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Christopher Paine's Blog

US Small Modular Reactor (SMR) Deployment Fades Further into an Uncertain Future

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Today, both small and large nuclear reactor proponents confront a US economic landscape that has shifted against nuclear power in the near term, while the longer-term outlook remains cloudy and uncertain at best, even with the prospect that gradual carbon emissions regulation in the electric power sector – a 15% reduction from present levels by 2030 -- will advantage low-carbon electricity resources, including nuclear.

In late May I attended the 5th Annual Small Modular Reactors (SMR) conference in Washington D.C., hosted by Platt's, a unit of McGraw Hill Financial. The mood of the roughly 200 attendees was restrained, even somber, despite the efforts of conference chair Donald Hoffman, the current President of the American Nuclear Society, to inspire the audience to greater political activism on behalf of SMRs and nuclear power in general. This was in decided contrast to the ebullient mood I had experienced at a similar conference three years ago in Columbia, South Carolina, the geographic epicenter of what was then expected to be a national "renaissance" of nuclear power.

Indeed, the lion's share of questions from the audience came from the two nuclear power sceptics in attendance (of which I was one) -- the rest of the audience seemed too demoralized even to pose questions. This lack of engagement may well have been due to the fact they had heard the pro-SMR spiel many times before at previous conferences, and now discounted its credibility or economic relevance. But it may also may have been because of the nuclear community's well-honed inability to engage in anything resembling constructive public introspection – for example, why was nuclear power, and the SMR effort in particular, slipping in the US market, and what had the nuclear power community itself done, or not done, to contribute to this outcome?

There was, for example, no acknowledgement by any of the presenters that the carbon emissions cap and trade bill that passed the House of Representatives in 2009 and then stalled in the Senate had been a major lost opportunity to spur the nuclear renaissance. This lost opportunity was due in part to the active opposition of major regulated utilities with nuclear power plants, and to the nuclear power community's penchant for pushing tailored federal subsidies and "regulatory reform" ahead of a market-driven approach that would lift all low-carbon boats, including nuclear. Only one presenter, Armond Cohen of the Clean Air Task Force, specifically mentioned "regulating carbon from fossil plants" as a critical feature of a future policy landscape that could advance the prospects for nuclear power,while the DOE's John Kelley simply noted in one slide that "meeting clean energy goals will require a shift" in the 1800 terawatt-hours of coal-fired electricity DOE currently projects for 2035 to lower-emission natural gas and/or SMRs.

Nor did any presenter make a case that the economics of an SMR power plant would prove superior to those of an advanced conventional nuclear plant, especially one available from cost competitive South Korean or Chinese nuclear vendors a decade hence, when the DOE envisions the US market will be ripe for commercialization of home grown SMR technology. Nor did any of the presenters comment on the irony that by unleashing a flood of cheap fracked natural gas, and exempting its extraction from federal environmental regulation, some of the nuclear power industry's most vocal proponents in Congress had directed a poisoned arrow straight into the heart of the "nuclear renaissance," so much so that the economic viability of even fully amortized conventional nuclear power plants, much less new ones, is now threatened in competitive wholesale electricity markets.

Finally, no speaker even mentioned the swiftly emerging reality that in 2025, potential SMR deployments will be competing against cleaner simpler renewable electricity *plus energy storage* systems – nuclear power will no longer be able to market itself by playing on customer fears of the "intermittency" of renewable energy sources. One would think, for a new nuclear technology seeking its place in the sun, that someone would be inclined to careful investigation of the future market environment for these plants, and to at least delineating their specific advantages within a fast-changing electricity supply system.

Instead, the old pro-nuke shibboleths were much on display: a resumption of high electricity demand growth – still perceived by this community as a societal virtue -- would eventually bring nuclear power back into favor, and "regulatory reform" would allow for more flexible siting of future plants and obligingly diminish future plant staffing requirements, thereby reducing future operating costs.

Generation mPower's Brave Face

Attendees were also still coming to terms with the implications of recent news that the company leading the charge for first deployment of an SMR in the US – Babcock and Wilcox's "Generation mPower" joint venture with Bechtel— was not only backing away from both its previously announced plan to submit a license application to the NRC in the 3rd quarter of 2014, but was also seeking revision of its 50-50 cost sharing agreement with DOE, under which the company had been spending at the rate of $80 million per year to complete its license application, but is now looking to cut that to $15 million per year while continuing its cooperative funding agreement with DOE.

