KKR

Market Review

Infrastructure
November 2024

The Digital Power Problem

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KEY TAKEAWAYS

- Two of our major themes, digitalization and the energy transition, are converging. Data centers and other large-scale power users are starting to have trouble sourcing enough electricity for their operations.
- Supported by transformative technologies like artificial intelligence, the increased demand for data creates a compelling backdrop to invest in the hard assets enabling the digital ecosystem. This starts with data centers, but also includes fiber optic networks, wireless towers, and other assets.
- Large-scale investment in both power generation and transmission will be needed to solve the digital power problem, along with new technology and creative solutions. We believe this will lead to an increase in energy transition investments and technologies, as well as ongoing opportunities in conventional energy.
- Digitalization, the energy transition, and the digital power problem are massive challenges that require scaled capital and deep sector expertise to solve, but also present a tremendous investment opportunity to those with the ability to solve them.

Exploring the Digital Power Problem

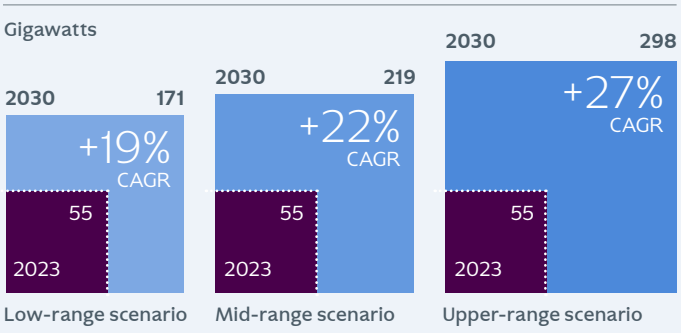
For years, digitalization and the energy transition have been two of our most important investment themes. As we head into 2025, we are seeing them converge. Power feeds the artificial intelligence revolution, but securing power is also the revolution's greatest obstacle, especially when everything from transportation to heavy industry is undergoing electrification. For infrastructure investors, we think this dynamic will yield substantial investment opportunities for the next decade and longer.

The current rise in demand for electricity comes after a long period of stagnation. Electricity demand in the United States was essentially flat from the early 2000s until recently, thanks to innovation and energy efficiency improvements.[1] Now, overall electricity demand is poised to grow 2.4% per year, according to our Global Macro & Asset Allocation team. The International Energy Agency estimates that the share of electricity in global final energy consumption will rise from 20% to 28% by 2050, and that number could be even higher if the drive to achieve net zero emissions results in dramatic change to the energy mix.[2]

Data centers are one of the key drivers behind rising power demand. Artificial intelligence, connected devices, smart cities, virtual reality technology, and driverless cars all consume and produce an enormous amount of data that requires vast and fast computing to analyze and process. Companies and institutions are also continuing a long-running transition from storing data onsite to in the cloud. Finally, more and more people are online both on broadband and mobile devices, using data-intensive applications like on-demand video, video conferencing, gaming, and cloud computing. The end result is that the amount of global data storage and processing could increase at an annual rate between 19%-27% between now and 2030, climbing from today's 60 GW capacity to 171-298 GW (Exhibit 1). As we discussed in February 2024, data centers are the hubs of digital infrastructure and are essential to enabling these systems and services, as are fiber optic networks and wireless towers. According to McKinsey estimates, developers will have to build in a mere six years twice the data center capacity brought online since 2000 to avoid a data processing deficit.

For data centers alone, electricity demand is projected to nearly triple by 2030.[3] A single planned data center campus typically requires 300-500 MW of power and requires an investment of $15 billion or more across data center and power equipment. Artificial intelligence is particularly power-hungry: McKinsey notes that average power densities have more than doubled in just two years and could nearly double again (from 17KW per rack to 30) by 2027.[4] Our macro team estimates that about one-third of the increase in U.S. annual electricity demand could come from data centers.

EXHIBIT 1: Global Demand for Data Center Capacity



Source: McKinsey Data Center Demand Model as of October 29, 2024. Note: The charts shows three scenarios representing an upper, lower, and mid-range estimate of demand, based on analysis of AI adoption trends, growth in shipments of different types of chips and their associated power consumption, and the typical compute, storage, and network needs of AI workloads. Demand is measured by power consumption to reflect the number of servers a facility can house.

1 U.S. Department of Energy. "Clean Energy Resources to Meet Data Center Electricity Demand." August 12, 2024. https://www.energy.gov/policy/articles/clean-energy-resources-meet-data-center-electricity-demand#:~:text=Now%2C%20in%20response%20to%20transformations,15%2D20%25%20in%20the%20next
2 International Energy Agency. "World Energy Outlook 2022." P. 44. https://www.iea.org/reports/world-energy-outlook-2022/an-updated-roadmap-to-net-zero-emissions-by-2050
3 Goldman Sachs
4 McKinsey. "AI power: Expanding data center capacity to meet growing demand." October 29, 2024. https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/ai-power-expanding-data-center-capacity-to-meet-growing-demand

The strain in the power generation system and its interplay with data center development is becoming apparent. In northern Virginia, the data center capital of the world, the local utility recently extended the time it will take for large (100MW+), new data center projects to connect to the grid to 4-7 years, up from 1-4 years previously. There have also been reports of hyperscalers backing out of development deals given a lack of clarity around obtaining sufficient electricity to power those projects. U.S. cities such as Columbus, Ohio, and Atlanta are increasingly attractive to large technology firms because of their abundant power. Waldemar Szlezak, who heads KKR's digital infrastructure investment business, points out that the cost of capital for data centers will continue to rise as power source risk increases. When we pursue data center investments, we consider access to power a key risk factor and focus on digital gateway cities with adequate supplies of power.

