Spark! Contest 2017: Team #11

10 Page Paper

‘“WHY SMR?"

THE UNIQUE ROLE THAT SMALL MODULAR REACTOR DEPLOYMENT COULD PLAY IN THE FUTURE CHALLENGES OF A GLOBAL ENERGY SUPPLY’

SMALL MODULAR REACTORS

A NEW SUPERIOR OR MASS HYSTERIA?

Some of the greatest technological advancements in history begin life with the odds piled against them.

With that said, would you bet on SMRs? If so, how do you choose a winner?

Nuclear power is already a challenging investment decision in the realm of the current, unpredictable energy market. So, what are the key characteristics of SMR technology that have earnt it promotion to the ‘*knight in shining armour*’ of the nuclear industry? Or has the energy industry been blinded by SMR hysteria? This report provides a realistic overview of the obstacles facing successful global SMR deployment, and identifies the key enabling achievements needed to implement this step change in the global nuclear market.

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With the threat of global warming now no longer seen as a myth, we have international coherence in engaging positive action towards restoring the environment to health. The Kyoto Protocol, and more recently the COP21 Paris Agreement 2015, has seen climate change become a core feature of national energy policies. Green – carbon free – alternatives to fossil fuels must be introduced to have a significant impact in the battle for decarbonisation. Renewable sources may be the solution for the idealist, yet in the world of reality low carbon energy is only feasible today with the evolution and revolution of our current nuclear portfolio.

Amidst this call for revolution of the energy market, an eruption of excitement in the nuclear field has grown. Now there is a fresh new perspective on how nuclear technology could play an even larger role in de-carbonising global energy. Small modular reactor (SMR) technology in most cases is evolutionary technology, however many believe that deployment of SMR technology could be a significant step change in the way nuclear technologies compete in the international energy markets. Playing a unique role in the future challenges of a global energy market.

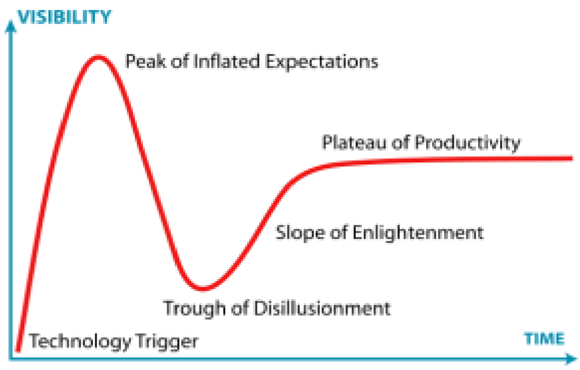

FIGURE 1 GARTNERS HYPE CYCLE [16]

The Hype Cycle, born from American scientist Roy Amara:

> *“We tend to overestimate the effect of a technology in the short run and underestimate the effect in the long run”*

The nuclear industry is at risk of having fallen victim to the Hype Cycle’s trap (Figure 1). If vendors do not begin to substantiate the claimed benefits of Small Modular Reactors and provide confidence in these massive investment decisions then SMR will forever fail, stuck in the trough of disillusionment.

