

Small Modular Reactors – Potentially Key Contributors to Future Nuclear Power Generation in the U.S.

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Goals and Objectives of EPIC

Partners

- University of Chicago
 - Harris School of Public Policy Studies
 - Booth School of Business
- Argonne National Laboratory
- *The Bulletin of the Atomic Scientists*

Products

- Interdisciplinary research and training on energy policy
 - Approach based in the social and physical sciences
 - Strong emphasis on quantitative economic analysis
- Communication of experts' research to decision-makers, the media, and the public worldwide
 - Conferences, workshops, seminars, and “studies”



Study Scope

- The U.S. Department of Energy requested Argonne National Laboratory, in collaboration with faculty at the University of Chicago and Stanford University, and subject matter experts to update the 2004 Study, “The Economic Future of Nuclear Energy”
- Release of two reports:
 - SMR Report:
<https://epic.sites.uchicago.edu/sites/epic.uchicago.edu/files/uploads/EPICSMRWhitePaperFinalcopy.pdf>
 - EPIC GW Overnight Cost Report:
<https://epic.sites.uchicago.edu/sites/epic.uchicago.edu/files/uploads/EPICOvernightCostReportFinalcopy.pdf>



New GW-Scale Nuclear Plants

Conclusions

- Overnight capital costs for new GW-scale commercial plants have doubled since the passage of EPLA 2005
- Key Factors at play
 - Project Maturation (Design and Technology)
 - Commodity price increases
 - Scope of owner's costs
 - De-risking
- Impacts of Fukushima remain uncertain
- Today , best characterized as a “exigent” competitive position
 - depends upon future behavior of natural gas price (or carbon pricing)



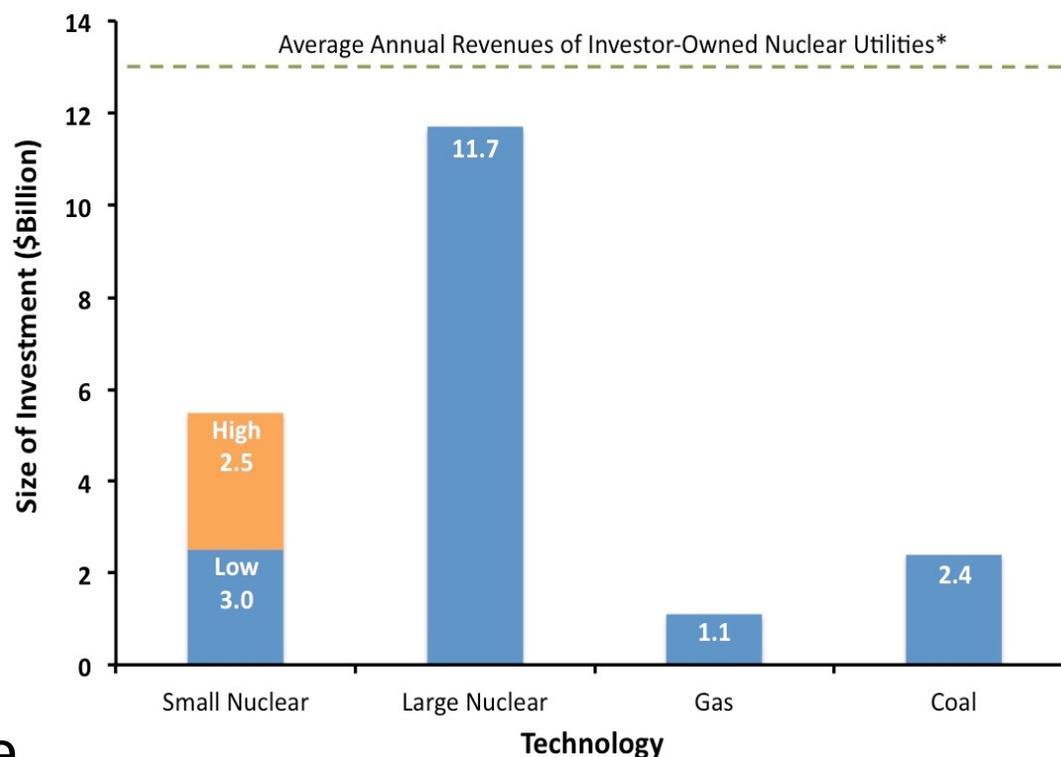
The SMR analysis identified several key topics

