Strategic Siting™

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Siting Hyperscale Data Centers & MegaCampuses For Artificial Intelligence Power Demand

The Artificial Intelligence (AI) infrastructure market, including data centers, networks and hardware is expected to reach $422.55 billion by 2029, growing at a compound annual rate of 44% over the next several years. Wall Street Journal AI implementation is having a profound impact on the demand for data center capacity and grid scale power. Viable sites and power (availability and cost) are consistently listed as two of the top challenges currently impeding AI capable hyperscale data center growth. Data Center Frontier

Energy demand from AI is projected to surge from ~ 18 gigawatts (GW) in 2023 to ~ 35 gigawatts by 2030 McKinsey & Company Open AI's CEO Sam Altman said at the World Economic Forum annual meeting in Davos on January 16, 2024: "*…an energy breakthrough is necessary for future artificial intelligence, which will consume vastly more power than people have expected*." (underline added) U.S. News & World Report Altman mentions both fusion and fission nuclear energy as possible solutions – more on nuclear power developments in the Power Frontier section of this discussion.

At the same time, power supplies and transmission systems in many U.S. markets are already strained. And according the North American Electric Reliability Corporation's (NERC) 2023 Long-Term Reliability Assessment (LTRA), there are retirements of 85 gigawatts of existing power plants, primarily gas and nuclear, are scheduled over the next ten years. The report has some sobering statistics and it warns of the risk of blackouts in some markets. NERC

Many data center operators have net zero (total emissions and for some facility specific) and environmental, social and governance (ESG) goals and are actively working to achieve them. But rapidly growing power demand for power intensive facilities, including data centers, is contributing to unintended consequence – namely keeping older, less efficient legacy power plants, including coal fired plants, online past their planned retirement dates in some markets.

Utilities in Virginia and Wisconsin are seeking to delay retirements of older gas and coal fired plants to maintain grid stability and meet growing energy demands. California recently delayed the retirement of Diablo Canyon Power Plant, the state's last operating nuclear power plant, by five years to support power reliability and grid stability. A requested exemption for 168 diesel fuel fired back up generators for a proposed data center in Maryland was recently denied. Energy Institute

How serious is the power situation for hyperscale data center development? That depends on the regional transmission organization, local utility, existing generation fleet, transmission system, and the target timeline to bring the data center online.

Bottom line, there will be strong demand for power rich digital infrastructure real estate over the next several years. This discussion explores 1) the existing power supply situation; 2) some technologies on the power frontier; and 3) strategies for siting new AI capable hyperscale data centers over the next several years. Power supply is a complex subject and the generation, transmission and energy storage landscape is dynamic. This discussion is an overview.

Generation - Primary Power Supply from the Grid

In 2021 the capacity weighted average age of the U.S. generation fleet was 28 years. Coal fired plants had an overall age of 43 years; oil fired plants 42 years, and nuclear plants 41 years. The capacity-weighted average age of natural gas fired power plants was appreciably lower at 22 years. S&P Global

As mentioned, there are about 85 GW of power plant retirements scheduled over the next ten years. Some of these retirements are being and will be delayed, and some retired plants will be repowered e.g., from coal to natural gas, or from combined cycle / baseload to simple cycle / fast ramping generation.

Developing new generation, conventional or renewable, is challenging. One of the most significant problems is the major congestion in the various interconnection queues. According to a report by the Lawrence Berkley National Laboratory, queue wait times have increased from an average of less than two years in 2008 to five years in 2022.

Year over year, the capacity of energy projects in interconnection queues in the U.S. grew by 40% in 2022 with some 1,350 GW of generation and 680 GW of energy storage waiting for interconnection agreements. The number of requests in the queues and resulting wait times are expecting to increase significantly due to increased renewable energy interconnection requests driven by the Inflation Reduction Act. Utility Dive

Onsite and Aligned Generation Trend

Onsite generation is gaining some traction with hyperscale data base developers, as is participation in utility scale generation located in relatively close proximity. The approach is appealing for a few reasons including reduced or no transmission risk, potential for lower average annual power cost, improved energy security and flexibility and advancement of lower carbon energy goals.

