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Powering the 4th industrial age

Pioneering a Data Centre Partnership with Advanced Nuclear Technologies

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Executive summary

Data usage and processing are poised to undergo a radical expansion alongside our **ever-growing need for heightened connectivity and Artificial Intelligence** to assist our daily requirements for efficiency, creativity, and automation of repetitive tasks. The combined electricity consumption of Big Tech firms is projected to exceed that of some developed countries because of the hyper-exponential growth of Data Centres (DC). One thing is clear: DCs are there to stay and a sustainable growth-planning process is crucial.

Powering this remarkable growth, alluded to as the 4th industrial revolution, needs to take heed of one of the greatest challenges of 21st Century: **the energy quadrilemma**, which refers to the affordability, sustainability, security of supply, and social impact of future energy systems. Renewables are our greatest hope for a sustainable and socially acceptable transition, yet they suffer from intermittency. Against this backdrop of increased demand for clean energy, advanced nuclear offers a complementary and emission free solution.

Addressing this DC growth requires a paradigm shift and a new form of energy partnership: **a transformative new approach that would plan DC construction and growth by adopting Small Modular nuclear Reactors** (SMRs), and respect all four aspects of the quadrilemma. SMRs are designed to last over 4 decades, require long-term high-skilled local employment and offer a perfect platform for green growth, provisioning for an AI-driven expansion and leveraging on the 4th industrial revolution to build lasting infrastructure legacies. Instead of adopting ephemeral solutions, DC planners have the means to make a difference and **change the course of the energy market**. They can be a catalyst for industrial clusters, and accelerate the Net Zero Carbon transition, for example by bolstering the H2 economy.

Despite offering affordability, security of supply, and sustainability, SMRs have thus far been overlooked. If their mass production is to **succeed in offering economies of scale**, both a secure supply chain and end-user agreements by energy intensive users are needed. This presents a unique partnership opportunity.

This paper therefore explores this opportunity through **the case study** of an integrated deployment plan for SMRs and DCs within a microgrid guided by principles of scalability and efficiency, exploiting synergies between growth phases, green job creation and long-term energy supply stability and sustainability.

Embracing this **partnership** could enable the Data Centre sector to play a pivotal role in shaping the future of 21st Century's clean energy infrastructure and fostering a new generation of meaningful employment opportunities.

Foreword

All the work that I have done in my life will be obsolete by the time I'm 50.
Steve Jobs

Those are memorable lines from an interview he gave in 1994. "Cathedrals and renaissance paintings will be admired for centuries – he went on to comment - while the products of the digital industry have a near-instant obsolescence to them." Yet it does not have to be so…

Data Centres (DCs) are now the prime machinery of the digital age, and they have the potential to be at the genesis of a new generation of integrated, digitalised and highly efficient energy systems. The scale of DC demands are growing to the extent that now **DCs can be the anchorage** around which industrial clusters can be formed, uniting complementary applications, exploiting the synergy between power-, heat- and water- intensive industries and creating highly integrated energy and fuel supply systems. This however needs a paradigm shift in the way future energy systems are planned. The choice however is clear: continue with siloed approach of segregated industries that leave no lasting impact, or **embrace integrated master-planning** of new industrial clusters that generate green jobs, support local communities and accelerate the transition to Net Zero Carbon through a resilient and decentralised energy infrastructure.
The unique contribution of Small Modular Reactors (SMRs) deserves a thorough examination. SMRs can offer clean, reliable and affordable energy to sustain industrial activity and community employment for decades, leaving a **permanent legacy** of growth, skills and self-reliance.

Figure 1 - Steve Jobs, a titan of silicon valley lamented the transience of digital word (photos: Steve Jobs archive).

1. Data Centres: a Hyper-exponential Growth Story

Klaus Schwab, the World Economic Forum founder, labelled in 2016 the current technological evolution as the fourth industrial revolution. Increased connectivity, smart technologies and digitalization have such an impact that it forces us to rethink how human societies are organised. Data Centres host the effective information processing machinery that powers this revolution and subsequently the need for DCs have also skyrocketed. A whole raft of statistical evidence is available that points to a hyper- exponential growth of data since mid-2000s. The trend is expected to continue beyond the first half of the century boosted by the advent of **Artificial Intelligence**. Global internet traffic has expanded 20-fold since 2010[1], and the trend continues to unfold on an exponential trajectory.

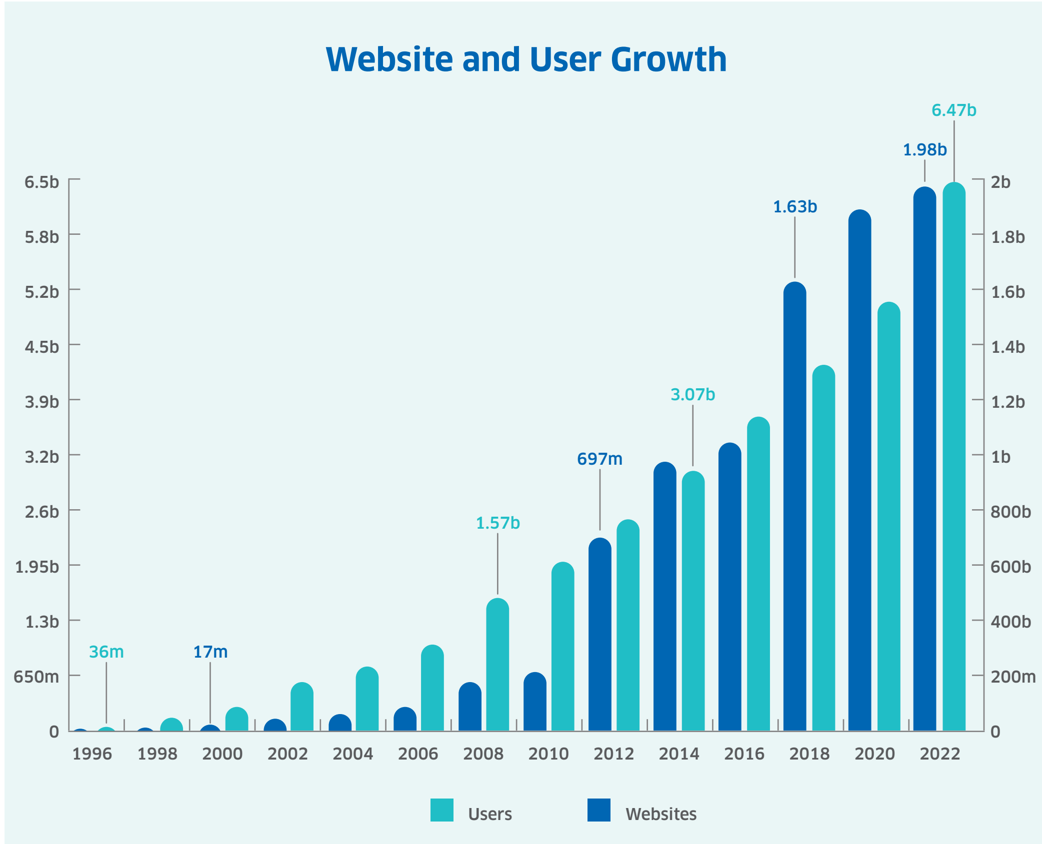


Figure 2 - Hyper-exponential growth of data services and internet (source Land Vault)

[1] *International Energy Agency, Sep 2022* (link)

At **2.5%** to **3.7%**, Data Centres globally have a larger GHG emission footprint than deforestation (2.2%), shipping (1.7%) or aviation (1.9%).

When did Data Centres become a Country?

This insatiable demand for data storage and exchange comes with a hefty energy penalty. Collectively, Data Centres worldwide are now estimated to consume between 3.6% to 6.2% of global electricity, and account for 2.5% to 3.7% of global greenhouse gas emissions[2]. At over 200 TWh/yr, global data centre energy consumption exceeds national energy consumption of most economies.

