Economic Aspects of Small Modular Reactors

March 1, 2012

Introduction

The potential for SMR deployment will be largely determined by the economic value that these power plants would provide to interested power producers who would evaluate their prospects in relation to other options for generating electricity. To help better understand this proposition, DOE enlisted the Energy Policy Institute at Chicago in 2010 to conduct an economic analysis of SMRs based upon what is known today. Their findings were summarized in a paper by Robert Rosner and Stephen Goldberg, released in December, 2011, titled "Small Modular Reactors – Key to Future Nuclear Power Generation in the U.S."

This brief paper will highlight some of the key finding from the study[1] with references to the original document for more detail. First, it will convey estimates of construction and electricity generation costs for a generic SMR. Second, it will examine the financial implications of nuclear power plant purchases for U.S. utilities. Finally, it will present evidence of learning effects that may be applicable to SMR development.

Estimates of SMR Construction and Generation Costs

The study team performed an initial estimate of the costs of SMRs Relying on very limited publicly available data. SMR design, licensing, and detailed engineering are in an early stage. Therefore, these estimates have a significant amount of uncertainty. Using information available from vendors, the authors arrived at a best achievable overnight cost estimate of $4,700/kWe, based on a fully mature SMR industry and six generic 100-MW SMRs of built-out plant capacity at a site.[2] This estimate is higher than a comparable one made by this study team in a separate study of the construction of gigawatt-scale AP1000s currently being developed in the U.S.[3] Factoring in owner's costs, contingencies, interest during construction, fuel, operations and maintenance costs, the best achievable levelized cost of electricity from this plant was calculated at $61/MWh.[4] The report emphasizes that these costs are assumed to be at the end of learning process that will drive down costs though repetitive construction and manufacturing of standardized designs. Figure 1 depicts this evolution with a range of electricity

[1] Robert Rosner and Steven Goldberg, *Small Modular Reactors – Key to Future Nuclear Power Generation in the U.S.,* Energy Policy Institute at Chicago, November 2011. https://epic.sites.uchicago.edu/sites/epic.uchicago.edu/files/uploads/EPICSMRWhitePaperFinalcopy.pdf

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[3] Robert Rosner and Stephen Goldberg, *Analysis of GW-Scale Overnight Capital Costs*, Energy Policy Institute at Chicago, November 2011. https://epic.sites.uchicago.edu/sites/epic.uchicago.edu/files/uploads/EPICOvernightCostReportFinalcopy.pdf

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prices for SMRs, reflecting uncertainties about learning rates, against a range of electricity prices for natural gas fired plants, reflecting uncertainties about fuel prices.[5]

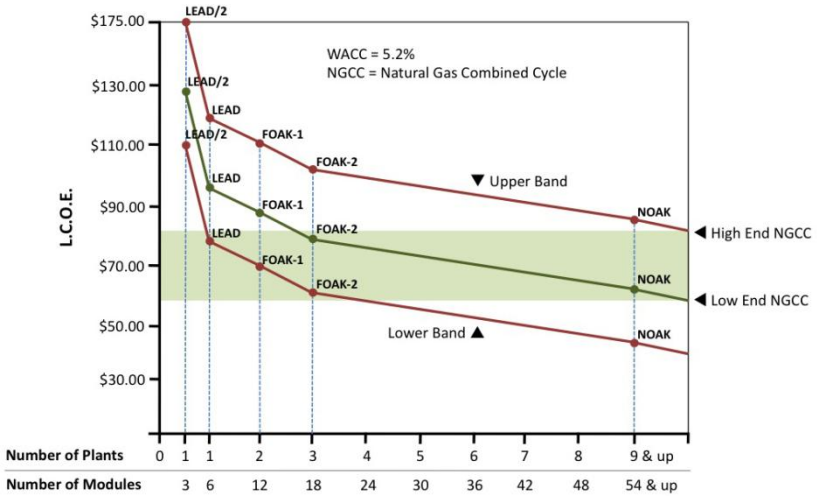

Figure 1

Nuclear Investment Financial Implications for U.S. Utilities

There may be a compelling business case for power producers to pursue an SMR project rather than a large nuclear plant even if the cost to construct the latter is lower on a per-kilowatt basis. A key reason for this is the financial strain that a large reactor project can put on the balance sheet of a typical nuclear utility. A report from Moody's in 2009 highlighted this challenge saying, "we view nuclear generation plans as a 'bet the farm' endeavor for most companies, due to the size of the investment and length of time needed to build a nuclear power facility."[6] The companies that would be most likely to pursue new nuclear construction in the U.S., though not small, are not of a scale that can comfortably make investments on a $10 billion scale. Figure 2 shows the relationship between power plant investment requirements and the revenues of a typical nuclear utility.