Data center developers may participate in power projects, including renewable energy, through direct investment or power purchase agreements (PPAs). Typically the utility that owns the transmission system that delivers power from the renewable energy project to the data centers is a directly involved third party. There is often private equity financing in these agreements, the capital requirements are typically significant. These investments appeal to private equity firms for the scale of capital deployments, relatively attractive returns and the security of the income streams / creditworthiness of the principals.

Mission critical data centers require power around the clock, every day. 24/7 power can be generated: using natural gas, but that isn’t consistent with most operators clean energy goals and isn’t feasible in many locations; using geothermal energy, which requires favorable geology; and potentially at some point in the future, using nuclear energy.

Generating a data center’s power supply 24/7 using intermittent renewable sources like solar and wind is a significant challenge. The U.S. Energy Information Administration lists the capacity factor for solar in Arizona at 29.1% (the highest in the western states); according to S&P Global, the average capacity factor for wind generation in the U.S. is 35.5% - it is important to understand that for both this is an annual average, at any given location there are days the capacity factor for a specific site can be zero.

Most hyperscale data center developments planning to employ onsite generation or alignment with existing or emerging renewable energy projects will be best served by hybrid power supply configurations connected to the grid – including through microgrid configurations. Among other things, this enhances power supply security and flexibility and can provide access to intrastate and interstate power - including renewable energy.

Backup Power

Engines: Currently, most piston engines use diesel or natural gas for fuel. Diesel can be transported to any site with adequate storage capacity. Natural gas requires access to a pipeline with adequate capacity. Natural gas is increasingly preferred over diesel as it burns cleaner and generates fewer emissions. For any piston engine based generation some jurisdictions will require an air quality permit and many will require zoning approval. Either or both can be challenging to secure and may serve as a hard constraint on the amount of time the generators can run each year.

Fuel Cells: Fuel cells generate electricity using an electrochemical reaction, not combustion. They are quieter than piston engines and produce somewhat less emissions. Where it is or becomes available, I think hydrogen will start being incorporated in mixed with natural gas or in pure form.

Microsoft and Caterpillar recently demonstrated 48 hours of successful backup power using pure hydrogen as fuel, two Cat Power Grid Stabilization 1260 battery energy storage systems combined with a 1.5 MW hydrogen fuel cell from Ballard.

Batteries: Battery energy storage systems of various technologies and durations will see increasing use for backup power, especially in areas where engine based generators aren't feasible or can't secure necessary permits. More on battery energy storage technologies in the Power Frontier section.

Transmission

In many U.S. markets the power supply problem isn't available generating capacity, it's the transmission system. In some markets, existing generation capacity exceeds the ability for the transmission systems to transport electricity by large margins. Some transmission systems are due for upgrades. Over 70% of the existing electricity grid in the U.S. is more than 25 years old. The average age of the existing grid nationwide is 40 years. U.S. DOE

New transmission lines can take ten years or more from planning to construction. The process from concept to construction involves utilities, regulatory authorities which may include federal, state and local governments, landowners and other stakeholders. It is a complex, expensive and time consuming process. Cost, timeline and project risk increase with distance for new transmission lines. Additionally, supply and logistic challenges have significantly delayed construction of transmission related infrastructure including substations significantly in recent years.

In 2022, the U.S. Department of Energy (DOE) launched the Building a Better Grid Initiative to facilitate the development of new and upgraded transmission lines nationwide and encourage investment to expand and modernize our national transmission system, shooting for ambitious goals of 100% clean electricity by 2035 and a zero-emissions economy by 2050. U.S. DOE The initiative is based on:

- Collaborative Planning
- Deployment of Federal Financing
- Improving Siting and Permitting

Some progress is being made. But, ongoing efforts by federal and state governments to streamline transmission construction timelines notwithstanding, the reality is that there is no easy or fast fix for transmission constraints in many markets. If new transmission or significant transmission upgrades are needed to make a given site viable, look for projects either under construction or fully approved and scheduled in the near term. Also, recognize that it's not uncommon for construction and upgrade timelines to be delayed.

Microgrids

Microgrids may be self-contained facilities or they may be connected to the grid. The purpose of a microgrid is to provide the user improved power security, flexibility and cost. Microgrids can enable the owners to aggregate generation of different types and separate resources. For example, a microgrid can incorporate solar, wind, battery energy storage and natural gas fired generation.

