Data Centers: a new dawn for nuclear energy?

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Nuclear energy is seen as a potential solution to the problem of providing sufficient reliable energy to decarbonize hard to abate industries such as steel, chemicals, and shipping, and to support new "hyperloads" such as data centers. Industrial users and IT companies are actively engaging with the nuclear industry to explore these options – and the needs and statements of these new actors suggest a change in the relative importance to the client between cost and deliverability of the energy supplied by nuclear plants.

In the first article in this series [1], Edward Kee explored the potential for recommissioning shuttered nuclear power plants such as Three Mile Island 1 (TMI-1) to support this new client base.

This paper looks in more detail at reasons for the interest from these new actors, specifically the case for data center support, and its challenges and implications for nuclear industry growth.

For brevity we will generically refer to Small Modular Reactors (SMRs) where we include both current light-water cooled designs and what are often referred to as 'advanced reactors' (AR) with other features. However we will go on to explain that in most development scenarios data centers will require advanced technology solutions – but in "small" modular plant designs – while in some other scenarios large gigawatt scale (GW) plants will be called for.

The evolving market for nuclear reactors

The civil nuclear power industry developed on the basis of quite a simple market model. An entity with very deep pockets – either a government agency, state-owned enterprise or power utility consortium – would identify a need or opportunity to supply regional- or national-scale electricity, usually in a regulated market, using a nuclear power plant. The entity would raise the significant up-front capital to build the plant through a combination of corporate treasury, bond issue, state debt, and shareholder equity. The cost would be passed through to ratepayers by government or regulated utilities. Once built, the nuclear power plant would provide baseload power for many decades, the capital cost being amortised through direct bills from power consumers or long-term power purchase agreements with large power users.

Market liberalization from the 1980s onwards, mainly in the US and Europe, and the resulting need to supply commoditised and fungible grid-scale electricity, changed the business case for such huge capital intensive projects. As a commodity, the nuclear plant's output became subject to the mercy of electricity market forces where marginal generating cost is the driving factor, especially where subsidized renewable supplies are guaranteed priority dispatch in merit-order markets.

This new market design became unworkable in the early 21st century for some US merchant nuclear powerplants such as TMI-1, and continues to make the financing of new nuclear plant development and operation difficult to justify, despite the development of a number of schemes – such as Olkiluoto 3's Mankala model, the Hinkley Point C Contract for Difference scheme, or the Regulated Asset Base concept intended for Sizewell C – which attempt to spread risk across such projects by replicating some features of the ratepayer recovery [2].

But another market model seems to be (re-)emerging. In the latter half of 2024 a number of well-publicised announcements by tech companies such as Google, Microsoft, Amazon and others pledged investment and support in SMRs, advanced reactor technology and recommissioned plants to help provide nuclear energy for their growing data center requirements (see **Box 1**). In this model, the client is a discrete enterprise which requires energy to run its operations directly, and revenue and profit are driven by other factors. This 'energy as input' model of energy consumption is not based on end-user cost-sensitive consumers; instead, as we explore in this paper, this new client base is attracted by nuclear energy's other deliverables – zero-carbon, reliable and flexible, and scaleable globally. Note that similar models have been considered before, such as by BASF in Germany in the 1960s/70s [3], but not implemented for various reasons that could also apply in the future, as we'll explore in this article.

The 'energy as input' model of nuclear energy provision will mature over the next decade, and its full implementation partly will depend on the successful development of a range of advanced nuclear technologies with the appropriate characteristics. As yet none of these concepts have been demonstrated commercially, and some of the proposed use cases, such as for remote or multiple siting and operation, will require changes to systems of regulation and security. Some may include fuel reprocessing as part of their business model, which would require a significant change in policy in a number of countries. Much comment and analysis at the moment is therefore highly speculative. However the recent publicity and statements by the tech companies, data center operators and potential nuclear vendors do give some indication of the possible direction of travel [4].

In this paper we will explore this direction of travel, how nuclear energy supply may help, and the implications for the nuclear sector – as well as some of the serious challenges it faces. As this sector is at present dominated by U.S. actors, our analysis concentrates on the U.S. but comments on implications for Europe and elsewhere.

