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Feeding the Hungry AI Lion: Navigating a Future of Increased Energy Demand and Limited Supply

By Neal Simmons[1], Peter Campbell[2] & David Shrier[2]

[1]Duke Univercity , [2] Imperial College London

V1.0 DRAFT January 2025

This paper was made possible through a collaboration with Payments Network Malaysia Sdn Bhd (Paynet)

Contact:
david.shrier@imperial.ac.uk

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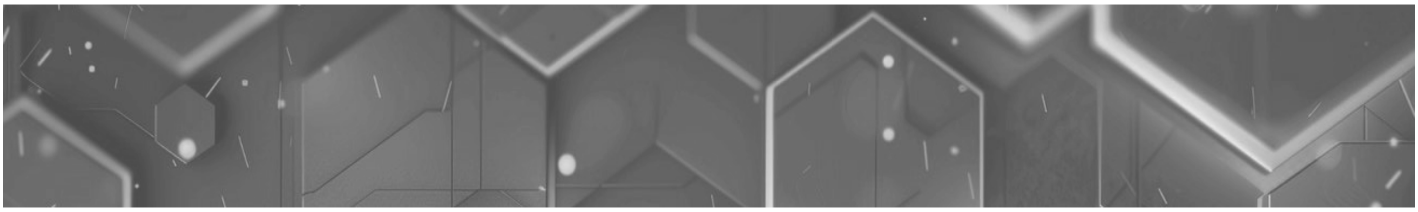
Executive Summary

We examine the escalating energy demands of artificial intelligence (AI) as its adoption and complexity expand rapidly, posing significant challenges for global energy systems. As AI technologies evolve, the energy required to power data centers and computational processes places increasing pressure on aging power grids, threatening reliability and sustainability. Despite incremental improvements in AI efficiency, the energy consumption associated with training and deploying AI models is projected to rise significantly, with AI data centers alone consuming a substantial share of global electricity by 2030. Our analysis included assessing the AI readiness of 25 countries using a proprietary methodology. We have provided a country scan and summary of our readiness index in Appendix A.

In this white paper, we highlight the critical need for investments in renewable energy, grid modernization, and energy-efficient technologies to ensure sustainable AI development. We emphasize the strategic importance of addressing these energy challenges to avoid disruptions, reduce reliance on fossil fuels (and explore further adoption of 'clean' technologies like nuclear), and promote equitable access to AI's benefits. Our findings underscore the urgency for a collaborative effort among policymakers, industry leaders, and energy providers to align AI growth with sustainable energy solutions, ensuring a resilient and equitable technological future.



1. Introduction

Artificial intelligence (AI) is revolutionizing industries globally, driving innovation, productivity, and economic growth. However, this rapid expansion comes with a significant demand for energy, placing enormous pressure on power grids. As AI usage increases, its applications become more widespread, and its models become more complex, and data centers proliferate to support them, the energy required to power these systems will rise dramatically and will exert a significant toll on already strained power grids.

The importance of raising awareness about these increasing energy demands and the significance that AI development will have on energy supply cannot be overemphasized. Without a clear understanding of the current trajectory, where energy consumption is rapidly outpacing supply, we risk hitting severe energy constraints that could stall AI's growth and limit its potential. The trajectory we are on suggests that AI could consume a substantial portion of available electricity within the next decade, straining grids that are already under pressure from other sectors. If this trend continues unchecked, it could lead to more frequent power outages,

increased reliance on fossil fuels, and a slowdown in the transition to cleaner energy. Stakeholders must recognize that the energy landscape is a critical factor that will determine the future of AI's development and deployment. AI models will become more efficient but not enough to counterbalance the paradigm shift that has already begun and incremental improvements (similar to what we have seen in the past with traditional computing) will be insufficient in the proliferation of AI's demand on energy.

This white paper explores the critical relationship between AI growth and energy consumption, emphasizing the challenges of balancing technological advancement with sustainable energy use. The soaring energy demands of AI are not a minor concern as they represent a significant problem that could fundamentally alter the trajectory of AI, global energy systems, and power grid stability. If left unaddressed, the strain on power grids could lead to severe disruptions, limiting AI's potential to revolutionize industries and improve lives. The competition for limited energy resources could force difficult choices, slowing down AI innovation and exacerbating global inequalities in access and the benefits of this important technology. The manner in which we manage the energy needs of AI today will determine whether we can sustain its growth tomorrow and energy scarcity will limit our technological progress and compromise our ability to achieve a sustainable, equitable future. Stable energy access and AI technological advancement are strategically important, and we need to recognize that our current energy demand projections don't account for all AI needs. A significant effort is required to understand gaps, update and increase infrastructure, and increase renewable energy production. Those that successfully invest resources will reap strategic advantages ranging from global influence and partnership, resilience and energy security, technological leadership and innovation, and economic competitiveness.

2. Background: The Evolution of Energy Needs and the Electricity Supply-Demand Landscape

2.1 Historical Context of Energy Needs and Grid Fragility

The post-World War II period marked a significant increase in energy consumption, driven by the widespread adoption of electrical appliances, air conditioning, and the expansion of suburban areas. This surge in demand led to rapid growth in power generation capacity, with fossil fuels—particularly coal—becoming the dominant sources of energy. However, the infrastructure built during this time was designed for a different era, and much of it has not kept pace with the evolving needs of a modern, electrified economy.

As energy demand has continued to grow, the fragility of the U.S. power grid has become increasingly apparent. Many parts of the grid were constructed in the mid-20th century and are now struggling to meet the demands of the 21st century. This aging infrastructure is particularly vulnerable to disruptions caused by extreme weather events, which have become more frequent and severe due to climate change. The grid's capacity to provide reliable electricity is now under significant strain, with blackouts and energy shortages becoming more common across various regions.

The shift towards renewable energy sources, while essential for reducing carbon emissions, has added complexity to the energy supply landscape. Renewable energy sources like wind and solar are inherently variable, as their output depends on weather conditions. This variability has introduced new challenges for grid operators, who must balance fluctuating supply with consistent demand. To address this, significant investments are needed in energy storage technologies and grid enhancements, such as advanced transmission systems that can better manage the integration of renewables. However, these investments are often slow to materialize, leading to a grid that is both outdated and overstretched.

Figure1 illustrates a concerning trend where the growth in peak electricity demand is outpacing the increase in on-peak resource capacity. This gap underscores the potential for future energy shortages, particularly during periods of peak demand when the grid is most strained. The limited growth in resource capacity compared to the rapid increase in demand highlights the urgency for accelerated investment in energy infrastructure, including both new generation capacity and the modernization of the transmission network. Without these investments, policy makers will need to chose how to best use a limited supply of electricity or sacrifice some reliability. While the data in figure 1 is from North America, this trend of peak demand outpacing new generation is global.