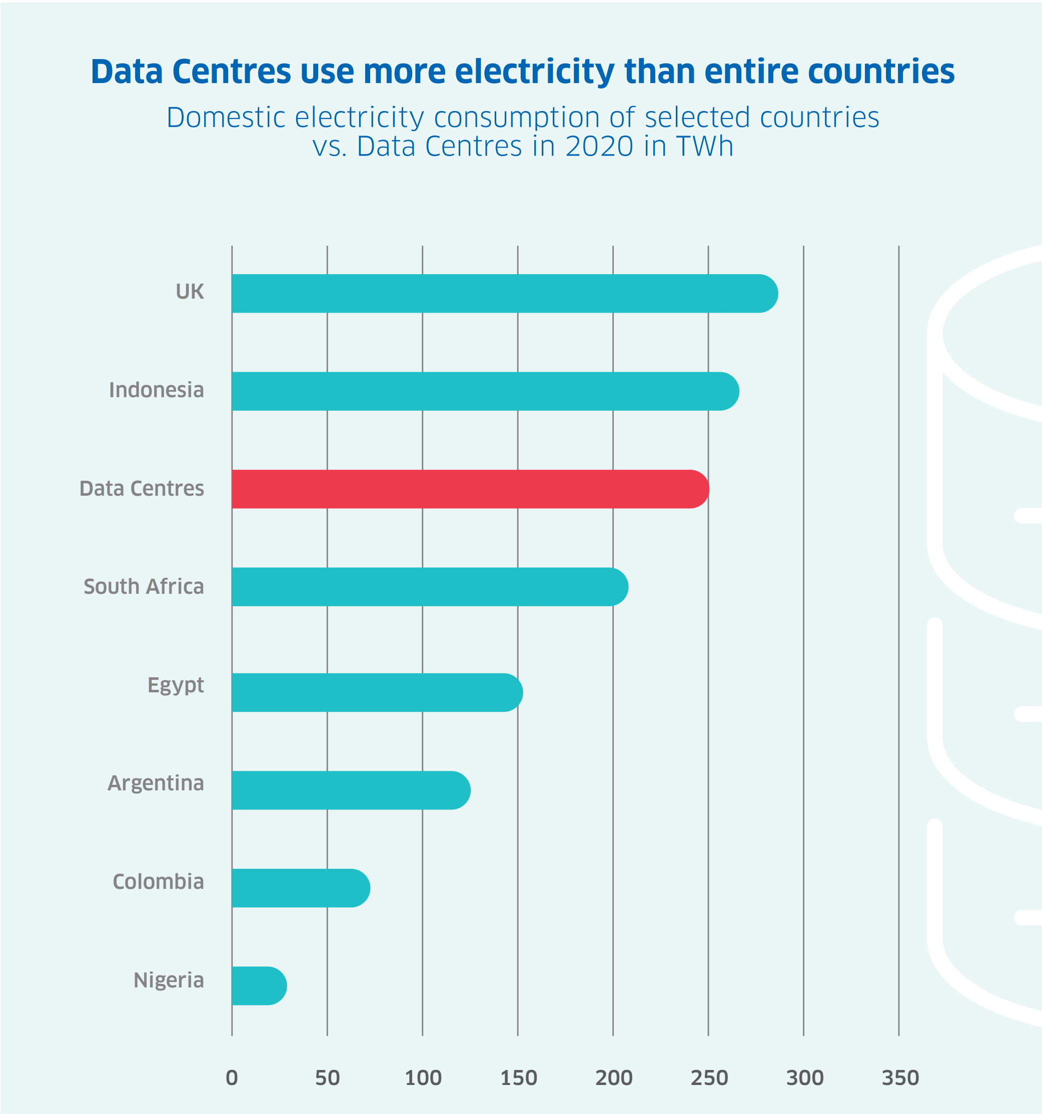


Figure 3 - based on US Energy Information Administration database (in which 218 countries are listed), only 22 countries worldwide have a bigger annual electricity demand than the global portfolio of DCs. That is to say nearly 90% of countries worldwide consume less electricity than the aggregated global DC demand. Colossal aggregated energy consumption, together with DC reliance on potable water for cooling results in an environmental impact that, given its growth trajectory, is becoming under closer examination of regulatory bodies.

[2] *Climatic database as reported in CIBSE Journal (June 2023)*

2. The Energy Quadrilemma

Cheap, available fossil fuels dominated the energy supply starting from the 17th century. It enabled the industrial revolution and the "IT revolution" to take place, alongside a sharp increase in energy demand throughout the three centuries. However, fossil fuels' impact on public health and global climate needs to shift way from these energy sources.

Affordability alone cannot be the only driving factor when planning an energy mix. The tangible effects of climate change call for solutions with minimal **environmental impact** while guaranteeing the **security of supply**, which remains the main concern of industrial end-users. This debated trilemma is further complicated by public perception and acceptance, jobs creation and inclusion of **local communities**.

It is indeed a major challenge for an energy source to find such a balance between the four aspects of the energy quadrilemma. That is where Small Modular Reactors could provide a response.

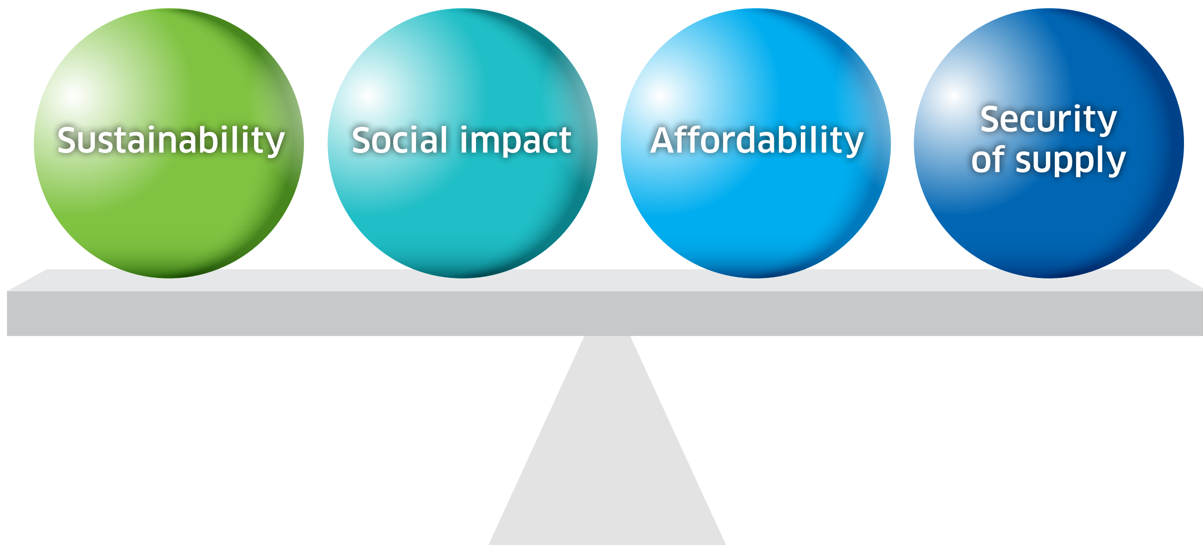


Figure 4 - The energy quadrilemma

Innovative low-Carbon energy sources such as Small Modular Reactors (SMRs) are being developed enabling new industrial applications and higher integration with final users, and becoming the perfect partner to foster the growth of industrial clusters.

In this document the **partnership** between Small Modular nuclear Reactors and Data Centres is **explored in a holistic way**, taking into account the four key issues in energy planning: affordability, sustainability, security of supply, and societal impact.