- **Google** has agreed to purchase up to 500 MW of electricity from multiple SMR units, which will be designed, built and operated by the California-based firm Kairos Power [35].
- **Amazon** has an even wider plan which includes investing directly in X-Energy, an SMR developer, including taking two seats on its board, and teaming up with two utilities, Energy Northwest (Washington State) and Dominion (Virginia), to investigate the deployment of X-Energy's SMRs [36]. Amazon Web Services also obtains nuclear energy from Susquehanna Nuclear Power Plant through Talen Energy [37].
- **Oracle** – Oracle is planning a 1 GWe data center powered by 3 SMRs. It has not revealed further details [38].
- **Oklo/Switch** – Oklo, a developer of advanced nuclear technology, and Switch, a premier provider of AI, cloud and enterprise data centers, have signed a non-binding agreement to deploy 12 gigawatts of Oklo Aurora powerhouse projects through 2044 [39].
- **Microsoft** – Microsoft has made a number of investments and announcements around advanced nuclear over the last two years:
    - **a.** In 2024 it agreed a PPA for up to 880 MW from Crane Clean Energy Centre (previously TMI-1), at an estimated price of $110/MWh, significantly above energy market rates [40].
    - **b.** Bill Gates is a founder of TerraPower, an advanced nuclear technology developer, which is building a sodium-cooled advanced plant in Wyoming, with a target date of 2030 [41].
    - **c.** In 2023 Microsoft arranged a PPA with Helion, a fusion tech developer, with a target date of 2028 [42].
- **Meta** – In December 2024 Meta issued a request for proposals to identify nuclear energy developers to help meet Meta's AI innovation and sustainability objectives — targeting 1-4 GWe of new nuclear generation capacity in the U.S. [43]

Box 1
Tech Company nuclear energy announcements

The growing data center industry

Power demand

A 'data center' is any facility which stores and shares applications and data (see **Box 2**). To do this, it will contain IT servers, storage systems and computing infrastructure. This equipment consumes power directly and also requires power for climate control (cooling and humidity) and building services, with the cost of power representing 60-70% of the operating costs [5]. The largest hyperscale data centers can require 100-500 MWe supply, with combined campuses now approaching 1-2 GWe. Improving power useage effectiveness (PUE) is an important development goal for data center owners but savings in this area will be outcompensated by increasing demand for data capacity.

The amount of data being collected by the global data economy continues to grow, driven by the increasing adoption of Artificial Intelligence (AI) applications, with some 95, 120 and 150 zettabytes being produced annually over the last 3 years [6]. This current and potential growth is driving huge and growing interest and investment in more and larger data centers, with JPMorgan estimating growth in energy demand from 150 TWh in 2023 to 600 TWh by 2030 [7][8]. There is much uncertainty around the accuracy of these growth predictions, and potential for rapid disruption as shown by the stock market quivers in early 2025 driven by the DeepSeek AI technology [9], but there is little doubt that energy requirements for data support, including AI referencing and training, will continue to grow significantly – in size, number and global distribution of data centers [10].

For 2025 the IEA estimates that the total data center power requirement is about 1% of global electricity demand but in some regions is already significantly more: for example one-fifth of Ireland's power demand is from data centers [11].

Siting

The USA dominates the data center count by country, with some 5400, almost twice the total of Europe – 2800 – and ten times that of the next ranked country, Germany.[12] The structure of the Chinese data center ecosystem is difficult to compare and will not be reflected in this article.

