From Smart Marketing to Building a New Energy System – Challenges for SMR Global Adoption

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This article is the first in a 3-part series by NECG in atw – International Journal for Nuclear Power, to explore the role that new technology in nuclear fission and in fusion can have in a New Energy System, and what challenges they will need to overcome.

PART 1/3

Nuclear energy is expected to have an important role in the global effort to provide clean, reliable energy while reducing or eliminating electricity sector carbon emissions. This implies a substantial program to build new nuclear capacity: besides large "GW" plants using proven designs, there will be a role for smaller units and advanced designs, generally referred to as "SMR"s.[1] Proponents of these smaller designs offer the promise of faster, cheaper, and safer deployment to help reach global new nuclear power capacity goals. But SMRs also face major challenges to reach the scale of deployment needed to realize their potential. This article discusses these obstacles and identifies questions that stakeholders in any global SMR deployment at the scale required still need to answer.

Introduction

Nuclear energy, with its ability to provide clean high-density energy and dispatchable power, is seen as an important contribution to pathways to Net Zero Emissions ("NZE"). The International Energy Agency (IEA) assumes that to achieve NZE by 2050 the global nuclear industry will have to build around 640 GWe of new capacity[(I)]. With around 420 GWe globally of existing capacity in 2023, of which an estimated 260 GWe is due to be retired by 2050, this new build requirement is a significant challenge. To put this in context, in the next two decades, some 400 EPRs, currently the largest reactor design at 1.6 GWe, would be needed to fill the gap; but in the past two decades only a few EPRs or other similar GW plants have been completed, all subject to well-publicised cost and risk burdens [(II)].

The significant construction risk and huge capital liabilities involved in such GW plants have prompted many actors around the world to explore the potential of SMRs. The proponents of these smaller, modular designs claim less cost, better risk profiles and greater agility for SMR deployment compared to GW equivalent capacity, which would open new markets and applications to nuclear power. This potential has led to significant marketing and lobbying to develop market share by vendors of SMR technology (**see Box 1** – "Smart Marketing Reactors").

The SMR concept builds on potential to reach commercially viable economies through large-scale fleet deployment, encouraged by the promise of reduced construction risk, new applications for industrial power delivery, advanced safety features, operating efficiencies and system predictability. To put this in context: more than 6000 SMRs would be needed

BOX 1: "Smart Marketing Reactors"

The International Atomic Energy Agency (IAEA) lists around 80 SMR designs in development around the world, with perhaps 10 or 20 of these likely to be credible and reach commercial readiness [(III)]. Many, if not all, of these designs claim significant safety and operating advances over earlier and current reactor technology, and additional deployment possibilities such as co-generation and direct heat. Most vendors are some way from having a design beyond a concept – let alone detailed fabrication design – but still aggressively lobby, publicise and seek investment, hence the sometimes used epithet "Smart Marketing Reactor".

Each technology vendor is seeking to grab as large a share as possible (i.e., by signing up customers early) in an uncertain and fragmented market, and this is generating considerable marketing hype, flashy websites and social media presence: nobody wants to end up as the Betamax of the SMR renaissance[(IV)].

Governments in several countries are engaged in developing SMR options in different ways, with R&D funds, regulatory reviews, feasibility studies, even pilot projects at Government sites and market support mechanisms. Numerous customers around the world – utilities as well as industrial interests (chemical, steel) – are signing up for "Development Programmes" and even "PPAs". What is less clear, in all these cases, is how significant the customer commitments are in terms of financial contribution and tangible take-or-pay commitments.

A different emerging technology choice for future energy systems are fusion machines. These in principle offer similar capabilities as nuclear plants, GW plants and SMRs. While they share some of the same challenges, fusion machines require potentially less regulatory overhead and promise other advantages. We will explore their risks and opportunities in the upcoming atw 5/23.

1 In this artice we refer to large, traditional reactors, usually >1000 MWe as "GW plants" and we use "SMR" to generically refer to small medium/modular and advanced reactors. "Modular" refers to the construction design (with factory assembled modules) and/or modular configurations of SMR units (e.g. 4 units with 77 MWe each for a plant total of 308 MWe with a combined control room).

BOX 2: "SMR opportunities and challenges"

The crux of any discussion about SMRs is an interaction between three perspectives: Economic, Industrial, Systemic.