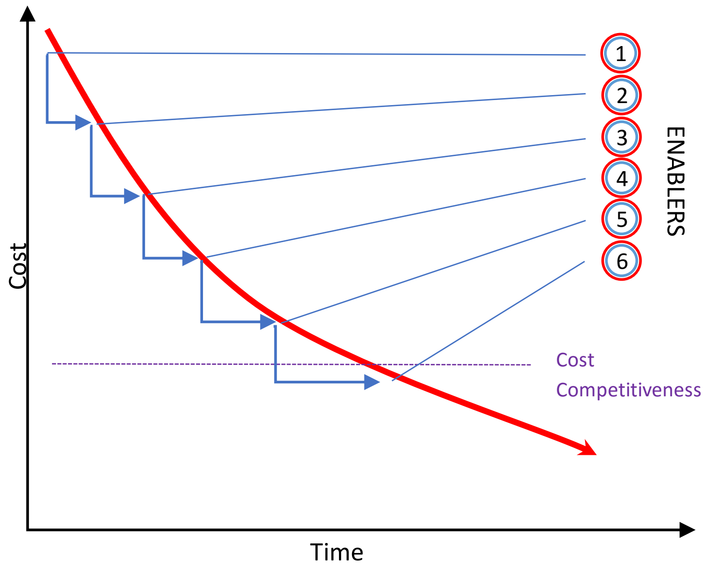

FIGURE 2 SMR PARALLEL DEPLOYMENT ENABLERS

PARALLEL DEPLOYMENT ENABLERS

I believe there are several key enablers in the build-up to SMR deployment that will make, or break, its success. No matter how ground-breaking a technology may be, technology vendors must present a rigorous business case above all, for it to reach deployment success. Figure 2 represents my model of parallel deployment enablers, demonstrating that no single feature will provide cost competitiveness alone. Without consideration of each of the following in unity, the feasibility of becoming cost competitive is hugely at risk:

1) Stratified Finance
2) Governmental Support
3) Collaborative Approach
4) Modular Regulatory Model
5) Securing Market
6) Realising Modularisation

I propose that SMR deployment is no longer about winning technologies, but about a winning business model. These enablers define part of a stratified, modular, programmatic approach to deployment that is required to overcome the new challenges that nuclear has yet to face before.

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1

MONEY, MONEY, MONEY

Economic competitiveness undoubtedly drives the success and failure of implementing SMRs into any national energy market. History has shown that the economy of scale is yet to better nuclear power against its fossil fuel competitors. Despite lessons learnt through previous build programmes the industry has developed a global reputation for escalating construction costs and continued programme delays. SMRs present an alternative model - an economy of multiples. This provides several potential opportunities to gain cost competitiveness through moving away from the one-off, bespoke project and supplying a market with multiple units. The highest financial risks for investors remain with construction and fabrication of the plant, SMRs can engage a spectrum of enablers discussed in this report to ease these risks and become more competitive.

Each SMR enabler highlights an uncertainty in the current SMR picture and as such, there is cost saving to be earnt from establishing greater clarity. It is hard, from the lenders' perspective, to understand what it is they are investing in. Vendors are not clear in whether they are providing: a technology, a factory, a utility, an R&D programme. Thinking of SMRs as programmes, rather than products or buildings, will lend itself to the economy of multiples and demonstrate better clarity for financiers.

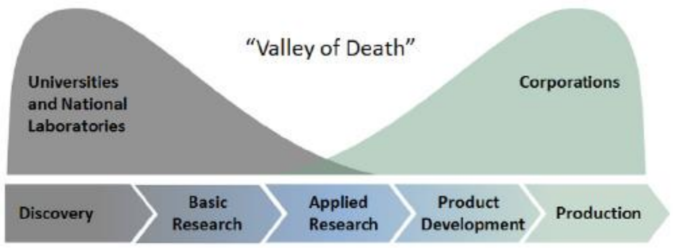

FIGURE 3 DEVELOPMENT VALLEY OF DEATH

SMR vendors are attempting to gain finance for incomplete and unlicensed designs, hitting development milestones is now crucial to demonstrate on time delivery to investors and attract more lucrative finance options.

Richard Beake describes three key financial enablers that must be achieved for SMRs to truly compete in a global marketplace (60-30-20 rule).

> ***60-30-20 Enabler – Richard Beake*** [3]
>
> Levelised Cost of Electricity < 60MWh^{-1}
> First of a Kind built before 2030
> Overnight Capital Cost < £2bn
>
> Wholesale price of electricity must be competitive **worldwide** which must be under £60MWh^{-1}.
>
> Deployment must be world leading to have best opportunity to succeed in a rush to market.
>
> Investment cost must be achievable else cost of borrowing will eliminate competitiveness.

SMRs, requiring lower capital investment, have more flexibility in how finance is delivered. Similarly, the programme model creates phases of delivery that make certain financial routes more attractive.

The current research and development period requires government direction and support. Yet, SMRs generally propose a transition away from government ownership models, such as EDF, CGN and Rosatom, into an entirely private enterprise. This will promote competition as a conflict of interest in a nationally owned technology is no longer present, as well as supporting globalisation of the programme. However, the state must still play a large part in providing initial enabling capital.

State financing has clear benefits over other forms of borrowing due to the more appealing interest rates [1]. Especially during the early phases where programme risk is higher, attracting finance at low cost is crucial in demonstrating cost competitiveness. As the largest market is likely to be domestic, there is a clear incentive for policy makers to support deployment without holding a financial stake, such as; greater energy security; growth for a domestic supply chain and wide socioeconomic benefits, to list a few.