Data centers have preferentially been sited in areas which can support their workforce and power needs, have easy access to large data-hungry populations and are close to internet nodes. This combination of factors has led to clustering in areas such as Northern Virginia, where the combination of the Washington DC metropolitan area and many trans-atlantic communication cables making landfall nearby make a compelling mix. This growth continues: Dominion Energy, the regional power utility for Virginia, reports that its contracted data center capacity rose from 16 to 21 GWe from 2023 to 2024 with another 12.8 GWe requested in the first 9 months of 2024.[13]

With the cost of energy being the largest ongoing expense for data centers, the efficiency of its climate control operations to maintain an effective temperature of 18-22C against its output temperature of 40C+[14] is crucial to the overall performance of the data center. Accordingly, data centers in warmer and more humid climates such as South Florida are up to 20 % less energy efficient than their counterparts in northern parts of the country like New York[15]. Besides siting in areas with lower average temperatures, hyperscale data centers, which are reaching power demands of over 500 MWe, are also increasingly moving to liquid cooling to drive down PUE.

While the strategic and economic value of data centers make them attractive to national, state, and local governments and developers, some jurisdictions are now limiting the amount of data center growth in an area: as data center size increases, local noise issues and water supply for cooling as well as grid load and stability become greater factors.

This article generalizes “data centers”. A more diligent market analysis requires to distinguish significant differences with respect to purposes/applications, networks, technologies, and business models and their respective needs and characteristics (e.g. latency, location, distribution, size, staffing, etc.).

- **Size and Space:** Data centers vary significantly in size, from small facilities to large hyperscale centers, which typically exceed 10,000 square meters.
- **Power Uses:**
  - **Power demand:** Hyperscale data center power demand ranges from 100–500 MWe, and upwards of 80% load, with a trend for further growth, with planned campuses now reaching over 2 GWe. At the other end of the range, edge computing consists of a growing number of distributed small units (5 MWe).
  - **PUE (Power Usage Effectiveness):** This metric, which measures energy efficiency, is calculated as the ratio of total facility energy to IT equipment energy. For example, if IT equipment uses 1 MW and the PUE is 1.5, total energy use equals 1.5 MW.
  - **Valid Range of MWh per PUE:** Typical data center PUEs range from 1.2 to 1.5. For example, with IT equipment consuming 1 MWh, total energy use would be between 1.2 MWh and 1.5 MWh. Hyperscale data centers often achieve PUEs closer to 1.1.
  - **Future Trends:** Improved cooling and renewable integration are driving PUE values downward. The global average PUE, around 1.57 in 2024, is projected to approach 1.2–1.3 by 2030. However, increasing IT loads from AI and machine learning could push total energy demands (MWh per PUE) higher, even as PUE improves.
- **Siting:** Depending on their role in data networks, data centers will be located near urban centers close to data "consumption", or where external factors (real estate, climate, etc.) are favorable, or they will closely follow users in highly distributed modes (edge computing).
- **Staffing:** Staffing requirements vary by scale, with large hyperscale data centers employing hundreds and smaller facilities operating with minimal staff or even being run remotely.

Box 2
Data Center Overview Facts and Figures (various sources)

Power supply

These rapid growth forecasts are now driving data center developers and operators to seek power sources which can match their future needs:

a. To date, power for data centers has been mainly sourced through grid connection to power utilities (such as Dominion Energy) with backup from behind the meter (“BTM”) diesel generators or other local supply[16]. However the rapid growth in data center power needs is putting significant pressure on the ability of regional utilities to guarantee supply and the capacity of the transmission system to connect and transmit, and also potentially impacting on the cost and availability of power to other consumers. Such concerns have led, for example, to the recent rejection of Talen Energy’s request for a 180 MWe upgrade in output from the Susquehanna nuclear plant to supply an Amazon data center[17], and are leading tech companies to consider BTM power supplies, independent from the regional grid.

b. Guarantee of data center uptime is becoming ever more crucial[18]. Highly time-sensitive activities such as automatic financial trading[19] can lose significant sums with any loss of service, and there is increasing need to support safety-critical

Data Center Tier Levels, which specify the design features required for a desired system availability (Source: Uptime Institute).

Tier I

A Tier I data center is the basic capacity level with infrastructure to support information technology for an office setting and beyond.

Tier I protects against disruptions from human error, but not unexpected failure or outage. Redundant equipment includes chillers, pumps, UPS modules, and engine generators. The facility will have to shut down completely for preventive maintenance and repairs, and failure to do so increases the risk of unplanned disruptions and severe consequences from system failure.

