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Small Modular Reactors: Licensing constraints and the way forward

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ABSTRACT

SMR (Small Modular Reactor) is an acronym for a group of nuclear power plant designs receiving an increasing deal of attention from the industry and policy makers. A large number of SMRs need to be built in the same site and across the word to compensate diseconomies of scale and be cost competitive with large reactors and other base-load technologies. A major barrier is the licensing process, historically developed for large reactors, preventing the simply deployment of several identical units in different countries. This paper, discussing Ramana, Hopkins and Glaser [1], enlarges the view to all the SMR-related implications on the licensing process, presenting their legislative implications and market effects.
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1. Introduction

Ramana, Hopkins and Glaser in Ref. [1] provide an extensive review of the LP (Licensing Process) of SMR (Small Modular Reactors) in five countries: USA, Russia, South Korea, China and India. The leading reactor vendors for SMRs belong to those countries and the respective governments are keen to support this industry because of the vast potential for establishing a competitive advantage and thereby significant market share afforded to the first movers. The LPs of these countries are particularly important because, in order to gain credibility and demonstrate the technology, the reactor vendors aims firstly to build SMRs in their own country and then to export the technology to other countries. Consequently, governments (and their regulatory bodies) are considering the revision of existing LPs in order to tailor them for the assessment of SMRs.

The attractiveness of SMRs, as investment, is mostly based on the principle of modular deployment fostering both economies of multiples and investment scalability [2–4]. Economies of multiples exist because of industrial learning, co-siting cost sharing and mini-mass production of components from suppliers. Scalability refers to the ability to echelon the investment and to decide if, and when, to increase the power (i.e. then the number of SMRs) installed in a certain site or utility portfolio [5]. The current research [1] primarily focuses on the issue of the EPZ (Emergency Planning Zone) because of the interest of coupling SMRs with other industrial plants; e.g. Ref. [6]. As such, it is important to locate SMRs close to industrial plants, hence the interest in EPZ. Although the EPZ is a key aspect of the LP it is important to be aware of other factors, as analyzed in this discussion paper. These aspects are crucial for the economics of SMRs.

2. Discussion

Five main additional topics should be considered while overviewing the challenge of licensing SMR:

1. Typology of licensing approach
2. Duration and predictability of the LP
3. Regulatory harmonization and international certification
4. Manufacturing License
5. Ad Hoc legal and regulatory framework.

2.1. Typology of licensing approach

The IAEA distinguishes between two major typologies of licensing approach: prescriptive based and goal setting (or performance based) [7].

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Prescriptive based approach (which is the most common: for instance, all countries mentioned into the paper adopt the prescriptive based licensing approach) is mostly based on the deterministic safety assessment [8,9]. The reactor design, material, components and the final facility are judged in their ability to respect pre-defined norms and principles. Under this approach, the regulator needs to develop (or to adopt) a wide range of codes and standards enabling this technical judgment [10]. Traditionally, the prescriptive based approach has worked properly, when few standardized reactors designs were deployed several times (e.g. France, South Korea, and Russia). From the licensing point of view, this approach is efficient because the codes and the standards are almost tailored to the specific reactor design and the country of construction. The main advantages of the "prescriptive based" LP (once it has been established) are the speed and efficiency especially for experienced industrial operators: reactor vendors, contractors, and operators. Furthermore, the approach aims to reduce the level of uncertainty and ambiguity of the LP and it aims to reduce the subjectivity left to the regulatory body [7,9]. For SMRs, the key challenge is the development of new "tailored" standards and codes enabling the issuance of prescriptive based LP. This is a challenge because the buyer-countries (but also vendors) may relay on different SMR-designs at the same time (because of technological, political, economic or strategic reasons); under such scenario, the regulatory burden could be a major challenge and a constrain. In particular [11] lists 30 designs under development, mostly in few nations (USA, Russia and Japan alone accounts for 21 designs).