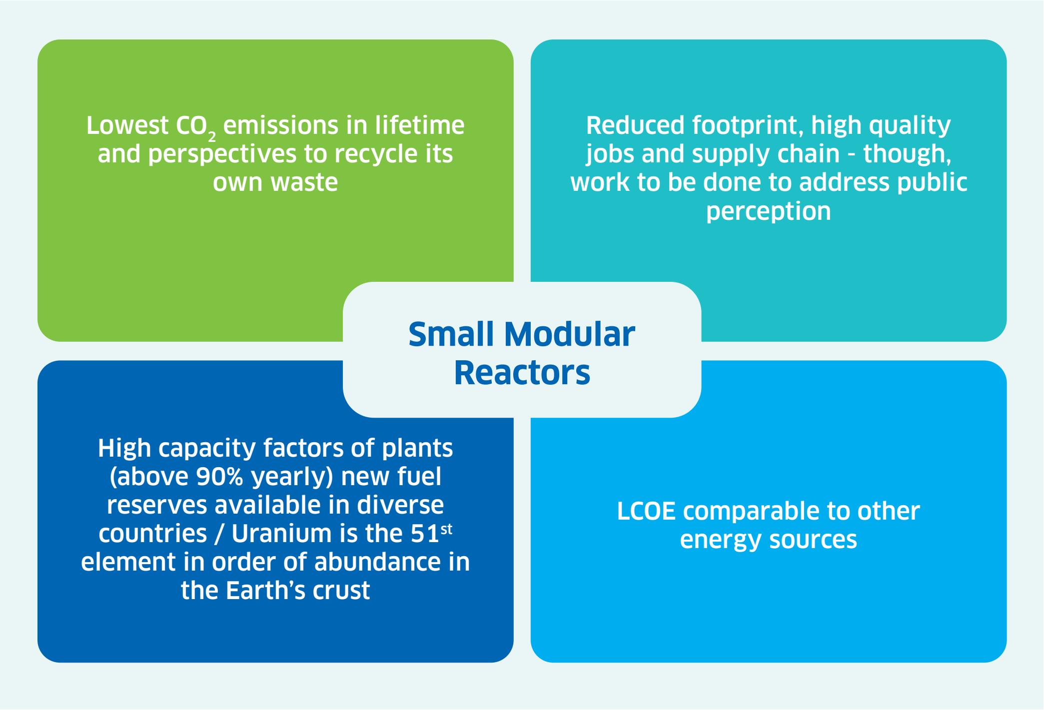


Table 1 - Nuclear technologies can bring a balanced response to the 4 aspects of the quadrilemma.

Reframing nuclear energy technologies: SMRs

Small Modular Reactors (SMRs) represent the nuclear industry's answer to the evolving energy market, aligning with the growing focus on renewables and Hydrogen. This response comes in light of significant challenges encountered over the past decade.

Boasting over 90 designs developed in under a decade, SMRs share a unified strategy:

- *expediting construction timelines through efficient manufacturing processes,*
- *incorporating passive systems and leveraging inherent physical phenomena to enhance safety features,*
- *minimizing capital expenditures through smaller, simpler, and standardized construction.*

This not only addresses safety concerns but also opens up increased financing opportunities.

The diversity of modular solutions covers power outputs ranging from 1,5 to 300 MW(e)

In response to that, over just the last 10 years, the nuclear industry has strived and achieved significant advances in developing Small Modular Reactors (SMRs), reflecting growing market interest and potential for this innovative technology. These advancements have been driven by various factors, including increased energy demand, the need for decarbonization, and a shift toward more flexible and distributed power generation systems.

This effervescence has given birth to more than 90 unique SMR concepts that encompass a wide variety of technologies: from evolutionary designs, improving today's water-cooled reactors, to promising next-generation nuclear reactors.

SMRs refer to smaller, simpler and standardized advanced reactors. They transform the traditional project-based approach of large nuclear endeavors to a product-based approach building on modular construction features to achieve the much needed promise of faster construction time.

3. SMRs and DCs: a perfect partnership

Addressing DC growth requires a transformative new approach that would plan construction and growth by incorporating SMRs. With an eye on matching the power growth and ensuring long-lasting security of supply, DC planners have the means to change the course of the energy market, be a catalyst for industrial clusters and accelerate the Net Zero Carbon transition.

Using nuclear as an option to decarbonise a Data Centre makes sense beyond SMRs: for the first time in January 2023, a first 48 MW Data Centre started operating in direct connection with the Susquehanna power station in Pennsylvania.

However, large power plants can be found on a reduced number of sites, which further limits the future possibilities of joint deployment. SMRs' reduced footprint and enhanced safety features will multiply the choice of sites, whereby co-location with DCs can become the norm.

3.1 Power matching

Two options can be foreseen when planning SMR-powered new DCs:

- Energy hub: Integration of a DC within a low-Carbon powered energy hub, where the overall installed capacity is comfortably above the DC demand. The SMR will provide the backbone of the energy supply, while storage systems and UPS can be integrated at need.
- Dedicated MMR plant: A perfect fit of Micro Modular Reactors and exact DC demand, enabling virtually parallel deployment of DC modules and reactor modules

What is a Micro Modular Reactor?

MMRs are generally defined as those reactors with power output below 10 MWe. Although originally designed for niche and remote applications, over the past 2 to 3 years their use has been explored for large industries.

Main advantages:
quick construction, high multi-modularity, versatility

Main disadvantage:
cost competitiveness

MMRs are likely to require quicker permitting times than SMRs, perhaps even shorter than DCs in a country where the first-of-a-kind has already been deployed. Moreover, the lifetime of the installations could be rendered compatible: MMRs usually have a design lifetime that depends on the power demand – the projected end-of-life of the plant and DC can be matched by calculation beforehand.

3.2 Security of supply and reliability

The concept of high availability is common for IT systems, where the required uptime to guarantee service continuity is very close to 100%.

A typical value is "5-nines", or 99.999% of uptime, corresponding to a downtime of slightly above 5 minutes per year. This concept is not applicable to single electricity supply systems (95% in the best-performing nuclear power plants, down to 25% for intermittent renewable energy sources such as solar panels).

High Availability of Data Centres cannot be guaranteed by the energy supply systems, but rather by the grid, usually a dedicated microgrid that can operate also in "island mode", in which different energy sources are complementing each other in all situations. Nevertheless, the higher the availability of the single sources, the least CAPEX on back-up sources or the need for idle assets while designing out excessive battery deployment eliminates mining of precious metals.

SMR powered microgrids eliminate network distribution losses that in the UK are 8% (grid power) and 8-10% (gas network)[3]. They can facilitate the clustering of complementary industries (i.e. power and heat intensive sectors). Thus, fuel utilization is optimized by distributing the surplus heat in agricultural, process and factory or space heating requirements via local DHN[4].

When the SMR and the DC cannot be located close to each other, "virtual coupling" is possible. The SMR is connected to the downstream energy system that provides emission-free power to the DC.

SMR can provide primary energy, while Fuel Cells act as secondary power supplies to achieve resilience and diversity. The onsite pink H_2 production replaces back-up engines and battery storage. Sufficient H_2 can be stored to power FCs when back-up are required. Surplus H_2 can enable a secure emission free local H_2 supply to support power, heating and transport vectors of energy.