While Generation mPower President Bill Fox put on a brave face– quoting Mark Twain that "the rumors of my death have been greatly exaggerated, " – the brevity and lack of a schedule for initial deployment at partner TVA's Clinch River site, suggested that the SMR effort had indeed suffered a heavy blow. A single conceptual slide on "SMR nuclear deployment opportunities and challenges," reinforced the point, continuing to show a ten year timeline from license application to initial operation for a two-unit 360 MWe "load-following" SMR power plant, and "7 + years" from "first customer commitment." Unfortunately, this schedule differs little from that of a conventional large nuclear plant built at an existing site, and thus weakens one of the main arguments for SMRs, that they would avoid the costs inherent in an extended construction period. Clearly, once up and running at the necessary scale – curiously this was never defined in any of conference presentations – experienced SMR production and deployment organizations with a "commoditized" SMR supply chain might well be able to shrink this deployment period significantly, but any prospective SMR buyer today obviously cannot count on any such projected "industrial learning" benefit, years before it is demonstrated.

Costs aside, the claimed features of the mPower design, shared in large measure with other leading SMR designs, remain attractive in comparison to current large nuclear units: a 2 x 180 MWe "twinpack" Mpower plant would have only a 40 acre footprint, with totally separate conventional and nuclear islands. In the event of a "station blackout" – a complete loss of offsite and onsite AC electrical power – the plant would have a 14 day "coping time" reliant only on passive cooling – "no sprays, no sumps." This enhanced passive safety would in turn allegedly justify an "Emergency Planning Zone" limited to within the plant boundary, vastly expanding the universe of potential candidate sites for deployment and cutting emergency planning costs.

Rigorous physical security measures would be required only around the small and largely below-grade "nuclear island" portion of the plant, cutting plant staffing costs. Reject heat dissipation requirements could be met with air-cooling alone, reducing the environmental burden on local water bodies. The power levels of the independent modules could be ramped independently, allowing operation in "load –following" mode to support a high level of intermittent renewable power on the grid.

The rub, however, is how many of these putatively beneficial SMR attributes will actually survive both the scrutiny of the NRC licensing process and the cost exigencies of competition in the marketplace for lower-carbon electricity. For example, while discussed early on as an inherent advantage of SMRs, fan-driven air cooling of a closed secondary coolant loop, in place of water-cooled "once through" condenser cooling, or the familiar iconic evaporative cooling towers, already seems to have faded in recent proposals, possibly because fan-driven air cooling imposes a larger parasitic load on the plant, and thus threatens the already precarious economics of these units.

Similarly, to maximize returns today's reactors are typically operated at the highest achievable load factors compatible with continued observance of the NRC's nuclear safety requirements – typically at 90% or more of the maximum nameplate annual output of a plant. "Load following" to support a high level of intermittent renewables deployment – for example, reducing nuclear output at night to allow an influx of wind generation on the grid – could compromise the economics of new SMRs, just as low-cost wind is now challenging, according to Exelon Corp., the economics of its *already paid for* nuclear plants in the Midwest.

Finally, will the regulator buy the idea that *multi-unit* SMR power plants can be operated with the same, or an even *lesser* number of control room staff than a single large reactor today, thus partly recovering in reduced operating costs what has been lost in the large decrease of unit size. These are among the major uncertainties currently clouding an understanding of the true risks and benefits of future SMR deployment.

Nu-Scale and DOE Mega-Contractor Fluor

On the brighter side for the SMR industry, the day before the conference SMR developer Nu-Scale Power, 55% owned by heavy construction giant (and DOE site contractor) Fluor Corp., announced that it had reached agreement with DOE for $217 million in matching funding over five years, and was looking to hire 100 people, including some of those laid off by the fading mPower project. On top of the 2012 cooperative development agreement with mPower for $226 million, this new agreement appears to exhaust the $452 million Congress authorized for DOE's Licensing and Technical Support Program for SMRs. (Consortiums led by Westinghouse and Holtec also have developed SMR designs seeking NRC licensing approval, but these have not received DOE funding support to date, and Westinghouse has backed away from a previously announced plan to pursue near-term deployment at Ameren's existing Callaway reactor site in Missouri.)