The "goal setting approach" (or performance-based) is typical of nuclear countries that base the nuclear program an open market principle (rather than a country development strategy promoting the domestic industry); United Kingdom is an example [12,13]. Despite the USA Licensing systems is sometimes considered a prescriptive based approach, it also contains several elements of the goal setting one (this is in line with the open market proposition associated to USA nuclear program) [14]. Goal setting approach relays more extensively to the risk informed regulation [15–17] in combination with the ALARA/ALARP (As Low As Reasonably Achievable/As Low As Reasonably Possible) principle [18–20]. The approach is more flexible in considering a new reactor design technology; the downside is that the LP is perceived more ambiguous and uncertain by the applicant. Furthermore, the regulatory body have higher degree of subjectivity. This licensing approach relies extensively on the "design certification" together with the "site certification" (or Construction + Operation license) [21]. Design certification considers the general safety characteristic of a reactor design and would permit to certify the SMR specific design. The remaining licenses (that may change depending on the country considered) are site and project specific. Since prescriptive norms are not in place (e.g. limit to the radioactive discharges into the environment or other relevant constrains) these boundary conditions are fixed though the "license conditions" [22,23]. License conditions can be understood as a flexible regulatory mean that apply to the specific NPP (Nuclear Power Plant) rather than be general and uniform across the nuclear programme [24]. Usually, the regulatory body considers the effort and the time associated to the issuance of license conditions on case-by-case basis. By contrast, prescriptive based LP is more rigid and any relevant modification of the facility requires a new LP (this is a major constrain for modular facility). In the first phase, SMR could take advantage of the wider flexibility offered by goal setting approach, especially during the early phases of a nuclear program, while more technologies are assessed.

Summary: The types of licensing approach is a fundamental determinant for the deployment of SMRs. At this stage of development, the "goal setting approach" seems the most favorable to the deployment for SMR. Conversely, most of the countries involved (as reactor vendor, buyer or both) into a SMR nuclear program adopt a prescriptive based licensing approach.

2.2. Duration and predictability of the LP

Some of the key advantages of modular SMRs are: the scalability of the investment (deploying SMR when the demand of electricity rises), the reduced construction time and risk (SMRs are mostly manufactured in factories reducing the number of activities in the site) [25,26]. These SMRs' characteristics are essential for being economically and strategically competitive.

The existing LPs have been designed for large nuclear power plants characterized by a long construction period. Large plants require various assessments that take time and are performed in parallel with their construction. SMRs are designed for a shorter construction, consequently the "parallel" LP time could be longer than the SMR construction schedule time preventing the expected time saving. These constrains are due to two macro groups of reasons.

Firstly, the existing LPs may require additional time in order to cope with SMRs because of their peculiarities:

- Novelty of the design technology
- Issuance of different safety principles with respect the conventional nuclear power plants
- Lack of experienced and specific regulatory framework

Secondly, administrative and institutional activities affect the duration of the LP. In most of the nuclearized countries, the regulatory body is the independent administrative institution entitled to perform the technical safety assessment. However, several other institutions are involved into the LP; Table 1 shows some examples [12,27]. The multitude of institutions involved, and the various bureaucratic passages between them, imply a long licensing time. For example, only the public hearing and enquiries use to take about one year in most of the nuclearized countries.

Summary: Existing LPs could extend the construction time of SMRs beyond the pure technical schedule undermining the overall economics.

2.3. Regulatory harmonization and international certification

One of the key debate concerning licensing SMR is about the regulatory harmonization [28,29]. In the nuclear industry, there are few major reactor vendors, contractors and "nuclear manufacturer suppliers". However, the nuclear industry operates internationally (several countries are interested in SMRs) while the LPs and the nuclear regulations are country-specific [28]. Consequently, a certain reactor vendor cannot "produce a standard plant" and

Table 1
Major institutions involved into the LP of nuclearized countries.

Country	Other major institutions rather than the regulatory body involved into the LP		
	Parliament	Government or ministers	Public hearing/Inquiry
Canada		√	√
Finland	√	√	√
France		√	√
India		√	√
Japan		√	√
Russia		√	√
South Korea		√	√
Unite Kingdom			√
USA			√

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