Because they have a relatively small footprint and tend to be located on land owned or controlled by the user, microgrids don't typically encounter the community resistance some transmission projects do, and they can be faster and more straightforward to permit.

Depending on the interconnection and configuration, full or partial cost recovery (typically in tranches over a few years) may be possible from the relevant utility for grid connected microgrids.

Anticipate some relatively large grid-connected microgrids in the central and western U.S. over the next several years. Some will incorporate major energy storage components, enabling price capture and potential arbitrage opportunities at scale.

Power Frontier - Selected Generation and Energy Storage Technologies

Geothermal Energy

Geothermal energy is not new, but geothermal power generation onsite for a hyperscale data center is – Fervo for Google in Nevada; uses technologies employed in drilling for hydrocarbons and fiber optic sensors – makes geothermal viable in locations where it otherwise wouldn't be. Data Center Knowledge

The U.S. DOE's *GeoVision analysis projects that, through technology improvements, geothermal electricity generation capacity has the potential to increase to more than 26 times* current deployment**.** *This would increase geothermal electricity generation capacity to 60 gigawatts (GW) by 2050—providing 8.5% of all U.S. electricity generation.* U.S. DOE

Geothermal will likely play an increasingly important role in our energy landscape over the next ten years in locations with the necessary geology to make it a viable option. It has high initial capital expenditure requirements relative to other renewable generation options, but it has the significant advantage of being able to produce power 24/7/365. Challenges for geothermal development include ensuring there are no adverse seismic impacts or releases of naturally occurring hazardous gases. Consumptive water use may also be a consideration in some areas.

Nuclear Energy

Bringing new nuclear generation online in the U.S. is challenging. The most recent conventional nuclear generation constructed in the U.S. are Georgia Power's Vogtle Units 3 and 4. The original budget for the two units was $14 billion and construction began in 2009. The units were scheduled to be in service in 2016 and 2017. Unit 3 began producing energy in 2023; Unit 4 is expected to be online in early 2024. The project's total cost is now estimated to be more than $30 billion. The current hope is that new reactor technology and configurations, including small modular reactors (SMRs), can accelerate nuclear power development in the U.S.

NuScale Power's VOYGR SMR was the most advanced SMR on the development path and the only fully licensed SMR in the U.S. Nuscale received substantial government funding through the U.S. Department of Energy, and the Idaho National Lab was working with Nuscale to construct the first installation, named the Carbon Free Power Project (CFPP).

NuScale was working with Utah Associated Municipal Power Systems (UAMPS) as the planned offtaker. The original plant was designed for 12 SMRs each producing 60 MW of power at a budget cost of $4.2 billion. The cost had increased to $6.1 billion by the time the Nuclear Regulatory Commission approved CFPP's design, and later the cost increased by another $3.1 billion. UAMPS was only able to secure commitments for 26% of the capacity and November 8, 2023 Nuscale and UAMPS announced they were cancelling CFPP. Science The CFPP cancellation is a setback for SMRs in the U.S. Ars Technica

Nevertheless, development of SMR technology continues to have strong financial support from Open AI's Sam Altman (Oklo) and Bill Gates (TerraPower). Both the Oklo and TerraPower SMR designs are different from NuScale's. Westinghouse's eVinci™ Microreactor has a number of features, including safety that are conceptually appealing, and it seems to be getting significant interest.

In addition to Oklo, Sam Altman has personally invested $375 million in Helion Energy, a company working to bring nuclear fusion into commercial production by 2028. Microsoft has signed a power purchase agreement with Helion Energy – probably the first ever utility scale PPA for electricity generating from fusion energy. Nuclear Fusion is considered to be something of a holy grail for energy because it is safer than fission reactors and doesn't produce any long lived nuclear waste.

In 2023, for the first time ever, scientists at the Lawrence Livermore National Laboratory produced net energy gain from a fusion reaction three times. American Nuclear Society; The Hill

Nuclear energy in some form(s) will likely be a key part of the lower carbon energy future in the U.S. and globally in the years to come. But in the context of this discussion, I think any meaningful implementation of new nuclear generation technology in the U.S. may be several years away.