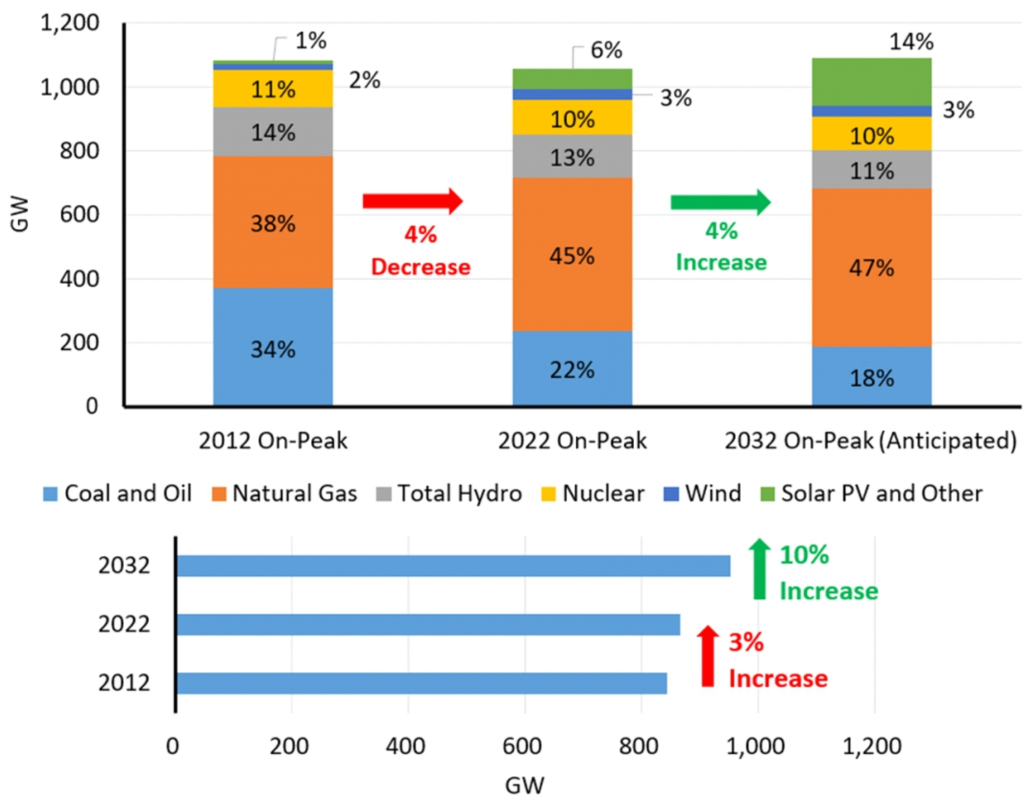


Figure 1: Change in Summer Peak Capacity and Demand Forecast 2012-2032
Source: NERC Long-Term Reliability Assessment 2023

2.2 The Shift Toward Electrification and Decarbonization

In response to the growing awareness of climate change and the need to reduce greenhouse gas emissions, there has been a global push to transition from fossil fuels to cleaner, renewable energy sources. This shift is being driven by ambitious decarbonization targets set by governments and international organizations, aiming to limit global warming and its associated impacts. A key component of this transition is the electrification of sectors traditionally powered by fossil fuels, such as transportation and heating.

The electrification of transportation, through the adoption of electric vehicles (EVs), and heating, via heat pumps, is accelerating. According to the International Energy Agency (IEA), global electric vehicle sales doubled in 2021, and this trend is expected to continue, leading to a substantial increase in electricity demand. As more homes and businesses transition to electric heating and as EVs become more prevalent, the pressure on the electricity grid is set to intensify. The surge in energy demand is occurring alongside the decommissioning of older, fossil fuel-based power plants, creating a potential gap between supply and demand.

Moreover, the increased reliance on renewable energy sources like wind and solar introduces variability into the power supply. Unlike traditional fossil fuel-based power generation, which can be adjusted to meet demand, renewable energy generation is dependent on weather conditions, making it less predictable. This unpredictability and since renewable energy generation is intermediate necessitates investments in more generation infrastructure and energy storage solutions, such as large-scale batteries and pumped storage, to store excess energy generated during periods of high renewable output and release it when needed. Additionally, modernizing the grid to handle these new challenges is essential but comes with significant costs and logistical hurdles. Increased and stable access to renewable energy will provide strategic advantages to countries as is required to meet current and escalating future demand, affords countries to be self-reliant for their energy needs, and provides a means of controlling energy and technological advancement. It will be required by citizens, companies, and trading partners to meet their energy needs, empower them, foster technological innovation, and provide a crucial means to decarbonization.

2.3 Current Energy Needs, Project Energy Requirements, and Energy Shortages

The combination of increased electrification, the retirement of older power plants, and the integration of variable renewable energy sources has created a scenario where the energy supply is not keeping pace with growing demand, particularly during peak periods. This is especially concerning as the effects of climate change as the power requirements significantly increase during extreme events. Extreme weather events, such as heatwaves, hurricanes, and winter storms, have exposed the vulnerabilities of the current energy infrastructure, leading to widespread outages and energy shortages in affected regions.

One stark example of these challenges was the winter storm in Texas in 2021. The state's power grid, managed by the Electric Reliability Council of Texas (ERCOT), was unable to meet the surging demand for electricity as temperatures plummeted. The result was a series of catastrophic blackouts that left millions without power for days. Such events underscore the urgent need for investment in grid resilience and modernization to prevent future shortages and ensure a stable supply of electricity, particularly in the face of a changing climate and the choices that governments can make in load placement.

In the PJM Interconnection region, the largest wholesale energy market in the US, which covers 13 states including Virginia, Pennsylvania, and Illinois, the latest capacity auction revealed a dramatic increase in prices. The clearing price reached $269.92 per megawatt-day for most of the region, nearly nine times higher than the previous year. These skyrocketing prices are a clear signal that the grid urgently needs new power plants to meet the growing demand. However, building new plants is a time-consuming process, often taking up to five years if constructed from scratch. As a result, these shortages could persist for several years, placing additional financial strain on consumers. Currently, PJM Interconnection is facing significant supply constraints. The region has experienced a wave of power plant retirements, particularly coal-fired plants, and is now relying on delayed retirements and new gas-fired generation to maintain reliability. Additionally, the aging U.S. power grid, much of which was built in the mid-20th century, is in dire need of modernization to handle the increased load from electrification, increasing numbers of AI data centers, and the integration of renewable energy sources.

The impact of rising electricity prices is already being felt by households and businesses. Utilities have warned that electricity bills will increase significantly, with some areas expecting double-digit percentage hikes in rates. For example, Chicago-based Exelon has reported that rates in its service areas will rise sharply due to higher capacity prices. This trend raises difficult questions about the fairness of passing on the costs of AI's energy consumption to consumers and whether the economic benefits of AI justify these higher energy prices.

Moreover, the financial burden on utilities and consumers could lead to political backlash and legal challenges, particularly as higher energy bills begin to affect a broader swath of the population. In response, some states are considering legislative changes that would allow utilities to invest in their own generation capacity, a move that could reshape the energy market in significant ways.

Even before the additional demand from AI data centers is considered, the global energy landscape is already facing significant challenges. Many regions are operating with tight supply margins due to the decommissioning of older, fossil fuel-based power plants and the slow pace of new capacity additions. The focus on renewable energy, while critical for achieving decarbonization goals, has introduced variability into the power supply. Wind and solar generation, which are increasingly being relied upon, are inherently dependent on weather conditions, making them less reliable for meeting consistent demand.

Regions like ERCOT and ISO New England (ISONE) are already grappling with the need to expand their generation capacity to meet rising demand driven by population growth, migration, and the ongoing electrification of the economy. These areas are investing heavily in wind, solar, and battery storage technologies. However, these resources cannot consistently deliver their full nameplate capacity over extended periods, posing a risk to grid reliability.

According to the latest Annual Planning Outlook and Emissions Update, electricity demand in some regions is projected to grow steadily at a rate of 2% per year, driven by new industrial projects, the electrification of transportation, and population growth. By 2050, overall electricity demand is expected to increase by 60%, with dual peaks in summer and winter due to agricultural demand and electrified heating. This increased demand, coupled with the decommissioning of gas generation facilities, could lead to inadequate generation capacity by 2030.

Planned nuclear facilities, along with ongoing competitive procurements, are intended to address these shortfalls, but significant execution risks remain. The Independent Electricity System Operator (IESO) recommends transmission projects to deliver new supply to the localities where it is needed and to replace aging infrastructure.

The North American Electric Reliability Corporation (NERC) Long-Term Reliability Assessment for 2023 stressed the mismatch between demand growth and capacity expansion and that this signals potential resource adequacy issues, particularly as older thermal generation is retired without sufficient replacement by firm, dispatchable resources. The report emphasizes the importance of timely investments in transmission infrastructure to mitigate these risks and ensure that new renewable resources can be effectively integrated to meet changing demand patterns.

