ANMT 2019

Key Topic: Outstanding Know-How & Sustainable Innovations

Focus Session International Innovation: Small Modular Reactors: a Major Element of the Future of Nuclear?

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The topical session "Small Modular Reactors: a Major Element of the Future of Nuclear?" was coordinated and chaired by the author of this report.

As the chairman explained in his short introductory statement, SMRs (small modular reactors or, according to a different use of the acronym, small and medium-sized reactors) might be an important element of the future of nuclear power. In the preceding AMNT plenary session, SMRs had been mentioned by several speakers from different institutions, one of them even calling them a "game changer" for the nuclear industry. The chairman noted that whereas for many years there had been much talk about SMRs but little tangible progress and the concept had stayed on a theoretical and "powerpoint" level, in the past one or two years the momentum seemed to have picked up, making the prospect of a major implementation of SMRs somewhat more realistic.

The chairman stated he was proud to present four speakers who were ostensibly qualified to deal with the major aspects of SMRs. *Alexiei Ozeretzkovsky* from the World Nuclear Association (WNA) would give an overview over current SMR projects and designs and about the WNA's efforts to enhance the global framework for SMRs. *Dr. Andreas Schaffrath*, Head of Safety Research Division of GRS, the technical support organisation of the German federal nuclear regulator, would concentrate on the main technical features of SMR designs. *Susan Vrahoretis*, Assistant General Counsel at the US Nuclear Regulatory Commission, arguably the world's biggest nuclear regulatory body which is currently prepared for a wave of licensing applications for SMRs, would put a spotlight on regulatory issues of SMRs. Last not least, *Dr. Helmut Engelbrecht*, former CEO of Urenco (which has developed its own SMR design) would concentrate on the economics and on implementing the necessary vision to enable future success of SMRs. With these four presentations, it was reasonable to expect a comprehensive overview over relevant aspects of SMRs.

The chairman proposed not to have a Q&A session after each presentation separately, but rather a panel discussion at the end where the audience was invited to participate.

As first speaker, *Alexiei Ozeretzkovsky* (staff manager of WNA's CORDEL SMR task force) presented on "**Current SMR developments and key enablers for deployment**". He commenced with an introduction to the work of the WNA and particularly of the Cooperation in Reactor Design Evaluation & Licensing Working Group (CORDEL) and its SMR task force. Next, he highlighted the benefits of SMRs which are likely to push their development, citing their small capacity (<300 MWe) which can be used in small grids or remote areas, the factory assembly of main components and their short construction time, the option for non

electrical applications (district and process heat, desalination, hydrogen production) and the enhanced fuel utilization. Challenges, on the other hand, were posed by regulatory issues, particularly by the fact that SMRs in some aspects require new licensing approaches and by the existence of diverging regulatory requirements in different countries. Challenges were also presented by economics, namely the availability of financing and the existing market structures. Yet the latest developments in the last year and half around the world gave confidence that there was trust in the capacity of SMRs to overcome these challenges in a step by step fashion.

Weighing the advantages and challenges, *Alexiei Ozeretzkovsky* identified key enablers for SMR development, mainly clear long-term political support, support by public enterprises to develop demonstrator projects, and innovations in licensing (predictable licensing processes, international harmonisation of regulations and development of a design certification process valid across national borders). He also stressed that industry needs to deliver: it must harmonize its codes and standards, deliver a first-of-a-kind (FOAK) project and develop the necessary manufacturing capacity. The CORDEL Roadmap for international standardization and harmonization was presented as a path to be endorsed by the key stakeholders to support international deployment of SMRs. He concluded that SMRs have the potential to be part of a decarbonized energy future but that challenges need to be overcome, with governments, regulators and the industry needing to keep working together to achieve this. Timely and streamlined licensing coupled with international cooperation was key to enable SMRs to take advantage of the series effect. In any case, activity around SMRs was pacing up and it certainly was a very exciting time to be in the nuclear industry.