ECONOMICS: How (or if) the benefits of smaller size outweigh the scale efficiencies of GW plants or advantages of other technologies and so deliver the expected advantages of multi-unit rapid deployment. This should be achieved in a combination of several factors:

- by reducing the SMR unit cost and improving the investment cash flow and risk profile;
- by finding special market segments or applications where SMRs create extra systemic value;
- by optimizing operation and maintenance efficiency.

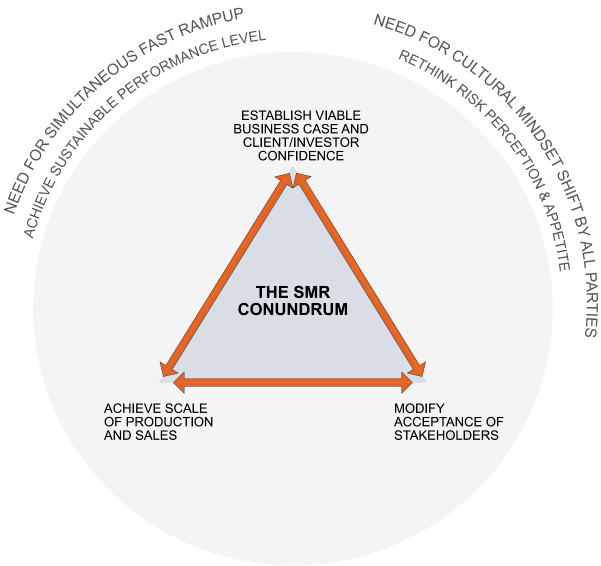
INDUSTRIAL: In order to reduce unit cost, the design, supply chain and manufacturing model must maximise the ability to simplify design (i.e. lower cost of materials and assembly) and replicate and deliver quality control. A UK report in 2016 [V] estimated that by manufacturing 10 units per annum, SMRs could achieve levelized cost parity with large reactors at 5 GWe of total deployment, with a potential further 20 % CAPEX reduction through design innovation and modern build and manufacturing techniques. Other studies suggest that the learning curve flattens after 5 – 7 units [VI]. Eventual build rate will be driven by a balance between manufacturing capacity (at the factory and in the supply chain) and market demand. This requires a successful design to achieve multi-unit manufacture and deployment and seize as much market share as possible.

SYSTEMIC: In comparison to GW plants which are primarily for grid supply, SMRs could be deployed in other locations (e.g. former coal plants or at industrial sites) and be better suited for other purposes besides power supply (e.g. very high temperature heat) or in the case of advanced reactors for recycling of radioactive substances (waste, plutonium). However, this prospect raises new questions regarding the licensing of sites, definition and requirement of emergency planning zones as well as local/regional permitting rules and capacities/capabilities of local/regional authorities to oversee the process.

to reach the abovementioned 640 GWe capacity, instead of 400 EPRs. In other words, by mitigating challenges that GW plants confront, the SMR business model faces challenges that a GW plant does not (see **Box 2** – "SMR opportunities and challenges").

The SMR conundrum:

In order for SMRs to be economically attractive, manufacturing needs to be at an appropriate consistent, high throughput level. In order to achieve that level, vendors and their supply chain need to grow and hold a sufficient order backlog. This in turn will be difficult to attain as long as the economic business case is not well established. – So the question is, what needs to happen if we are to believe that SMR deployment can happen at sufficient scale (i.e. significantly more than just one or two government sponsored pilot projects) and in an appropriate timescale to support net-zero needs?



In this paper we examine the ability of the market to support this need for fleet deployment and estimate what market share SMRs can reach, by asking two questions:

1. What scale of SMR deployment is achievable to support NZE pathways?
2. What needs to be done to facilitate global SMR deployment at scale?

What scale of SMR deployment is achievable to support NZE pathways?

The IEA, in its World Outlook 2022, offers scenarios for forecasting future energy profiles and requirements. The most aggressive is Net Zero Emissions (NZE) which targets a limit of 1.5 deg C global temperature rise and net zero GHG emission by 2050, and the least aggressive is STEPS, which assumes existing (2022) policy commitments are kept. Each of these scenarios assumes a proportion of total demand is met by nuclear energy, and from these we estimate that there is a requirement to build by 2050 between 358 and 640 GWe, where only the high end of this range can meet net zero targets (see **Box 3** – "IEA Scenarios" for a summary of the IEA scenarios and the derivation of these figures).