The demand projections do not sufficiently take into account all future AI needs and the dependence of AI growth on increased and stable energy sources. Even as AI models become more efficient the proliferation of AI usage and hence demand will outpace our current energy supply based on the current trajectories. Current energy demand models are significantly understanding future demand as the US grid could increase by two to three times by the 2050s. The North American Electric Reliability Corporation (NERC) forecasts 78 gigawatts (GW) of peak demand growth over the next 10 years, an amount that has almost doubled since it was previously forecasted at 40 GW of growth only two years ago.

3. AI and Energy: Current and Projected Needs

3.1 Fundamentals of Electrical Consumption from AI Chips and Data Centers

AI systems are powered by specialized hardware, particularly GPUs (Graphics Processing Units) and TPUs (Tensor Processing Units), designed for the intensive parallel processing tasks that AI workloads require. These chips are essential for both training complex AI models and running large-scale inference operations, and they are extremely energy intensive. For context, CPUs (Central Processing Units; the predecessor to GPUs) ran on roughly 150-200 W/chip. GPUs for AI increased this first to about 400 W/chip, but subsequent generations of AI chips would see this figure rise to 700 W/chip in 2023, and finally up to 1,200 W/chip in 2024. Inside data centers, typical designs see about 80 of these chips being contained inside a “rack”. The typical power density per rack sat at about 36 kW in 2023, and is expected to increase to 50 kW by 2027. Meanwhile, the latest generation of TPUs—Google Cloud TPU v4—use between 200 and 250 W/chip, but this figure too has been rising with each successive generational advancement.

The computational processes involved in AI, especially in training large language models like GPT (Generative Pre-trained Transformer), demand vast amounts of electricity. These processes require thousands of GPUs running continuously for weeks or even months, consuming substantial energy not only for computations but also for cooling the data centers housing these chips. This dual requirement for computational power and cooling significantly contributes to the overall energy consumption of AI technologies.

In the context of AI, GPUs (Graphics Processing Units) are critical for accelerating the training and inference of large models, handling tasks that require processing vast amounts of data simultaneously. Their architecture, which allows for thousands of cores to work in parallel, makes them much more efficient for these types of computations compared to traditional CPUs (Central Processing Units). This capability has made GPUs indispensable in data centers and AI applications, though it also leads to significantly higher power consumption due to the intensive nature of their workloads. Nvidia's upcoming Blackwell generation, a new line of high-performance GPUs designed for advanced AI and high-performance computing (HPC) applications, will dramatically increase power demands. The B200 model will consume up to 1,200W, while the GB200, which combines two B200 GPUs with a Grace CPU, is expected to draw an enormous 2,700W. This represents up to a 300% increase in power consumption in just one generation of GPUs, as AI systems drive energy demands to unprecedented levels.

GPU power consumption is rapidly increasing for all GPUs on the market. MI250 accelerators draw 500W of power, reaching up to 560W at peak, while the MI300x peaks at 750W, representing a 50% increase. Intel's Gaudi 2 accelerator consumes 600W, with its successor, the Gaudi 3, consuming 900W—again, a 50% rise over the previous generation. Intel's upcoming hybrid AI processor, codenamed Falcon Shores, is projected to consume 1,500W per chip, the highest power consumption seen in the market. This increase in computing and concomitant power consumption driving the concentration of energy requirements which place increased stress on the power infrastructure compared to more diffuse energy growth from other sectors.

Studies suggest that by 2026, data centers could consume double the electricity they did in 2022, largely due to the growing demands of AI. By 2030, data centers are projected to consume 8% of the U.S. power supply, up from 3% in 2022. Globally, there are more than 8000 data centers with a large percentage located in the US (33%), Europe (16%), and China (10%). In Ireland, data centers consumed 21% of the country's total electricity in 2023, more than all residential use, and the IEA projects this number to be an astonishing 32% in 2026. This surge in energy use translates to a significant portion of global energy generation, highlighting the growing challenge AI poses to the world's energy infrastructure.

Unlike traditional computing workloads, AI workloads require constant, reliable power. These workloads often run continuously and demand high levels of computational power, making them less adaptable to fluctuations in power supply. U.S. utilities will need to invest approximately $50 billion in new generation capacity solely to meet the energy demands of data centers. Additionally, analysts predict that the increased power consumption from data centers will generate an additional 3.3 billion cubic feet per day of natural gas demand by 2030, necessitating the construction of new pipeline infrastructure.

While the big tech firms at the center of this boom do not often disclose the exact amounts of electricity consumed by their operations in the AI space, or even data centers at large, they do provide information on total electricity usage. It is well-established that data centers account for substantial portions of the electricity usage captured in these topline figures. However, to fully understand the context informing this data, it is necessary to observe other sectoral trends that would impact energy usage. One such trend is the recent downturn in the cloud computing market, which carried with it reductions in electricity demand. These reductions would certainly serve to offset any increases in electricity demand due to the rise of AI. With that context in mind, the strong upward trends in electricity usage from big tech firms shown in Figure 2.1, 2.2, and 2.3 are all the more striking, and it is all the more reasonable to infer that AI data centers are major drivers in these growth trends, likely with much steeper upward-facing trend lines. The figures below (2.1, 2.2, 2.3) capture electricity consumption from Google, Microsoft, and Meta: three of the largest players in the AI space.

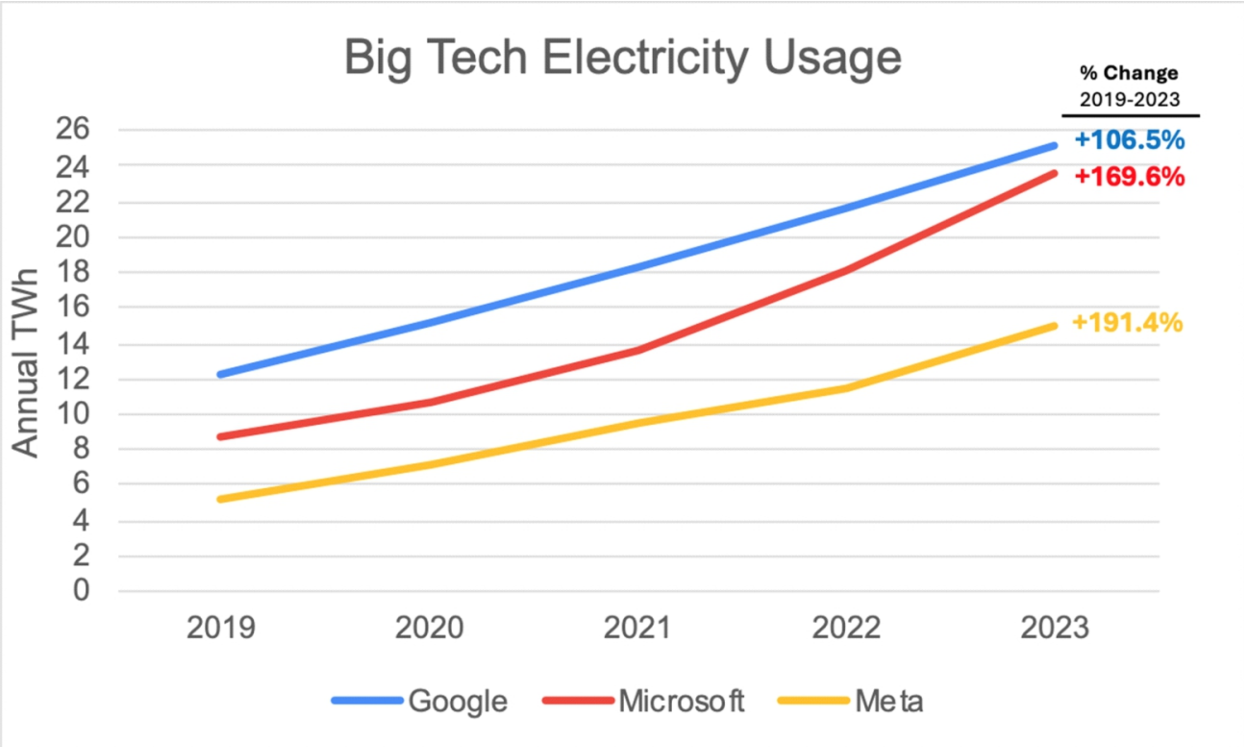


Figure 2.1: Electricity usage by Google, Microsoft, and Meta from 2019 to 2023
Sources: Public disclosures from Google, Microsoft and Meta in official sustainability and environmental impact reports

Figure 2.2: Growth in LLM active users and model parameters from 2019-2023
Sources: Active user data is sourced from OpenAI estimates, LLM parameters data tracks official OpenAI model data via 365DataScience

These numbers are not fully representative of the increases in power due to AI, the broader cloud computing market has seen a downturn recently, so reductions in demand from this sector could be offsetting increases due to the addition of new AI computers. As we wind through sectoral adjustments, we expect that AI-specific growth will more clearly be illustrated in future figures.