Next, *Andreas Schaffrath* (Head of Safety Research Division of GRS) spoke about "**SMRs – Overview on International Developments and Safety Features**". He set out by explaining why GRS, even in spite of the changed political framework in Germany and the legal ban of new build licences, conducts research into SMRs: The firm government position was that Germany shall continue to have a permanent influence on reactor safety in Europe, which required an appropriate knowledge and analysis of reactor design possibly employed in the future for new build in the neighbourhood of Germany. The current boom in SMR construction and development made it mandatory to look at SMRs in this framework. GRS's objective was to promote comprehensive safety reviews and ambitious binding targets; this required an extension and validation of the GRS nuclear simulation chain and evidence tools.

Therefore, GRS had performed a Study on Safety and International Development of SMRs (which is available on the GRS website). Given the variety and multitude of designs in various stages, GRS identified selected trends as a basis for investigation. The most important of these trends were: factory fabrication and transport; compactness and modularity; core design; and finally, improved safety features of reactor coolant system (RCS) and the containment. Indeed, as *Andreas Schaffrath* mentioned, SMRs could be – if proven by corresponding safety analyses – among the safest nuclear equipment ever made.

Next, he turned to the issue of competitiveness of SMRs. Different studies indicated a significant market potential in the medium term; however, this was based on certain assumptions, namely that all entry barriers have been overcome, that series production in a

factory is implemented and that efficient transnational licensing procedures have been established. Efforts for the latter aspect were under way, and in this context GRS planned to further develop and validate its nuclear simulation chain and evidence tools for safety analyses.

Next, *Susan Vrahoretis* (Assistant General Counsel at the US Nuclear Regulatory Commission) talked about "**Flexible, Innovative Regulation of Small Modular Reactors and Other New Technologies**". She set the scene by pointing to a recent development: the U.S. NRC staff requested Commission approval of potential transformational changes to the agency's regulatory framework, culture and infrastructure in order to increase and enhance the agency's effectiveness, efficiency and agility and more fully enable the safe, secure use of new technology in civilian nuclear applications. The Commission was currently considering the staff's recommendation. Next, *Susan Vrahoretis* explained the statutory role of NRC as regulator, the main yardstick being that the Commission must have reasonable assurance of adequate protection of human health and safety and common defence and security. The NRC had developed a regulatory framework for use in regulating large light-water reactors which was adaptable for use in regulating small modular light-water reactors, advanced non-light-water reactors, micro-reactors, and other new technologies.

However, in the general strive to enhance the NRC's approaches, besides initiatives to modernise large LWR licensing, there was also a move towards flexible design and licensing approaches for SMRs. Basically, applicants for a licence under NRC regulations had the choice between two options: the traditional approach under 10 C.F.R. Part 50 involving a construction licence and an operating licence, and the more recent process under Part 52 which provides for one single combined licence which can be joined to pre-licensing steps such as design certification or early site permit. Issues investigated by NRC staff with respect to SMRs were licensing of modular power plants (the preferred approach, as *Susan Vrahoretis* noted, featured one application for all modules at a site with individual licenses for each module), control room staffing and operator licences, emergency preparedness and insurance and liability aspects (here, the problem was that a facility composed of multiple small reactor modules that each produce electrical power less than 100 MWe, but, in combination, produce more than 100 MWe, may have insufficient insurance and indemnity coverage in the case of an insurable event).

Next, *Susan Vrahoretis* turned to preparing and planning for licensing advanced non-LWRs and micro-reactors. She highlighted two recent legislations in this respect: the Nuclear Energy Innovation and Modernization Act (NEIMA) and the Nuclear Energy Innovation Capabilities Act (NEICA), both of January 2019. The U.S. NRC's vision and strategy for non-LWRs had three strategic objectives: enhancing technical readiness; optimizing regulatory readiness; and optimizing communication. In this context, a new Regulatory Guide 1.232, Advanced Non-LWR Design Criteria, had been completed and published in the Federal Register in April 2018. Finally, *Susan Vrahoretis* highlighted the US NRC's international activities, such as the NRC's participation and leadership role in the Multinational Design Evaluation Program (MDEP) and in the IAEA Small Modular Reactors Forum.