Ireland is a prime example of what can happen when a market overcommits: Dublin was a popular destination for data center development in the decade up to 2022, at which point data centers were taking up close to 20% of the grid's capacity.[5] In 2022, the national utility regulator told national grid operators to consider the location of data centers, their ability to generate or store more energy than they use, and their flexibility to reduce electricity consumption if necessary, before approving new data centers. Moreover, a de facto moratorium was placed on approvals of new data centers in Dublin specifically until 2028. In one case, a data center developer reportedly had already gotten plans approved and secured land to develop brownfield and greenfield data center projects when word of the moratorium surfaced. The developer's pending application for a grid connection was ultimately refused, and the business entered voluntary liquidation.[6] There have been reports of other developers moving their applications to other parts of Ireland, and industry representatives have called for greater clarity about the future of data center approvals in the country.

One way to avert a power supply problem is to bring your own power, an idea gaining more attention among hyperscalers and developers. Some developers are considering building new data centers close to natural gas lines or near nuclear power plants. "Behind-the-meter" solutions would have data centers install sources of power such as natural gas turbines or renewables on site and directly power the facility, thereby bypassing the regulatory approvals needed for a connection to the grid. On the other hand, bypassing integral utility providers creates serious cost efficiency and self-sufficiency challenges, particularly if something goes wrong and the facility needs the grid for backup power.

For their part, utilities are grappling with the need to make very large investments and want to be sure that data center operators will be long-term customers. Should they make substantial investments based on long-term demand estimates that turn out to be wrong, other businesses and residential users could be left to pay the balance of the cost. We expect the best path forward will be one where utilities, power consumers and power generators work together in a mutually beneficial way to solve the digital power problem. In Ohio, for example, a variety of stakeholders such as labor unions, a private economic development corporation called Jobs Ohio, and representatives of state government are partnering with the utility to determine how best to attract data centers in a responsible way.

What no one doubts is that generating and transmitting more power to support increased demand will require expanding existing infrastructure, investing in new technologies, and coming up with creative solutions.

5 Ireland Central Statistics Office. "Data Centres Metered Electricity Consumption." June 12, 2023. https://www.cso.ie/en/releasesandpublications/ep/p-dcmec/datacentresmeteredelectricityconsumption2022/keyfindings/