3.2 Projected Energy Demand from AI

The energy demands of AI are projected to grow dramatically over the next few years. The World Economic Forum reports that AI's computational needs are doubling every 100 days, with the energy required for AI tasks growing annually by 26% to 36%. By 2025, AI computing could consume up to 90 TWh annually, equating to roughly 10 GW of demand on the grid, excluding the additional electricity required for cooling and other data center operations.

By 2026, demand from AI computing could reach 40 GW. Considering a Power Usage Effectiveness (PUE) ratio of 1.2, a common efficiency metric for modern hyperscale data centers, this translates to approximately 48 GW or roughly 3.7% of the current capacity of the entire U.S. grid. Such growth would represent a significant strain on existing energy infrastructure.

Generative AI, a particularly power-intensive branch of AI, is expected to increase its power demand by 70% annually through 2027. The global energy demands of AI systems are substantial and rapidly growing, with projections suggesting that by 2028, AI's energy usage could surpass the entire national consumption of Iceland in 2021. Furthermore, research firm SemiAnalysis estimates that AI will account for 4.5% of global energy consumption by 2030, equating to 2000 TWh, a level of consumption that would add significant pressure to global energy resources.

Currently, data centers, AI, and cryptocurrency collectively contribute a significant share of global electricity consumption. Estimates suggest that these sectors could double their energy demand by 2026, adding the equivalent of an entire country's worth of electricity demand to the global grid.
When we examine energy supply, planned capacity and grid stability, we see a widely heterogenous landscape of AI readiness and capability:

Our market scan outlined in Exhibit Awill cover: US, Canada, UK, Australia, Japan, Continental Europe: Nordics, Germany, France, Switzerland, big4 Africa: Nigeria, Kenya, Egypt, South Africa, ASEAN Nations, particularly: Malaysia, Singapore, Indonesia, Vietnam, Thailand; Latin America: Mexico, Brazil, Colombia, Chile, India.

3.3 The Environmental Impact and Response to AI's Energy Demands

The environmental impact of AI is a growing concern. While AI technologies offer numerous benefits, including increased efficiencies and capabilities across industries, their energy consumption presents significant challenges to sustainability efforts. Big tech companies, such as Microsoft, have acknowledged that the rapid growth of AI-related infrastructure and energy needs could potentially hinder their climate goals, despite substantial investments in renewable energy.

Addressing these challenges requires a multi-faceted approach. This includes the development of energy-efficient hardware and algorithms, improvements in data center efficiencies, and an increased reliance on renewable energy sources. Additionally, legislative measures, such as setting benchmarks for energy use and mandating environmental impact assessments, are crucial for managing AI's growing energy footprint. The challenge lies not only in managing the rising energy demand but also in ensuring that this demand is met through sustainable means, minimizing the negative impacts on the environment.

3.4 The Strain of AI on Power Grids

The rapid increase in AI's energy demands is placing significant strain on power grids. For example, generative AI queries can consume up to 30 times more energy than traditional searches, leading to a substantial increase in overall power consumption. As AI becomes more embedded in various applications, the demand on power grids is expected to grow by approximately 70% annually through 2027.

AI data centers, some of which consume as much as 200 megawatts each—comparable to the power usage of a small city—are exacerbating this strain. This increased demand is already leading to higher energy prices and potential bottlenecks in power supply, especially in regions where the grid is already operating at near capacity.

In the U.S., the power grid, which produces about 1,250 gigawatts (GW) from 9,200 generating units, is experiencing rising demand for the first time in a decade. Future demand is projected to grow at a rate of 2.1% to 2.8% per year, with AI data centers contributing significantly to this increase.

Overall, AI's rapidly increasing power demands are creating significant challenges for energy infrastructure, necessitating substantial investments in new capacity and more efficient energy solutions to meet these growing needs.

4. Challenges to Expanding Energy Supply

The rapid advancement of AI is reshaping industries and driving economic growth, but its growth is constrained by energy supply. Expanding energy capacity to support AI-driven demand is challenging due to several key constraints:

●**Capital** - While capital markets are well established, the large quanta of funds required for energy infrastructure will be difficult to source. Even before large growth from data centers are incorporated an estimated average $3.5B USD of annual capital investments are required to meet 2050 climate goals, over three times larger than current worldwide investment of approximately $1B USD.1 This required increase in capital deployment over an extended period of time (>20 years) and the long build time of energy project will stress current capital markets.

●**Supply Chain** - Vendors for large infrastructure components and equipment are limited with significant barriers to entry. Demand for energy infrastructure has been relatively flat for the last two decades resulting in few vendors employing an aging workforce. To meet the rapid need, vendor capacity and diversity will need to be increased significantly.

●**People** - A shortage of skilled workers in energy-related fields like engineering, construction, and project management creates bottlenecks in scaling infrastructure. Training new professionals takes many years, while the competition for talent from other tech-driven sectors, including AI itself, exacerbates the labor gap.

●**NIMBYism** (Not In My Backyard) - Local opposition to energy infrastructure projects, generating stations, transmission lines, and power plants, can delay or block development. Even environmentally beneficial projects often face resistance due to concerns about aesthetics, property values, and local environmental impact, complicating project certainty, increasing project timelines, and raising costs.

●**How We Pay for It** - The most challenging constraint is determining who bears the cost of energy expansion. Public utilities, private companies, and governments must balance investment risks, ratepayer affordability, and long-term societal benefits. Disagreements over funding mechanisms, such as taxes, energy rates, or public-private partnerships, often slow project approvals and financing decisions.

5. Recommendations for Policymakers and Innovators

Policy makers are now facing significant and difficult decisions over the next five years regarding energy overall, and within that supporting artificial intelligence systems.

On the one hand, global economic growth is softening, which places significant and growing constraints on government budgets. The long-term impacts of the war in Europe continue to create problems for Germany and other core eurozone economies; the UK continues to see the after effects of Brexit; the incoming Trump administration is actively stating its plans to destabilize one of the largest trading pacts in the world among Canada and Mexico and the US; various Latin American economies are challenged by ongoing inflation and other issues; and Southeast Asia remains under the looming specter of a potential PRC invasion of Taiwan. India remains a bright spot and Africa has some signs of growth, although is grappling with new potential pandemic risk. The MENA region is looking at a longer term economic pivot, with navigation around passing 'peak oil' central to many planning strategies.

On the other hand, demand for artificial intelligence systems remains strong, propelling the magnificent seven companies to record market capitalizations.

Ticker	$ trillions
AAPL	3.51
AMZN	2.29
GOOG	2.33
META	1.5
MSFT	3.09
NVDA	3.23
TSLA	1.24

Magnificent 7 market capitalisations at market close 14 January 2025

Without question, a material component of their market appreciation has been due to the growth of usage of artificial intelligence (and, likely, a bit of the growth of artificial intelligence hype). These supranational 'corporate states' are engaged in a running negotiation with political bodies over span, scope, capabilities, and areas of operations, ranging from data privacy limits that in turn impact capability of AI models (such as in the EU, where GDPR and the DMA have caused some tech companies to restrict functionality), to restrictions on export of key technologies necessary for AI to function (such as in the US, where recent Biden Administration rules on AI chip exports are creating restrictions on the abilities of 120 countries to access the latest technologies).