Within this range, what size is the likely or necessary market share for SMRs? As of 2023, estimating the demand for SMRs over GW plants is simply a guess with wide variations in approach in different regions, as well as demand signals varying between grid applications and other industrial uses.

We can examine a number of cases for global manufacture and deployment which give us insight into the future for SMRs (see **Table 1**).

BOX 3: "IEA Scenarios"

The IEA examines three scenarios in its 2022 World Energy Outlook. These are:

STEPS – Stated Policies Scenario – prediction of how the global energy system evolves assuming current policies, including the US Inflation Reduction Act, remain in place. STEPS assumes global nuclear supply of 4260 TWh [VI] in 2050, or 530 GWe capacity.

APS – Announced Pledges Scenario – includes further ambitions of governments not yet enshrined in policy, and assumes that pledged targets are met in full. This scenario requires global nuclear supply of 5103 TWh in 2050.

NZE – Net Zero Emissions by 2050 scenario – the normative scenario, taking a route to net zero emissions by 2050. This scenario assumes a nuclear supply by 2050 of 5810 TWh [VII], which the IEA states requires 813 GWe of capacity. Taking into account the decommissioning of existing plant, the NZE indicates some 640 GWe of nuclear capacity needs to be built between 2021 and 2050. The IEA also examines a low nuclear case of the NZE where nuclear supply falls from 413 GWe in 2022 to 310 GWe in 2050, requiring a similar increase in other forms of clean energy capacity. It concludes that this scenario is valid, but would result in higher investment and consumer costs, additional strain on clean energy supply chains, and higher exposure to fossil fuel market prices.

The IEA does benchmark the NZE against other published scenarios for nuclear energy and concludes that this scenario is 'broadly similar to that of the 97 scenarios assessed by the IPCC that limit warming to 1.5 deg C (with a greater than 50% probability) with no or limited overshoot', although the overall 2050 nuclear power output in these scenarios ranged from 1000 TWh to 26000 TWh[1]. As a further comparison, the IEA notes that in a 2021 IAEA Study, estimates of nuclear capacity ranged from 830 GWe (high case), similar to the NZE figure, to 415 GWe (low case).

So the IEA models can give us a reasonable estimate of the upper bound (NZE – the capacity required to meet Net Zero targets) and lower bound (STEPS – the capacity already envisaged) of required nuclear capacity to 2050. The IEA report states that for NZE scenario the required capacity to be built between 2021 and 2050 is 640 GWe, taking into account a model for capacity planned to retire over that period. The STEPS model does not specifically state a new build requirement but we can use the stated 2050 capacity requirement of 530 GWe and compare it to the NZE figures to assume a new build requirement under STEPS of 358 GWe[2]. **So in this paper we will assume the range of new build nuclear capacity between now and 2050 is 358 – 640 GWe.**

1 Our task is made more difficult by different sources choosing to use either TWh power output or GWe capacity; the conversion is not always straightforward as the assumed plant capacity factor is not always quoted.

2 NZE capacity in 2050 is 812 GWe; STEPS capacity in 2050 is 530 GWe; the difference between the two is 282 GWe; subtract this from the NZE new build requirement of 640 GWe to obtain 358 GWe.

- For example if SMRs are as successful a concept as some of the excitement in the market suggests, then the market and investors would pile in, small plants would dominate the market and most or all of the NZE 640 GWe requirement to 2050 would be supplied by SMRs (Case 4 in **Table 1**). This upper boundary would require in the order of 6000 SMRs, to be supplied by between 20 and 80 SMR vendors.
- In another extreme, we estimate the minimum demand for a viable SMR industry to be some 20 GWe for SMR capacity to 2050 (Case 1 in **Table 1**): this would allow the SMR sector to realise commercially viable production economies. If this is not met, then SMRs will not reach series production, making it unlikely they could achieve more than niche roles at best. This could provide commercially viable work for between one and three vendors, depending on how many units each can build per year. A more optimistic low case, with 50 GWe SMR capacity by 2050, would allow for between 2 and 7 vendors (Case 2 in **Table 1**).