Tier II

Tier II facilities cover redundant capacity components for power and cooling that provide better maintenance opportunities and safety against disruptions.

The distribution path of Tier II serves a critical environment, and the components can be removed without shutting it down. Like a Tier I facility, unexpected shutdown of a Tier II data center will affect the system.

Tier III

A Tier III data center is concurrently maintainable with redundant components as a key differentiator, with redundant distribution paths to serve the critical environment. Unlike Tier I and Tier II, these facilities require no shutdowns when equipment needs maintenance or replacement. The components of Tier III are added to Tier II components so that any part can be shut down without impacting IT operation.

Tier IV

A Tier IV data center has several independent and physically isolated systems that act as redundant capacity components and distribution paths. The separation is necessary to prevent an event from compromising both systems. The environment will not be affected by a disruption from planned and unplanned events. However, if the redundant components or distribution paths are shut down for maintenance, the environment may experience a higher risk of disruption if a failure occurs.

Tier IV facilities add fault tolerance to the Tier III topology. When a piece of equipment fails, or there is an interruption in the distribution path, IT operations will not be affected. All of the IT equipment must have a fault-tolerant power design to be compatible. Tier IV data centers also require continuous cooling to make the environment stable.

Box 3
Data Center Tiers[44]

functions such as autonomous driving. As a result, permanent, reliable and sufficient power is an essential requirement, with any large data center requiring at least “Tier 4 reliability” (99.995 % see **Box 3**) and increasingly the ‘five nines” or 99.999 % uptime.

c. While data centers operate at continuous high loads, they do have some variability and potential volatility. This will be due to external factors (seasonal and other weather conditions) as well as operations modes which can differ depending on applications being run (e.g. AI training versus different types of online services). Accordingly they will require a power source that can load follow and/or include backup or storage capacity. Estimates indicate data centers operating in a range of 80 % to 100 % of power load.

Google – Aiming to achieve net-zero emissions and 24/7 carbon-free energy [45]

“At Google, our goal is to achieve net-zero emissions across all of our operations and value chain by 2030. We aim to reduce 50% of our combined Scope 1, 2 (market-based), and 3 absolute emissions (compared to our 2019 base year) by 2030, and plan to invest in nature-based and technology-based carbon removal solutions to neutralize our remaining emissions.”

Amazon's Climate Pledge [46]

“We believe we have an obligation to stop climate change, and reducing carbon emission to zero will have a big impact. We want to reach net-zero carbon emissions by 2040, a decade ahead of the Paris Climate Agreement. In 2019, we set an ambitious goal to match 100% of the electricity we use with renewable energy by 2030. We are proud to have achieved this goal in 2023, seven years early, with 100% of the electricity consumed by Amazon matched with renewable energy sources.”

“As society's energy needs are changing, from electrifying vehicles to streaming a movie, Amazon continues to plan for this growth while remaining committed to our Climate Pledge commitment of reaching net-zero carbon by 2040. To do so, we're investing in nuclear energy, a critical energy source that can be brought online at scale and has a decades-long record as a reliable source of safe, carbon-free energy. We're helping develop next-gen nuclear technology, investing in existing nuclear reactors, and supporting research on topics like nuclear fusion, and more – all to help power our operations more sustainably, and help everyone transition toward a carbon-free energy future.”

Microsoft [47]

“By 2030 Microsoft will be carbon negative, and by 2050 Microsoft will remove from the environment all the carbon the company has emitted either directly or by electrical consumption since it was founded in 1975”.