[3] *UK parliament record on energy network losses (available online)*
[4] *District Heating Network*

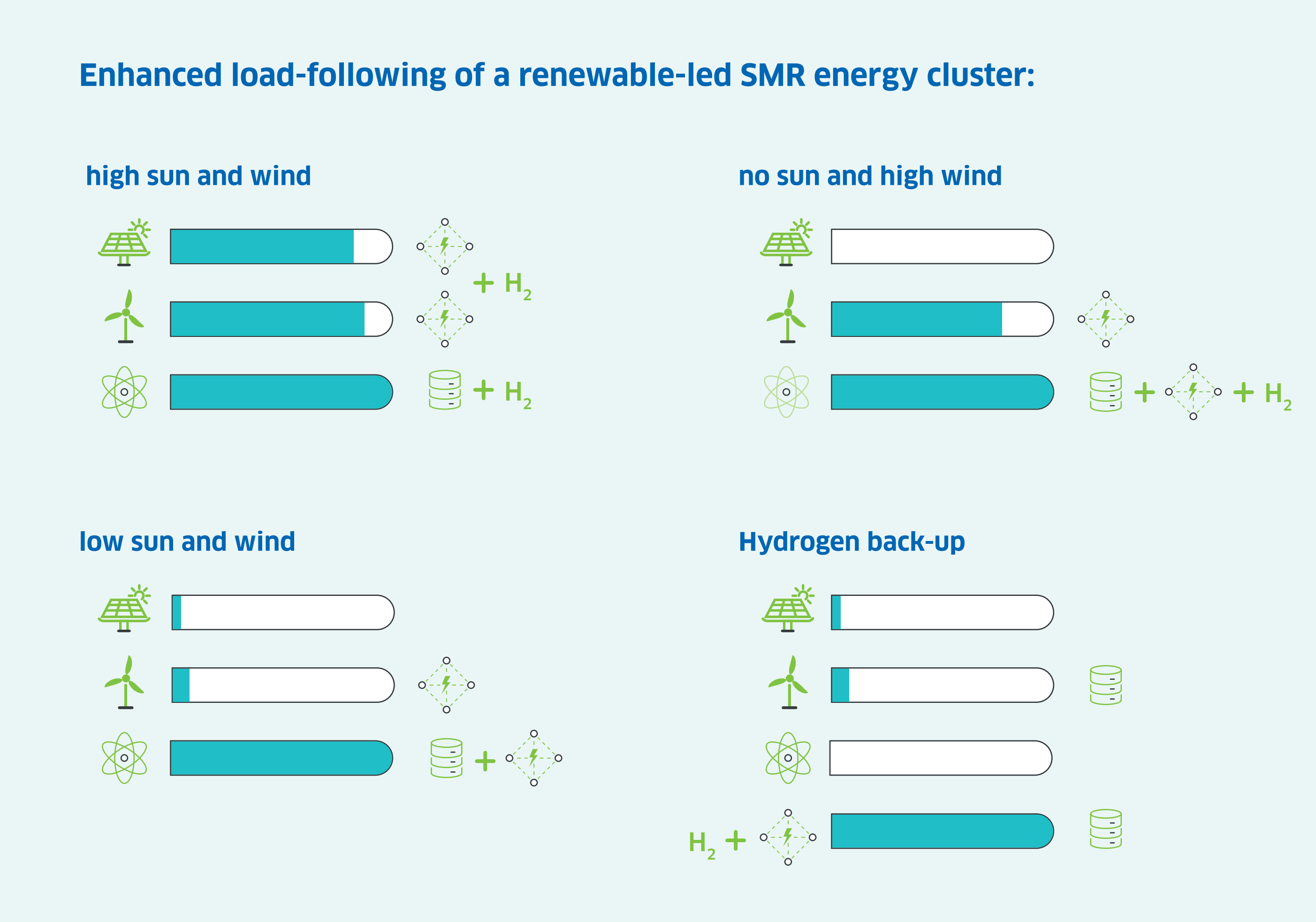


Figure 5

3.3 Time to market and lifetime (Planning a decarbonized SMR hub)

Only a decade ago, designing and building a Data Centre typically took around 18-24 months. These days the facilities can be completed in 12-18 months if based on standardized designs and an efficient construction management. Even larger hyperscale Data Centres (generally 20MW+) can be built **in modular phases**, which can easily be aligned with SMR installation as part of a larger modular approach.

Likewise, construction times for SMRs can be reduced thanks to their smaller, standardized, and simplified features, however they will likely take longer than the ones of DCs. The lifetime difference of DCs[5] (15-20yrs.) and SMR (60yrs.) also needs to be reconciled within a master planned local energy network partnership to avoid a negative business case due to a single demand (the DC). An energy hub planning philosophy therefore needs to be **forward-thinking**: new DCs could safely join an existing off-takers cluster after the Commercial Operation Date of the SMR. Benefits of such energy hub are examined more closely in the next section.

[5] *One exception may be the Micro Modular Reactors, see dedicated box*

Depending on location around the globe, permitting will also need to be considered as part of the timeline. On that subject, nuclear permitting timelines are likely to always be longer than DC ones. However, there is an opportunity to find synergies between the two permitting procedures to shorten the overall duration.

3.4 Socio-economic Impact

One of the policy challenges of global economic growth is to decarbonize as rapidly as possible, while maintaining/improving citizens' earning power and quality of life. The UK example demonstrates that low-Carbon economy sectors can grow four times faster than the rest of the economy as a whole[6].

To achieve the greatest socio-economic benefit while maintaining growth, the approach widely adapted is to facilitate a close partnership of government, business and civil society, foster innovation and recognize the centrality of local employment. An SMR-enabled local energy network meets all of these objectives.

As a heavily engineered critical infrastructure, SMRs require alliance of multiple parties, will provide meaningful and long-term local employment while forming decentralized pillars of an advanced and emission-free energy system.

Most SMR technologies are designed for a lifetime duration above 40 years. By exceeding the design lifetime of DCs, SMR deployment has the ability to **support the creation of a local energy hub** that can bring together power and heat intensive industries, as well as fuel supply chain operators. SMRs work most efficiently by a stable demand, which can be enabled by a **multi-vector energy system** (power, heat, H_2 and grid support services). These energy vectors unite players from multiple industries and reinforce the creation of local employment in green industries. The multiplicity of users involved adds flexibility across energy vectors (i.e. power-to-gas or H_2) and is identified as an essential component of integrated local energy systems[7]. Local community energy needs (such as heating via a district heating network) can further improve SMR plant efficiency, maximise the synergies of complementary local industries (heat, power, e-fuels) and add vacancies that ensure longevity and resilience of SMR's microeconomic benefits.

[6] *The Clean Growth Strategy (2017), UK BEIS department, available online*
[7] *Rebecca Ford, A Framework for understanding and conceptualizing smart local energy systems (2019)*