These dynamics, in turn, will impact not only total energy consumption, but also in which geographies, specifically, energy will be consumed.

Bridging the AI Power Gap

Against this backdrop, the energy infrastructure challenges play out. Policy makers need to address how to stimulate advantage with artificial intelligence and create greater national security by promoting sovereign AI, while doing so in a fiscally responsible manner that takes into economic realities.

Private sector companies are taking action preemptively, with both Google and Microsoft announcing new nuclear power initiatives. The energy industry is taking a fresh look at small modular nuclear reactors as one potential solution that balances cost, and time to build, with energy production. Additionally, Bill Gates, among other ultra high net worth individuals, have been directly investing into nuclear power for a number of years through his investment vehicles. Corporate market participants outside of AI companies have been developing solutions that can accelerate AI adoption. As an example, Hitachi and GE have a JV around Small Modular Reactors (SMRs) working in collaboration together with Ontario Power Generation (OPG). These SMRs with a higher efficiency capability on energy generation, along with lower nuclear waste generation than other types of fission reactors.

Supply independence is one factor for those countries deciding to go down the nuclear route. Fissile materials are tightly controlled and in short supply from a limited set of sources. As corporates and governments consider how to deploy SMRs, they need to consider not only the up front capital investments, but also access to ongoing materials, disposal of hazardous waste, and talent capable of managing the systems.

Fusion remains a desirable technology and some forecasters predict commercially viable exothermic reactors to come online in the middle of the next decade (around 10 years from now). This requires additional engineering development beyond today's currently demonstrated capabilities, so in the interim, fission remains the more proven nuclear technology that can address needs within the next decade.

Other types of power generating systems are, of course, in play, ranging from extensive fossil fuel utilisation, efforts to apply solar and wind, and geothermal power. Hydroelectric is an intriguing technology, given that the power generation needs to be scaled to meet peak demand, but that often there is latent or unused capacity in between. Hydroelectricity is a dispatchable renewable energy source allowing for water to be stored during times of low demand and released through the turbines at high demand.   For less time-sensitive compute requirements (versus on-demand real time AI compute), demand response from compute may be useful, increasing computing and power usage during hours or days where there is excess power and throttling back during times of peak demand.

Policy Concepts for AI Enablement

In making policy decisions around energy and artificial intelligence, policymakers benefit from the application of a framework approach.
We recommend that

First, countries engage in a diagnostic, to understand their capabilities and capacities. The following is a simple framework to apply to generate a first approximation:

DEMAND	GENERATION	PARTNERS	PEOPLE
What is your current energy demand? What is your forecast demand over the next 10 years? How might this increase with more AI activity?	What is your current generating capacity? What is your forecast added generation over the next 10 years?	Which public sector, nonprofit and private partners are you engaged with?	Do you have the skilled personnel capable of operating the type of power you have selected

Nuclear is an active potential solution that is being discussed, and countries with robust nuclear manufacturing infrastructure, that are providing nuclear generation capability to other nations, are also providing technical assistance and training, along with loan incentives, so that it is easier for recipient nations to establish sovereign capability. Supply (input) independence on fuel is another issue that several countries are grappling with.

Second, they should elaborate a plan for engaging private sector action, catalysed by public sector funds and interventions but not exclusively supported by them.

For example, Microsoft and Amazon have announced plans to engage in nuclear-powered data centers. Private sector participants will be more likely to scale their generation activities with tax incentives, assistance with regulation and permitting, loan guarantees, and other types of interventions that encourage further confidence and capital to deploy against generation capability.

Finally, a robust (if accelerated) consultation process can ensure that public interest, industry knowledge and constituency advocacy needs are met in formulating an appropriate set of interventions.

6. Conclusion

The rapid advancement of AI is reshaping industries and driving economic growth, but its escalating energy demands present a critical challenge that requires immediate attention. As AI systems become more complex and data centers expand to support them, the strain on already stressed power grids is becoming increasingly significant. Without proactive efforts to address these challenges, the energy required to fuel AI's growth could lead to power shortages, higher costs, and disruptions in energy availability.

The relationship between AI growth and energy consumption is not merely a technological issue but one with far-reaching implications for sustainability, economic equity, and global progress. A failure to align AI's expansion with adequate energy infrastructure and renewable sources could slow innovation and exacerbate disparities in access to technology and its benefits.

Moving forward, addressing AI's energy needs will require collaborative efforts from governments, industry leaders, and energy providers. It is crucial to expand infrastructure, invest in renewable energy, and develop more efficient power systems to meet AI's rising demands. Though AI technology is expected to become more energy-efficient, these improvements will not suffice to keep pace with the explosive growth in AI applications.

The future of AI is tightly bound to the future of energy. Without careful planning and investment, energy limitations could stifle AI's potential to transform industries and improve lives. However, those who act now to integrate AI's energy needs into broader infrastructure and sustainability plans will be best positioned to harness the full potential of this transformative technology while ensuring a stable, sustainable energy future. By addressing the energy crisis, governments and businesses can secure technological, economic, and societal strategic advantages, and will be successful in the emerging global green economy and will ensure long-term sustainability, security, and resilience.

APPENDIX A

Readiness Scores

For the purposes of this paper, 25 countries were assessed, selected based on a combination of AI capabilities (as described in our 4Q 2024 Sovereign AI whitepaper), geographical dispersion and economic impact. Based on the qualitative and quantitative information available on each of these markets, a numerical score was produced to compare the level of readiness of each country's electrical grid to meet their respective projected increases in AI-driven energy demand.

Recognizing that the ability to meet this projected electricity demand, and the ability to do so in an environmentally sustainable way are different concepts, two parallel scores have been produced. The first score considers country's ability to meet the power needs irrespective of generation source and green house gas emissions, the second score ("GHC considered") has and additional metric with favorable weighting to countries with cleaner electricity generation sources and planned growth.

AI Power Demand Readiness Index (out of a maximum potential of 1.00)

Methodology

These scores were produced by examining two dimensions of each country's readiness:

1. Demand Growth: The national projected growth in electricity demand directly associated with AI and data centers
2. Demand Readiness: The key indicators that the country is ready to meet its projected electricity demand

To assign values to the expected AI-driven growth in electricity demand in each market, financial forecasts from 2024 to 2029 were used as a directional proxy. Meanwhile, in order to assess a country's level of readiness to meet these approximated demand forecasts, a wide range of factors were considered, such as current grid reliability. Each of these factors were assigned a binary score based on their expected impact on the ability of the country's electrical grid to meet the energy demand expected to come from AI, and these scores were then aggregated. The above methodology yielded "like terms" for both Demand Growth and Demand Readiness, which were then hybridized into a single score which captures both dimensions.