Box 4
Big Tech Climate Pledges

d. Clean energy is becoming an imperative, with all the large tech companies, which are publicly traded, having made overt public pledges to reduce or eliminate their carbon emissions (see **Box 4**). As a result, they are seeking ever more aggressive ways to balance the tension between continued rapid growth, guaranteed uptime, and carbon reduction.

e. The large tech companies have strong credit ratings and balance sheets, which could allow them to overcome the obstacles other nuclear investors have with regard to financing multi-billion multi-year merchant nuclear projects. E.g. the Big Four tech companies between them spent $108bn on investments, in 2024 alone. [20]

f. There is a cultural alignment between the IT technology sector and other areas of innovation such as clean energy technology. The large tech companies have an interest and the means to support development of alternative clean energy sources and projects including somewhat courageous investments such as by Microsoft and OpenAI in Helion, a fusion technology developer which has agreed a PPA with Microsoft for 2028 [21].

g. The growth of data center campuses – groups of data centers on the same site – is further increasing the size of individual sites, with associated demands on power, land, communications and heat sink. This rapid growth in data center infrastructure is occurring at all scales, from hyperscale campuses of over 1GWe with ‘the size of Manhattan’ [22] to smaller edge data centers currently up to around 5 MWe. This requires access to a range of collocated energy sources which can scale to the data center’s energy requirement and also suit its local area, with its constraints.

Some sources of energy are difficult to match with these requirements: natural gas, whilst deployable quickly and flexible in response, in some locations is not readily available; and although the new Trump administration has indicated that new natural gas fired generation would be welcome in the U.S., it is not well aligned with long-term sustainability pledges and international policies. Wind and solar are not reliable enough on their own and, for the largest power requirements, firming up such intermittent generation with battery backup is expensive, difficult, and risky. The conflation of these factors is pushing the data center industry to consider nuclear energy for certain situations, with its unique ability to provide large amounts of high-density, clean, sustainable, reliable electricity at very high availability factors. [23]

Data center requirement	The problem	How nuclear technology can support
Scaleability of power	Currently (2025) hyperscale data centers can require 100-500 MWe supply. This will increase significantly with combined campus needs potentially several times this. Meanwhile smaller data centers require tens of MWe but seek future scaleability	SMR and AR vendors are offering plant types with outputs from 5 MWe to 470 MWe, and increasingly are targeting data center requirements in response to this perceived market demand, with some vendors, such as Deep Atomic [48], marketing exclusively to this sector. As power requirements rise, there is also a case for Gen III+ large plants such as AP1000 or CANDU to support large 1 GWe+ campuses. As seen with TMI-1, using existing or recommissioned plant is also an option.
Reliability of power	Need to be Tier 4 – 99.995% or more for AI; needs to be close to data center and in same national/regional boundary	Current nuclear technology has a capacity factor of over 90 % [49]. Plant designs which can be refuelled 'on the go' (existing designs such as CANDU, or most advanced designs) have the potential to supply power at the highest reliability. Multiple units on site, as envisaged by some SMR deployment models, can provide multiple redundancy and backup options. For light-water SMR and GW plants, the need for refuelling outages would need to be factored in to any use case, leading to excess capacity on site that can be shared with other users.
Flexibility of power	Data center power load has inherent volatility due to a number of factors such as season, time of day and tasking.	Most SMR/AR designs incorporate controlled ways to vary their output, such as load following response, heat take-off and energy storage. TerraPower's NATRIUM design targets this characteristic with the ability to ramp from 345 to 500 MWe using stored hot sodium [50]. Gen III+ large plants such as EPR or AP1000 also have design load following and load rejection capabilities which could be appropriate.
Clean power	Power sources must be in accordance with data center operator's clean energy pledges and support their stated decarbonisation goals – see **Box 4**	Nuclear energy is clean and aligns with data center operator's and customers decarbonisation pledges. Increasingly, nuclear energy is aligning with investor ESG and green bond criteria [51].
Cost of power	Power is 60-70% of data center operating costs and so must be commercially viable for data center operator	Data center PUE continues to decrease as data center seek greater efficiency and move to liquid cooling. Cost will always be a significant factor but the other factors outlined here have an equal or stronger importance [52]. Maximum power output of a nuclear plant may not be as cost elastic as other sources, making it easier to match with peak load i.e. less dependent on (a) grid connection and (b) outside climate conditions.
Siting	Choice of site needs to: - minimise latency, environmental heat; - maximise appropriate access to cooling, workforce and to internet nodes; - take into account land use and community support	Owing to enhanced safety and operational characteristics, advanced nuclear technology plants may have smaller emergency planning zones and less regulatory and practical constraints to siting, allowing more options for siting close to population centers [53], improving latency, especially for edge computing. In particular, the footprint of a 5 MWe advanced nuclear plant will be significantly less than that of a solar or wind farm. Some vendors optimistically propose future uncrewed SMR operation, allowing a power unit to be co-located with a data center in remote areas.
Community support	Tech companies are very keen to have local support and avoid reputational damage	Nuclear energy has historically had a fractious relationship with its stakeholders and wider public. This is improving and a number of studies show significant and growing support for nuclear energy, which makes it more attractive for tech firms [54].
Technology advances	The culture of tech companies is to support innovation, cutting edge technology and to 'move fast and break things'. An alignment with a power sub-sector which shares these values is of value.	Advanced nuclear technology has a good cultural fit to IT tech community, for example as demonstrated by the involvement of Bill Gates/Microsoft in TerraPower and Helion, and Sam Altman in Oklo and Helion. The tech companies have strong credit ratings (eg Microsoft AAA; Alphabet AA+ (S&P)) and balance sheets, which provide the deep pockets needed to engage in nuclear.

