31st USAEE/IAEE North American Conference

Investigating the Economic Viability of Small Modular Reactors (SMRs)

Ahmed Abdulla, Inês Lima Azevedo, and Granger Morgan
Department of Engineering and Public Policy, Carnegie Mellon University, Pittsburgh PA

Overview:

There is much talk of the potential for small, modular reactors (SMRs) to become players in the field of energy provision. These small reactors, which range in size from tens to several hundreds of megawatts-electric (MW_e), are being developed in a dozen International Atomic Energy Agency (IAEA) member states, and encompass a range of both light water and non-light water designs [1].

Vendors promise that SMRs will ameliorate many of the concerns surrounding large, conventional nuclear power plants. Some non-light water technologies, for instance, promise increased safety, reduced proliferation risk, and innovative approaches to spent fuel stockpile management [2]. Meanwhile, vendors of light water SMRs promise to upend nuclear power's unhealthy economics. Small, standardized reactors, these vendors suggest, can be built on an assembly line, achieving high levels of quality control while harnessing factory fabrication economies [3]. Also, small reactors will incorporate passive safety systems and allow for innovative approaches to siting that are infeasible for large reactors, such as underground construction. Perhaps most importantly, even if they cost more per unit of power, these reactors' small size will allow for a wider range of applications: more utilities will be able to acquire and operate nuclear plants without "betting the company", and it may even be possible to operate them in places with challenging geographies or underdeveloped grids.

At this stage of the technology's development, the question of capital cost is starting to take center stage. This is because, where nuclear power is concerned, capital cost dominates operating costs. Because none of the light water SMRs has been built, there are no data that allow for a bottom-up analysis of this capital cost. The few studies that do address SMR economics adopt large reactor cost estimates as natural anchors. Here, we adopt a systematic, top-down approach to light water SMR capital cost estimation. We focus on light water SMRs because light water reactors are more in line with the existing regulatory framework employed by the U.S. Nuclear Regulatory Commission (NRC). Therefore, they are likeliest to hold potential for deployment in the near term.

Methodology:

Through a technical, wide-ranging, structured elicitation process, we elicited the judgments of twelve experts concerning five nuclear reactor deployment scenarios. To provide a baseline, the first scenario involves a 1,000MW_e Generation III+ (Gen III+) reactor; the other four cover versions of two light water SMR designs. Questions range from the elicitation of overnight cost for each scenario to thoughts on the potential for SMRs to compete on the energy landscape. To protect the anonymity of the experts, we assigned a letter to each; it is this letter that is attached to expert responses in the results section below.

Results:

Figure 1 below shows the values we elicited for the overnight cost of each of the five scenarios. The first (scenario 1) is a 1,000MW_e Gen III+ plant; scenario 2 refers to a single small light water SMR producing 45MW_e; scenario 3 sees five of these smaller SMRs co-sited to produce 225MW_e; scenario 4 sees 24 of them co-sited to produce a Gigawatt (1,080MW$_e$); and scenario 5 refers to a single large light water SMR producing 225MW$_e$.

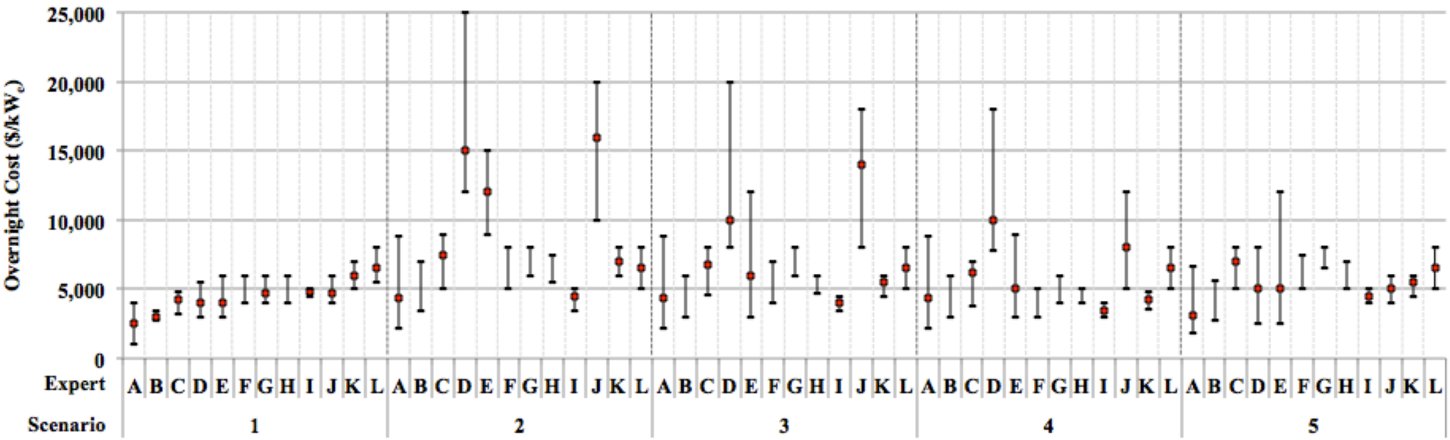

Figure 1: *Overnight cost estimates elicited from each expert for each of the five scenarios. Please note that Expert L included owner's cost in his estimates of overnight cost.*

The overnight cost value we elicited refers to the lump sum payment that a *utility* transfers to a *vendor* to acquire the plant in question. In other words, it is the cost of the plant to the utility in 2011 dollars, excluding financing and owner's cost. Also, the cost is that of an nth-of-a-kind (NOAK) plant: we assumed that the vendor has recouped the cost of engineering and licensing the design, has exploited all technological learning, and has streamlined construction management. When experts asked about site-specific factors, we emphasized that the plants are being built in a "favorable" regulatory environment. We suggested that the regulatory body is mature and fairly competent: it has stringent requirements and considerable experience. Public attitudes towards nuclear power are assumed to be an important, but not insurmountable, factor in the decision to build. We invariably suggested the southeastern U.S. as a possible candidate for these projects if pressed further. Finally, we assumed the reactor designs in question have been certified, that the owner has licensed the site, and that the scenarios in question are licensable.

Conclusions:

There was little consensus among the experts interviewed on the cost of various NOAK light water reactor deployment scenarios. The overnight cost of a small (45MW$_e$) single-unit SMR plant is estimated to range anywhere from $2,200/kW$_e$ to $25,000/kW$_e$, while a larger (225MW$_e$) single-unit SMR plant is estimated to cost anywhere from $1,800/kW$_e$ to $12,000/kW$_e$. In comparison, estimates for a conventional 1,000MW$_e$ Gen III+ plant ranged from $1,000/kW$_e$ to $7,000/kW$_e$. Even if we choose to adopt the upper bound estimates of overnight cost for the single-unit SMRs we investigated, however, there is no question that this technology will cater to a larger market than conventional nuclear does.

References:

[1] Subki M. Global Development and Deployment Plan of Small-Medium Reactors (SMRs). International Atomic Energy Agency [Internet]. Presentation; Vienna, Austria. 2011 March 4 [cited 2012 April 26]. Available from: http://www.iaea.org/INPRO/cooperation/5th_GIF_Meeting/Subki.pdf

[2] Safety & Security. Gen4 Energy [Internet]. 2012 [cited 2012 April 26]. Available from: http://www.gen4energy.com/technology/safety-security/

[3] Carelli M, Garrone P, Locatelli G, Mancini M, Mycoff C, Trucco P, Ricotti, ME. Economic features of integral, modular, small-to-medium size reactors. Prog Nucl Energy. 2010; 52: 403-414.