Source: Imperial College London

AI + Energy Report 2025

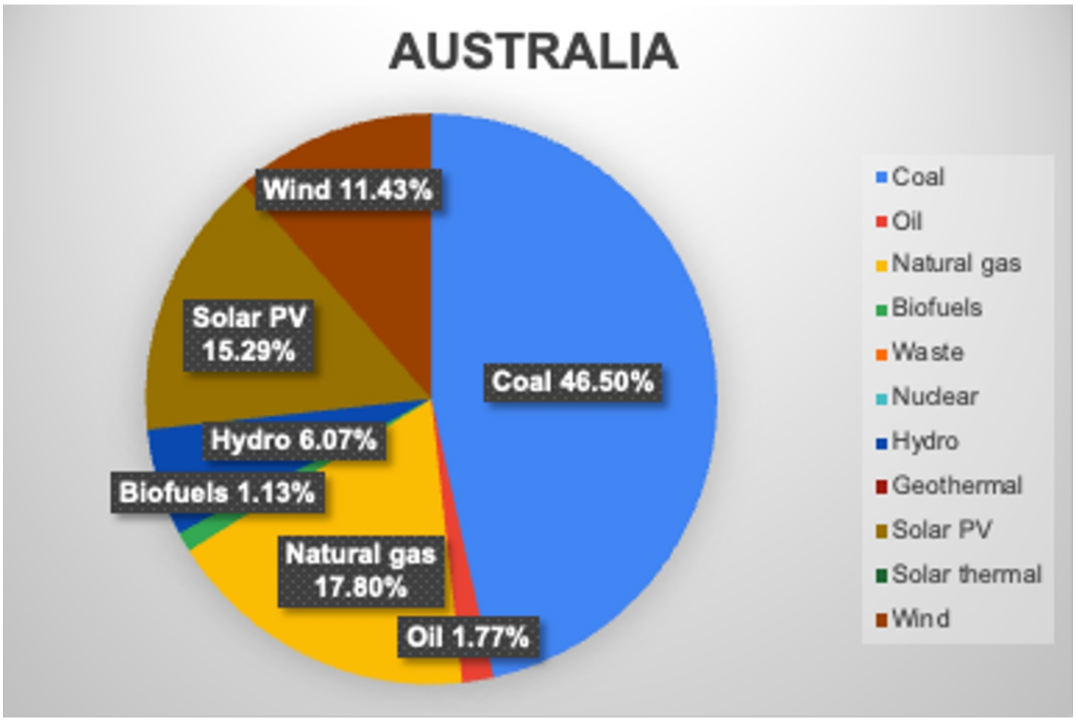
http://aicollab.org

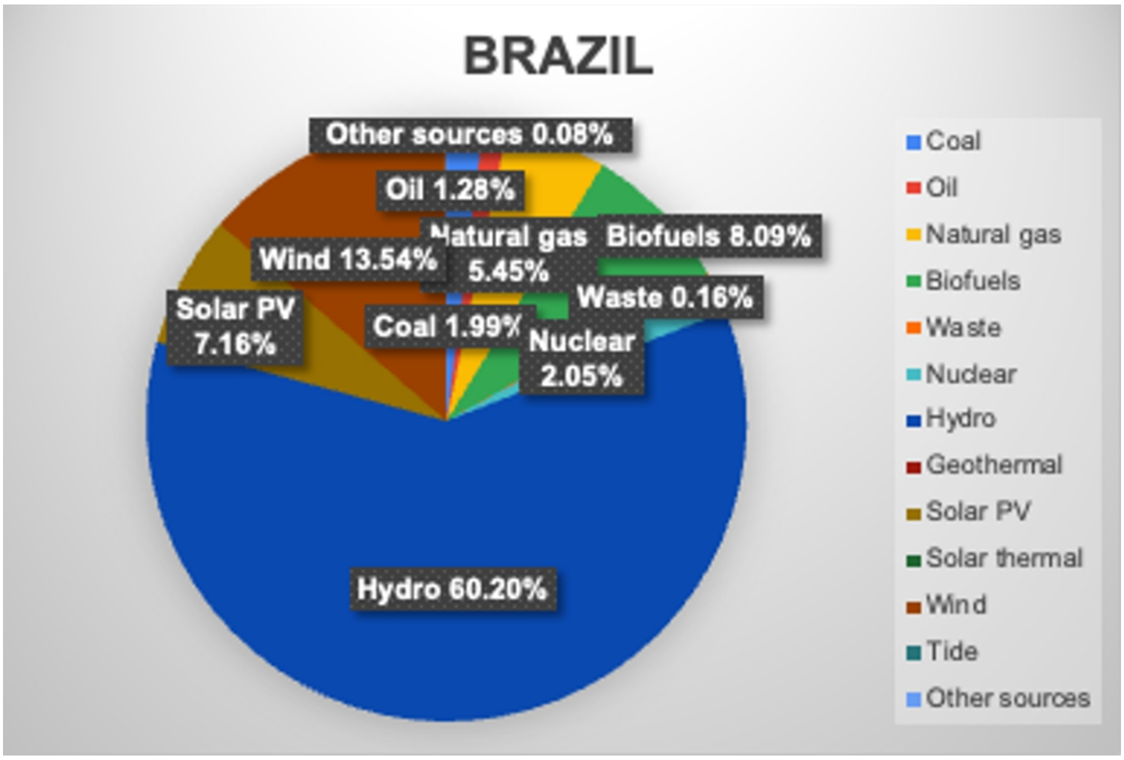
	AI Power Demand Readiness Index	AI Power Demand Readiness Index (with GHG metric)
Sweden	0.79	0.79
Australia	0.77	0.72
Canada	0.77	0.72
Switzerland	0.76	0.76
Norway	0.74	0.75
Colombia	0.74	0.70
Malaysia	0.73	0.68
Vietnam	0.72	0.68
France	0.70	0.72
Brazil	0.69	0.71
Singapore	0.69	0.65
Indonesia	0.69	0.64
Germany	0.68	0.64
Denmark	0.67	0.62
UK	0.67	0.62
Kenya	0.66	0.68
Thailand	0.65	0.61
Japan	0.64	0.60
US	0.64	0.58
Chile	0.62	0.59
India	0.61	0.58
Mexico	0.56	0.53
South Africa	0.52	0.50
Egypt	0.38	0.35
Nigeria	0.29	0.28

Appendix A

Country Scan

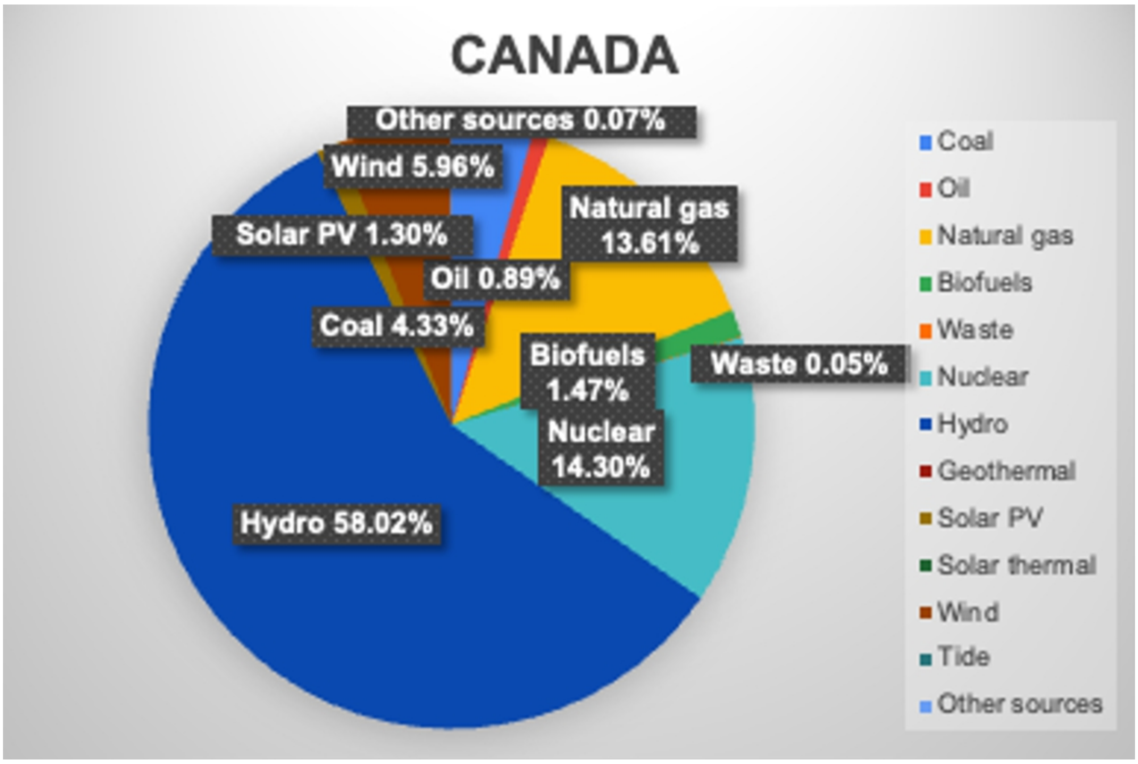
We have assessed below energy demand and generation in each of a selection of [number] individual countries, in order to contextualise the issues and opportunities.