Table 1
How nuclear technology can support future data centers

Nuclear's role in data center support

Why nuclear can be a compelling case

In light of the critical factors for data center power supply outlined in the previous section, there is a clear alignment of some key characteristics of nuclear energy, such as zero-carbon emissions and high reliability, with data center needs. This makes it a tempting choice for future data center development, and is why the big tech firms are investing in nuclear energy. Furthermore, advanced reactor technology potentially offers more responsive power output, less regulatory constraints over siting, and smaller land footprint, prompting some tech investment specifically in AR designs, such as Google and Kairos. **Table 1** provides more detail about how nuclear technology may help to support data center energy requirements.

There may also be a good cultural fit between the data center and nuclear industries: They share external security concerns, both operate in high resilience modes, and there has even been some discussion about modelling any future regulation of AI on nuclear licensing [24]. Interestingly, there is also increasing work to use AI in support of nuclear deployment, with a potential for it to make design, permitting and operations more cost effective [25]. At the same time, when considering the slow nuclear regulatory progress from analogue to digital I&C systems historically, it may be deemed courageous to introduce AI in safety relevant nuclear processes.

There are a number of ways that SMRs could be deployed to power a data center campus:

a. "captive" SMR: the plant (or plants) is co-located BTM with the data center and designed to load follow the data center requirements, potentially including suitable power storage capability such as with TerraPower NATRIUM.
b. "natural hedge" grid solution: the SMR operates in a normal grid supply mode and the data center draws its power needs from the grid;
c. "district" solution: the SMR is located close to the data center and is operated BTM according to its needs; but the SMR additionally supplies excess power and possibly direct heat to the local/regional distribution grid;
d. "cogeneration" solution: the campus includes other industrial energy users such as ammonia or hydrogen producers, and the SMR is scaled to supply the needs of both industrial users and the data centers, balancing demand variations from both for greatest efficiency. An example of this is the potential expansion of the Surry Power nuclear power station in Virginia, with up to six SMRs of undisclosed type added to the site of the existing PWR [26].

These configurations are not mutually exclusive and the high power density of nuclear plants gives more flexibility in designing efficient options around cogeneration and heat offtake. They do raise questions such as whether co-located loads require the provision of wholesale transmission or ancillary services, and related cost allocation issues, as well as potential resource adequacy, reliability, affordability, market, and customer impacts. [27]