- Input from vendors on nth-of-a-kind cost estimates (best achievable numbers)
- Extrapolation to earlier plants not straightforward: i.e., no firm estimates on the early movers, have to do scenarios
- Natural gas and their impact
- Tangibles and intangibles in establishing whether SMRs are worth the government's investment
- The order book: for SMRs, this is key – nationally and internationally



Size Matters

- Risk premium is very sensitive to the relative size of the investment to the size of the firm
- This, in turn, impacts nuclear energy's relative competitiveness
- Generally, SMRs exhibit low relative investment ratios, close to the relative investment ratios of coal-fired and gas-fired units



* Before the announced mergers of: (1) Exelon and Constellation; and (2) Duke and Progress.



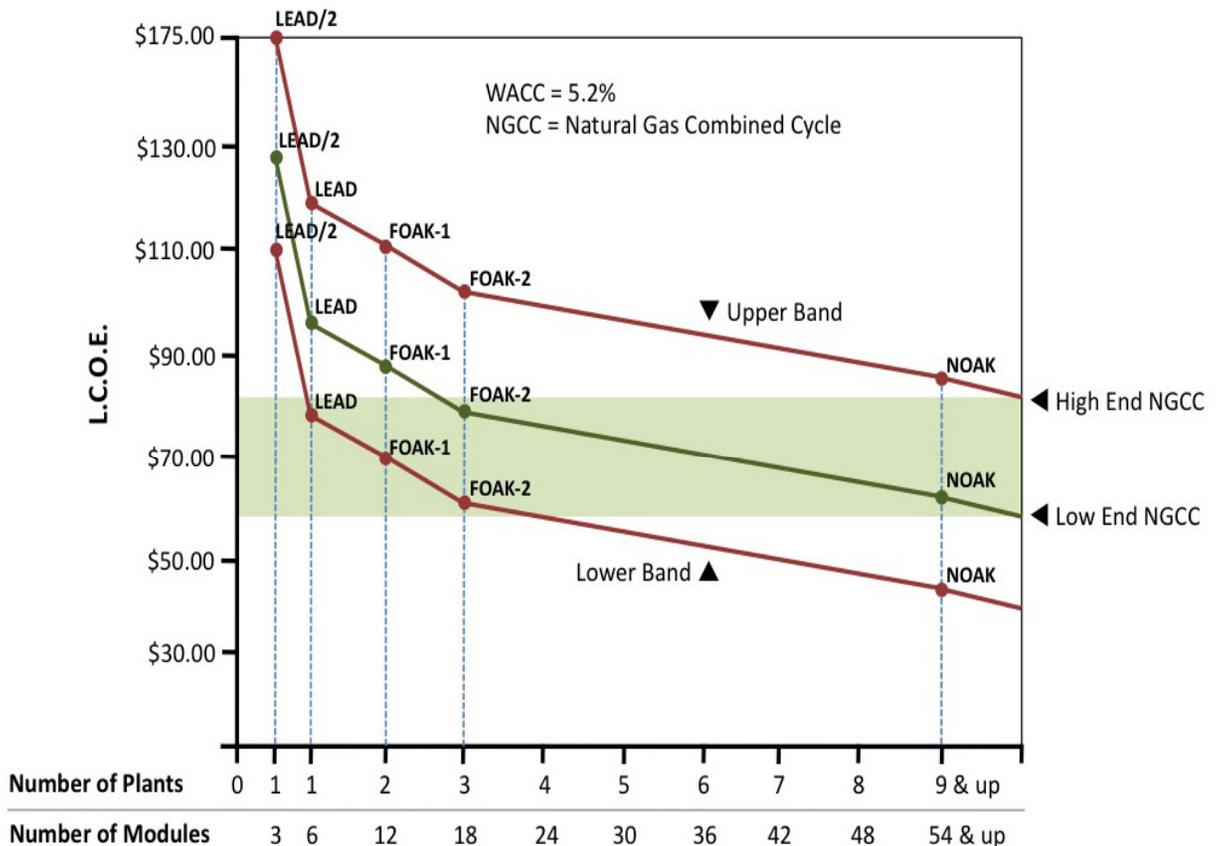
SMRs are Amenable to Significant Learning Improvements