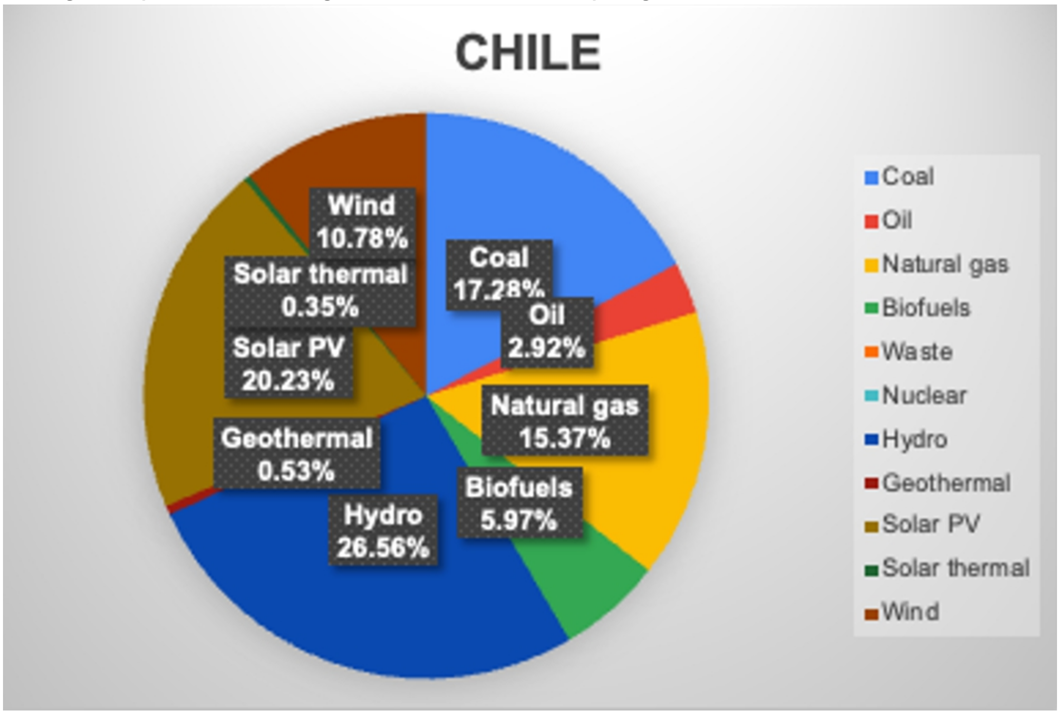
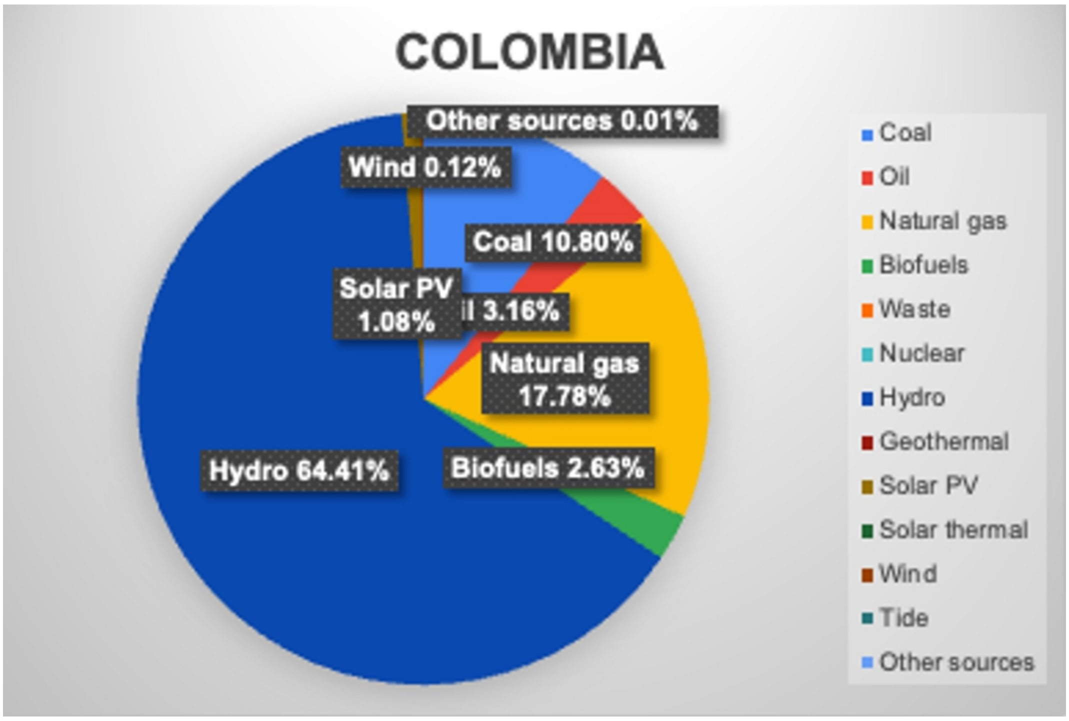
Country	Narrative Summary
Australia	Australia's data center market is projected to reach $7.06 billion USD by 2029, with a 2024 estimate of $5.40 billion. The sector, comprising 214 data centers, represents 5% of national electricity consumption (1,050 MW) and is expected to grow to 8% (2,500 MW) by 2030. Data centers are driving electricity demand, straining supply and raising costs, with peak wholesale prices projected to rise 70% by 2030 to $525/MWh. They now account for nearly a quarter of industrial power demand, growing 16% annually. Experts warn this surge was underestimated, urging adjustments to prevent grid instability, worsened by rising AI-powered data center usage. 
Brazil	Brazil's data center market is expected to reach $7.05 billion USD by 2029, with a 2024 projection of $5.32 billion. The LatAm region has seen significant growth, with Brazil leading at 67% of regional inventory. Supply has doubled since 2020, growing 127% by 2022. Climate change impacts, such as severe droughts in 2021, strained Brazil's hydroelectric-dependent power grid. In response, the government imposed regulations on energy consumption by data centers. Addressing energy transmission and distribution bottlenecks is critical for meeting demand. Brazil's rapid data center expansion reflects its role as a regional leader, but sustainability remains a challenge.



Canada

Canada's data center market is projected to reach $10.60 billion USD by 2029, with a 2024 estimate of $8.08 billion. The clean energy grid, low temperatures, and affordable electricity make Canada a top location for data centers. It hosts 239 facilities, led by Ontario (105), Quebec (57), British Columbia (35), and Alberta (22). The Alberta Electric System Operator (AESO) has six applications pending, needing 2,000 MW of electricity. In Quebec, the QScale Q01 facility is redirecting 100 MW of waste heat to households, showcasing energy efficiency. Utilities are incorporating data center growth into forecasts, reflecting their rising energy impact.



<table>
<tr><td>Chile</td><td>Chile's data center market is projected to reach $1.76 billion USD by 2029, with a 2024 estimate of $1.40 billion. Environmental concerns are shaping development, highlighted by Google halting a $200 million data center project in 2024 due to water usage issues amid a drought expected to last until 2040. Chile is becoming a key data center hub in LatAm, with 16 centers approved in Santiago over the past 12 years and plans for 28 new facilities announced in 2024. However, insufficient energy supply in some regions poses challenges to the sector's rapid growth.