Why nuclear may not be the ideal choice

Whilst nuclear energy can be an attractive choice for these emerging data center needs, there are a number of issues which need to be solved before nuclear can become a commercially effective and commonplace source of power for data centers:

a. The upfront capital cost for a nuclear plant, compared to gas or renewables, will be a significant consideration, albeit in the context of the similar capital sums being spent on the largest data centers themselves. The through-life cost of the nuclear plant and $/kWe considerations would be part of the overall cost of the data center business enterprise. With energy being the most significant part of a data center's operating costs, there will always be a drive to reduce this, and the nuclear energy industry cannot rely on its new 'energy as input' model as a free lunch to save it from cost pressures. This applies throughout the nuclear value chain, so all nuclear stakeholders must take a clear view of through-life cost and seek to minimise it. It also includes regulation, which imposes significant external cost to any nuclear project.
b. There is as yet no precedent in the civil nuclear industry to how nuclear licensing and permitting requirements, necessary owner/operator certifications, security issues, radioactive protection and waste management, etc. would be solved in a manner suitable for mass-deployment of nuclear reactors to multiple data centers worldwide. Also, the time needed for project specific planning, licensing/permitting, and operator training for nuclear power installations may not match the project development timelines of data center projects.
c. The speed at which data center energy demand is growing in the US and globally, plus the need to rapidly decarbonise to meet company and international pledges, imply that much of the energy requirement will have to be put in place in the next decade, a timescale that the nuclear sector is not well placed or well versed to meet.
d. Apart from recommissioning shuttered plants it may not be possible to get nuclear energy supply online before at least the early to mid 2030s, and perhaps later. This may mean that the otherwise attractive option of nuclear energy supply for data centers is sidelined in favour of natural gas, then renewables and battery storage, with the distant hope of fusion as the long term perfect energy supply.
e. For SMRs to stand a chance at significant market share they will need to develop, sell and deliver standardized designs suitable for expeditious, scaled roll-out – including manufacturing, build and construction, staffing, fuel supply.

One of the advertised key advantages of a nuclear plant is its longevity, with most vendors proposing at least a 60-year plant life, perhaps three times that of a renewable equivalent. However, it remains to be seen if this is suitable for data centers with their rapid growth and technology redevelopment; there is a risk that data centers could have very different requirements in 10 or 20 years, making any nuclear investment now a stranded asset in two or three decades.

Looking ahead just ten years one cannot simply extrapolate from current data center technologies and business models:

- Innovation in the IT sector will lead to different ways how information technologies will operate and what infrastructure will be required. As seen in the past, innovation often leads first to scaling in size and then to optimization by descaling: from abacus to mainframe computers to PCs to handheld devices and fast forward to edge computing; from Germany's first commercial, 340 MWe PWR in Obrigheim to 1600 MWe EPR to SMRs.
- AI can be used to make data centers more cost efficient and profitable, by optimizing their power use within a global network based on real-time electricity prices, grid conditions, and regional renewables availability in order to monetize flexibility.

Such optimisation and evolution will impact the designs of data center energy islands, e.g. calling for dispatchable SMR/AR scale units.

The implications for nuclear sector growth

Throughout its life, the nuclear industry has been bedevilled by problems of cost, project execution and public perception. In the last two decades, particularly in the West, it has struggled to compete with other sources of energy, with early closure of plants such as TMI-1 and significant cost and time overruns of new build projects such as Vogtle 3&4, Olkiluoto 3, Flamanville 3, and Hinkley Point C.

The advent of SMR and advanced nuclear technology is supposed to address these issues, and the developers of these technologies are not shy to extol the virtues of their technologies, as we have described previously. [28] But, despite the imperative of net-zero targets and much marketing hype and hope, development and commercialisation of these technologies is still proving to be a long and risky task, for example as shown by the 2023 collapse of NuScale’s first project in Utah. [29] There is significant work still required by all vendors to reach commercial viability and scalability, for some more than others. Consequently, many commentators still doubt the commercial viability or practical suitability and necessity of SMR and advanced reactor designs, and even for nuclear energy in general. [30]

So the emergence of a new data center ‘energy-as-input’ market, driven by a new enthusiastic tech client base, has led to talk of a ‘new nuclear renaissance’ and significant rises in some reactor vendor stock prices. As always, much of this remains hype. The relatively small investments made by the tech companies so far indicate that they believe in principle that nuclear technology may have a part to play in their future energy supplies, both through current plants and future more exotic nuclear technology. But such R&D spending, or portfolio hedge investment, is still a far step removed from IT companies betting the farm on nuclear, or even committing to full scale pilot projects. Until the future of both clean energy and data centre growth becomes clearer, the biggest impact on nuclear industry growth that these investments give is credibility and publicity.