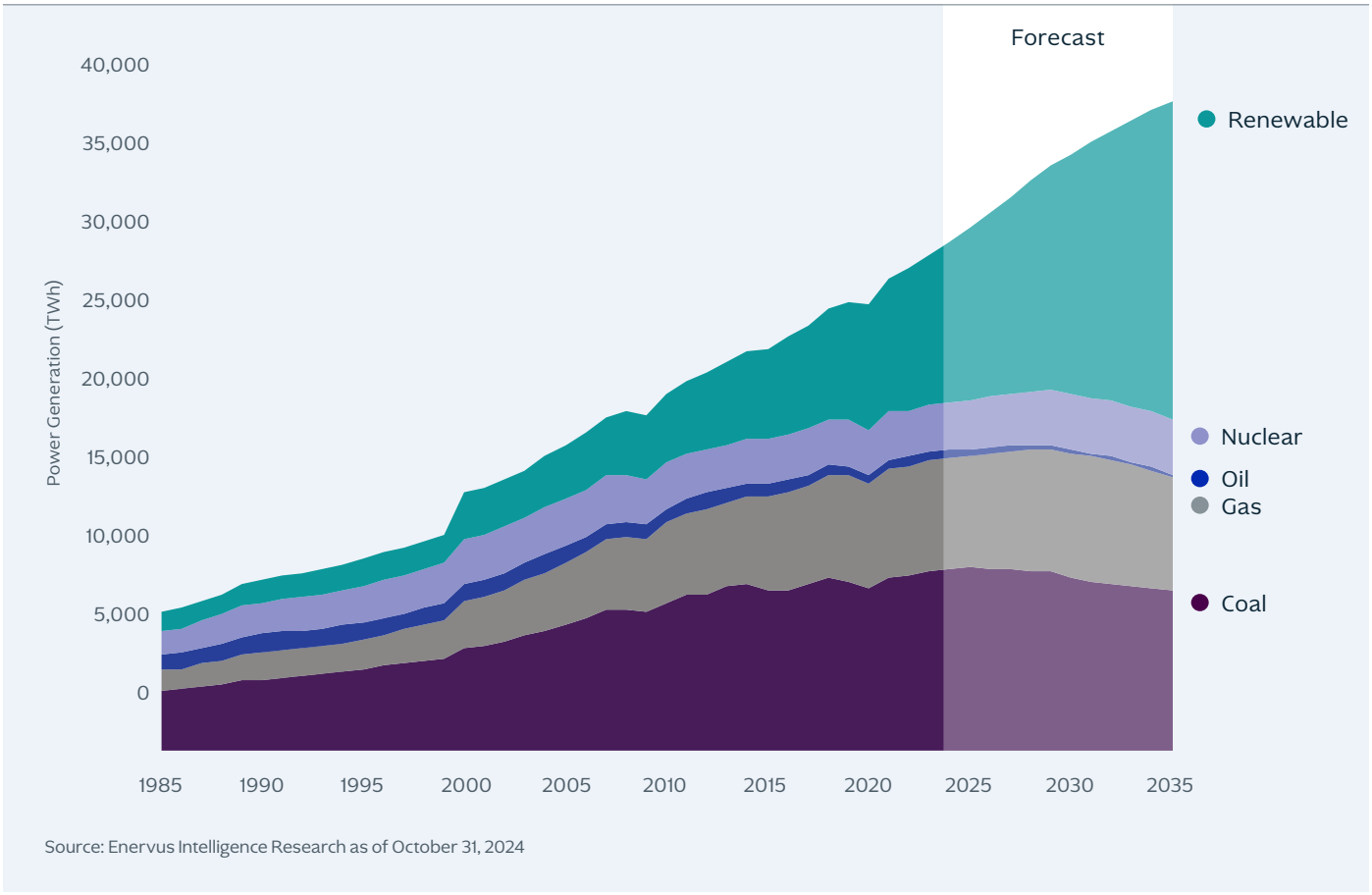
6 Moss, Sebastian and Dan Swinhoe. "Ireland's Dataplex enters voluntary liquidation after Eigrid denies power contracts at two data center sites." Data Center Dynamics. August 8, 2022. https://www.datacenterdynamics.com/en/news/irelands-dataplex-enters-voluntary-liquidation-after-eigrid-denies-power-contracts-at-two-data-center-sites/

Renewable Energy

We continue to believe renewable energy is an important part of the power solution (Exhibit 2). Renewables have become cost-competitive and relatively quick and practical to deploy (Exhibit 3), The commitments governments and companies alike have made to attain net-zero carbon emissions in the coming years add to the support for renewables. Our investment this year in Avantus, a utility-scale renewables developer; CarbonCount Holdings, a joint venture to invest $2 billion in clean energy assets; Greenvolt, a large-scale Portuguese developer of wind, solar, and storage with sustainable biomass and residential solar businesses; and Encavis, a leading renewable energy platform and independent power producer operating solar and onshore wind farms across Western and Northern Europe, shows our confidence in the sector.

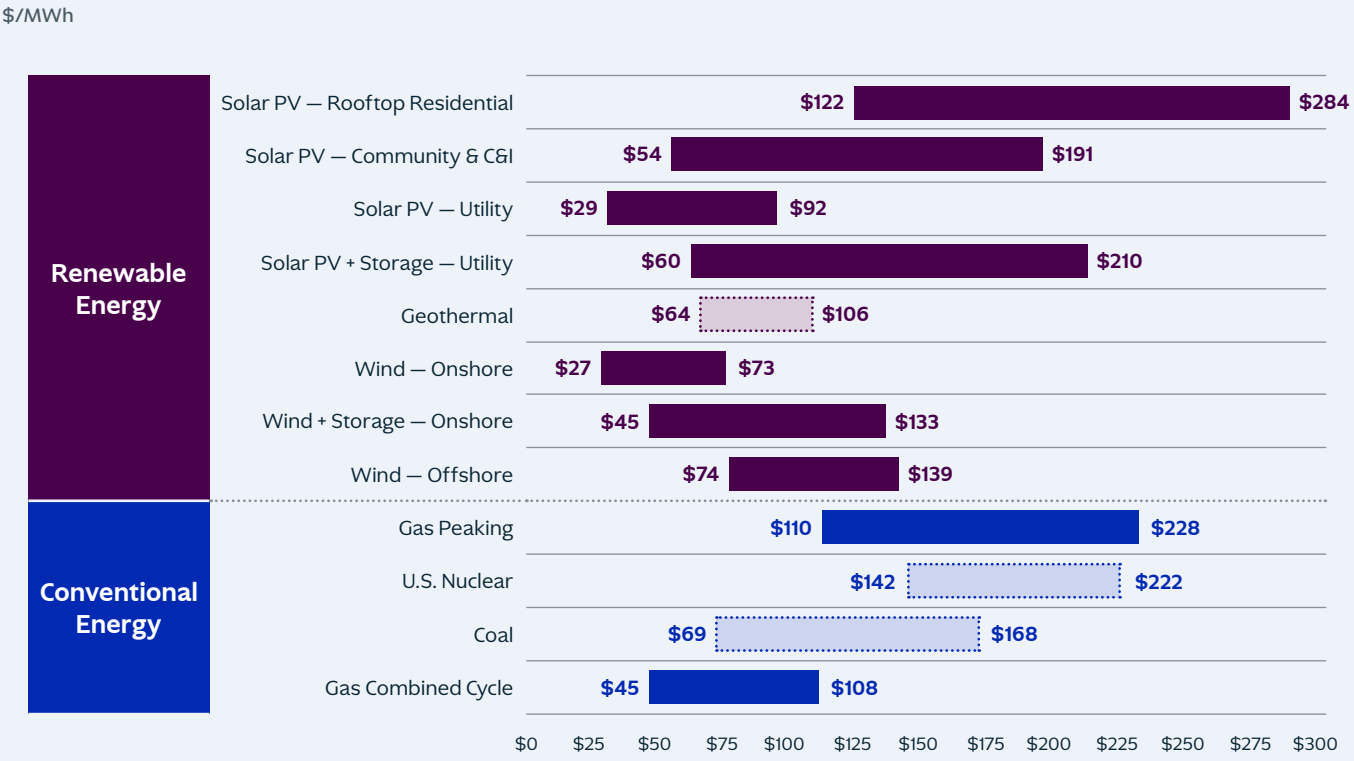
With all the new demand in the system, we expect an increase not only in renewable energy investing, but also new energy transition technologies. Splitting water into hydrogen and oxygen and using the hydrogen gas to create electricity has been a popular idea in energy circles, for example. However, hydrogen fuel is only considered green if the energy used to split the molecule comes from renewable sources. Emmanuel Lagarrigue, co-head of our global climate strategy, has pointed out that hydrogen was an idea that got some investors prematurely excited, but the bubble has more or less burst. Serious investors in this space must contend with higher costs of production than they do with other energy sources, risks in transporting the gas, and the lower efficiency of hydrogen engines compared to diesel engines.

