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Licensing small modular reactors

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ABSTRACT

Small modular reactor designs with power levels of less than 300 MWe are being developed in several countries. While there are several potential advantages with these reactors, they are also confronted with multiple challenges. Important among these challenges is to have these new reactor designs licensed by national regulatory bodies. Because of the many novel features incorporated in different SMR (small modular reactor) designs, careful and thorough licensing procedures are critical to maintaining safety of the nuclear fleet. This paper examines how different countries have engaged in the process of licensing new reactor designs, and demonstrates both similarities and differences between countries. In many cases, designers have emphasized the safer design and deployment features of SMRs and attempted to use those features as reasons to get existing licensing requirements diluted. This raises the concern that the promised safety enhancements in SMR designs could be offset by a simultaneous relaxation of licensing requirements.

1. Introduction

In recent years, there has been widespread interest in SMRs (small modular reactors). These would generate between 10 and 300 MWe of electricity, with power levels much smaller than those of reactor designs that are now standard [1–3]. These reactors are aimed at solving some of the multiple problems plaguing the nuclear industry and allow the possibility of using nuclear power in market niches that have previously been difficult to enter. These market niches include developing countries with smaller electric grids, remote locations, water desalination, and industrial heat supply [4–6].

There are a very wide variety of SMR designs with distinct characteristics that are being developed. Many of them are light water reactors, the leading reactor-type that is currently deployed around the world,[1] but there are also many designs that are radically different (Table 1). Several countries are developing and planning to construct SMRs, including the United States, Russia, China, France, Japan, South Korea, India, and Argentina.

Many expect the SMR market to be large. One widely cited assessment from 2009 concludes that there could be between 43 and 96 small modular reactors (SMRs) in operation around the world by 2030 [8]. In 2006, Advanced Systems Technology and Management, Inc., a management consulting company, projected that SMRs will capture 30 percent of the future market for nuclear reactors, which it estimated at around 1000 GW; assuming "an average SMR size of 300 MWe, this implies some 1000 units by 2050" [9]. For the United States, the Energy Policy Institute in Idaho projected a "moderate case" involving about 150 SMRs and a "disruptive case" involving about 550 units by 2030 [10].[2] Though these figures are only tentative projections, the belief that there will be a substantial market for SMRs seems to be widely held by policy makers in many countries. There are, of course, many who are skeptical of this proposition [12,13].[3]

Further, the general expectation is that the first movers will have a considerable advantage in capturing the global SMR market and this would help create domestic jobs in the design and manufacture of these technologies. Partly for this reason, many countries have provided substantial government support for the development of such reactors. In the United States, for example, the Department of Energy has offered up to $452 million to support engineering, design certification, and licensing of two SMR designs.

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[1] According to the International Atomic Energy Agency's PRIS database, among the 437 operating power reactors, as of March 2013, there were 354 LWRs (270 Presssurized Water Reactors and 84 Boiling Water Reactors). There are historical, political, and technical reasons responsible for nuclear power being "locked into" light-water technology [7], and this is likely to persist at least for the near-term future.

[2] The trade organization *Nuclear Energy Insider* estimates that just in the United States, replacing coal power plants that are to be shut down offers a market opportunity of over $30 billion [11].

[3] Michael Dittmar [12] is explicit in his assessment: "During the last years some newspaper reports about future "small" scale wonder nuclear reactors appeared… However, looking at similar claims and plans from past decades one might give them not much more credibility than most people give to snake oil medicine".

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Table 1
Design and status information for select reactors.

Reactor design	Country	Technology	Status	Additional applications
AHWR	India	Light water cooled, heavy water moderated	Pre-licensing design safety review	Desalination
HTR-PM	China	Graphite moderated, helium cooled	Preliminary safety analysis report review	Industrial heat
ACP-100	China	Light water moderated and cooled	Under development	Desalination and industrial heat
SMART	South Korea	Light water moderated and cooled	Standard design approval received	Desalination
KLT-40S	Russia	Light water moderated and cooled	Licensed	Desalination
SVBR-100	Russia	Lead-bismuth eutectic cooled, no moderator	Under development	Desalination and industrial heat
mPower	United States	Light water moderated and cooled	Under development	Not currently envisioned
NuScale	United States	Light water moderated and cooled	Under development	Not currently envisioned
Westinghouse SMR	United States	Light water moderated and cooled	Under development	Not currently envisioned
HiSMUR (Holtec)	United States	Light water moderated and cooled	Under development	Not currently envisioned

However, most of these countries also realize that there are multiple vendors offering such products. The U.S. Department of Commerce's International Trade Administration, for example, sees "intense foreign competition, primarily by state-owned or state-aligned enterprises" as a significant challenge or obstacle [14]. Likewise, South Korea also stresses "export competitiveness" because of "intense competition among nuclear suppliers" [15].