Instead of these boundary cases, for the purpose of this article we may consider a moderate **Reference Case** at the level of 200 GWe by 2050 (i.e. roughly 2/3 of the IEA STEP case and 1/3 of the IEA NZE case): this would call for some 2000 SMR units to be manufactured and deployed over 20 years (Case 3 in **Table 1**) and allow for between 7 and 25 vendors, which may provide a more comfortable target market for existing SMR designers and a reasonable global/regional competition and range of applications. Of note, this Reference Case would call for an average annual completion rate of 100 SMR units per year, and would likely need upwards of 500 sites to be developed. **Box 4** outlines some of the implications of this scale of deployment. These orders of magnitude – and compared to the current stage of development where neither the designs, the supply chains, the customers or the regulators nor the energy and financial markets are ready for the scales in question – demonstrate the size of the challenge to facilitate an SMR deployment at scale.

What needs to be done to facilitate SMR deployment at scale?

In order to develop a fleet deployment approach of sufficient scale, the SMR concept requires solutions to issues the nuclear sector has not yet solved or perhaps even traditionally encountered. These are outlined below; each will need more extensive discussion in future papers in our series. In market communications on the potential of SMRs, from vendors, governments or other proponents, we have not yet heard compelling answers how these challenges are being recognized and overcome, although a number of influential commentators are raising similar analyses [VIII], [IX], [X].

– Issue 1 –
The scale and profile of financial support for SMR deployment

The scale of the deployment required to approach NZE requirements is huge, for any technology, not just nuclear. The SMR concept offers possible advantages over GW plants in that the capital cost is spread over multiple units, giving the ability to use revenue from early units, either through offtake or asset sale, to fund the ongoing build with more favorable cash flow and risk profiles.

The first question is unit cost: experience with GW plants showed that any cost estimates are highly uncertain. The current GW "Gen III+" plants were designed to improve on cost – total plant cost and MWh cost (or LCOE) – over previous "Gen II" and "Gen III" generations, through simplification and modularization. Instead, they experienced huge (> factor 3) cost increases in practice. With 30 years learning curves GW plants may ultimately bring cost down to expected levels, but this is an experience SMRs cannot afford to repeat if they are to achieve necessary high booking and production rates.

Furthermore, considering the numbers of SMR units required per year, the financial burden on the vendors and investment needed is very significant. SMR capital costs in 2023 are not yet accurately defined and long-run capital cost will be affected by numbers, but as shown in **Box 4** any deployment in significant numbers will imply substantial completion risk – and a need for sufficient vendors and clients able to carry this effort. *Which, if any, entities have the capacity and desire to absorb such large investment risk exposure, let alone completion risk, or even have the balance sheets to allow to carry the work-in-progress?* And, as we showed in **Box 4**, quite large numbers of such large players would be needed.

BOX 4: Implications of deploying 2000 SMRs between 2030 and 2050

Case 3 of Table 1 estimates that a global demand of 200 GWe as part of the NZE pathway will require 10 SMR vendors between them to manufacture 10 SMR units annually for 20 years, giving a total of 2000 units (at 100 MWe mean output each).

Assumptions:
All 2023 prices
Capital cost of each 100 MWe SMR unit - $1bn
Build time – 3 years

Each vendor would have 30 units in the manufacture and build process at any one time, requiring a cash float of at least $10bn and a completion risk of $30bn continuously. If manufacturing does not begin in earnest by 2027, then this cash need will increase by at least 15 % as the available period to 2047 will reduce.

Over the 20 year period the total required investment in SMRs will be $2 trillion.

If we assume an average SMR plant site to take 4 * 100 MWe units, i.e. 400 MWe total, this would require 500 sites to be developed, presumably most or all of these not being previously licensed nuclear sites. However, note 400 MWe is a fairly high average, since many site needs will be lower, and except in special use scenarios, larger sites would be more suitable to GW plants; i.e. the total number of future SMR nuclear sites could be significantly greater.

If we assume each client on average will buy 10 units, then this Case requires some 200 clients for SMRs globally, each of whom must manage an exposure of at least $10bn. Some SMR vendors propose a leasing arrangement, which retains the capital risk with the vendor.