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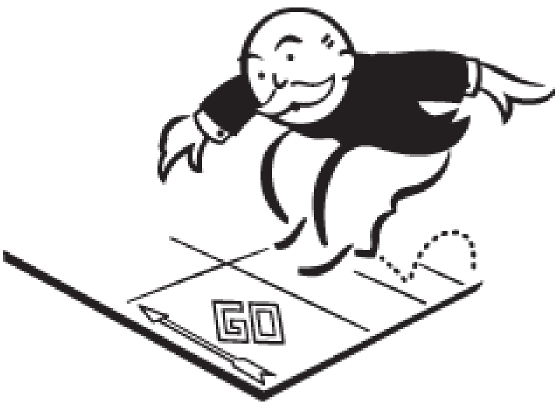
The concept of a consortium of organisations has been presented in the case of a number of SMR vendors to date. This model allows for the sharing of assets and liabilities to programme in order to better provide clarity to investors. In some cases, the consortium could in fact finance the initial phases without cost of borrowing at all, however this lays too great a risk at the foot of the partnering organisations. Without the direct tie with government, the programme also lacks significant benefits that state partnerships provide, including influence over the energy market and regulatory resource.

The First of a Kind (FOAK) deployment phase would again heavily rely on negotiations with state. Risk mitigation through government incentives enable private finance options to become more preferential.

An alternative model would be to access the deployment capital through initial public offering (IPO) and issue of bonds. This is feasible due to lower capital requirements compared with large reactor programmes, circa £1-2bn [1]. This model has already been utilised by several national nuclear programmes including China [2], South Korea [3], and Romania [4]. These shifts in routes to accessing capital are potentially what SMRs need to avoid huge borrowing liabilities, and offer public ownership of the power industry.



The transition to Nth of a Kind (NOAK) production, brings the programme to a point of much greater clarity for the large scale investment into a production line infrastructure. With the rate of borrowing at this stage lower, with the proven technology and market more secure, bank financing could now provide greater opportunities. The use of export credit agencies also provides similar finance options and better guarantees the globalisation of the technology.

Economics will be a defining feature of SMR success and vendors must begin defining what they can offer investors, aside from technology. SMRs are about revolutionising the industry and, as such, enable a cost effective finance route, a state-public-private enterprise should be pursued through government provided enabling capital and early deployment financed through IPO. The collaboration of state and industry optimises the capability of the supply chain and influence over the energy market, legislation and price guarantees.

2

GOVERNMENT LEVERAGE

Nuclear energy presents a difficult choice for policy makers. Although the nuclear industry is convinced of the necessity to deploy nuclear plants, the truth is nuclear has yet to demonstrate clear value for money for many developer nations. In addition, it has been argued that, nuclear energy is the least attractive options for combating climate change, due to its slow pace, huge costs and endless uncertainty [5]. By chasing nuclear technology down a rabbit hole, we divert vast amounts of funding and opportunities that could be allocated to the rapidly growing renewables sector and not only this, governments are stuck with the decision for decades to come. For many countries, nuclear energy also provokes great controversy in the public eye, making it an uneasy choice to pursue. Regardless, a commitment from government must be part of the deal in order to begin establishing enabling momentum.

Gaining an extensive order book for achieving the cost benefits of the economy of multiples, a domestic market will play the leading role in this. Export opportunity will be the next crucial phase and for both, government support will leverage SMRs position when entering these markets. As discussed there are a wide scope of benefits for national governments beyond the direct financial incentives.

SMRs provide greater flexibility in deployment and the replacement of fossil fuel plants as they come offline. The lower operational expenditure required for nuclear plants also allows for greater confidence in predicting the unpredictable energy market costs. SMRs, though generally considered base load generators, provide a greater ability to load follow [6] with many of the SMR vendors claiming 24-hour loading ranges from 100-20% [7]. This can allow co-depending renewable-nuclear power generating sites with complimentary operating regimes.

Historically, it has been government policy, support and commitments, that have made the entry of new technologies to market even possible. Through levies, subsidies and other financial incentives such as the CfD, the financial risk is reduced, providing better confidence in the future price of electricity. However, it is worth noting that in the UK incentives for renewables have been under threat following the EU referendum decision, notably renewable power sources becoming exempt from the climate change levy scheme [8].