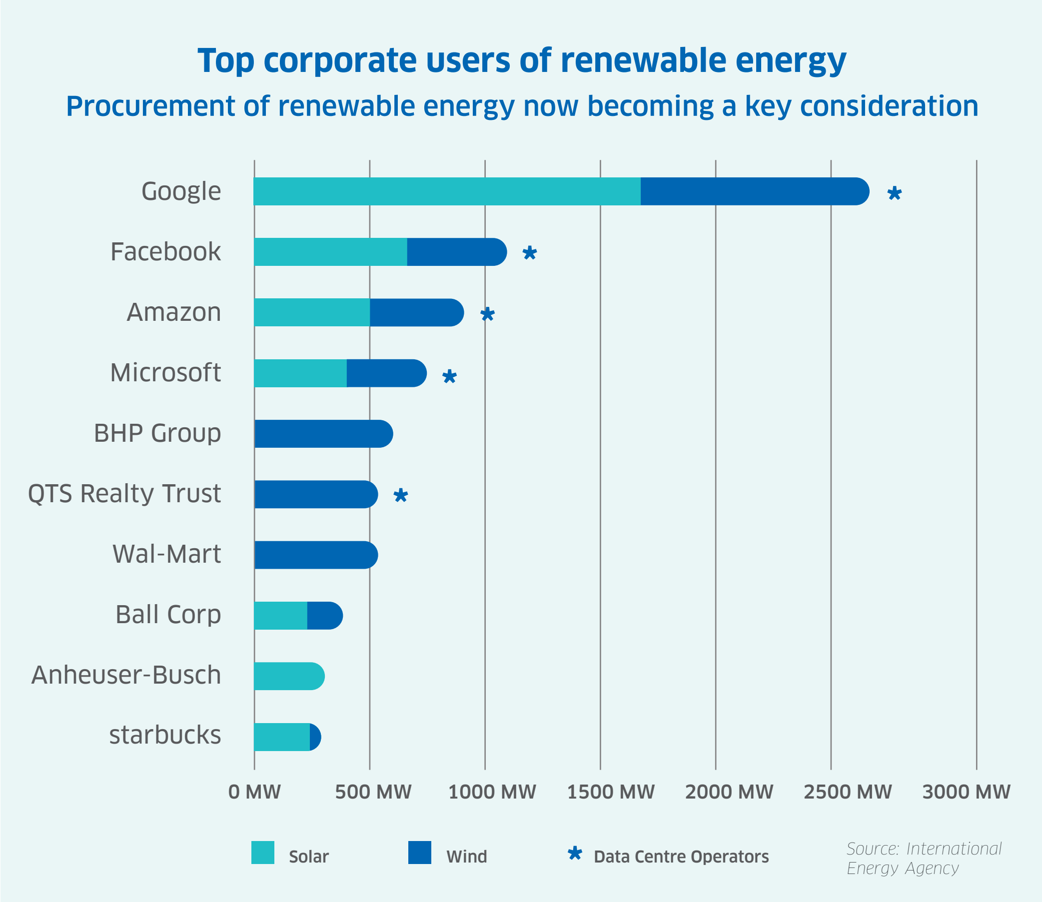


Figure 6

3.5 Potential Investment Profiles

Climate change found among the first responders the Top corporates in tech sector (see fig.6) were found to be among the first in adopting renewable energies and forward thinking about their environmental impact and decarbonization objectives. The global energy crisis and supply chain crisis have pushed more organizations and accelerated the efforts of those already seeking low-Carbon advanced energy sources.

Several high profile organisations have also made bold commitments to the development of advanced energy sources, clearly signaling their eagerness and need for large low-Carbon energy sources. For instance, Microsoft recently signed a new hourly energy-matching agreement with Constellation Energy Corporation (for Microsoft's data centre in Virginia (US)) in order to get very close to the goal of 100% Carbon-free operation. Cyrus One, a US based colocation developer are one of the largest and are actively promoting nuclear technology on social media, together with some data centre developers, openly considering suitability of SMR's for their future projects on social media.

> *Data center planners and owners wield significant influence in guiding technological decisions and expediting the adoption of innovative technologies. Their expression of interest, albeit secondary to deliverability, is a potent force that presents a golden opportunity for SMR vendors to bolster their business case.*

4. A Case-Study

Nuclear power is a capital-intensive commitment, but with the benefit of guaranteeing long-term stability of the supplied energy prices. When brought together to support the growth of a DC provider, **smaller Modules** (e.g. a 10 MWe MMR) have the benefit of closely and economically matching lower DC loads at the initiation of the microgrid. As the microgrid and DC growth evolves, **multiples of larger SMRs** that can be deployed together with initial units would offer resilience, diversity and load following capabilities. The following image illustrates a 4 phase microgrid evolution using a succession of 10, 50 and finally 150 MWe reactors to create a permanent microgrid scheme offering 260MWe with cogeneration potential.

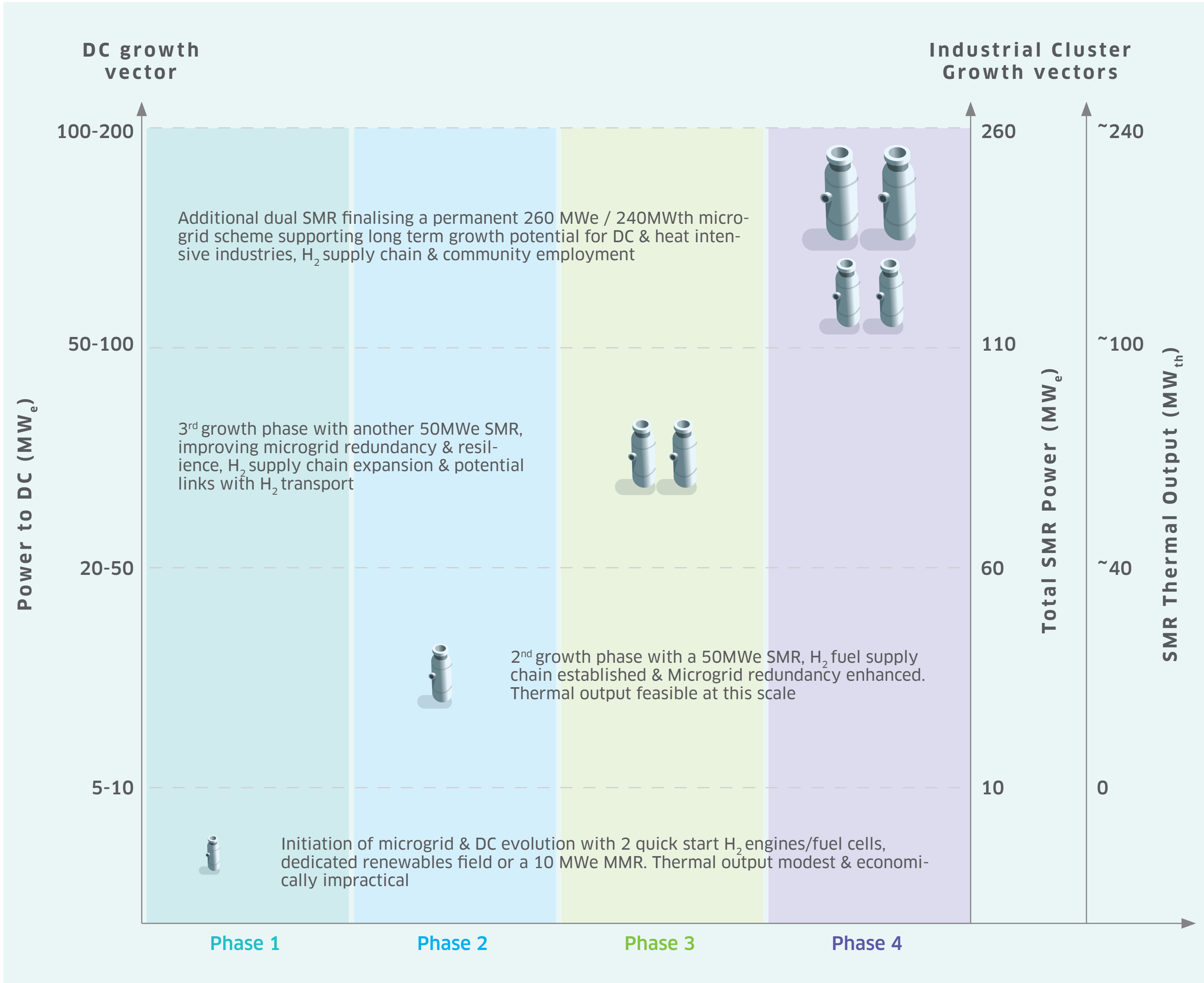


Figure 7 - An SMR-based microgrid timeline supporting the gradual evolution of a DC within a wider industrial cluster.

Additional power can **support by-products** such as H2 fuel supplies which enables the energy partnership bodies to expand its offering and enhance economic returns. The combination of SMR's and DC's yields significant heat outputs which can be utilised in other applications without distribution losses or discharging into the atmosphere. These may include (but are not limited to) the following:

- Low grade heats for local residential/commercial developments or district energy networks within a radius of up to around 20km (beyond which heat losses become significant).
- Agriculture and green house food production.
- Direct (or cascaded) thermal export to process & manufacturing industries.
- H_2 production for fuel cells, industrial processes or Hydrogen vehicles and infrastructure.