According to the World Nuclear Association website, in 2010 NuScale pegged the "overnight capital cost" – i.e. before financing and other owners costs -- for a 12-module, 540 MWe plant at "about $4000 per kilowatt." By 2013, this projected overnight cost had risen to $5000/kWe. Hence the "all-in costs" of a NuScale power plant are likely to exceed $6000/kWe, no better than the cost of the large conventional LWRs under construction today in Georgia and South Carolina. This intuitively stands to reason, as each NuScale module produces only 45 MWe, making each multi-module power plant seemingly the most capital intensive of all the candidate SMR design.

In his conference presentation, Mike McGough, the company's chief commercial officer, countered this notion by highlighting the radical simplicity of NuScale's design, which eliminates all the complex and costly active safety systems that ensure large LWR core cooling in a pipe break accident accident or complete loss-of-power scenario: " [the] NuScale design has achieved the "Triple Crown" for nuclear plant safety. The plant can safely shut-down and self-cool, indefinitely, with: No Operator Action; No AC or DC Power, [and] No Additional Water."

There are some unsettling aspects to DOE's new cooperative funding agreement with NuScale. The company majority owner and main investor, Fluor Corp., also leads the multi-billion dollar contract consortium that operates DOE's Savannah River Site (SRS) and Savannah River Laboratory in South Carolina. In March 2012 the US DOE signed a memorandum of agreement with NuScale regarding construction of a demonstration unit at its Savannah River site in South Carolina. Fluor is one of DOE's largest contractors, responsible for managing massive environmental cleanups and nuclear defense waste disposal at multiple DOE sites.

Eight months after he resigned in January 2013 as head of DOE's sprawling nuclear weapons complex, which includes tritium processing and plutonium disposition operations at SRS, Tom D'Agostino's joined Fluor's Government Group (FGG) as the senior vice president for Strategic Planning and Development, based in the company's Greenville, S.C., office. Bruce Stanski, president of Fluor Government Group, remarked at the time: "Tom is one of the most well respected leaders in our industry, and I am confident he will be invaluable in terms of developing and implementing successful strategies that will drive our government business to new levels of success." All of which raises the question whether NuScale, nearly bankrupt in 2011, is suddenly prospering now because of the intrinsic merits of its innovative design, or because it has sold itself to a heavy-weight "player" like Fluor with long and deep connections to DOE's nuclear establishment?

An Elusive Future "SMR Market"

Nuclear reactors historically have evolved to very large single-unit sizes in order to distribute the very large initial fixed capital costs of nuclear power over a larger base of electricity sales, or put another way, to reduce the fixed capital cost requirement per megawatt-hour of electricity produced. But a multi-unit SMR inverts this economic logic, producing fewer kilowatt hours from a larger physical capital investment per unit of capacity. To produce a given level of electrical output, multiple units also require more uranium fuel than a single large unit of equivalent capacity, and thus appear likely to incur, assuming constant technology, a higher level of operation and maintenance costs than a conventional large unit. Hence the speculative economic case for SMR's rests on overcoming the loss of these unit-scale cost advantages via overall project cost reductions, putatively derived from the following:

(1) "industrial learning" gained over the course of ramping-up factory-based, highly efficient mass manufacture of standardized and simplified integral reactor/steam generator modules that do not require costly "active" (i.e. pump-driven) emergency core cooling systems;

(2) less on-site project-design, management, welding, cabling, and quality assurance activities, areas which have traditionally been the source of significant cost increases for conventional nuclear plants;

(3) staged deployment of multi-module plants scaled to regional demand growth, with lower initial capital investment requirements and borrowing costs, and shorter payout periods until first revenue is generated; and

(4) Reduced Emergency Planning Zone (EPZ) and security requirements, due to the smaller radionuclide inventory of each SMR unit, and a smaller geographic footprint for the plant.