The construction of power plants creates thousands of jobs in local regions - over 7000 nuclear related jobs in the Cotentin region, home of the Flamanville site [9] - and the local economies will often be gifted a wide range of other benefits too. EDFs relationship with Bridgwater College has strongly developed during the negotiations for Hinkley Point C and now with construction underway, the National College for Nuclear creating a workforce for tomorrow. This investment in the future of national industry has vast intrinsic value for the development of industry and futureproofing its workforce. Considering the hope of global deployment, these benefits are repeated across multiple sites.

Trawsfynydd

As well as the new siting prospects, there is an aging fleet in established nuclear nations that offer obvious locations for transitions to SMR, having already had considerable regulatory substantiation. The Trawsfynydd site, Wales UK, is one such site that currently homes a now, non-operational Magnox power station. The Magnox power station has for many years generated electricity in the magnitude of SMRs, as well as providing the local region with industry and purpose. With the site now commencing with decommissioning activities there are huge concerns for the Welsh Government, regarding the future welfare of the surrounding community. So much so, now the government is heavily promoting the area as a first deployment site for an SMR programme. Generally nuclear meets a wave of public resistance in such circumstances and yet, here, a first of a kind build is being welcomed with open arms. The value to this community and many others like it is large, as the cost avoidance for governments by combating unemployment and associated drains through state aid programmes is even larger. Part of enabling government support will be in associating a value to these social benefits and demonstrating this in a governmental agreement [10, 11].

FIGURE 4 TRAWSFYNYDD LAKE, WALES [19]

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Without more explicit direction early in the SMR programme from an industrial and political standpoint the likelihood of success will diminish. Government support eases issues such as; establishment of the crucial domestic market, building up enabling finance, de-risking investment, engaging export opportunities, guaranteeing future electricity prices. Though nuclear may be a difficult political choice, it has a huge part to play and SMRs present a unique opportunity for developer, consumer and newcomer nations. Vendors must take advantage of the socioeconomic benefits in the deployment of SMRs to leverage govnerments to enable the programme.

3

Two heads, better than one

Collaboration is part of the SMR philosophy, and already many organisations are engaging a domestic supply chain to support their programmes. However, these partnerships rarely surpass national borders, perhaps to better demonstrate to governments that economic benefits will be retained. As discussed, the financial benefits do not have to be the focus of winning government support. SMR must be a global programme, but currently vendors create barriers to the global market by chaining themselves to national programmes. The benefits of international collaborative programmes are extensive and have demonstrated great success in a number of industries, even nuclear.

The fusion programme, ITER, has transcended national borders and fundamentally relies on the sharing of: skills, financing, academia, resource and risk across some of the greatest global powers. For the good of science and potential truly futureproof energy source, governments and other funding bodies are willing to overlook a possibility that fusion power may never even be mastered. There is a broader political driver for scientific progression and solving a global challenge - energy. International cooperation fosters better and faster advancements, space exploration has benefitted in this way, and the energy industry – especially in renewables – has also seen similar successes. In addition, this is not necessarily at a financial loss, as the funding model for ITER allows for members to deliver contracts for construction, resourcing and manufacturing. This will in turn gain economic benefits from membership as well as committing to a global endeavour.

ITER has paved the way for businesses to explore new markets and led to developments in engineering capabilities for its members. In many cases, demonstrating a growth in employment and new enterprises, providing a platform for smaller and larger organisations to interact and develop new relationships to add value to industry [12].

SMRs have taken the opposite approach as the deployment mission has a focus towards finances, ignoring the benefits to science and climate change. Fuelled by national competition, SMRs run the risk of saturating the market, complicating the investment decision and potentially missing the optimal technology insertion point due to a lack of fundamental consistency and direction. It is this commercialisation of the technology that seems to have driven negative competition, where arguably the best scientific endeavours have been achieved working together [13].

Without an export market, SMRs will remain uneconomically feasible regardless of domestic success. National gains are important in garnering

FIGURE 5 LEGO ITER MOCK-UP CREATED BY SACHIKO AKINAGA [10]

government support, however it is crucial that there remains a focus on providing levels of sponsored collaboration with international partners. These partnerships would not only facilitate exports, but better provide a global solution to energy challenges.