The traditional N+2 configuration that underpins the conventional DC design can be met by ensuring redundancy consideration in deployment of SMR units, but also given the complementary of SMRs with H2 fuel supplies, electrolyzers combined with fuel cells can be configured to replace the traditional diesel backups. SMRs and fuel cell technologies have evolved to have exceptionally high reliability attributes (respectively able to achieve 90%-95% and 95%-99% in configurations incorporating redundant components) which can meet the **Uptime Institutes** ties III and IV adequately.

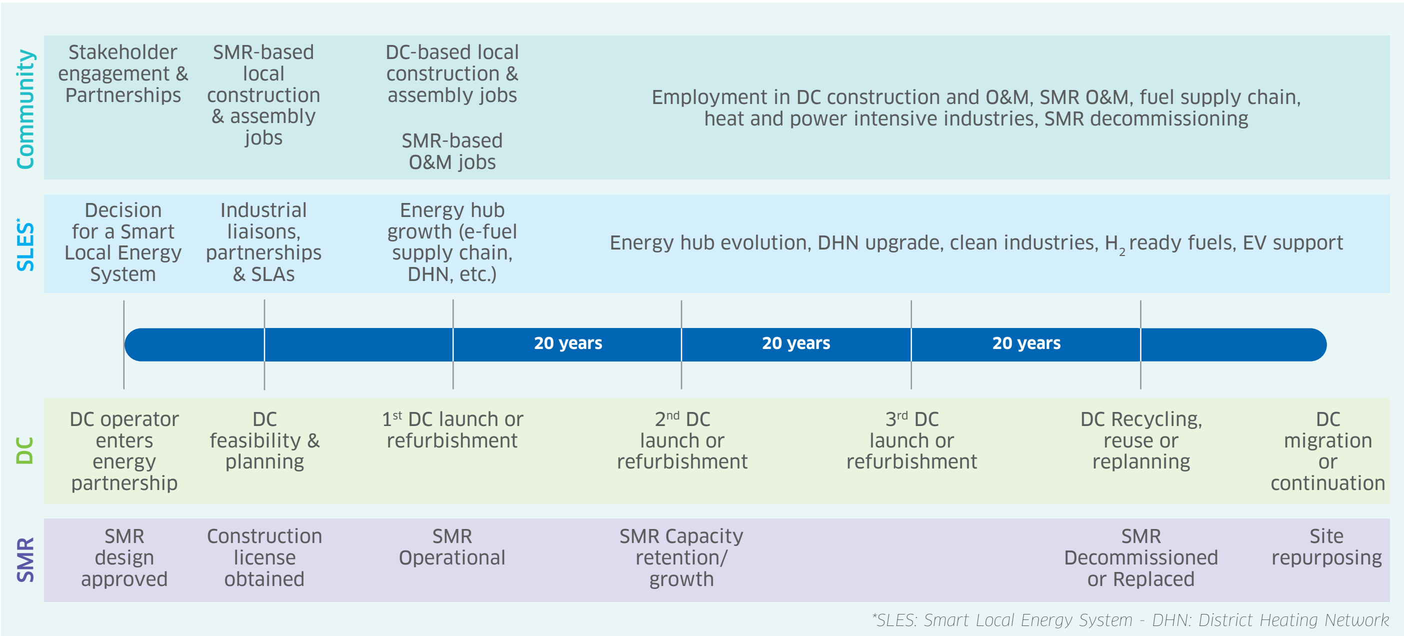


Figure 8 - Key actors, beneficiaries and indicative timeline of a SMR-powered DCs partnership. The centrality of local employment is of prime importance to the community and regulator that stand to benefit from such advanced infrastructure programs.

As outlined in the fig. 8, establishing a SMR-based scheme requires **multiple stakeholders**, local communities and regulatory bodies to collaborate closely. However with timely formation of energy partnerships and stakeholder engagement, it will be possible for SMR powered DCs to initiate a long-term program of infrastructure building that offers the host community meaningful employment not only during construction and refurbishment phase, but also consistently throughout the lifecycle of the industrial cluster.

5. Conclusions

Small Modular Reactors (SMRs) can provide zero-emission, reliable, and sustainable energy to data centre communities to support their **long-term growth**. They can help decarbonise existing data centre portfolios that may be spread across different locations. Furthermore, civil nuclear facilities have a track record of creating skilled jobs for host communities over many years.

SMRs will enable the DC sector to become the **foundation of the 4th industrial revolution** and a driving force behind new energy and infrastructure building partnerships. These collaborations will lead to significant investments in regional infrastructure, the creation of meaningful and lasting employments and the consolidation of international fuel and resource supply chains.

The deployment partnership will follow a phased construction process and will take advantage of the modular design of both DCs and SMRs. This approach will make it possible to initiate a long-term programme of infrastructure building around future data processing campuses.

When Data Centre planners **express interest** for a technology, the influence over strategic decisions is significant and dearly needed by SMR vendors, that could use this opportunity to accelerate their deployment and bolster their business case.

What does it take to build a Data Centre?

Data Centres consume a large quantity of energy in terms of electrical power but also have other demands and challenges when planning a new site:

- Water demand for evaporative cooling – Data centres consume billions of litres of water per year for evaporative cooling to optimise power usage. This can overburden water supply networks and significantly impact on water resources and communities. Utilising cooling technology operating at higher heat rejection temperatures can largely eradicate the use of evaporative water in most climates or lead to a substantial reduction in water consumption. However, this will result in an increase in power, that could be met by guaranteed electrical output of an SMR-driven microgrid with zero-emissions.
- Spatial requirements, often meaning locating in remote areas rather than inside cities and towns – Data Centres take up large surfaces so more remote sites are often targeted to enable the size requirements to be met. Challenging construction programmes, typically 6-18 months. This will vary dependent upon the capacity of the data centre, the size of each phase of the build and if there is a template design in place or whether a brand new design is required by the client or prospective tenant.
- Power availability – Not only are large amounts of electrical power required, the availability and reliability of this power is important for the smooth, uninterrupted operation of the IT servers. Network connectivity – Data Centres require sites that have excellent connectivity to the public network and its prospective customers, preferably in close proximity. Back-up generators and battery systems are often idle assets, contributing to CapEx, Opex and WLC[8] of the design. There will be bottlenecks (short to medium term)[9] in the supplies of lithium and cobalt while these components are replaced with more abundant elements within an ethical supply chain.

[8] *Whole Life Cycle Carbon*
[9] *MIT report* (available online)

