Chapter 7. **Market and industry perspectives/SIAP report**

Market issues

Since the creation of the Generation IV International Forum (GIF) in 2000, market conditions have never ceased to evolve and they are a common concern between users and developers of Gen-IV concepts. In this sense, the Senior Industrial Advisory Panel (SIAP) has actively worked in better understanding the core drivers, opportunities and constraints related to the market environment, with the objective to identify the most appropriate ways to perform GIF activities. It always works in close collaboration with the System Steering Committees (SSCs) chairs and Task Forces (TFs), and with the guidance of the members of GIF Policy Group (PG).

Following the conclusion of the Paris agreement 2015, numerous countries initiated major endeavours to reduce CO_2 emissions related to economic activities. The decarbonization of the electricity sector has concentrated most of the efforts over the last years with the massive capacity additions of variable renewable energy resources (VRE) such as wind and solar power. As recently illustrated by the International Energy Agency (IEA)[1], low-carbon electricity demand is set to increase by 2040 and the mobilisation of all low-carbon technologies will be needed in order to meet the climate engagements. For instance, according to the *Sustainable Development Scenario* set out by the IEA, nuclear capacity should increase of 60% compared to today's levels[2]. Nevertheless, several issues are challenging the economic rationale of nuclear slowing down the development of nuclear power.

The cost of VRE has been steadily decreasing enabling a higher penetration of this type of technologies in the current electricity systems. This trend, combined with cheap and abundant fossil fuels (especially in the United States), is undermining the profitability of nuclear projects in a *Levelized Cost Of Energy* (LCOE) basis. At the same time, and partly due to the long hiatus in nuclear new build since 1990s, recent nuclear project are finding difficulties to being delivered on time and on budget in OECD countries increasing the risks perceived by investors.

On the other hand, it is important to highlight that the irruption of VRE resources is shaping electricity systems and new opportunities are emerging. Dispatchability attributes are becoming more valuable in the light of intermittent electricity generation and the absence of large-scale storage solutions. Distributed generation is also gaining momentum. Furthermore, the decarbonization of the energy systems also involves low-carbon heat generation for domestic and industrial processes or also hydrogen massive production.

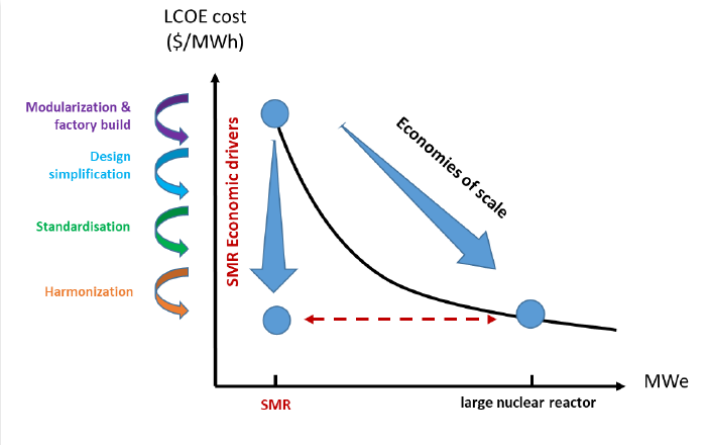
All these aspects were explored during the GIF Workshop on Flexibility held in May 2019 in Vancouver. This event gathered Economic Modelling Working Group (EMWG), SIAP and SSCs members with the objective to assess the flexibility of the different Gen-IV systems. It was a good opportunity for SIAP to share with the GIF community the main findings of the 2018 SIAP charge with a strong focus on the flexibility of Gen-IV systems and the opportunities associated with hybrid systems. The workshop confirmed that all Gen-IV concepts have significant flexibility features to meet emerging energy market needs in terms of load-following, scalability and heat generation and hydrogen production. Those technologies with lower Technology Readiness Levels (TRLs) have the highest potential as they face reduced constrains from a design standpoint. The different flexible options may allow Gen-IV systems to better adjust to more uncertain and turbulent energy markets. Nevertheless, integrating flexibility in Gen-IV designs may come at a cost and should be fairly compensated through adequate market designs.