Whether, to what extent, and when these various cost savings may become manifest is obviously one of the largest sources of uncertainty dogging the current SMR effort. SMR's do not actually promise to *reduce* the high cost-risk of new nuclear power so much as *shift it* from the owner's construction site to a vendor's factory floor and supply chain, which in large part does not yet exist. To bring such an efficient SMR factory/supply chain into existence, and then drive down nuclear-grade manufacturing costs through mass production, requires billions of dollars in new capital investment, and such investment (in the form of either risk capital or debt) is not likely be forthcoming until sufficient customer orders, or at least "letters of intent" materialize to justify financing of the factory and supply chain *at the scale needed to capture the forecast cost reductions*. Despite questions from the audience, none of the speakers were prepared to venture a forecast as to what this necessary scale might be.

Three recent examples from other industries are instructive. The costs of solar PV modules did not begin their recent precipitous plunge toward "grid parity" until large orders, principally from German and Spanish solar mandates, sparked the construction of massive silicon ingot, wafer, solar cell, and module assembly plants in Asia, driving down not only the cost of the manufactured modules but the also the cost of the capital equipment used to make the intermediate and final products. Today, only China is building nuclear plants and investing in nuclear component manufacturing capacity on a scale that seems likely to affect the secular trajectory of nuclear power costs vis a vis competing low-carbon resources.

The second example is far more limited in scope, but comes from within the global nuclear supply chain itself, and illustrates the importance of future customer commitments. While the United States Enrichment Corporation (USEC), spun off from DOE's nuclear weapons enterprise in the mid-1990's, enjoyed a 20 year insider monopoly on the marketing of Russian-supplied enriched uranium from dismantled nuclear weapons, and dithered with commercially unproven laser enrichment and mega-centrifuge technologies spawned by DOE's nuclear laboratories in the 1970's and '80's, the European URENCO consortium quietly stole USEC's market, signing-up long-term advance purchase agreements with US nuclear utilities that allowed it to internally finance a large new modular centrifuge enrichment facility in Eunice, N.M. sized to meet currently expected demand, and that can easily be expanded to meet future demand.

Finally, there is Elon Musk's proposed $5 billion giga-factory for EV powerpacks. While the popular perception is that this plant is a massive gamble on expanding the future market for his high-cost Tesla EVs, Musk actually appears to be predicating his investment on *already existing global emissions compliance mandates* for *fossil-fueled* vehicle fleets. To comply with these mandates while continuing to produce large numbers of combustion-engine vehicles, major vehicle manufacturers in Europe and the U.S. need to produce a certain number of zero-emission electric vehicles annually as one component of their compliance strategies, and to minimize their EV R&D and production costs while doing so, they will be strongly inclined to buy some or all of their powerpacks from Musk's low-cost giga-factory. In other words, Musk's massive investment may be less of a "gamble" that it first appears, because he knows where his future customers are coming from.

Absent a state-socialist nuclear deployment mandate, like that currently driving the Chinese nuclear program, or a regulatory emissions reduction regime strong enough to drive SMR deployments as an essential component of an emissions compliance strategy -- either of which might serve to close the "chicken and egg" gap between an empty SMR order book and the scale of investment, production and cost-reduction needed to attract firm future orders -- it is by no means clear how the US SMR effort will ever "get to scale," particularly if it remains divided among multiple competing vendors, each trying to establish their own unique nuclear-certified supply chains.

Moreover, the same problem -- too many vendors chasing an ill-defined and fast changing market for low-carbon electricity – also exists at the international level. As shown in the table below, no fewer than seven nuclear exporting countries, including commercial nuclear powerhouses China, Russia, France, Japan, and South Korea, already have state-sponsored SMR development efforts involving industry- standard pressurized water reactor (PWR) technology (more visionary small fast-reactor development efforts are not listed). If the U.S. SMR development effort is ever going to make it to the threshold of global commercial viability – the avowed goal of the program – some form of international partnering, at least at the component-supplier level – will almost certainly be required.