EXHIBIT 2: Global Power Generation Forecast



Source: Enervus Intelligence Research as of October 31, 2024

EXHIBIT 3: The Levelized Cost of Energy



Source: Lazard LCOE Analyais as of June 2024

That said, we think that a second wave of more practical investment ideas is emerging. We are proud of our new partnership with the Spanish company Ignis to develop green hydrogen and green ammonia (a sort of second derivative of green hydrogen), in a platform that also includes advanced renewables projects that we see as a form of potential risk mitigation. Our commitment will fund investments in hydrogen solutions for industrial uses in sectors that are difficult to decarbonize. Importantly, the hydrogen projects are expected to be located near the large steel refiners and chemicals/fertilizer manufacturers that have already agreed to buy them, as opposed to the speculative production that has sometimes failed to materialize in other business models. (It remains to be seen whether hydrogen can directly offset data center energy consumption or whether the effects will be more indirect — freeing up power from other sources for use in data centers, for example.)

At this point, however, renewables cannot be the sole answer to the increase in energy demand. The energy they produce must be transmitted over long distances from sunny, windy, open spaces to densely populated areas. In the United States, existing grid infrastructure needs both basic investment and new technology to make this possible. The Department of Energy estimates that 47,300 gigawatt-miles of additional transmission infrastructure will be needed by 2035 to provide the country with enough power for a future with a greater amount of clean energy power generation, but moderate increases in load.[7] That's a 57% increase.

7 U.S. Department of Energy. "National Transmission Needs Study: Draft for Public Comment." February 2023. P. 130. https://www.energy.gov/sites/default/files/2023-02/022423-DRAFTNeedsStudyforPublicComment.pdf

Given the demands on the power system from both artificial intelligence and related digital technologies and increases in traditional manufacturing, it seems inevitable that there will be a tremendous need for additional investment in transmission regardless of the fuel mix, which creates opportunities for infrastructure investors. To complete the transmission and distribution investment required, we believe that permitting and regulatory processes will need to be streamlined, as it can take as long as a decade to get long-range transmission lines built and approved.

Storing power is another obstacle to renewable solutions. Storing power is costly, and existing commercial battery technology typically provides storage capacity of about 4-8 hours, with longer durations becoming economically challenging. When the sun is not shining and the wind is not blowing, data centers powered by renewables need a backup plan. The largest data center company we own, CyrusOne, has even repurposed diesel locomotive engines that can power the data center if the backup generators fail. There are many technologies being explored for longer-lasting power, including sodium batteries, but repeatable, scalable, and economically feasible power storage technology does not yet exist.

It seems inevitable that there will be a tremendous need for additional investment in transmission regardless of the fuel mix.

A Note on the Energy Transition and Recent Elections

Voters in the United States and other nations expressed frustration with inflation in 2024, including higher energy prices. Their clear message is a reminder that a politically sustainable energy transition has three pillars: environmental responsibility, consumer affordability, and resilience/security.