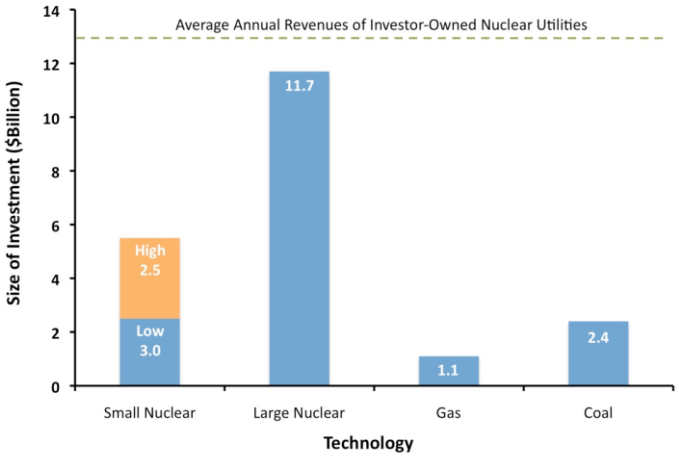

Figure 2

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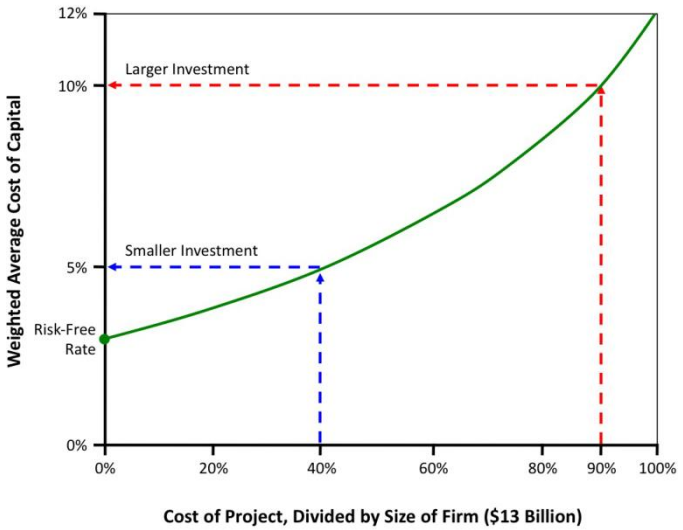

Figure 3

The study team pursued this issue further to assess how the risk of a large investment relative to the size of the company would affect the business case for a power plant. Figure 3 depicts a rough estimate of the relationship between the weighted average cost of capital that a company would be expected to bear as a function of project size to compensate for the risks that a large investment could pose to the company as a whole.[7] This model helps to explain why power producers would be interested in SMRs even if other nuclear plants could be built at a lower per-kilowatt cost.

The study team also identified the benefits of SMRs regarding the mitigation of risk as compared with larger plants in three areas: (1) relatively short construction schedules (24-36 months); (2) less power needs to be sold into the grid and is more comparable to gas-fired and coal-fired units; and (3) greater flexibility to build capacity on as-needed basis.

Manufacturing Lessons from U.S. Naval Shipbuilding

A significant aspect of the business model for successful SMR deployment is the promise of reducing costs through learning that is maximized in factory settings using modern fabrication approaches. In producing the learning curves shown in Figure 1, the study team relied upon learning rates estimated in a previous study[8] but emphasized the experience of naval shipbuilding as an analog that reinforces and potentially expands the envelope of what is possible in this regard.

The key point resulting from the shipbuilding techniques is that by maximizing the level of effort that takes place in a controlled factory setting as opposed to in the field, the construction can be much more efficient. This movement of work out of the field is enabled by building the ship in factory-fabricated modules that are then connected with relative simplicity. General Dynamics offers a 1-3-8 rule of thumb for these effects: tasks that can be accomplished in one hour in a factory setting can be expected to take

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[8] *The Economic Future of Nuclear Power: A Study Conducted at The University of Chicago*, August 2004, chapter 4.

three hours in a staging environment and eight hours at the final fabrication stage.[9] Figure 4 reflects the impacts of both of these effects.[10] The chart on the left shows the dramatic and rapid impact of learning through the reduction in labor hours in successive ships. The chart on the right provides a sense of how significant the modular concept has been in reducing the error rate on first-in-series ships.

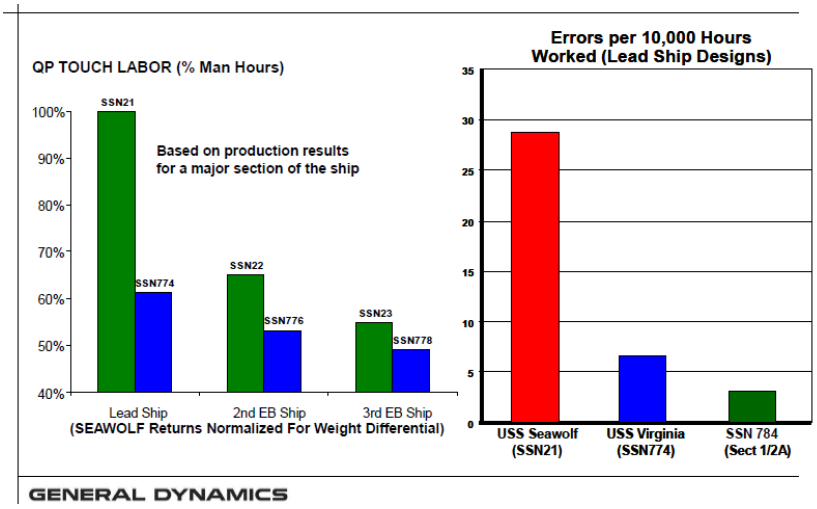

Figure 4

The business strategy is to apply these same techniques to SMR construction – perhaps by using many of the same companies – to remake how nuclear plants are built.

[9] Jim Moody, "Affordable Small Modular Reactors – Effective Integration of Modular Design, Manufacturing and Construction Techniques," presentation to Platt's Small Modular Reactor Conference, June 28, 2010. http://www.platts.com/IM.Platts.Content/ProductsServices/ConferenceandEvents/2010/pc030/presentations/Jim_Moody.pdf?S=n

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