4

A New Rule Book

Nuclear regulation plays a fundamental role in the deployment of any reactor technology and for developer nations rigid structures of governance are well established and engaged in the SMR discussion. The regulatory environment has however been shaped by the large reactor markets and thus will restrict the potential in SMR. With the rush to market a crucial enabler in delivering economic feasibility, the regulatory framework that currently exists could be a colossal roadblock, both at a domestic and international level, without considerable attention.

The cost of regulation is substantial, regardless of which national body is being considered. SMR technology is reliant on an economy of multiples and this will require tens of reactors to gain license approval. Similarly, being heavily reliant on principles of lessons learnt, design changes and alterations will present considerable programme setbacks. It is suggested that the cost of putting the AP1000 Westinghouse reactor through the UK’s Generic Design Approval (GDA) process under the Office of Nuclear Regulation (ONR) is in excess of $100mil - with approval gained in the US, China and the IAEA prior. Currently, any export opportunity could require complete re-licensing, at least for a FOAK build, which will impact directly onto the capital cost and therefore cost competitiveness.

Regulatory organisations generally follow either prescriptive, performance, or goal setting approaches. Prescriptive regulation, although simpler in regards to sentencing compliance, for SMRs will be difficult to achieve on an international level as it will present conflicting or constricting requirements in differing national regulation. It also presents great administrative burdens on the regulators and does not promote better practice [14].

Performance frameworks, such as the regulatory structure used in Finland, provides operator flexibility in demonstrating compliance with legislation. This engages operators directly in the management of safety and supports the improvement in safety performance through objectives. This does require better capability of the regulator; the burden is technical and not administrative which would be less costly to the regulator.

The Office of Nuclear Regulation in the UK, sentence compliance using the As Low As Reasonably Practicable (ALARP) principle, grading hazard and risk to inform the level of effort required to protect the system safety. This approach engages the operator in providing the most appropriate measure of resilience to safety based on a cost benefit analysis. This, as well as the performance based approach holds the benefit of an interpretive framework, allowing for an adaptive regulatory structure that would facilitate SMRs requirement for flexibility.

The CORDEL working group - Cooperation in Reactor Design Evaluation – have identified current regulatory approaches as a huge challenge for SMR [15]. They suggest there are two fundamental routes to consider, establishing new nuclear regulation in newcomer nations and modifying the current regulatory approaches in existing developer nations. Fundamentally, the changes must be supportive of international transferability and ultimately a global regulatory scheme.

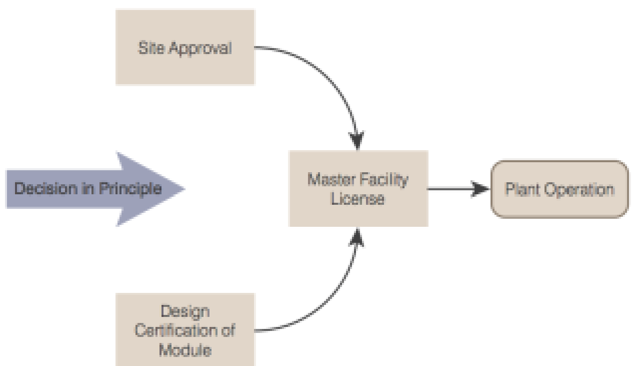

FIGURE 6 THE CORDEL LICENSING PRINCIPLES

As discussed, there are many fundamental changes that are required in order to aid the process of gaining design and site licensing approval. A model of regulatory programmes (Figure 6), demonstrates an approach that can support modular reactor licensing on an international scale.

Governments will be able to assist progression through regulatory approval, by providing design in principle agreement for a project. This could be an initial enabler for beginning construction works that are not safety related. By shortening the overall programme, operational periods will then be realised sooner providing earlier payback periods.

Modularised design approvals will promote flexibility in design. Customisation of deployment and changes in design due to lessons learnt can be facilitated by the differentiation of the licensing of modules rather than full systems, easing the burden of applying improvements and new technology. For large reactors, the ability to integrate modern technologies is a massive challenge, as gaining safety justification is too costly. Similarly, with plants that offer multiple uses such as desalination, combined heat and power and cogeneration with renewables, the operation and function of sites will require a more flexible regulatory approach, further supporting the use of a non-prescriptive framework.