The new administrations and governing bodies in the United States and other nations will almost certainly alter certain aspects of energy policy, and these changes will likely affect the investment landscape for both conventional and renewable energy. However, we believe the energy transition is a secular and enduring shift rooted in the longer-term factors described in this note—increased needs associated with digitalization, opportunities for energy independence and security through homegrown and more distributed sources of energy, and the reshoring of manufacturing. It's also true that some components of U.S. energy and infrastructure policy are bipartisan. We do not see potential shifts in policy as determinative or binary for our investments. Moreover, our investments typically endure beyond any particular two-year or four-year election cycle, and so we take a long-term view.

In the end, we do not seek to make investments that depend on predicting specific policy outcomes. Rather, we seek investments that align with government priorities and policy and enduring societal objectives and will continue to look for compelling investment opportunities in both renewable and conventional energy.

Conventional Energy Sources

Conventional energy sources will also be critical in solving the power problem, providing a reliable source of power supply that can balance out the intermittency of renewables and serve as a gap-filler until investment and technology in renewables, storage, and other technologies can catch up.

At this point, conventional energy sources are still essential to supporting everyday life. As demonstrated in Exhibit 2, fossil fuels make up well over half of power generation today and are expected to do so in the foreseeable future as well. Coal is still the second-most important fuel for electricity generation in the United States (Exhibit 4). Even in Europe, fossil fuels account for some 29% of electricity generation, with coal responsible for nearly 16% (Exhibit 5). Switching from coal to other fuels is an ongoing part of the energy transition.

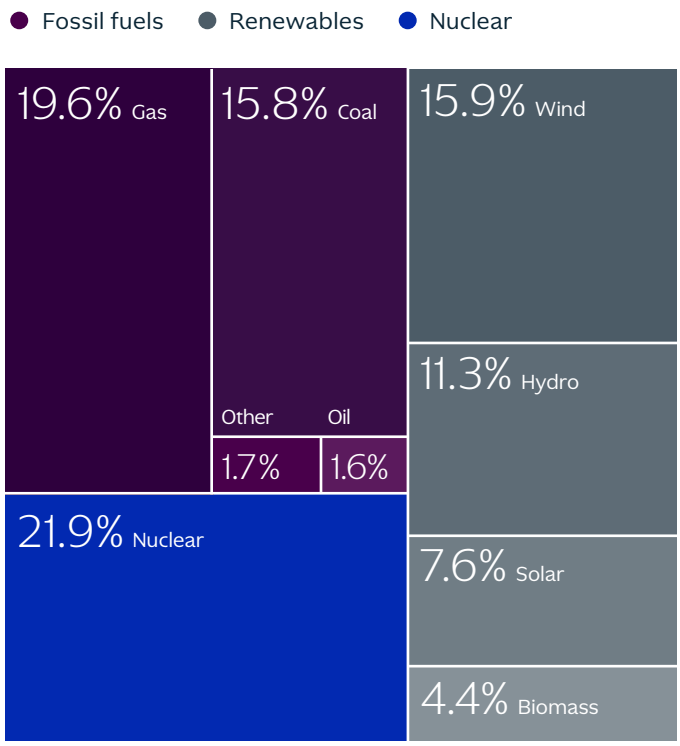
Natural gas will be a critical tool in lowering emissions intensity and continuing to support the energy transition.

EXHIBIT 4: U.S. Utility-Scale Electricity Generation

Energy source	Billion kWh	Share of total
Total — all sources	**4,178**	
Fossil fuels (total)	**2,505**	**60.0%**
Natural gas	1,802	43.1%
Coal	675	16.2%
Petroleum (total)	16	0.4%
Petroleum liquids	12	0.3%
Petroleum coke	5	0.1%
Other gases[3]	11	0.3%
Nuclear	**775**	**18.6%**
Renewables (total)	**894**	**21.4%**
Wind	425	10.2%
Hydropower	240	5.7%
Solar (total)	165	3.9%
Photovoltaic	162	3.9%
Solar thermal	3	0.1%
Biomass (total)	47	1.1%
Wood	31	0.8%
Landfill gas	8	0.2%
Municipal solid waste (biogenic)	6	0.1%
Other biomass waste	2	0.1%
Geothermal	16	0.4%
Pumped storage hydropower[4]	**-6**	**-0.1%**
Other sources5	**10**	**0.2%**

Source: U.S. Energy Information Administration, preliminary data as of February 2024. (1) Utility-scale electricity generation is electricity generation from power plants with at least one megawatt (or 1,000 kilowatts) of total electricity generating capacity. Data are for net electricity generation. (2) Small-scale solar photovoltaic (PV) systems are electricity generators with less than one megawatt (MW) of electricity generating capacity, which are not connected at a power plant that has a combined capacity of one MW or larger. Most small-scale PV systems are at or near the location where the electricity is consumed and many are net metered systems. Smaller PV systems are usually installed on building rooftops. (3) Other gases includes blast furnace gas and other manufactured and waste gases derived from fossil fuels. (4) Pumped storage hydroelectricity generation is negative because most pumped storage electricity generation facilities use more electricity than they produce on an annual basis. Most pumped storage systems use electricity from an electric power grid for pumping water to the storage component of the system. (5) Other (utility-scale) sources includes non-biogenic municipal solid waste, batteries, hydrogen, purchased steam, sulfur, tire-derived fuel, and other miscellaneous energy sources.

