stages of commercializing new products, with an opportunity now to integrate identified future market requirements into early stages of their designs. Studies like this can provide these reactor design teams with information allowing them to make evidence-based decisions with a realistic understanding of future requirements in large markets, helping demonstrate the compelling growth potential for the future of advanced reactor technology."

Key Findings

- Advanced reactor developers should aim for a CapEx of less than $3,000/kW.
- Increasing or decreasing the weighted average cost of capital (WACC) by a percentage point changes the maximum allowable CapEx by around 8 – 9%.
- Fuel cost and fixed O&M expenses are material considerations—as these decrease allowable CapEx increases.
- Depending on specific market conditions, it may also be beneficial to co-locate thermal energy storage. A 12-hour thermal energy storage system (ESS) enables higher allowable CapEx, assuming it receives capacity payments. Across ISOs modeled, co-locating ESS makes economic sense, on average, for less than $1,126/kW. Without energy storage, a plant's capacity factor suffers in zones with high variable renewables.
- Developers should note that higher variable renewable energy penetrations reduce average energy prices and therefore also reduces allowable CapEx.
- A 'fleet' deployment of advanced reactors (meeting these cost targets) and combined with energy storage can lower the total cost of energy delivery in the market.
- Capacity price is critically important. A 'mid-range' capacity price of $75/kW-year, relatively consistent with today's prices, allows for:
  ~$2,500/kW CapEx without storage
  ~$3,500/kW CapEx with storage

About the Study

The study asked the following questions about market conditions in 2034 when advanced reactors are expected to be a commercialized and available:

- What is the maximum allowable CapEx?
- What is the value of integrated thermal storage?
- Are there significant differences between key markets?
- How do OpEx and fuel costs affect allowable capital cost?

The study examines two future scenarios in 2034 across four of the principal power markets in the U.S.: ISO-New England (ISO-NE); Pennsylvania, New Jersey, Maryland Power Pool (PJM); Midcontinent Independent System Operator (MISO); and California ISO (CAISO):

1. 'Low renewables' (Low RE) baseline scenario, assuming continuation of existing renewables policy, and current renewables build rates.
2. 'High renewables' (High RE) scenario based on NREL Regional Energy Deployment System (ReEDS) low renewables costs and low natural gas costs scenario.

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Press release:14 July 2020

Additional Findings

Three additional scenarios and potential market conditions were examined in PJM, yielding these additional findings:

- **CO_2 price:** Future power markets may include CO_2 prices. This dramatically improves the maximum allowable CapEx requirements. For example, in the PJM mid-capacity price case, (assuming the high renewables scenario with thermal storage) if a price of $75/tonne for CO_2 is established, the maximum allowable CapEx goes from $3,591/kW to $6,609/kW. Design teams are strongly cautioned not to assume there will be CO_2 prices in the future.

- **Fleet deployment:** As the advanced reactor plants have low marginal costs, adding more of them to a market reduces electricity prices. A large fleet supplying 2/3 of firm generation in PJM (with co-located thermal storage) dropped the maximum allowable CapEx by ~$500/kW (from the 1st plant to last plant).

- **Increased O&M and fuel costs:** O&M costs are critical to future plant profitability. Increasing the fixed O&M assumptions from $31/kW to $61/kW reduces the maximum allowable CapEx by $377/kW. Raising fuel cost from $4/MWh to $12/MWh reduces allowable CapEx by ~$750/kW.

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NOTES TO EDITORS

1. Media Enquiries: info@lucidcatalyst.com or kevin.fitzmaurice@hq.doe.gov

2. LucidCatalyst is an international consultancy specialising in thought leadership and strategic interventions designed to bring about rapid decarbonisation and prosperity for all. The LucidCatalyst team are leading analysts for nuclear costs, and cost reduction strategies. www.lucidcatalyst.com

3. The ARPA-E MEITNER (Modeling-Enhanced Innovations Trailblazing Nuclear Energy Reinvigoration) Program seeks to identify and develop innovative technologies that can enable designs for lower cost, more flexible advanced nuclear reactors.

4. The full report: *Cost and Performance Requirements for Flexible Advanced Nuclear Plants in Future U.S. Power Markets Report* for the ARPA-E MEITNER Program (July 2020) is available here: www.lucidcatalyst.com

5. To perform the grid modeling and underlying financial analyses, LucidCatalyst used PLEXOS® electricity production cost modeling software to estimate the revenues earned by a generic high-temperature advanced nuclear plant in deregulated power markets in the mid-2030s. These revenues were then analyzed in a power plant financial model to determine the maximum allowable CapEx for which a plant must be delivered to achieve a market rate of return.

6. The Regional Energy Deployment System (ReEDS) is NREL's flagship capacity planning model for the power sector. It simulates the evolution of the bulk power system—generation and transmission—from present day through 2050 or later. https://www.nrel.gov/analysis/reeds/

7. LucidCatalyst is grateful to the following reviewers and advisors:

   - Steve Brick, Senior Fellow, The Chicago Council on Global Affairs
   - Charles Forsberg, Principal Research Scientist and Executive Director, MIT Nuclear Fuel Cycle Project
   - Jesse Jenkins, Assistant Professor, Princeton University
   - Abram Klein, Managing Partner, Appian Way Energy Partners
   - Mike Middleton, Practice Manager Nuclear, UK Energy Systems Catapult
   - David Mohler, Former CTO and SVP, Duke Energy; Former Deputy Assistant Secretary for Clean Coal and Carbon Management, Office of Fossil Energy, U.S. Department of Energy
   - Bruce Phillips, Director, The NorthBridge Group
   - Dave Rogers, Former Head of Energy Practice, Latham & Watkins

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