For data center operators who seek GW scale power today, the fastest and lowest risk path to nuclear energy supply would appear to be a current operational GW nuclear plant, where the technology and costs are well known (e.g., the Talen energy on-site data center). Even allowing for the novelty and unknowns, recommissioning a nuclear power plant closed for decommissioning is currently the cheapest, fastest, and lowest risk way to obtain GW-scale nuclear supply. This thinking is clearly in play with the restart of plants such as TMI-1, Palisades and Duane Arnold. [31] There are also suggestions about completing the half-built AP1000 units at V C Summer, [32] a notion which would have been ludicrous only a few years ago.

This train of thought naturally leads to the building of new large plants – nuclear or other – to support further GW scale campuses, with huge projects such as Meta’s proposed 2.2 GW Lousiana plant, powered by natural gas, [33] taking the tech company to significant future capital outlays including a $65bn CAPEX spend in 2025. [34] The scale of this proposed spend and development potentially makes the cost and risk of an AP1000 or other nuclear plant more digestible in the context of hyperscale mega-projects.

Looking beyond 2030, if data center energy demand growth continues, there is a good case for both GW and SMR nuclear power to be part of the mix, for the reasons outlined above and in Table 1.

To put this into perspective: going by the above referenced JPMorgan estimate of 600 TWh power demand for data centers by 2030 and a benchmark 500 MWe for a hyperload data center operating at an average 90 % load, this would require a total supply of 75 GWe or 150 data centers. If – for example – one third of those are to be powered with SMRs, each with five 100 MWe units, this would require production of 250 units. Even in the SMR vendors’ wildest dreams this is unachievable by 2030, but many have a credible trajectory to commercial deployment. – What’s needed is a real, significant demand signal of multiple firm orders from a data center operator to prompt the confidence and investment required to scale up SMR manufacturing and deployment.

Conclusion

In conclusion, we see a clear potential for nuclear energy supply to data centers in certain situations. However there remain many uncertainties and obstacles in the way of its implementation and scaling.

Nuclear energy offers advantages to data center operators for the following reasons:

a. Data center revenue has strong future expectations and is driven by data sales: hence energy provision to a data center enterprise, is simply one of the enterprises' cost inputs (albeit the largest) and may be driven more by deliverability (clean, reliable, flexible) than short term market prices.
b. The attributes of nuclear energy, specifically advanced small modular reactor technologies, are well suited, and potentially uniquely so, to the growing data center economy and energy requirements. As outlined in **Table 1**, nuclear energy for data centers can – in theory – deliver at the right scale and quality.
c. Data center investors have ambition, deep pockets and strong credit which they are not afraid to deploy on developing innovative technology – such as advanced nuclear – on a large scale.

Nevertheless, issues of cost, risk and acceptance remain, and will take significant time and upfront effort to overcome. Tech companies wrestling with a high near-term dynamic growth and their long-term planning in competitive global markets may not have the time or patience to accomodate nuclear supplies.

We see the Big Tech companies hedging their bets with investment and engagement in all potential areas of energy supply, including nuclear. Their recent announcements indicate an incipient demand signal for nuclear power, but they have rapidly emerging and changing needs. To capitalise on this opportunity, the nuclear sector needs to focus on this new class of impatient and adventuristic customers, understand their needs and requirments, and find credible ways to respond in time. – Let's see if they can ...

... to see where industry stands, we supplement this article with a separate short analysis using the 'Nuclear Pathfinders 8 Issues' model to assess the key gaps that nuclear industry needs to overcome in order to capture its opportunity.

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NUCLEAR PATHFINDERS
VALUE THROUGH COLLABORATION

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The authors wish to acknowledge their Nuclear Pathfinder colleagues' advice and suggestions for this paper: Ed Kee, Paul Murphy and Jay Brister. The authors also wish to thank James Warden (Greensabre, Researcher) and David Herman (Data Technician, Microsoft) for their input.

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