Input-Output Analysis and Economic Models for Small Modular Reactors: Model Construction, Development Options and Future Considerations

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Background

A team of researchers developed the first US economic input-output analysis model and resulting impacts for small modular nuclear reactors (SMRs) in 2009-2010. The team sought to answer the question, "What are the potential impacts of the manufacture, construction, and operation of SMRs in the US through 2030?" The resulting study was published as a report by the Center for Advanced Energy Studies' Energy Policy Institute as *Economic and Employment Impacts of Small Modular Nuclear Reactors (2010).* The report was first presented by members of the team in Washington DC at the Center for Strategic and International Studies. Subsequently the US Department of Energy (DOE) has regularly used the report as a benchmark in public presentations regarding SMRs, and economic impacts were a required element in proposals to responding to the $452 million Funding Opportunity Announcement for DOE to provide Nuclear Regulatory Commission licensing and design certification support for the first SMR designs.

At the time of the initial study not much information was publicly available in regard to the specific designs, costs, and supply chain for the manufacture, construction, and installation of reactor units. Likewise, there was significant uncertainty regarding the degree of carbon regulation and the future of US economic growth. To answer the research question, the team utilized Input-Output Analysis by designing a custom, national model through IMPLAN, using four adoption scenarios based on market penetration under varying assumptions. Because of the numerous designs and thermal/electric outputs, the team chose to adopt a 100 MWe output with electricity as its only marketable product, so as not to privilege any design or vendor.

Since the report's publication, there has been steady demand from government officials, nuclear reactor and services vendors, and supply chain vendors for a more refined model as more information has become available. The team has worked to refine the model using new data and linking the I-O analysis to a cost model based on the Code of Accounts from the Gen IV Forum. In addition, the US government has effectively backed iPWR light water designs through the program mentioned above, providing more focus for modeling and cost model efforts. The revision of the team's model adds impacts from design, developing an advanced manufacturing facility, and moving from First-of-a-Kind to Nth-of-a-Kind reactor manufacture. The model and I-O analysis are flexible enough to be modified for specific reactor designs, supply chains, and reactor installation locations and markets. Along with other SMR research activities including a marketing study, the team plans to publish the model and research relating to its design through a number of articles in peer-reviewed journals that focus on nuclear energy and energy policy. Follow-on work in regard to Levelized Cost of Electricity, life cycle analysis of carbon emissions, net jobs versus other sources of energy, appropriateness for different electricity markets, and a predictive decision support system for country-specific SMR adoption overlaid with geographic risk maps based on non-proliferation concerns have all been proposed by various stakeholders to the research team.

Challenges and Lessons Learned

Probably the most important challenge and lesson to be learned is that the national context in a given nation impacts I-O analysis. Overall impact of an SMR sector will be largely dependent on national policies to incent them or adopt them due to their costs per unit.

At the time of the initial study little was known about the costs of SMRs, their manufacture, and their competitiveness in a future regulatory environment. Since the time of the initial study, more is known about the US regulatory environment and a timetable for design certification with the NRC. Because the initial study was heavily reliant on cost estimates and timetables provided in the trade press and public statements, the initial model underestimated the costs of SMRs and the market price for electricity generated by them. It is noted here that electricity is the only market product for commercial nuclear plants in the US, with no significant co-product market anticipated in the next few decades. Likewise, the manufacturing schedules and timetable for individual unit completion were overly optimistic, but the deployment schedule for completed units was not too heavily impacted assuming there will be an order queue at some point (i.e. once manufacturing is underway for a few years, units will be completed in quick succession even if a given unit requires 36-54 months to complete). The overall effect of these too cheap estimates was to underestimate the economic impacts of individual units because less cost and investment lead to less economic impacts (and vice versa – more expense means more impacts). At the same time, market penetration may be affected by aggressive estimates of market competitiveness by SMRs. Even as SMR designs are more refined and costs better understood, there is a propensity for vendors to "plan to targets" in costs through reverse engineering—executives know at what cost range SMRs will be competitive in certain markets. The flip side is that the team has been involved in discussions with vendors, and vendors can utilize a detailed I-O analysis of their proprietary design to validate or at least check internal cost models.