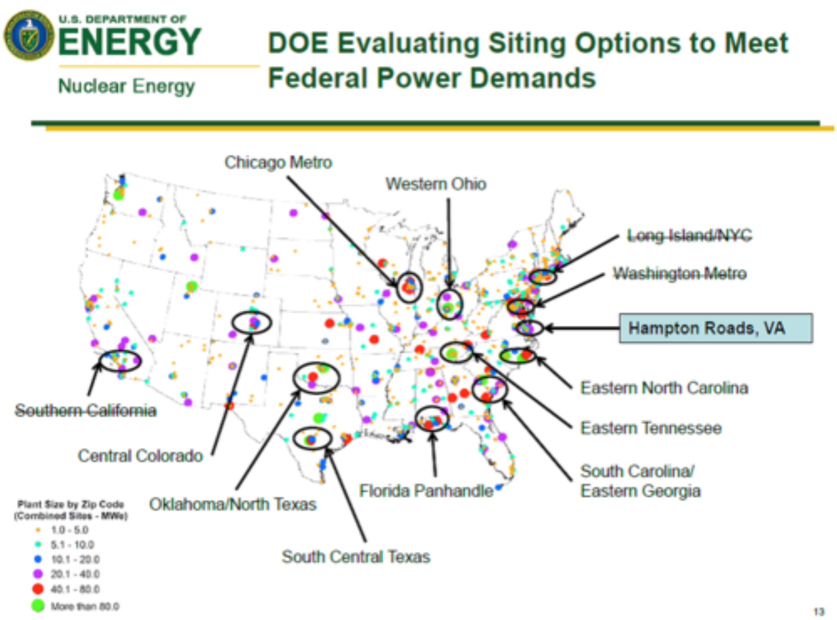
**LOTS OF POTENTIAL PLAYERS AWAIT THE FORECAST "EMERGENCE"
OF A GLOBAL SMR MARKET DRIVEN BY CLIMATE CONCERNS**

- **Name Capacity Type Developer(s)**
- KLT-40S 35 MWe PWR OKBM, Russia
- CAREM 27 MWe PWR CNEA & INVAP, Argentina
- HTR-PM 2x105 MWe HTR INET & Huaneng, China (high-temp, gas- cooled reactor)
- VBER-300 300 MWe PWR OKBM, Russia
- Westinghouse 225 MWe PWR Westinghouse, USA
- mPower 180 MWe PWR Babcock & Wilcox + Bechtel

- SMR-160 160 MWe PWR Holtec, USA + CB&I Shaw, URS
- ACP100 100 MWe PWR CNNC & Guodian, China
- SMART 100 MWe PWR KAERI, South Korea
- NuScale 45 MWe PWR NuScale Power + Fluor, USA, Rolls Royce, UK, Enercon Services, USA
- NP-300/ 100-300 MWe PWR Areva TA + DCNS, France
  Flexblue
- IMR 350 MWe PWR MHI + Kyoto University, CRIEPI, and JAPC
- *Source: World Nuclear Association, 2014*.

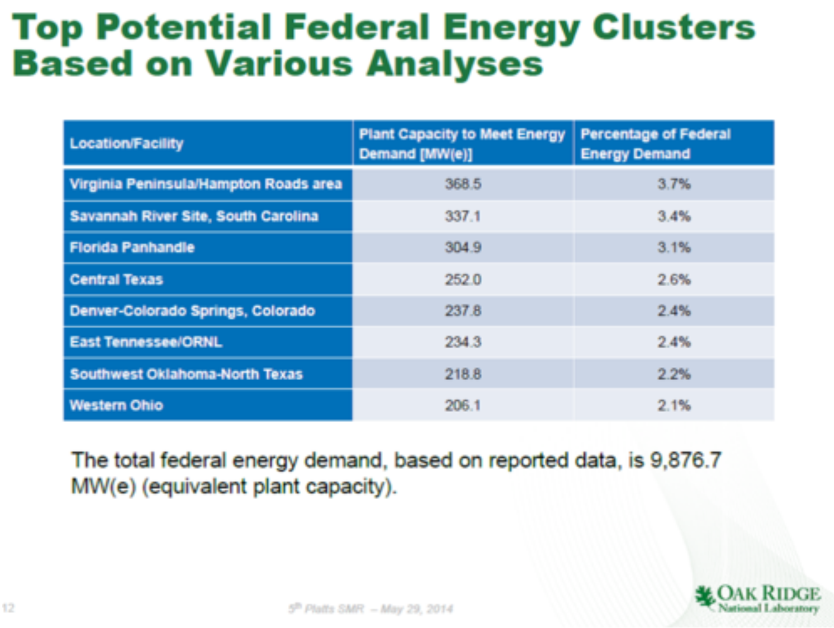
DOE's Current Plan for an "SMR Industrialization" Strategy