The answer to this Issue will likely require new, bespoke business models, which might be set up by Governments and/or Specialized Venture Funds, and which might build on infrastructure leasing models or regulated energy monopolies. Some of the ideas we discussed in our 2021 article in atw (XI) have been taken forward, e.g. in the UK with "Great British Nuclear" – but to date no comprehensive plan

Tab. 1 – Market Case Scenarios

Four Cases (1)	Global nuclear capacity uplift to be supplied by SMRs by 2050 (2)	Number of SMR units required per annum (average 100 MWe per unit) (3)	Number of vendors needed to supply the global market if each vendor produces N units pa		
			N = 4 (4)	N = 10	N=16 (5)
Case 1 – minimum capacity for one SMR vendor to achieve commercial viability	20 GWe	10	3	1	1
Case 2 – minimum capacity with multiple vendors	50 GWe	25	7	3	2
Case 3 – a possible scenario if SMRs become the technology of choice and commercially viable	**200 GWe**	**100**	**25**	**10**	**7**
Case 4 – upper bound; all nuclear capacity is supplied by SMRs	640 GWe	320	80	32	20

(1) Case 1 is provision of 20 GWe from SMR technology over the period 2030-2050, or 1 GWe per annum, which estimates the lowest realistic SMR requirement where one vendor can supply the global volume needed to be commercially viable. Case 2 assumes SMRs will supply 50 GWe over the two decades, and illustrates that between 2 and 7 vendors can supply the market. Case 3 assumes SMRs will supply 200 GWe, a significant proportion of the total requirement but perhaps not unrealistic if the SMR concept is commercially viable. Case 4 provides figures for the number of SMRs and vendors needed to provide the whole 640 GWe NZE requirement.

(2) We assume that all SMR deployment will take place from 2030 at the earliest, so delivery of capacity will be during the two decades 2030-2050. (Some vendors state earlier completion dates from around 2026 but these are for FOAK units and may not be credible.)

(3) Current SMR designs vary in power output per unit from around 20MWe to 300MWe, with a few, such as the Rolls-Royce SMR, with higher outputs. For ease of illustration, we assume here that an 'average' SMR is 100 MWe.

(4) We assume around 4 units per annum is the lower bound for realising cost parity with large plants; below this number it will be more cost effective to build a large plant. As SMRs are likely to take around 3 years to build, this implies that each vendor will have at least 12 units in their manufacturing pipeline at any one time.

(5) We take here 16 units per annum as a rough upper bound, which would put severe strain on the vendor's supply chain, with up to 48 in each vendor's pipeline at any one time. It also illustrates the limit of the market being able to support multiple vendors in Cases 1 and 2.

that could achieve the levels of investment needed to achieve NZE Targets has yet been presented to the interested public.

– Issue 2 – The capacity and agility of the Supply Chain

To support global SMR deployment at scale, the supply chain will have to become more agile and distributed. The most publicised example of a nuclear supply chain bottleneck is the limited capacity globally to forge RPV castings, but at each level of manufacture and supply there are existing supply chain risks, and a wholescale change in scale and speed will be needed to support the envisaged SMR production lines. Even if SMRs may require less demanding manufacturing capabilities (e.g. reduced size of forgings, which may provide an advantage for SMRs over GW), they will still need to comply with nuclear grade quality processes (although see the comment in Issue 7 about areas outside the nuclear island). Also, for many SMR/AR designs, the fabrication for novel nuclear fuel types will need to be set up from scratch. The global supply chain and its workforce will also have to grow significantly to supply both SMR and GW requirements at the same time as supporting increasing demand in other energy, technology, and defence sectors.

As experience with GW plants in the last quarter century has shown, the effort, cost and risks of building a nuclear grade supply chain and taking plant designs from conceptual stage to site specific fabrication design and execution are significant. While in the SMR model they can be spread over a large fleet, the benefits from this model will only occur if and when a steep learning curve is achieved on a large scale across several vendors, clients and sites.

– Issue 3 – Modifications to Energy Market Design to accommodate SMR advantages

Current energy market designs do not always compensate best use of SMR characteristics such as load following and load shedding. In order to encourage and support SMR deployment at scale, energy market mechanisms will have to be revised to recognise such advantages. If the primary impact of load following and flexible operation are financial losses (i.e., a loss of revenue while operating costs are fixed), this will hurt the business case for SMRs in volatile markets. Without other incentives, investors/operators will not choose SMR technology with flexible operation as a design feature, losing some of the advantages of the SMR concept. As an example, Bruce Power (i.e., existing 8-reactor CANDU facility in Ontario) provides several hundred MWe of fast-response load following service to the Ontario grid/market operator, because Bruce Power is compensated for this in their power contracts with the grid/market operator.