1. World Energy Outlook 2019, www.iea.org/reports/world-energy-outlook-2019
2. Tracking Clean Energy Progress 2019, www.iea.org/reports/tracking-power-2019/nuclear-power

In this context, small modular reactors (SMRs) are capturing the attention of the nuclear industry as they potentially offer a more attractive business case in current market conditions. SMRs are nuclear reactors with power output ranging between 10 MWe and 300 MWe that integrate by design higher modularisation, standardization and factory-based construction in order to maximize economies of series (or series effect). The different modules can then be transported and assembled on-site, leading to predictability and savings in construction times. More recently, vendors are proposing Micro Modular Reactors (MMRs), with power outputs lower than 10 MWe, capable of semi-autonomous operation and taking advantage of higher levels of transportability compared to larger SMRs.

The series effect, among other conditions, plays a central role in the economic competiveness of SMRs. In fact, the small size of this type of reactors introduces a considerable economic penalty in terms of LCOE (diseconomies of scale). The cumulative effect of modularisation, simplification, standardization and harmonization may drive the series effect, necessary to compensate the scale penalty, and potentially improving the economic performance of SMRs. This effect is illustrated below The potential of the economic drivers of SMRs is supported by experience in other industries (e.g. aviation). Nevertheless, it still needs additional empirical evidence for SMR technology. In this process, the access to a global market allowing the large-scale deployment of SMRs will be essential.

Beyond LCOE issues, the value proposition of SMRs also includes unique features such as access to off-grid/remote areas and non-electric applications. From a financial perspective, SMRs may represent an attractive investment principally due to the lower overall capital outlay compared to large reactors. This implies that private investors will face lower capital at risk, which could make SMRs a more affordable option. In turn, this could attract new sources of financing and lower the cost of capital. The ability to add modules incrementally provides additional financial flexibility, especially under sudden market shifts. Moreover, the shorter construction period may allow for shorter paybacks.



According to the IAEA[3], there are more than 50 SMRs concepts under development with different technology and licensing readiness levels. Among these concepts, around 50% are Gen-IV concepts also called, Advanced Small Modular Reactors (ASMRs). HTR-PM, a 200 MWe model of gas-cooled high-temperature reactor, is under construction in China. Some other are under a licensing process. Even if most of these projects are backed, to some extent, by GIF member states government, the involvement of the private sector has been increasing.

Countries like the United States and Canada have made significant progress in development of policies and licensing frameworks to accelerate the time-to-market of SMRs. Nevertheless, several challenges need to be overcome in order to achieve commercialization. Currently, there is a wide variety of ASMRs and this represents both an opportunity and a challenge. In the near term, the role of the first demonstrators will be crucial, not only to trigger the subsequent investments necessary to build a module factory, but also to downselect the most performant concepts. Additional efforts will be required to revisit the currently licensing frameworks, which rely extensively on the experience developed with Gen III/III+ and Gen II light water reactors. At

3. Advances in Small Modular Reactor Technology Developments 2018 https://aris.iaea.org/Publications/SMR-Book_2018.pdf

the same time, enabling policy frameworks and international collaboration will be continued to be key components for the timely deployment of new reactor concepts.

SIAP 2019 charge and response

Based on the market and industrial conditions described in Section 6.1, particularly those related to the ASMR ecosystem, SIAP was tasked in July 2019 to generate ideas and recommendations on how GIF should envisioned its interaction with private ASMR vendors. The development of the 2019 SIAP charge followed a first contact with private vendors held in May 2019 in Vancouver. Aspects covered in the charge included:

- The evaluation of the mutual benefits of higher involvement of the private sector in GIF activities including the right way for GIF to interact with vendors and addressing the need of reciprocity;
- Identification of R&D areas suitable for mutual co-operation with the objective to accelerate ASMR demonstration phase;
- Initial steps to involve ASMR designers.