- The learning process has the potential to significantly reduce SMR costs
- However, understanding whether the potentially higher learning rates are achievable will require more detailed design and engineering work
- Learning process needs to be supported by
 - Favorable NRC licensing decisions
 - Maximum reliance on factory-assembled equipment
 - Demonstrated in-factory learning
 - Continuous stream of orders
- Future work is focusing on this key area

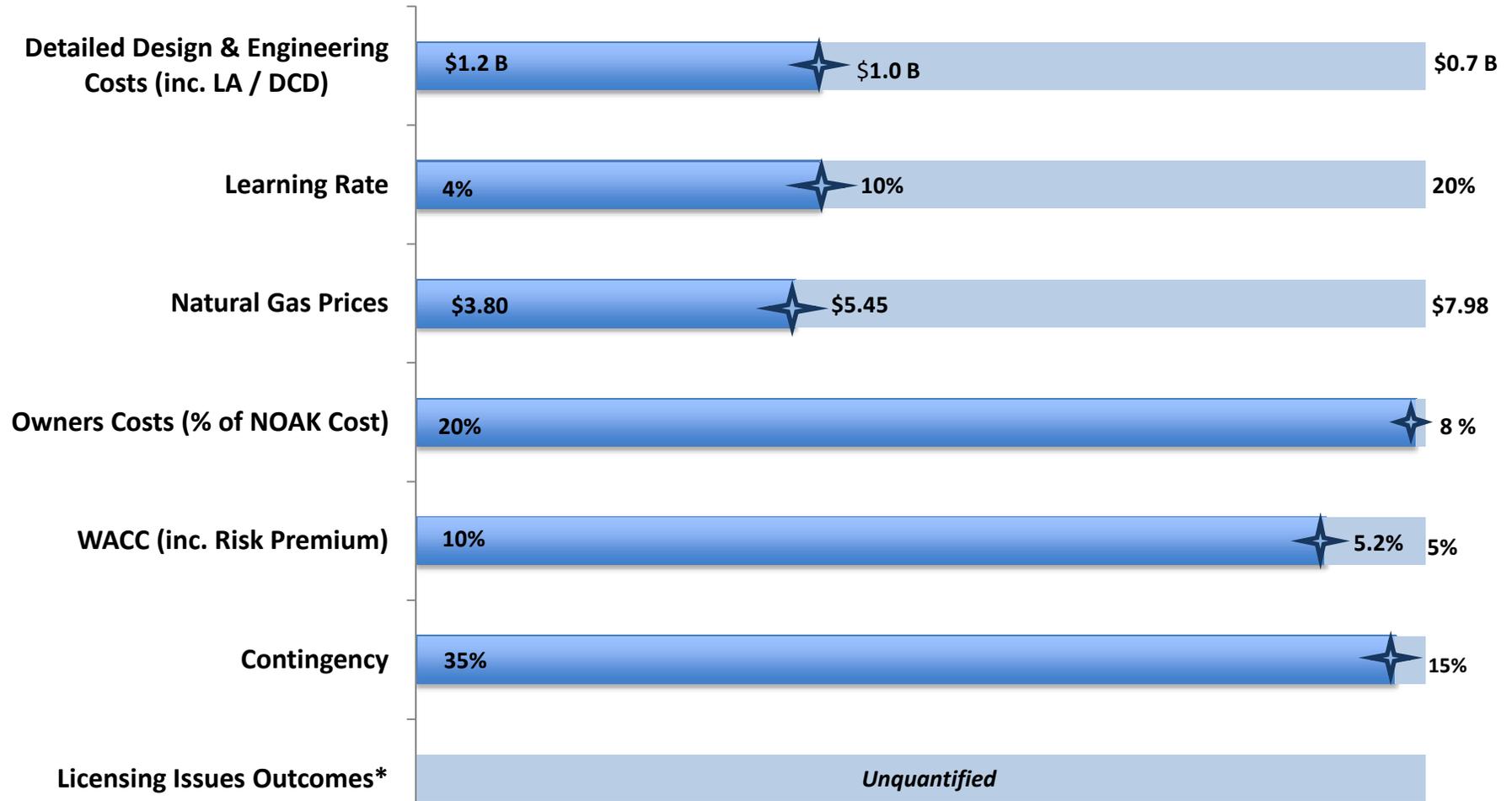


SMR Economies of Mass Manufacturing