– Issue 4 – The technology implementation risk in SMR designs still not (fully) eliminated

SMR designs such as GE-Hitachi BWRX-300, NuScale VOYGR and Westinghouse AP300 rely on well-understood LWR operating and design principles and, of current SMR technologies, are likely to be first to operation, but they aren't there yet. Advanced designs use different and novel reactor technology which brings significant additional development risk.

So, the introduction of SMR technology implies an increase in risk over GW plants in two areas: firstly, getting a first-of-a-kind (FOAK) SMR unit licensed and in operation will mean a lot of work and risk that would not be present in a proven GW design[2]; this is especially pertinent for advanced technologies. Secondly, these new SMR designs do not have the 60+ years of operating and maintenance learning that is present for proven GW designs, increasing risk of cost and performance issues after commercial operation of SMR units.

This also leads to questions for investor decision making: Advanced reactors offer additional benefits, whether safety features, special capabilities (e.g. consuming radioactive wastes or nuclear materials, generating high temperatures), and/or less operational risk - but they still carry more development uncertainty. Is it better to move fast with more traditional designs or hold out for later but more favourable assets?

– Issue 5 – Alignment of design and site licensing requirements across jurisdictions

In other sectors such as aviation, automotive and maritime transport, regulations and essential design requirements are largely common across global jurisdictions. Despite efforts since more than 25 years to harmonize international licensing requirements, the need remains to address each country's nuclear

2 Of note, some SMR vendors offer SMR designs which are based on already licensed GW designs, such as GE-Hitachi BWRX-300 (based on ESBWR, licensed but not built) and Westinghouse AP300 (based on AP1000, licensed and built, and AP600, licensed but not built). The link to licensed GW designs may lower the time, effort, and cost to license these SMR versions.

regulatory requirement *ab initio* and provide safety justification in a different form to a different philosophy. This adds significant cost and risk to any nuclear power plant design and subsequent deployment. To deliver sufficient nuclear capacity for NZE, whether SMR or GW, regulators would need to move to align their essential needs to allow more efficient licensing of technology designs, and allow common work across some aspects of site licensing such as cooling, ground requirements and grid connection.

Real progress will require fundamental shifts in public acceptance and legal and regulatory frameworks, but it is noted that moves to harmonise and share regulatory information are increasingly being explored [VII] and this is welcomed.

– Issue 6 –
Successful SMR deployment will encompass significantly more nuclear sites

An SMR success story will involve thousands of units and hundreds of sites, in unconventional surroundings, putting new organizational demands on local/regional authorities. Multi-site, multi-unit deployment is site-specific and for SMRs involves siting closer to densely populated and industrial sites, with corresponding new permitting challenges.

This involves significant local regulatory time, cost, and risk – and these will scale more or less proportionally to the number of sites. Identifying and developing these sites will be a huge challenge and to be succesful will require regulatory and cultural (see Issue 7) changes as well as sufficiently qualified resources at vendors, clients, authorities. This is in addition to the huge required growth in other energy sources such as GW plant, renewables, hydrogen and the energy infrastructure for transportation, distribution, storage and use.

Introducing nuclear power plants globally to regions, countries and sites without existing nuclear infrastructure also may raise new practical, political and ethical questions on e.g. waste management and non-proliferation.

– Issue 7 –
Nuclear industry culture is driven by excess risk aversion

The nuclear sector, and its associate functions in national regulation and government policy, were developed to support GW plants. This, along with the well-known GW accidents, has over decades instilled a culture of 'large megaprojects', extreme risk aversion, stovepiping, 'nuclear is different', and public scepticism. Such a culture runs counter to the need to develop agile, fast deployment for ultra-safe SMRs at sites which may be near to communities and for uses which are new to nuclear. Above all else, this culture, across all stakeholders and the public, will have to change if SMRs are to reach their potential.