One of the first outcomes of the 2019 SIAP charge was the necessity to define a set of criteria to evaluate/classify/downselect ASMR vendors. The selected vendors should be – at least – aligned with the GIF goals[4] and propose a mature design. Using the TRL scale, a level of 4 and 7 was judged as acceptable. SIAP members also highlighted the importance of a commitment from vendors to engage over an extended period of time. A potential way to rapidly engage with vendors may require the preparation of a set of questions using as starting the SIAP questionnaire developed in 2016 complemented, as appropriate by questions coming from SSCs chairs and other GIF TFs.

SIAP concluded that, in order to interact with the ASMRs designers in an effective manner, intellectual property rights (IPR) issues should be handled with care. IPR is a central issue in the setting up and operation of GIF, allowing public funded information to be exchanged among the partners, and this should not be endangered by involvement of the private sector. The same rules should apply to future private partners. Past experience within the GIF, shows that reaching an agreement in IPR aspects may require considerable efforts and this might discourage potential ASMR vendors.

The NEA NI2050 also provides valuable insights on the possible ways to interact with the private sector. Collaboration is easier at low TRLs as few intellectual property (IP) has been generated at this stage. As the concepts move to higher TRLs, IP on technology becomes more relevant hindering international collaboration. According to NI2050 finings, co-operation on the qualification of the technology may be more effective. The term “qualification” covers both industrial (i.e. codes and standards) and regulatory (i.e. licensing) qualification. If indeed countries could work together to reach common approaches (i.e. harmonization) of qualification processes of technologies/designs, this would greatly help reduce the time-to-market and broaden the potential market. In other words, if it would be possible to create a “common qualification pipe” that should attract ASMR vendors. GIF SSCs could also benefit from this *frame* as their activities are essentially technology focused. This topic might constitute the subject for a new cross-cutting task force within GIF. SIAP and NEA could also assist GIF to further develop this ideas and exchange with other organizations cumulating significant experience on the topic such as *Standard Developments Organizations* (SDOs), *Multinational Design Evaluation Programme* (MDEP) and the *Committee for Nuclear Regulatory Activities (CNRA)*.

The main following joint R&D activities may be of interest for the private sector, going beyond the pure technical topics. Potential areas include:

- advanced materials and manufacturing;

4. Sustainability, economics, safety and reliability, and proliferation resistance and physical protection.

- development of a common R&D infrastructure to accelerate qualification and demonstration;
- risk-informed methods and new related requirement to assist the licensing of advance concepts using alternative coolants and fuel arrangements;
- fuels and fuel cycles (both front-end and back-end activities);
- in-service inspection methodologies and their common qualification (i.e. European ENIQ experience).

Additional specific topics could be included after consulting the different SSCs. It is important to note that the aforementioned topics have strong cross-cutting dimensions, in line with the recent trends observed in GIF with the establishment of more horizontal working groups and TFs.

To initiate the interaction with the private sector, SIAP recommended GIF to set up a small group of experts to pre-select a first group of ASMRs vendors while keeping in mind the possibility to broaden later depending on market trends. A questionnaire could be sent then to the selected vendors in order to evaluate their responsiveness and willingness to join GIF communities. Based on their responses, a series of well-designed ad hoc meetings could be held with a first group of ASMRs vendors. Meetings could take place at the SSC levels (vendors could be regrouped by coolant type) or with more cross-cutting working groups or TFs (economics, safety, advanced manufacturing, etc.).

Additionally, and in line with the main R&D areas depicted above, two contiguous workshops will take place in Paris in February 2020: one on advanced manufacturing immediately followed by another on R&D infrastructures needs and opportunities. Using as a base the outcomes of the 2019 SIAP charge detailed in this chapter, these events will provide additional insights to properly assess the potential win-win areas for long-term co-operation between GIF and the private sector.

SIAP intentions for 2020

Since inception, the GIF has keyed on and supported the (necessary) R&D elements to support Gen-IV systems. The commercial SMR thrust has recently awakened more interest in nuclear power. SIAP seeks to advise and support GIF to harness this new momentum.

SIAP stands ready to support GIF looking at streamlining, establish an information campaign, how to convince the power generation community that the ASMR systems are ready to replace fossil fuel plants, and promote make nuclear licensing more international/transportable.

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