- First analysis to quantify learning
- Take 2-3 early movers to enter the competitive range
- Natural gas price outcomes will be a key factor



SMR Cost Estimates (Green Curve) Reflect a Mix of Conservative and Optimistic Assumptions



* Issues include security and physical protection; aircraft impact; operating room configuration and staffing; emergency planning; and use of probabilistic risk assessment.



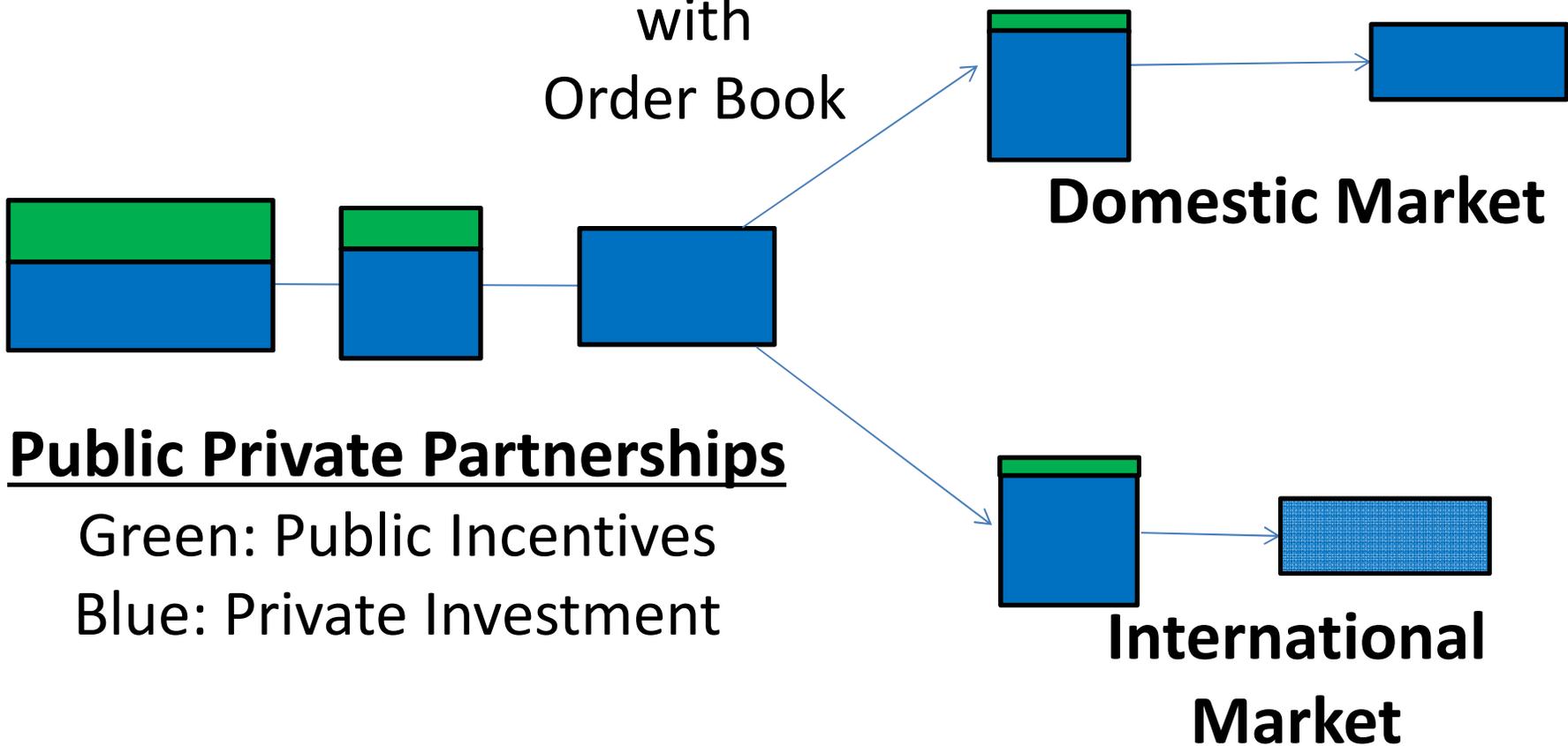
Characteristics of SMRs can Broaden the Potential Opportunities for Commercial Nuclear Power