EXHIBIT 5: Net Electricity Generation in the EU by Fuel Type



Source: Council of the European Union as of 2022. Note: Geothermal energy, which represents 0.2% of energy transmission is not included due to legibility.

Natural gas will be a critical tool in lowering emissions intensity compared to coal and continuing to support the energy transition. In both the United States and Europe, it is the single most important fuel source in electricity generation and an important tool in supplying cleaner energy. Burning natural gas yields half the amount of carbon dioxide emissions as burning coal and roughly one-third that of oil.[8] Global demand for liquified natural gas (LNG) is growing, particularly in Europe and Asia. We see this uptick through the many North American natural gas businesses to which we're exposed, such as Sempra Infrastructure and Pembina Gas Infrastructure. We see an ongoing opportunity for investors to invest in natural gas assets around the world.

Nuclear

Nuclear continues to be floated as a potential solution to the digital power problem, an idea made more credible by the announcement that Microsoft is leading the rehabilitation of Three Mile Island. While nuclear has the potential to be a carbon-free solution over the long term, it comes with both financial and timing risks and capital challenges.

Small modular reactors (SMRs) are smaller, more distributed nuclear reactors designed to generate 200-300 MW of power at a lower cost than traditional nuclear reactors. Waldemar Szlezak has suggested these reactors could be sited at decommissioned coal plants, which have the extensive land, access to water, and relatively remote locations that reactors need. There is some precedent for this in Bitcoin miners reviving coal plants long since taken offline. However, SMRs have not yet been commercialized, and we do not think they currently provide the investable risk-return framework that fits our infrastructure pools of capital.

Creative Approaches

Private infrastructure investors have a unique opportunity to help provide creative solutions to the digital power problem. Our recent announcement of a $50 billion strategic partnership with Energy Capital Partners (ECP), the largest private owner of power generation and renewables in the U.S., to pursue global development of data center, power generation, and transmission assets shows how we are thinking about the partnerships that will be needed for the private sector to successfully tackle the digital power problem.

8 Center for Climate and Energy Solutions. "Natural Gas." Accessed November 13, 2024. https://www.c2es.org/content/natural-gas/

A digital power problem requires a digital power solution: in this case, ready-to-deploy capital that combines expertise and relationships in both the data center space and the power supply space. Hyperscalers operate at the bleeding edge of technology and have stringent requirements for developers to ensure that data centers can meet their requirements and operate reliably, with no downtime. They increasingly want to work with a consolidated list of partners that they know can deliver capital and power at scale, and they place a deep value on experience and track record. Our partnership aims to deliver exactly that.

EXHIBIT 6: KKR Data Center Investments

4 platforms worldwide	100 data centers
$40B in enterprise value	$110B pipeline

Digital Investments in the Middle of a Hype Cycle

It isn't yet clear which combination of these technologies or those that remain undiscovered will power data centers as demand for data processing grows. Another area of uncertainty and risk is exactly how artificial intelligence will be commercialized into products consumed by businesses and consumers. We see the explosion in data as a rising tide that lifts all digital infrastructure boats, but also acknowledge that there is a certain amount of hype in the sector, and valuations have gone up accordingly. We are focused on long-term, contracted projects and developers with asset-based protection. Creativity is also helpful in this arena. CyrusOne, our portfolio company and one of the largest data center developers and operators in the world, has been pursuing corporate partnerships in areas where outright buying of assets doesn't make sense or is prohibitively expensive.

We continue to focus on hyperscalers, who have strong market positions and can commit to long-term leases. For now, the cycle shows no signs of softening, but when it does, we think that developer/operators that rent short-term space in their data centers will likely be impacted first. Investors have been enthusiastic about funding these companies, which tend to have access to the limited supply of GPU chips that can power AI algorithms, but we are focused on those businesses that we believe will weather the inevitable ups and downs of the market.

In 2025, we expect to continue to advance our data center development and transmission through our ownership of CyrusOne and other investments. These include a stake in Singtel's regional data center business, Nxera; a consortium investment with Singtel in the Singaporean regional data center player STT; and European data center platform GTR (Exhibit 6). Given the competitive nature of the space, we have been focused on developing deep relationships with hyperscalers, chip manufacturers, AI developers, and other players coupled with the investments, knowledge, and value-add we bring with our large private equity franchise.