As a conclusion, while reminding participants that the NRC did not promote any particular technology or design or the use of nuclear energy in general, she pointed out that SMRs and non-LWRs could be designed and licensed under the NRC's current regulations given their built-in flexibility. To increase the efficiency of its reviews, reduce uncertainty, and focus on safety and risk-significance in new technologies, the NRC had updated its policies and procedures and was considering additional improvements through rulemaking.

Last not least, *Helmut Engelbrecht* (former CEO of Urenco and former WNA Chairman) brought a definite message to the auditorium: "**SMRs – it's all about the economics …**". He set out by showing some designs, among them micro reactors such as Westinghouse's eVinci and Urenco's U-Battery which, he stated, were distinct from other SMRs and mainly designed for being employed off-grid. *Helmut Engelbrecht* took the "S" in SMR to stand for four aspects: safe-small-simple-secure. He claimed that in order to find public acceptance, future energy generation needs to be inherently safe so there will be no harm done to anybody outside the facility. In this respect, SMRs had definite advantages, such as their small size and small power density which minimised the main problem of nuclear safety, namely the decay heat removal. The small size of SMRs had other advantages as well: it enhanced flexibility, enabled a "plug and play" approach for customers and reduced financing risks. Being "simple" as well, SMRs required no operator, offered enhanced reliability and facilitated handling. Finally, they were "secure", both in terms of nuclear security and in providing for a secure electricity supply.

As to the "M" in SMR, standing for modularity, *Helmut Engelbrecht* noted that it was key to offset the economies of scale, which seemed to be in favour of large reactors, with economies of numbers, provided by the concept of modules or entire plants built in factories and shipped to the site.

Next, *Helmut Engelbrecht* shortly sketched the results of a study done by students of World Nuclear University (WNU) in 2018 under his guidance. The study first made an assessment of electricity customers' requirements and then applied these requirements to different electricity generation means in different markets (mature – industrial – emerging/remote). The outcome was that SMRs were not more competitive than wind and gas (with micro reactors being more competitive in comparison to "larger" SMRs). In *Helmut Engelbrecht's* view, this result was alarming; it showed both that nuclear industry must focus more on their customers' needs and expectations and that it must also develop new visions capable of inspiring young emerging leaders, such as those participating in WNU. In particular, he pointed out that even if nuclear can be shown to be competitive if full costs are accounted for in energy prices, this fact does not automatically determine public debate because many other political and societal issues will also come into play.

Helmut Engelbrecht concluded his presentation with a positive but challenging message: Nuclear energy, he said, was bound to succeed because it was the only sustainable energy that can be operated on demand; provided, however, that industry tailored nuclear energy to meet customers` needs and provided energy prices reflected the real value created.

After the four presentations, a discussion among the panellists and with the audience gave ample opportunity to follow up on many of the issues.

One of the participants stated that in his view, harmonisation of safety requirements was key to implementation of SMRs. *Alexiei Ozeretzkovsky* and *Christian Raetzke* agreed and emphasised that the very concept of SMRs, namely the fabrication of the entire plant, or at least of modules, in factories to an identical design regardless (at least to a large extent) of the eventual country of destination, would be put into question if the design had to be adapted to different regulations in different countries. *Christian Raetzke* added that the international efforts for harmonization in nuclear safety requirements, which had been under way for some time now and which, with regard to traditional LWRs, were rather slow to take effect, might receive a boost by the prospect of imminent implementation of SMR fleets across different countries.