Some if not all prospective U.S. SMR vendors appear to be counting on an initial commercialization strategy based on aggregating federal power purchase agreements (PPA's) from areas with a high concentration of federal facilities, as shown in the first slide below from the presentation of John Kelly, DOE's Deputy Assistant Secretary for Reactor Technologies. An area of high current interest is apparently Hampton Roads, Virginia, with its concentration of military installations and excess industrial capacity for heavy component manufacturing. Another large federal energy consumer is DOE's own Savannah River Site (SRS), and next in line is the Florida panhandle-southern Alabama region, with its high concentration of military installations.



With funding from DOE's nuclear energy program, Oak Ridge National Laboratory has developed a many-layered geographic information systems (GIS) screening tool to look nationwide for candidate sites to deploy SMRs. It subdivides the surface area of the US into 2.5 acre cells and then aggregates then into 50 acre blocks for screening as candidate SMR sites against a wide range of environmental and socio-economic criteria normally used in the siting analysis for new nuclear power plants. A graphical user interface for this ORNL siting tool is supposed to be become available online sometime in July 2014 from DOE's Nuclear Energy (NE) program http://www.energy.gov/ne/office-nuclear-energy

If all the federal facility clusters listed in the second slide below signed PPA's for electricity from SMRs, roughly 10 GWe of nuclear capacity would be needed to meet that demand. Assuming an average 45 -180 MWe per SMR module, that's a demand for 56 to 222 modules, which may or may not be a sufficient number to realize the hoped for economies-of-scale from industrial learning and mass production, and thus permit the confident private financing of a factory to supply a commercial domestic and global SMR market at competitive cost. That, anyway, appears to be the current state of DOE's plan for an "SMR industrialization" strategy.



Top Potential Federal Energy Clusters Based on Various Analyses

Location/Facility	Plant Capacity to Meet Energy Demand [MW(e)]	Percentage of Federal Energy Demand
Virginia Peninsula/Hampton Roads area	368.5	3.7%
Savannah River Site, South Carolina	337.1	3.4%
Florida Panhandle	304.9	3.1%
Central Texas	252.0	2.6%
Denver-Colorado Springs, Colorado	237.8	2.4%
East Tennessee/ORNL	234.3	2.4%
Southwest Oklahoma-North Texas	218.8	2.2%
Western Ohio	206.1	2.1%

The total federal energy demand, based on reported data, is 9,876.7 MW(e) (equivalent plant capacity).

12 5th Platts SMR – May 29, 2014 Oak Ridge National Laboratory

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Comments

Michael Keller — Jun 14 2014 01:11 AM

There is another SMR that takes a completely different approach than the smaller cousins.

For starters, nuclear and fossil fuels are used together. The plant produces over 900 Megawatts of power using a single generator and single reactor (~620 megawatts thermal). Thus economies of scale are used to produce a very competitive power plant - there is no particular need to build hundreds of the plants to make a profit. While the plant does achieve massive reductions in CO2 and nuclear waste, these are just happy by-products. The main objective is to make a lot of money while providing low-cost power for generations to come.

By way of a simple explanation, the patented hybrid-nuclear technology uses a helium cooled graphite reactor to drive the decoupled air compressor of a combustion turbine. That means nearly all the combustion turbines power drives a generator. There is more to it than that, but the hybrid-nuclear plant would be the most efficient (~80%) fossil plant ever deployed.

If you would contact me a m.keller@hybridpwr.com, I will forward our report sent to the Department of Energy in response to DE-SOL-0006807 which was an information request for advanced reactor technologies. You may draw whatever conclusion you wish from our report (which is a public document).

PS I believe we are actually mentioned in the WNA source you cited.

Jim Holm — Jun 14 2014 01:12 PM

I generally agree that things look dismal for today's nuclear reactor market. And well they should.

Virtually all of the SMRs in the above list (save the INET HTR) were conventional low temperature water cooled reactors (PWRs).

Here's hoping the sun is really setting on an obsolete technology.

Recall the fate of the Newcomen steam engine? After about 70 years it was replaced by the much better technology of the Watt steam engine.

Comments are closed for this post.