Fixed-line networking businesses are generating less hype than data centers, and the sector has encountered turbulence in recent years due to heavy competition among retail fiber players in certain areas. However, we continue to believe that fiber optic cable is a critical component of the digitalization story. We focus on building wholesale networks that can accommodate multiple providers and focus on investments with long-term contracts. In this vein, we have been extremely active in the sector over the past few years. As long-term investors in heavy assets, we listen to the long-term signal rather than the short-term noise of the investment cycle. Residential consumers and small-to-medium sized businesses are demanding faster, more reliable internet that can easily handle video calls, streaming content, and connected devices. Fiber is the fastest and most reliable way to access the internet. We think there is still a great long-term opportunity to expand broadband access by

building and acquiring fiber optic networks where we can offer compelling alternatives to slower, less reliable technology while also protecting our investors' capital. We are particularly proud to have acquired Telecom Italia's fixed-line network this year and entered an agreement to acquire Metronet in the United States in a joint venture with T-Mobile.

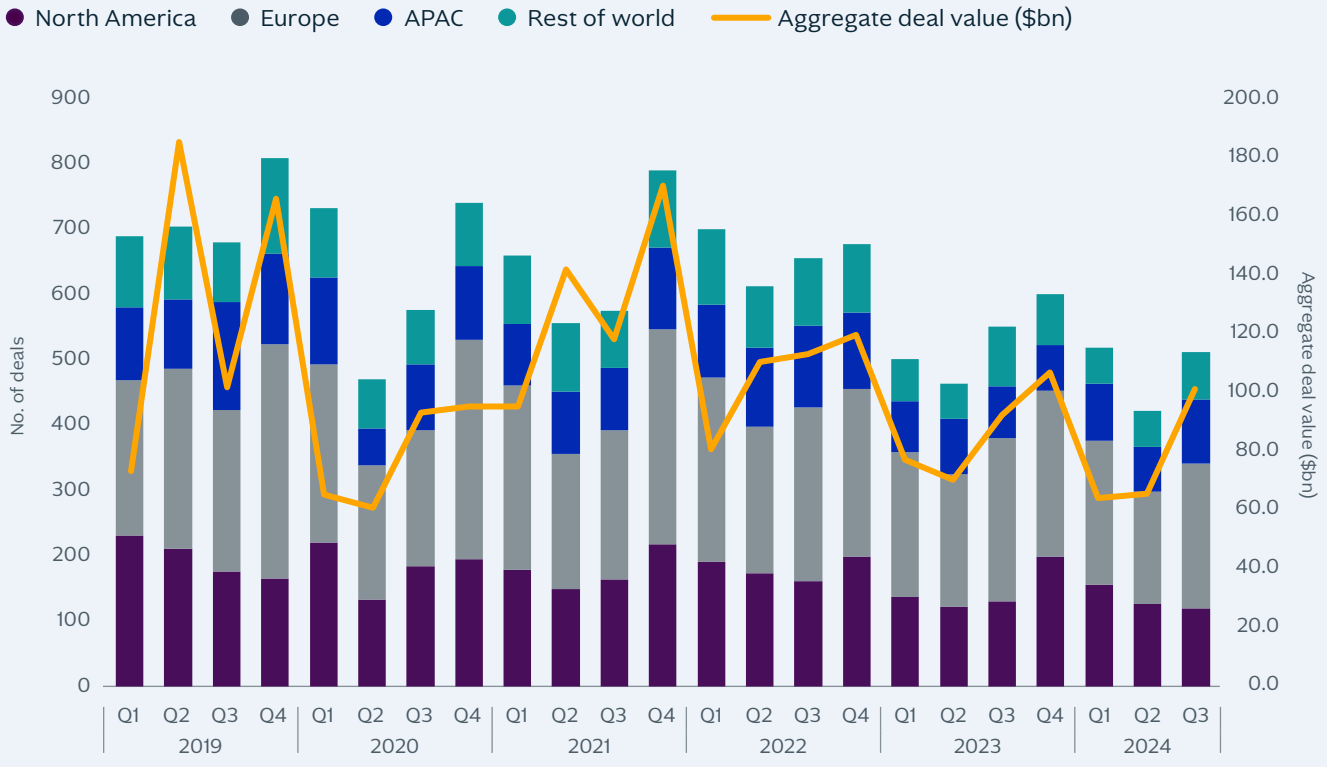
As the mobile revolution continues apace, we continue to see wireless towers as an attractive, core sector, with contracted cash flows backed by large and creditworthy companies, regulatory protections, relatively low levels of churn, and built-in inflation adjustments. This year, we bought more than 1,000 wireless communications towers in Colombia in a leaseback deal that will add to our digital infrastructure portfolio in Latin America, which also includes fiber investments in Chile and Colombia.

Is the Market Ready to Solve Big Problems?

The scale of the digital power problem is one that will require scaled investment and tremendous coordination and collaboration among many stakeholders to solve. Overall private infrastructure transaction volumes ticked up in the third quarter of 2024 (Exhibit 7), a trend that reflects the strong deal activity we have seen in our own pipelines over the last few quarters.