A key regulatory enabler for deployment will be a design and license passport system. The transition to multiple unit siting and a broader market will be demanding on regulatory resource and therefore need considerable funding. By offering programmatic licensing, instead of unit licensing, a mass SMR market is possible and the installations become more financially attractive. The management of licensing can be more centralised and this will then allow for wide deployment, domestically and internationally.

To enable SMR technology deployment, the international regulatory philosophies must better align and provide a standard that offers multinational licensing. There will be likely challenges in the regulation of factories and operating facilities in different regions; misalignment of codes and standards; protection of IP and management of design change. But the aerospace industry operates under similar critical safety restrictions with modular components manufactured all over the world. The industry is not capable of enacting such drastic change overnight, however a step change towards global regulation is key. It must be advised by industry but driven through international political negotiation.

5

Hitting the Mark

Despite the many challenges ahead there is, without a doubt, a market for SMR deployment. It is not surprising that nuclear power is a strong consideration for base load power, but the SMR model relies on engaging areas of the market that are yet to be untapped in the nuclear arena. Climate change initiatives and the electrification of industry is generating a new demand for clean and versatile electricity providers. The energy solutions of today must meet the needs of the grid of tomorrow. Looking ahead towards combined heat and power, globally accessible power, mobile generating stations, remote generation, flexible operation, energy storage, district heating networks are the potential needs of the global energy future …

… and within the capabilities of SMRs.

As reactor vendors have historically limited their market opportunities following an economy of scale. Vendors must begin to differentiate their 'real' market potential from the exaggerated proposals suggested in marketing media.

One of the greatest risks for the SMR market opportunity is saturation. Without clear directive from policy makers the many design proposals on the table are creating stifling competition. For example, the UK trying to adopt multiple large reactor technologies simultaneously has strained the regulator, divided the market opportunity, as well as limited prospects of SMR progression. Developer nations with government ownership of utilities, such as CGN and EDF experience this to a lesser extent, however these nations have the issue of a conflict of interest against new nonnational vendors entering the market. Both scenarios present challenges and for these reasons, an internationally collaborative consortium for SMR deployment could prove a more convincing business case.

Within this report, there are too many proposed technologies to deliver a specific market strategy for enabling deployment success. But in all cases, it is irresponsible to perceive an entirely successful rush to market. New technologies require extensive periods of improvement in which mistakes can be made and lessons learnt adopted. Fortunately for SMRs, the costs associated with this learning period are much lower and the rate of learning should be much faster [16]. Nevertheless, SMRs will not be the knight in shining armour, striding into the market gracefully. They will stumble and trip, as all new technologies do, and it is only with the supporting enablers in place that the market persevere.

Instead of comparing the strategies of the potential winning vendors, it is more useful to consider other industry strategies in which modular build has been revolutionary. There are regular comparisons made to the ship building and aerospace industries, where modularisation has had a significant impact in lead times and quality. But the vision for SMRs should be wider, as this is no longer a technological argument, but a commercial one. IKEA has become a global household name in household goods, the Swedish ready-to-build furniture turned over revenue of over £30bn in 2016 [17]. Though the technologies are miles apart the market radicalisation is the same. Vendors should be looking at organisations just like IKEA to understand how to minimise manufacturing costs; develop standardisation to its limits; break in to new international markets and overcome vast competition. Vendors must begin to learn how to operate in a faster market to truly deliver on the SMR potential. Flat-packed reactors are exactly what SMRs are, so why not learn from the experts.

The enabling features of the market already exist, however the routes to market are the key phases that require more clarity. As discussed, the opportunity to work alongside national governments is vital in the FOAK phase. However, as key domestic milestones are achieved, there needs to be international partnerships in place, and agreements for deployment. An interesting case study is that of the South Korean power generator, KEPCO (Korean Electric Power Generations Company). The rapid growth of a domestic reactor design from the turn of the century has led to international deployment in the United Arab Emirates, with four APR-1400 units agreed. This reflects the route SMR globalisation will face into newcomer nations and its associated challenges, such as accountability of operation, design safety and fuel supply.