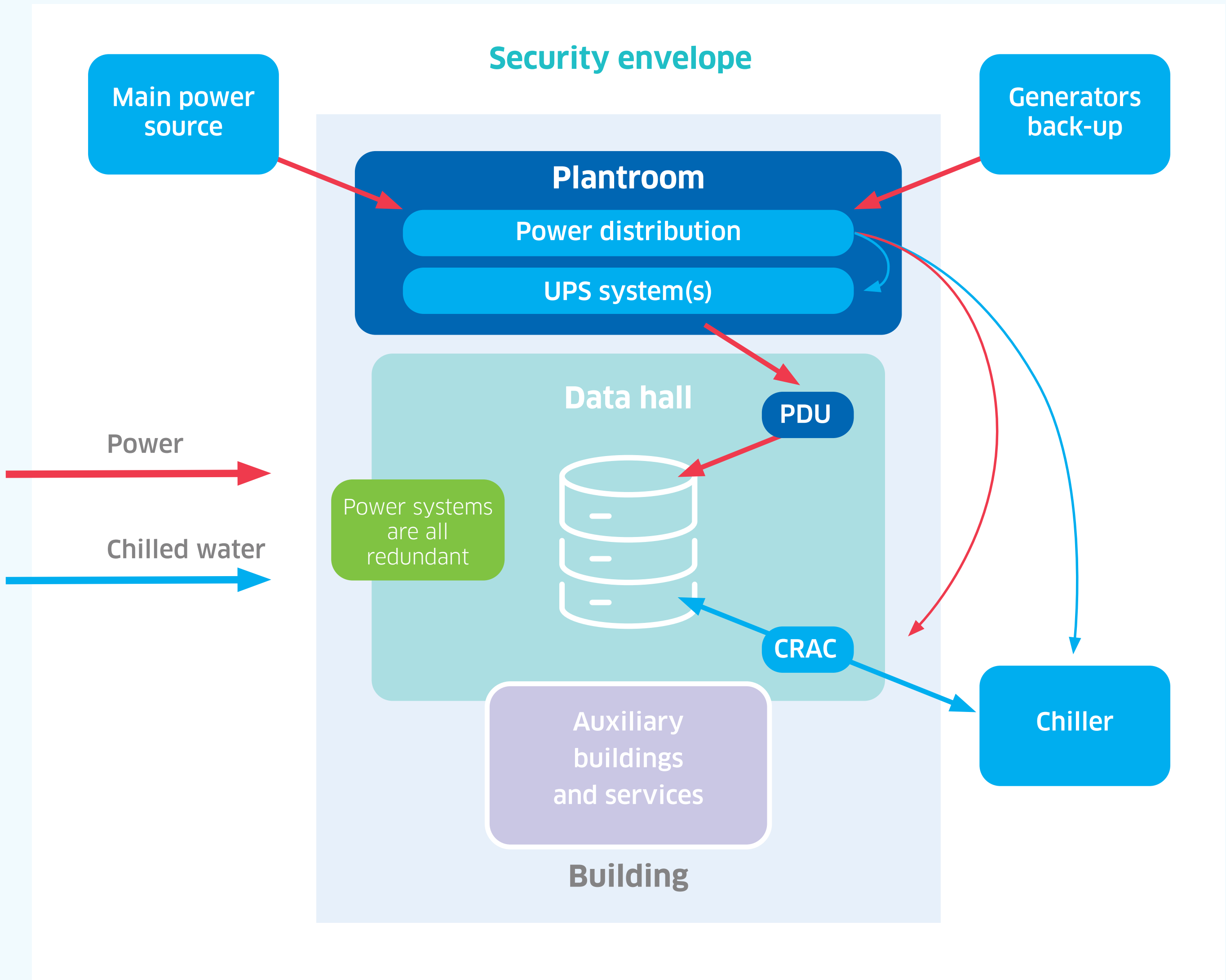


Figure 9 - Typical Data Centre components (reproduced from CIBSE KS 18). Keys: Power Distribution Units (PDU), Computer Room Air Conditioning (CRAC), Uninterruptable Power Supply (UPS).

SMRs in a nutshell

SMR Affordability

By shifting from economies of scale to a mass production of standardized and simplified designs, SMRs are cutting by orders of magnitude the maximal exposure investors may face. Indeed, with capital investments in the billion dollar range or below (rather than typical tens of billions for large reactors), SMRs bear **financial** risks more common to large industrial companies.

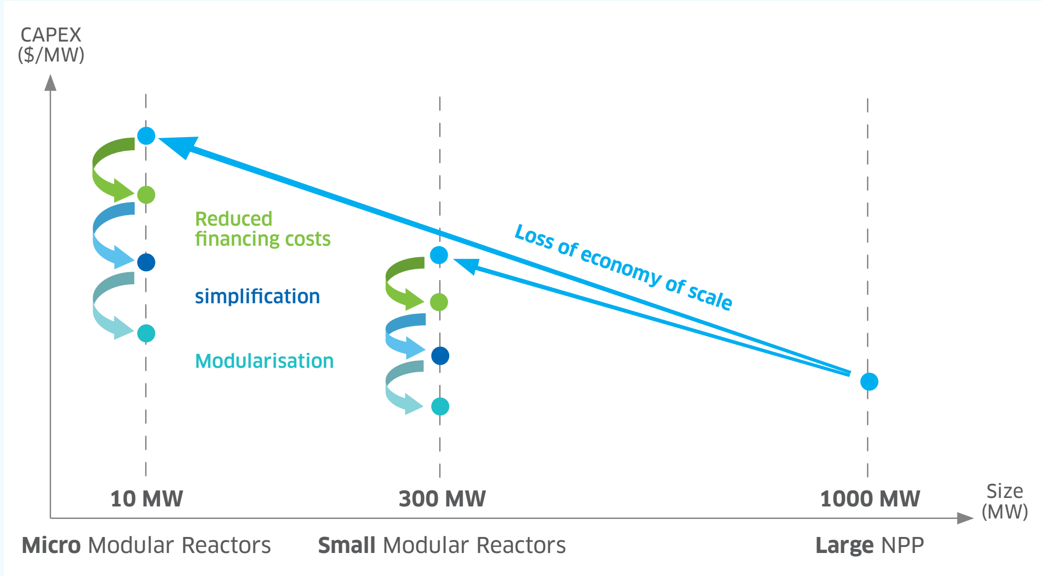


Figure 10 - Reduction of financial risks, simplification and modularization in SMRs are expected to drive down capital costs below large nuclear projects. It is not possible to identify an optimum size, as other factors enter into play (reactor type, fuel type,…). Focus is made on CAPEX as it is the main component of the final energy cost (~80%), while OPEX remain marginal. However, their weight may be reversed when decreasing the size to micro reactors.

Their **simplified** design due to the smaller size allows for further cost-cutting at the level of the structures, systems and components. The example of the 300 MWe Boiling Water Reactor BWRX-300 of GE Hitachi is a simplification from the already licensed Economic Simplified BWR, although the size was reduced by a factor of 5, the volume of the civil structures was reduced by a factor around 10.

The **modularity** aspect of the Small Modular Reactors consists of their large reliance on factory-manufactured modules that are transported and assembled on site, with the objective to decrease the site construction efforts.

Security of supply

In a future energy scenario dominated by intermittent energy sources, the volatility of the energy prices will surpass what we have experienced recently. Negative prices will become more frequent when the wind blows or the sun shines, while very high prices will prevail when it is not the case. Technologies that can compensate such variability will have a strong business case.

SMRs are designed to accommodate load variations; some of them even integrate energy storage to supply peaks of power for short durations. Little dependent on critical materials[10] and on fuel cost[11], SMRs will deliver energy with high availability (overall over 90%) combined with enhanced deployment possibilities. As their footprints are smaller than large nuclear power plants, they can be located closer to industrial installations and end-users, reducing energy transmission costs.

With 40+ years lifetime and a fuel supply that is requested only every few years at best, nuclear technologies shift the energy strategy from a day-to-day basis to long-term planning.

Resilience in the age of Hydrogen

DCs are critical infrastructures. They require additional energy generation and storage capacity available on site to ensure continuity of service under any circumstances. Building this spare capacity results in disproportionately high levels of embodied Carbon, as well as in assets that are idle and underutilised for most of their working life.

If coupled with an SMR, a "pink" nuclear-generated Hydrogen production line together with fuel cells can replace the traditional approach of building redundancy (which involved multiple back up engines and batteries sitting idly). Surplus Hydrogen production can easily support the wider energy network on transport, heating and power generation, while sufficient Hydrogen can be stored on site to guarantee backup power at all time. The Hydrogen production gives more flexibility for DC to grow at any pace, while the SMR asset operates at full capacity to bolster the local electricity and Hydrogen energy vectors.

The UK Hydrogen Strategy pursues 10GW of low-Carbon H2 production by 2030 to power its economy. Japan, Australia, China, Chile plus most of the EU member states have national Hydrogen strategies.