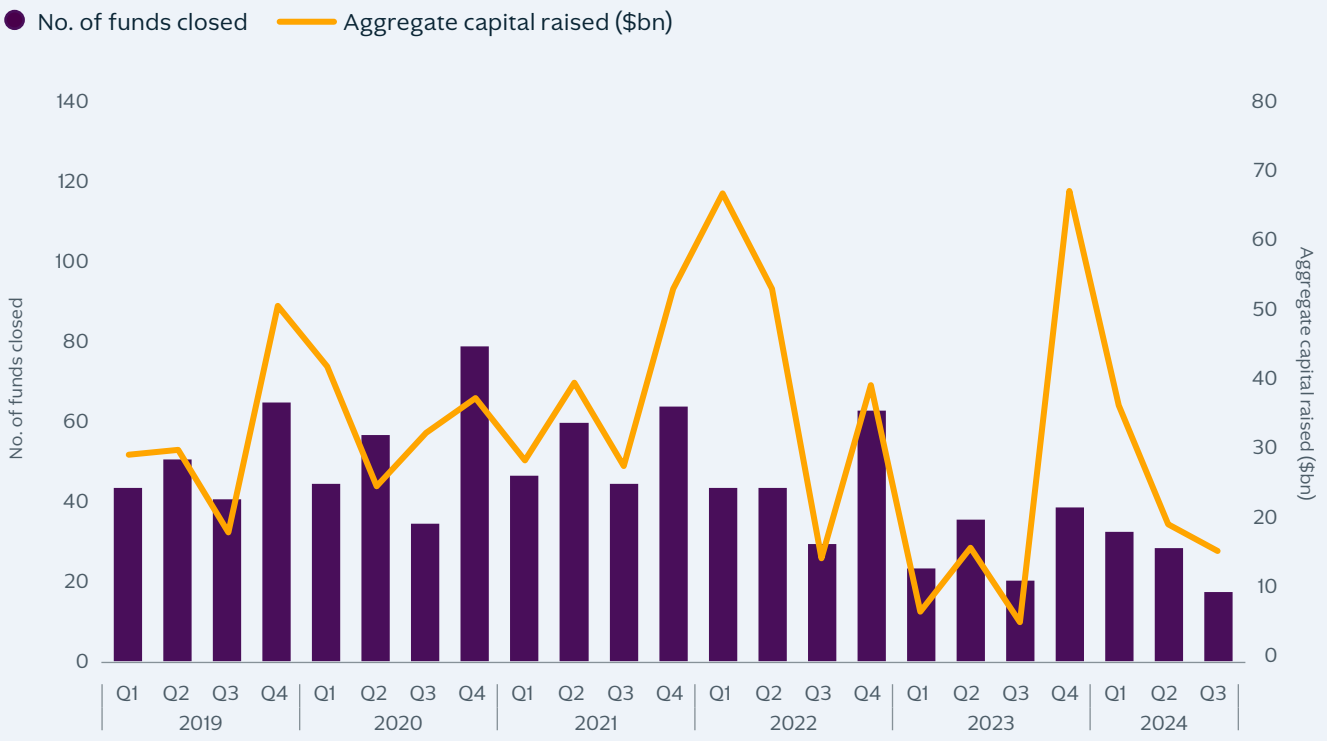
That said, the fundraising environment in the overall market is soft (Exhibit 8). We also note that infrastructure capital is relatively concentrated and still consolidating through ongoing M&A. The top four infrastructure managers on Infrastructure Investor's top 100 list have

EXHIBIT 7: Infrastructure Deals by Volume and Value



Source: Preqin as of September 30, 2024

EXHIBIT 8: Private Infrastructure Fundraising Activity



Source: Preqin as of September 30, 2024

raised over one-third of the group's aggregate capital.[9] As the No. 3-ranked infrastructure manager, we think KKR is positioned to provide scale and depth of resources.

We think stability in valuations, higher business confidence, and the reopening of the credit markets, in addition to the evolution of the digital power theme, should boost overall transaction activity in 2025. Our Global Macro & Asset Allocation team's Regime Change theory remains intact in the new U.S. political landscape, with continuing fiscal deficits, geopolitically driven supply chain reorientation, an energy transition funded with private capital, and a higher neutral inflation rate all likely to continue in 2025 and beyond. These are all factors that favor investment in infrastructure and other inflation-linked asset classes.

The themes of energy transition, digitalization, and their convergence in digital power are structural shifts that will continue to unfold over the coming years and decades, rather than over months or election cycles. The scale of the issues we are trying to solve in this arena are so massive that not only is the use of private capital inevitable, but successful players must also have access to scaled capital, deep sector and technical experience, the ability to form creative partnerships, and geopolitical perspective to win. In 2025, we expect to see scaled players leading in data center development and developing the creative solutions we will need to solve the digital power problem.

We remain committed to our risk-based approach to investing and our focus on capital preservation, particularly at a time of great change. But caution should conceal neither our conviction nor our excitement to help solve some of these pressing challenges and capture the tremendous investment opportunity in responsible ways. This is a time rich with opportunity, and we feel firmly positioned on the front foot as we look to capture it.

9 Infrastructure Investor. "The Top 100 Infrastructure Fund Managers." November 1, 2024. https://www.infrastructureinvestor.com/infrastructure-investor-100/

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