For fusion reactors, the waste disposal issue will still need to be addressed. And regardless of the technology employed, any nuclear generation development will likely get tough scrutiny and pushback in some communities. Designing a practical and safe fusion reactor or failing that, a safe, cost effective modular fusion reactor and a method to cost effectively neutralize nuclear waste at scale would be worthy goals for artificial intelligence.

Long Duration Energy Storage (LDES)

The U.S. Department of Energy (DOE) has made commercialization of LDES a priority. Worldwide, there has been $58 billion in private and public commitments to ~ 57 GW of long-duration energy storage projects between 2020 and 2022. Utility Dive Wood Mackenzie

The federal government appropriated $505 million for the development of long-duration storage in the 2021 infrastructure law and the Inflation Reduction Act provides tax credits for long-duration battery projects of up to 70 percent of the cost.

Battery Energy Storage

The U.S. Energy Information Administration anticipates utility scale battery energy storage installations will reach 30 GW by 2025. To date, virtually all battery energy storage systems (BESS) have used lithium-ion based battery technology, typically with four hour durations. The U.S. DOE's Long Duration Storage Shot target's reducing the cost of grid-scale energy storage for systems that deliver 10+ hours of duration within the decade.

For battery energy storage, the longer the duration and lower the total effective cost per megawatt hour (MWh) the better. There are emerging technologies that have meaningful potential to achieve durations that are a multiple of lithium-ion configurations at far less cost.

One example is iron-air (flow) batteries, which cost a fraction of lithium-ion configurations and are capable of four day durations, versus typical four hour durations for lithium-ion batteries. The primary component, iron ore, is an abundant resource, mined cost effectively at massive scale in countries with democratically elected governments, the rule of law and meaningful protections for miners and the environment. Form Energy's iron-air battery technology is gaining meaningful traction, with LDES BESS facilities planned in California, Minnesota, New York and Washington. Utility Dive

Battery energy storage may be the power technology with the most potential for significant near term improvement(s) from AI. Consider that in its early stages, Google's DeepMind AI tool has helped discover more than 700 potential new materials. MIT Technology Review Microsoft's collaboration with Pacific Northwest National Laboratory's (PNNL) yielded an AI assisted discovery of a novel material that could potentially reduce lithium use in batteries by up to 70%. Tech Times

It isn't hard to imagine that there will be meaningful battery technology breakthroughs in the next few years in terms of cost, energy conversion efficiency, charging times, storage capacities and discharge durations. And batteries can be widely deployed and interconnected at voltages from distribution to transmissions, on virtually any size footprint.

Hydrogen

Hydrogen is coded by "colors" according to its method of production:

- green – produced from water using surplus renewable energy
- blue – produced from natural gas with carbon capture
- gray – produced from natural gas without carbon capture
- pink – produced from water using nuclear energy
- yellow – produced from water using solar energy
- turquoise – produced from methane with carbon captured as a solid
- white – naturally occurring geologic hydrogen

According the U.S. DOE 95% of the hydrogen currently produced (2023 data) in the U.S. is derived from natural gas. Hydrogen will play some role in our power supply, including for data centers, not least because the federal government committed ~ $7 billion though the Inflation Reduction Act to build regional hydrogen hubs.

The current focus is hydrogen as a fuel for transportation. In the near term, Hydrogen may be most useful viable as a method of capturing and storing surplus energy (of any origin) from the grid. Special tariffs may be employed to enable lower prices for surplus renewable energy.

Specific to its use by data centers, I think for the next few years hydrogen will primarily be used as fuel for backup power from fuel cells, and in some situations may be blended with natural gas.

As a practical matter, hydrogen is a small molecule and its properties make it trickier than hydrocarbons to transport and store. Any type of energy conversion including storage runs into the pesky laws of thermodynamics, there is energy lost in the conversion cycles.

Power Supply Strategy – Hyperscale Data Centers & Megacampuses

When siting power intensive, mission critical facilities my power supply objectives are the Three R's: Robust, Resilient, Reasonably priced; a fourth R, Renewable, is becoming more important all the time, especially for data centers.