For example, a traditional nuclear site is a wasteland of concrete and steel, designed to make it easy to avoid and clean up contamination. But an operational SMR site, with zero emissions, little noise, limited on site movement and proven safety, may seek to move away from such a look; indeed, some vendors, such as Rolls Royce SMR and Oklo, are depicting in marketing material their SMR sites with green landscaping and trees. Perhaps we should develop SMR sites with fruit trees, beehives and wildlife havens to burnish their green credentials and prove to the local community that the risk of contamination is at an acceptable low level? Could the plant areas outside the nuclear island be subject to standards less onerous than existing nuclear quality requirements? Perhaps a two-tier system of risk assessment needs to be developed, for SMRs and for GW; although this would likely be more acceptable in countries that don't yet have an established nuclear (safety) culture.

Perhaps the public acceptance of nuclear energy will grow as risk perceptions change. Perhaps the advantages and necessity of clean, cost-effective, reliable energy from SMRs will become more accurately defined in the context of climate change and new energy supply challenges. Yet, as with all culture changes, this will be a significant challenge with considerable political and societal implications and obstacles, but must be addressed in concert by all stakeholders if SMRs are to reach scale.

– Issue 8 –
Competition from fusion

Looming on the horizon is the promise of fusion energy, the only other technology which offers the same prospect of high-density, dispatchable energy. Private investment in excess of USD 3 billion in the last 2 years is spurring growth and governments are providing funding for private developers in addition to big international programs (as ITER). Near term (the next 2–3 years) demonstration machines are expected to demonstrate proof of concept for these technologies. Private developers are pointing to the end of this decade to early in the next decade for their fusion powered machines to deliver electricity, similar to the target deployment dates for many SMR vendors; this implies that the window of opportunity for SMR fission energy may be short-lived.

Or will fusion remain "the next great thing always 30 years away"? We will explore these prospects in our next article in this series in the upcoming atw 5/23.

Conclusion

The need to increase global clean energy production capacity to meet NZE targets is a significant challenge. The IEA 2022 scenarios indicate a need of up to 640 GWe new nuclear capacity to be built between now and 2050. Whilst we cannot predict what proportion of that need can or will be met by SMRs, we can estimate that a minimum of a few tens of GW will be required to reach any semblance of commercial viability for the SMR concept. This implies that SMRs must rapidly demonstrate clear advantages over GW plants and other energy sources in order to grow sufficient market share by 2030, and to thrive in a crowded energy market and perhaps, in the next decade, compete with fusion energy.

In order to leverage the potential advantage of the SMR concept, the supply chain, energy systems and global regulatory regime need to be updated. These changes will need to be put in train early to encourage the growth in market share.

To enable and sustain its growth and be able to deploy number of units at a scale to make a dent in the NZE targets, the SMR concept must quickly generate credible financial support to provide at least $10bn risk capital backing per client and vendor, for a large number of clients and sites. This is likely to need government or specialized fund intervention and will need to be in place as we approach the end of the decade to allow manufacturing volumes to develop.

The success of SMR deployment at scale requires a change in culture from all stakeholders. SMRs need a manufacturing and volume mindset more akin to the aerospace or shipbuilding sectors; and the general public as well as politicians and regulators would need to accept this change in approach. Without this, it may be that the SMR concept will not reach the scale needed to support its vendors, and will fail or at least not be able to contribute in a meaningful way to NZE targets.

The as yet unsolved challenge we see is that all of these building blocks are interdependent and need to be in place on a large global scale, in the near foreseeable future, in order for SMRs to be able to contribute the Net Zero targets in a meaningful way.

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Based in the UK, John Warden is an expert in structuring and financing nuclear projects, with special interest in SMR and advanced reactor technologies, as well as advising on skills and strategic workforce development in the nuclear and engineering construction sectors. John is a Director of Greensabre Consulting and was previously CEO of the Nuclear Institute, a Royal Navy submariner, reactor physicist and nuclear engineer.
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Rudy Koenig supports market players in the clean energy industrial value chain, structuring complex business transactions in large capital projects and managing lean business operations. He has held executive responsibilities for suppliers in the nuclear front- and back-end and has helped a large utility investor develop and ultimately sell several nuclear new build projects. His current main business theme is The Transition Gap, i.e. the holistic challenge that decommissioning and regeneration (incl. SMRs) constitute in the critical chain of the energy transition. Rudy works closely with JACOBS for their European growth strategy.
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