Sustainability

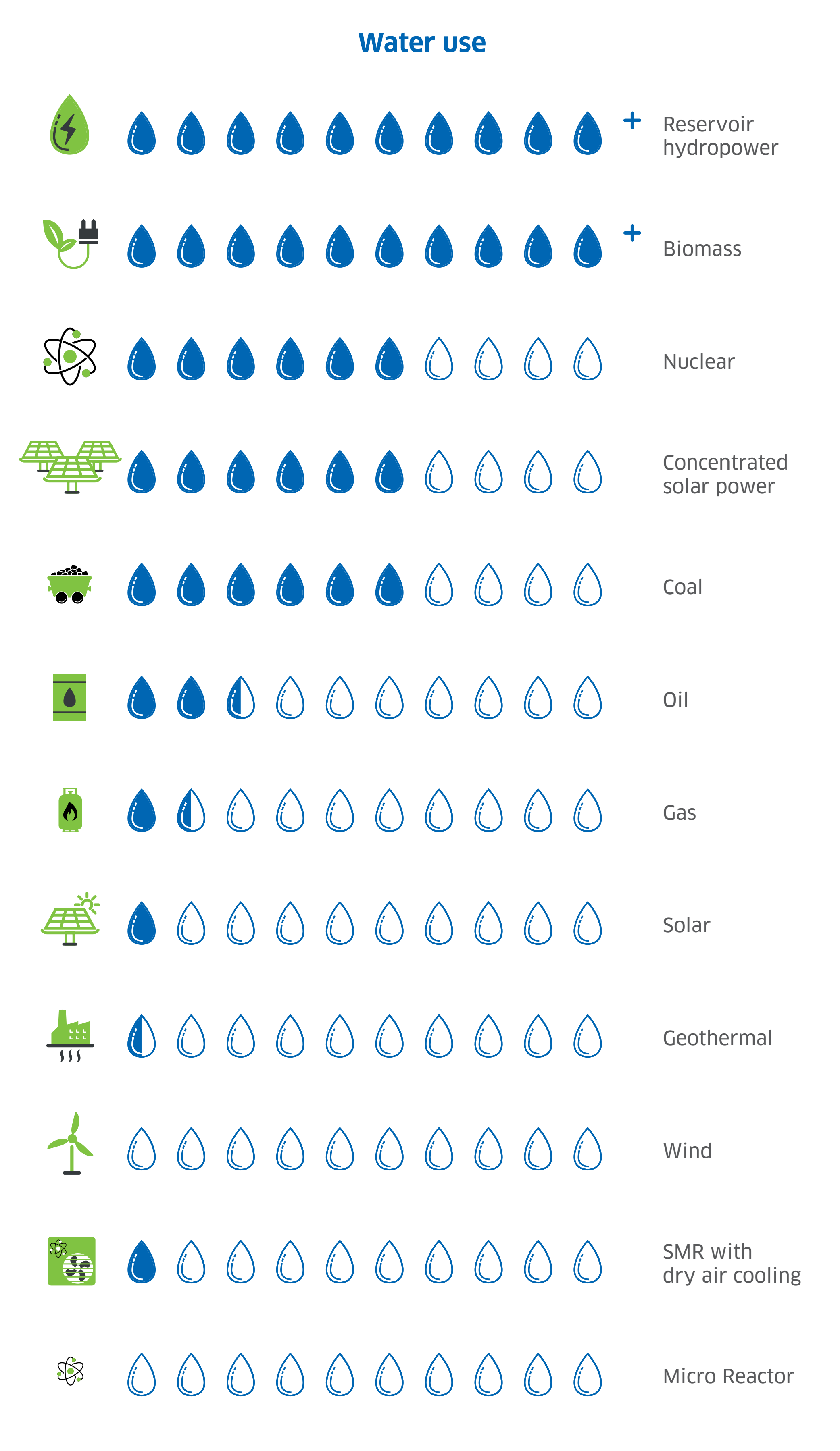
Nuclear is the most energy dense of all emission-free sources of energy. It requires 350 times less space than onshore wind, and over 5000 times less than biomass for an equivalent amount of power generation.

Land required by different energy sources to match the amount of electricity produced by a 1,800 MW nuclear power plant.

Source: joint research by NTNU and GIoT (link)

- most critical resources are the ones for **concrete structures** (that SMR are striving to reduce), and **graphite blocks** (only for certain reactors)
- radioactive waste is limited to **manageable volumes** as a very little amount of fuel is required to produce vast amounts of electricity. The yearly electricity consumption of an average person in developed countries (about 1 MWh) will generate around 3-4g of spent uranium fuel (about 5g of high-level waste in total). Producing 1MWh results in and amount of all types of waste including low- and intermediate-level of radioactivity equivalent to the size of a brick on average.
- The water **consumption** is rather **limited** and equivalent to that of a concentrated solar power plant. An SMR will consume even less water.

[10] *Gibon, T., Arvesen, A., & Hertwich, E. G. (2017). Life cycle assessment demonstrates environmental co-benefits and trade-offs of low-Carbon electricity supply options. Renewable and Sustainable Energy Reviews, 76, 1283-1290*
[11] *IEA-NEA, Projected Costs of Generating Electricity, 2020 Edition*



Advanced nuclear in the world

The current nuclear renaissance finds its expression at many different levels:

- Dozens of new **technology developers** appeared over the last 20 years, which aim to demonstrate promising technologies by the end of the decade. They include NuScale, the first nuclear start-up quoted on the stock exchange, Terrapower, founded by Bill Gates and working on 2 different designs, and the Italian Newcleo, that recently announced investments in the French territory at the level of 3 billion euros.
- Several countries have included advanced nuclear in their **energy planning**: UK's plan - https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution/title#point-3-delivering-new-and-advanced-nuclear-power, France, US
- **IPCC** mitigation pathways[12] require global nuclear capacity to double or triple, reaching up to 1160 GW of electricity by 2050[13], up from 394 GW in 2020, while the **International Energy Agency** global pathway to net-zero CO_2 emissions in 2050 implies doubling the production of electricity from nuclear by 2050, by adding up to 30 GW per year to the global capacity. The scenario include government support for advanced nuclear technologies.
- **Electric utilities** have started investing in Small Modular Reactors (EDF, OPG, Constellation,...)

[12] *IPCC, 2022: "Climate Change 2022: Mitigation of Climate Change"*
[13] *International Energy Agency, 2021: "Net Zero by 2050, A Roadmap for the Global Energy Sector". iea.li/nzeroadmap*

About the authors

Fabio Nouchy is an adaptable nuclear engineer with over a decade of experience. His career has been dedicated to developing a holistic perspective on the industry and addressing challenges in clean energy. Initially focused on the fuel supply chain and nuclear fuel back-end, Fabio later redirected his expertise toward Advanced Reactors and Small Modular Reactors. He has actively contributed to numerous pre-feasibility studies of SMR deployment, assisting industries in leveraging these technologies for the decarbonization of their assets.

Tony Playford is a Chartered Engineer and Technical Director for RED Engineering Design. He has over 16 years experience in Data Centre design, delivery and project lead roles from concept and detailed design through construction to practical completion for a variety of hyperscale, banking and colocation clients. He looks after multi-discipline teams in both the Bicester and London offices and has a passion for advances in nuclear technology and their potential in the future of data centre design.

Mohammad Royapoor is a chartered engineer with 17 years of involvement in research and design of low-Carbon buildings and integrated energy systems. His design and research work has involved international collaborators in UK, Europe and Africa within project teams involving engineers, architects, computer scientists and energy economists. His current role involves delivering RED Engineering Ltd research and design programmes on future fuels and energy systems, artificial intelligence, demand side response, flexibility markets, microgrid design and optimisation and whole life Carbon assessment.

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