	<u>First Mover GW-Scale LWRs</u>	<u>Nth-of-A-Kind SMRs</u>
Ability to serve more markets different sizes	1,200-1,600 MW	45-600 MW
Rate adjusted cost of capital	7.5% WACC (w/o loan guarantee)	5.2% WACC
Safety Risk	Not Fully Passive	Fully Passive Systems
Enhanced Spent Fuel Management	Largely above ground systems, with heavy reliance on pool storage; current capacity is less than life of plant	Underground system designed for life of reactor



SMR Business Model

Stage 1: DD&E **Stage 2:** LEAD Plant **Stage 3:** Module Factory with Order Book **Stage 4:** Learning FOAK Plants **Stage 5:** Competitive NOAK Plants



Public Private Partnerships

Green: Public Incentives
Blue: Private Investment



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Overall Findings: Economics and Business Case

- Analyses provide an Initial Bounding Analysis, but significant uncertainties are embedded in the assumptions
 - % of SMR capital costs that can be shifted to the factory
 - Investment cost and financing for the facility
 - Size of factory and production ramp-up rate
 - Outcomes of the NRC licensing process
- SMR incentives will be smaller and more effective if complemented by market transformation efforts (e.g., market pull to complement technology push)



Examples of Market Pull Activities

- Federal purchases from LEAD and possibly early FOAK SMR facilities
 - Concentrated to one large federal complex (Oak Ridge model)
 - Spread among many facilities to mitigate market risk; perhaps use PMAs as vehicle to overcome federal market fragmentation
- U.S. SMR export offering
 - Coordinated interagency export strategy needed
 - Utilizes existing Federal export credit programs (EXIM/OPIC)
- Domestic coal fleet replacement
 - Preliminary estimates of up to 70 GW of retirements
 - Market potential needs to be clarified as EPA finalizes Clean Air Act rules
 - Nuclear-specific siting issues (e.g., seismic, emergency planning) need to be better understood



Final Thoughts

- Surmounting development, licensing and commercialization risks are the key ingredients in making SMRs economically viable ...
 - Detailed design and engineering costs and paying for traversing the learning curve
 - Developing a domestic supply chain and infrastructure
 - Adapting industry codes and standards that are designed today to address GW-level LWRs
 - Achieving regulatory acceptance of innovative approaches
 - Achieving investor acceptance (i.e., overcoming ‘first mover reluctance’)



Final Thoughts (contd.)

- Safety and security: Greater reliance on passive safety for these designs, and placing reactor underground are significant positives
- SMRs may represent the most economically sensible route for the U.S. to remain a credible player in the international commercial nuclear power supplier chain ...



Questions