There are multiple challenges that confront vendors of SMRs [16], with an important one being their licensing. While not strictly necessary for exports to other countries, the general expectation is that each SMR design should be licensed in one or more countries, typically their "home" country as the first step to deployment.[4] This, in turn, is based on the assumption that countries may be more hesitant to purchase a SMR when the design has not received its originating nation's regulatory stamp of approval.[5] The IAEA (International Atomic Energy Agency) offers the following recommendation to countries considering their first nuclear power plant: "Choosing a nuclear reactor design that is finalized and frozen, particularly one that has undergone licensing review in other countries, can minimize project uncertainties. While some modifications may be needed due to local regulatory requirements or due to the special characteristics of a site, a complete design helps to ensure that the project will be within budget and schedule" [18].

Many analysts have observed significant differences in the regulation of nuclear power in general [19–21]. Therefore it should not be surprising that the process of licensing new reactor designs varies significantly from country to country. These differences are related to a number of country specific factors, primarily relating to the characteristics of its nuclear energy program, and will affect the pace of deployment of SMRs as well as the kind of SMRs that may be deployed in the near to medium term.

This paper offers a survey on the state of licensing SMRs in different countries. We focus on the United States, Russia, China, India, and South Korea. The United States is arguably the country that has the largest number of SMR designs under development and the country that has the greatest financial investment into SMRs. It is the source of both the PWR (pressurized water reactor) and BWR (boiling water reactors) designs that dominate today's nuclear reactor landscape. The US is followed by Russia, which has also exported many standard-scale reactors and which has ambitious plans for both standard-scale reactors and SMRs. South Korea is a more recent entrant to the nuclear exports world, having secured a contract with the UAE, and China and India have ambitious plans for nuclear expansion and exporting reactors [22–25].[6]

While the SMR design process has advanced to different extents in different countries, and the procedures adopted in licensing them has been different, there have been some similarities. An important similarity is that SMR designers have tried to get credit for various design and deployment features (passive safety, smaller radioactive inventory, underground construction) and sought to get one or more typical licensing requirements for large reactors diluted. One thrust has been to get regulatory authorities to eliminate the requirement for an EPZ (emergency planning zone) or at least reduce the size of such a zone.[7] Despite this similarity, as we describe in each of our country studies, there are variations in the way different countries have treated the issue of EPZ size.

We start with a description of the challenges involved in licensing SMRs.

2. The importance and challenges of SMR licensing

The hazards that stem from nuclear accidents have long been recognized and the consequent importance of ensuring safety at all levels has been often emphasized. The centrality of licensing reactors as part of ensuring safety has been emphasized by the International Atomic Energy Agency, which has produced guides on how this is to be carried out [32]. Analysts argue that nuclear power plant licensing plays a dual role and "should: (a) protect interests that may be affected by the new plant; and, at the same time, (b) enable investments that are assessed to be in the overall public interest" [21].

Licensing of SMRs is not likely to be straightforward. To start with, licensing any new nuclear reactor design, especially in the

[4] For example, China purchased Westinghouse's AP1000 reactors after the U.S. NRC (Nuclear Regulatory Commission) certified the design in January 2006.

[5] To cite a non-SMR example, when India was preparing to import and construct VVER nuclear reactors from Russia, India's nuclear regulatory agency stipulated that "the design of such a plant should be licensable by the Federal Nuclear and Radiation Safety Authority of Russia" [17].

[6] We do not include two countries that may have been expected in this list: France and Japan. Following the Fukushima accidents Japan's nuclear policy has been in a state of flux. France, too, has had some questions raised about its future nuclear policy following the election of Francois Hollande [26,27]. Further, its nuclear reactor design organization, Areva, has stated that its priority in the SMR field "has been on markets outside traditional electricity namely the industrial process heat market" [28]. For this reactor, Areva's focus has been on the United States and HTGR reactor has been selected by Next Generation Nuclear Plant Industry Alliance—a US based group of companies interested in promoting, developing and commercializing HTGR (high temperature gas cooled reactor) technology, with a focus on process heat applications (petrochemicals, oil recovery, synfuel production) as well as power—as "the optimum design for next generation nuclear power plants" [29]. Given the general state of flux that has been apparent in the nuclear energy policies of different countries [30], this state of affairs could well change in the future.

[7] The IAEA in fact advertises a "reduced emergency planning zone" as a perceived non-technological advantage for SMRs [31].