A challenge for any I-O study is the issue of net benefits or net jobs, the purpose of which is to compare a given option against another technology or alternative. Net benefits quickly become a complex issue for a number of reasons. Determining net jobs may become confusing because of job years calculations—construction jobs are for a short-term and operational jobs long-term for a specific plant—and whether indirect and induced impacts are included in an analysis. Also, there are many reasons to carry out a net benefit analysis. The purpose of a net benefits analysis may be to evaluate a specific spending program (stimulus), a specific regulatory policy (or lack of), a given sector (investing in energy or education), or a specific technology. The team's experience is that net jobs relating to SMRs in the US should be discussed only in terms of alternative power generation technologies. Even when comparing similar technologies, such as power generation, there are many options for comparative metrics, which will require careful scoping (e.g. cost per MW/h, overall employment, import/export mix and balance of payments, etc.).

For the 2010 study, the team utilized US Energy Information Administration, Electric Power Research Institute, and International Atomic Energy Agency forecasts and models that largely accounted for different technology adoption under different scenarios. By using these scenarios and assumptions, the team assumed that SMRs would take away market share from large nuclear plants. This assumption was somewhat controversial at the time within the nuclear industry but is much less so now due to material statements by SMR executives that costs are on par with large nuclear plants. The team has discussed some metrics versus other technologies on a MWh basis but has not yet arrived at a decision. Utilities and states have made inquiries as to the benefits if older coal plants were replaced by SMRs.

Another lesson learned from I-O analysis is that "beauty is in the eye of the beholder" in regard to large economic benefit numbers that include direct, indirect, and induced effects. There is more skepticism evident when large figures are presented in the US, especially since many renewable or "green" projects jobs numbers are not readily apparent or been realized, either because companies or projects have not been sustainable, or projects in less populated areas are not maintained or serviced by local technicians—the perception is the benefit calculations have not been borne out by experience. It is best to produce a number of subset analyses and graphical representations to better target the appropriate metrics for the intended audience, whether government officials, general citizenry, industry, or certain interest groups.

Additionally, it is important to balance whether a study should incorporate a dynamic or static macroeconomic model or forecast. The limitations of a budget for a study may be determinative, but there are more I-O software packages that have flexibility for more dynamic models—not just macroeconomic but others may include regulation, etc. Static models are easier to understand for most, but dynamic models may be more representative of reality. At the same time, the more complicated the model and the greater the inputs into forecasting, the more options for error as well as opportunities for it to be misunderstood as a “black box.” Another option is to link an I-O with other models or tools that are dynamic and well-vetted.

There is also the issue of data collection and data availability for I-O tables and software applicability. The team utilized IMPLAN because of its team members experience with it, and it is the oldest and most tested of the packages available. The team has had discussions with IMPLAN in regard to developing data packages for specific countries, and it is relatively easy and inexpensive for Western Europe because data is readily available. For other countries it would require a substantial undertaking and possibly expense, as well as significant collaboration between researchers, data collection agencies or authorities over repositories/databases, and I-O developers.

Finally, I-O analysis can provide insights into workforce development and education investment needs. The installation, servicing, and operation of SMRs will require specialized workers in varied fields of engineering, operators, health physics and radcon, etc. These investments may be significant but also could have spillover impacts in other industries. As mentioned above, the national context will be important because of human capital and existing capability to provide needed value-added services. Vendors may seek to prioritize providing global services for their own designs, so it is important to work through the potential for developing local capacity in a given country.

This discussion of lessons learned and challenges is by no means exhaustive, especially when analyzing an industry that is rapidly changing and very dependent on government investment and a viable international market.

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