- **Robust** – existing and near term new generation and transmission capacity in excess of the area's current and anticipated future needs
- **Resilient/Reliable** – The key thing in this respect is redundancy. Balanced conventional/renewable generation fleet including fast ramping peak generation and energy storage; redundant transmission
- **Reasonably priced** – Electricity can comprise up to 70% - 80% of a data center's total operating cost (TOC) T&D World the cost of power cost, especially for hyperscale data centers is an important consideration
- **Renewable –** most utility scale renewable energy projects to date have been solar and wind and that is likely to continue to for years; some major data center owners are now looking to achieve their carbon footprint targets using geothermal and eventually, nuclear power

Power Supply Landscape The Next Several Years

Installations of solar and wind facilities will continue at major scale and rapid pace in the U.S. The challenge is to maintain supply reliability and grid stability with the increasing amount of intermittent renewable energy coming online. In an effort to address this issue, most major renewable energy projects will include a substantial energy storage component. In the near term most of that will be battery energy storage. Cost effective, long-duration battery energy storage at grid scale could have a major positive impact some point in the not too distant future.

Retirements of some older coal, natural gas and nuclear plants in some U.S. markets will be delayed by necessity. And some retired power plants will be re-powered e.g., replacing coal with natural gas. Dispatachable natural gas fired generation, both combined cycle baseload including spinning reserves, and fast ramping/peaker configurations, will continue to play a critical role in power reliability and grid stability.

Utilities with modern natural gas generation fleets including fast ramping generation, advanced natural gas power projects and the natural gas supply necessary to fuel them will be well positioned to address major increases in energy demand in a timely manner while maintaining reliability and grid stability. Some additional positives for utility scale power supply include:

- Modern and balanced generation fleet
- In progress and advanced generation projects
- Substantial fast ramping generation and energy storage
- Stable local and regional transmission systems
- In progress and advanced local and regional transmission projects
- Regional pricing/trading hub
- Natural gas transport pipelines

Strategic Siting – Plan and Execute

Plan – Define goals and plan for critical points including:

- Coordinate with utilities, and other critical stakeholders early and concurrently
- Be focused and fierce in preliminary due diligence
- Target in service timeline(s) will help define viable sites and interconnections
- Power demand: underestimating can result in less than optimal capacity; overestimating can mean unnecessary delays in bringing the data center online. Area Development
- Anticipate taking an active role in the primary power supply – being part of the solution rather than part of the problem
- Consider locations in close proximity to primary generation
- Explore existing and emerging potential to develop in concert with power projects

The goal is securing sites that have all the attributes requisite for hyperscale data centers and ideally ones that have competitive advantages in terms of total required capital expenditure; timeline to commercial operation; and ongoing operating costs, especially power. The optimal interconnection configuration, primary and backup power supplies will be site and data center design specific. Generally, relatively large sites will offer more optionality.

Execute – Secure viable site(s) and start the development and interconnections processes.

Standard data center site requirements:

- Robust, reliable, reasonably priced power
- Fiber connectivity, multiple backbone lines a plus
- Relatively large parcels close to critical interconnections
- Geologically stable
- Low risk of natural disasters
- Water legally and physically available
- Straightforward zoning path, friendly jurisdictions
- Economic incentive packages

There are known site options meeting the requirements above with preliminary due diligence completed have a head start. There are also existing and emerging opportunities at the intersection of hyperscale data centers and power development – developing in conjunction with and/or aligned with advanced power projects, including utility scale renewable energy projects.

In some cases the power projects are located in the general area and will interconnect to the same local transmission system. For others, the power projects are adjacent, which may serve to reduce interconnection costs and configurations, optimize power supply options, and accelerate timelines. Viable sites and adequate power supplies are finite in a given area and timeframe. Hyperscale data center developers may find themselves playing musical chairs for the best site and power supply options.

The limited supply of hyperscale data center capacity and the explosive demand from widespread implementation of AI is creating hyperscale data center and related infrastructure investment and development opportunities at major scale. Investors and developers who plan strategically and execute purposefully will have a meaningful advantage.

Strategic Siting™ Trey Champie sites large scale, mission critical projects on both supply and demand sides of the power grid. Email: champie@headquarterswest.com mobile: 520-235-3577

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