6

THE M IN SMR

One of the saving graces of the SMR challenge is the potential to modularise and standardise the famously complex nuclear systems, unlocking programme cost and time saving. With successful deployment requiring upwards of 50 reactors produced, the lessons learnt in manufacture and construction will generate significant benefits. Yet it seems that the word modularisation is now thrown into the mix without a clear understanding of what modularisation truly means and whether these vast benefits are in a realm of possibility.

[Modularisation]: *used for reducing the complexity of a system. This system is deconstructed into more or less independent units (“modules”). The modules should be able to exist independently from each other, but the system as a whole can only function as an integrated structure.* [18]

The concept of modularity can be compared to Lego building blocks. The construction of a system using simpler modules and sub-modules which are easily swapped out, repaired and redesigned. Though bespoke parts exist, the standardisation of components allow for extensive customisation and re-design. The volume production of the sub-components mean that the quality control and fit-up of modules and full systems is carried out with ease. The kits or parts are delivered to customers of varying capability, but the generic parts are delivered with procedure and process predefined and so construction and operation is simplified. Then, once the system reaches the end of life, deconstruction and dismantling is simple and well understood.

To meet demands of different national energy markets, modularity can provide customisation and flexibility in fabrication, deployment and regulation. As discussed, the ability to alter and change a module rather than full systems allows vendors to adapt to fluctuation in market and legislative demands. The tragic events of Fukishima led to industry wide modifications to safety considerations in operating sites. With modularity, these additions and repairs would become much less costly.

The division of systems in modules and sub-modules will ease the costly manufacturing and construction phases. But the benefits to programme management and delivery of multiple installations simultaneously will be equally enabling when establishing Nth of a kind production.

Modularisation also inherits the ability to transition many on-site activities into a factory. This build environment is better controlled and adjusted, improving quality assurance and control significantly. Nuclear power, compared to similar industries, experiences much lower rates of progress through design iterations [19] [20]. The volume production of SMR however allows for the lower learning rates to still deliver significant cost savings. This will only be true for design for manufacture across the entire facility, instead of only the reactor island.

Warehousing of spares, and the lead time on the large critical components no longer presents such a risk to the programme. Due to the standardisation of parts and modules, the compatibility of sub-components means that

floating stock does not have to be extensive, more easily balancing cost against programme delivery benefits.

Decommissioning modularisation

The nuclear industry suffers from a lack of foresight when considering the implication of decommissioning. The UK especially has experienced huge financial repercussions due to practices carried out in the rush to nuclear market in the dawn of atomic power.

Modularisation is a valuable tool in the manufacture and construction phases, but vendors can also consider these methodologies for decommissioning. The engagement of future requirements in the design stages should extend to end of operation activities, leading to further cost saving. Regulation surrounding both radiological and chemical hazards rely on control and understanding of the hazards. Modularity can offer solutions to containment and risk reduction.

Similarly, the modularity concept can encompass the decommissioning and waste management sector through the introduction of modular platforms and containers that can adapt to the requirements of the modular plants. With multiple units of the same design, the decommissioning activities will become more prescriptive and as such, the tools and technologies will require less bespoke capability. As well as this, module and parts are more easily recycled and reused for the next of a kind plant.

Conclusion

It is easy to understand how an industry of the technical minded has been drawn into the technological success, without significant consideration of the economic and commercial requirements. In the UK, competition is beginning to have a damaging effect on the deployment of SMR and has emphasised the overestimations of new technology hype.

Nuclear power will be a sizeable force in the global journey towards carbon free energy and SMR technology extends the nuclear reach to new markets and industries. There is, nevertheless, a significant journey ahead for the vendors ready to be bold and pursue SMRs into the new, nuclear economy of scale. The obstacles that lay ahead will require a number of key enablers, implemented into a stratified programmatic approach to plant deployment.

1. Novel and collaborative financing will create value for money whilst engaging partnerships and influence that will deliver programme value beyond the bank balance.
2. A transition away from state run utilities must be achieved with contradiction, through substantial provision and direction from government.
3. The global vision must be maintained through national collaboration, securing a foothold in the international market.
4. Extensive oversight is required in order to make changes to the regulatory governance, offering international transferability of SMR technology.
5. More realistic analysis of market potential should be demonstrated to support investment decisions and forge a route to programme deployment.
6. Understanding how modularity can be applied to the wider programme functions, as well as to construction and deconstruction, will help achieve greater savings in the lifetime of the system.

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