Concerning the economics of SMRs, one participant challenged the panellists on how they would arrive at putting a price tag on a particular reactor. The participant stressed the particular challenge of equipment and process qualification, which might be extremely cumbersome to obtain for an SMR factory, involving many engineer hours and potentially jeopardising the budget. *Andreas Schaffrath* agreed that no one could put price tags on SMRs right now. However, he emphasised the fact that the risk of construction delays, which had blown up the budget of many new build projects in the last years, was almost non-existent for SMRs since they were built in factories. This made calculation for SMRs more reliable. *Alexiei Ozeretzkovsky* seconded with a striking comparison: If the initial price tag of the first large-scale wind turbines, which must have been quite prohibitive, had been the only factor of decision, wind power would not have taken its tremendous development. However, the early adopters focused on the potential of the technology and supported it. He pleaded that price tags should reflect the prospect that at least the more successful SMR designs will be built in great numbers, echoing the "economies of numbers" proclaimed by *Helmut Engelbrecht* in his talk.

In the same context, a participant noted that according to the presentations about 70 or 80 SMR designs were under development. Where would the money and the capacities come from to go through a licensing process for so many designs, particularly if for each design the process would need to be done in many countries? The panellists and the chairman responded that not all these designs would turn out to become real. Furthermore, they pointed at the importance of international cooperation resulting, if possible, in an international certification, which would mean it could be dispensed with 10 or 20 different national licensing processes for any given SMR design. *Christian Raetzke* mentioned the commercial aircraft industry as a possible model, where the market was dominated by a small number of players. A participant picked this up and mentioned that aircraft licensing, even if done in each country separately, was more or less determined by the licensing process in the few leading countries, the results of which were more or less accepted by smaller regulators. *Helmut Engelbrecht* supported this approach, stating that even in the nuclear field a comparable approach was being followed for transport casks. Here, certifications issued by one regulator were validated by others.

Continuing with regulation, the chairman asked the panellists whether safety or security was a greater issue for SMR development and licensing. *Susan Vrahoretis* responded that security requirements (sometimes referred to as "guards, guns, and gates") were very explicitly set in the US NRC's requirements and that it was possible to determine, when reviewing an application, whether they were met. By contrast, safety assessment of new or novel technologies was perhaps more difficult since demonstration of the safety of new features, particularly those not common to large LWR designs, posed some challenges for the regulator, especially where the design continued to evolve or change or there was no operating experience. When a participant stated that he had concerns about non-proliferation with respect to SMRs, *Andreas Schaffrath* noted that a number of SMR designs were not designed for refuelling on the spot, but rather for being taken back to the factory after the fuel cycle (between 2 and 10 years, depending on the SMR concept) for reuse and refuelling. This meant that for these SMRs there was no way of getting access to the fuel without destroying the reactor module. *Helmut Engelbrecht* seconded that almost all gas cooled SMR designs relied on fuel with a robust structure (TRISO) which made it almost impossible to extract the fissionable material.

Another regulatory issue was how SMRs can be brought to developing countries. The chairman asked a provocative question: if SMRs followed a "plug-and-play" concept with "walk-away" safety, was it really necessary to develop a nuclear regulatory infrastructure in the host country? *Helmut Engelbrecht* took the view that it was not necessary. Instead, the solution was to make the reactor inherently safe, even "fool-proof", so nothing could happen. *Andreas Schaffrath* objected: in his view, no reactor anywhere should be operated without a regulatory structure overseeing it; *Susan Vrahoretis* agreed. This started a lively discussion. SMRs were compared to the "first car" driven in a developing country and it was asked whether the driver of the first car would have had a driving licence. There was no common outcome but everyone felt the question of regulatory infrastructure for SMRs in small and developing countries and support that could be brought by experienced countries was a crucial one.

Helmut Engelbrecht brought the discussion to a thought-provoking end by stating that in any case industry had to adapt to the need of its customers and try new approaches in doing so. The history of nuclear was long but not entirely successful; it was time to give it a new start.

Accepting this as a good concluding statement, the chairman expressed his thanks to the four panellists who were awarded a strong final applause from the audience.