</td></tr>
<tr><td>Colombia</td><td>Colombia's data center market is projected to reach $2.07 billion USD by 2029, with a 2024 estimate of $1.69 billion. The country is exploring sustainable data center designs through an innovative pilot program. These centers, operating at full utilization, consume 5,000 kWh per month—20% less energy than standard models—highlighting Colombia's commitment to energy efficiency in the sector. This approach positions Colombia as a forward-thinking player in the data center market, balancing growth with sustainability to meet increasing demand while minimizing environmental impact.

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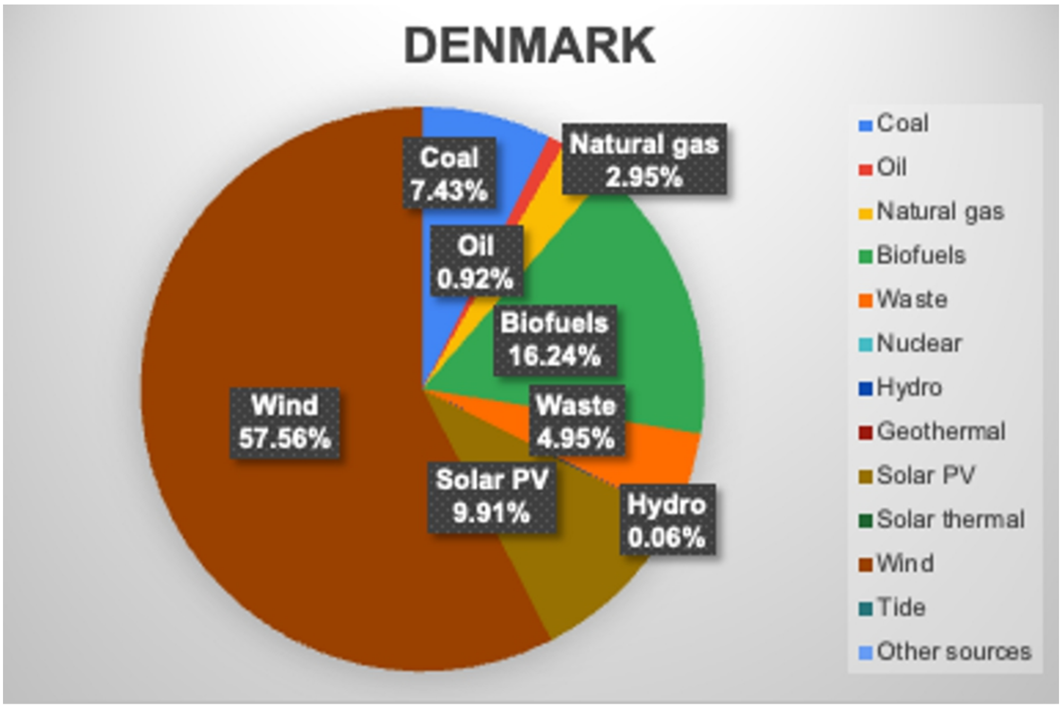
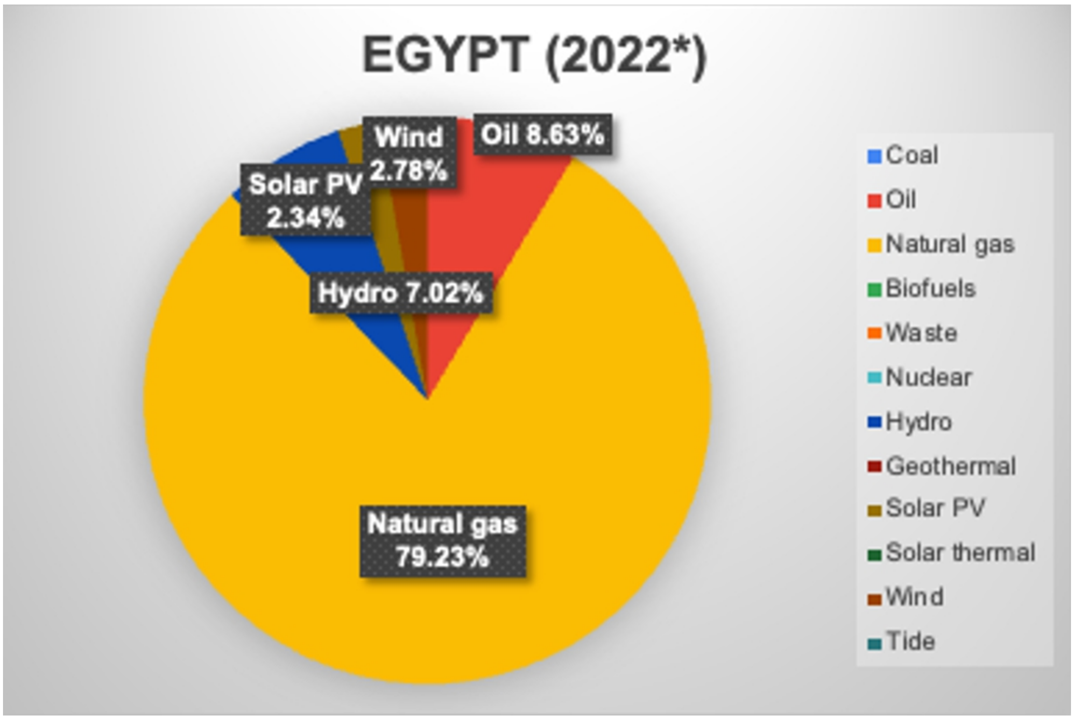
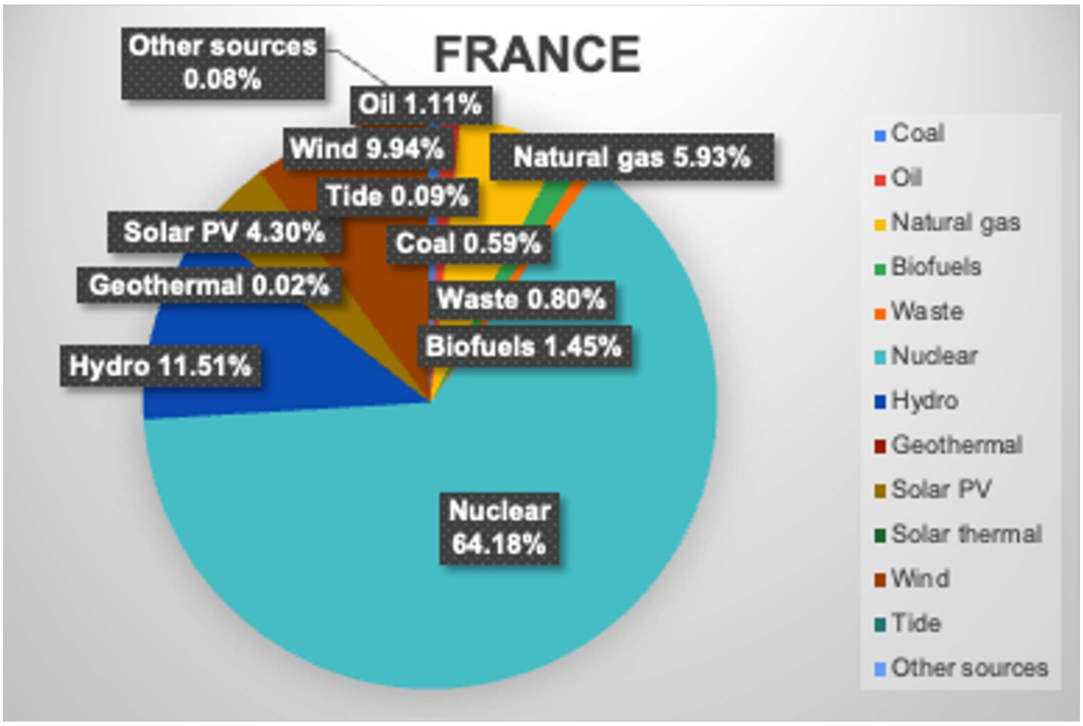
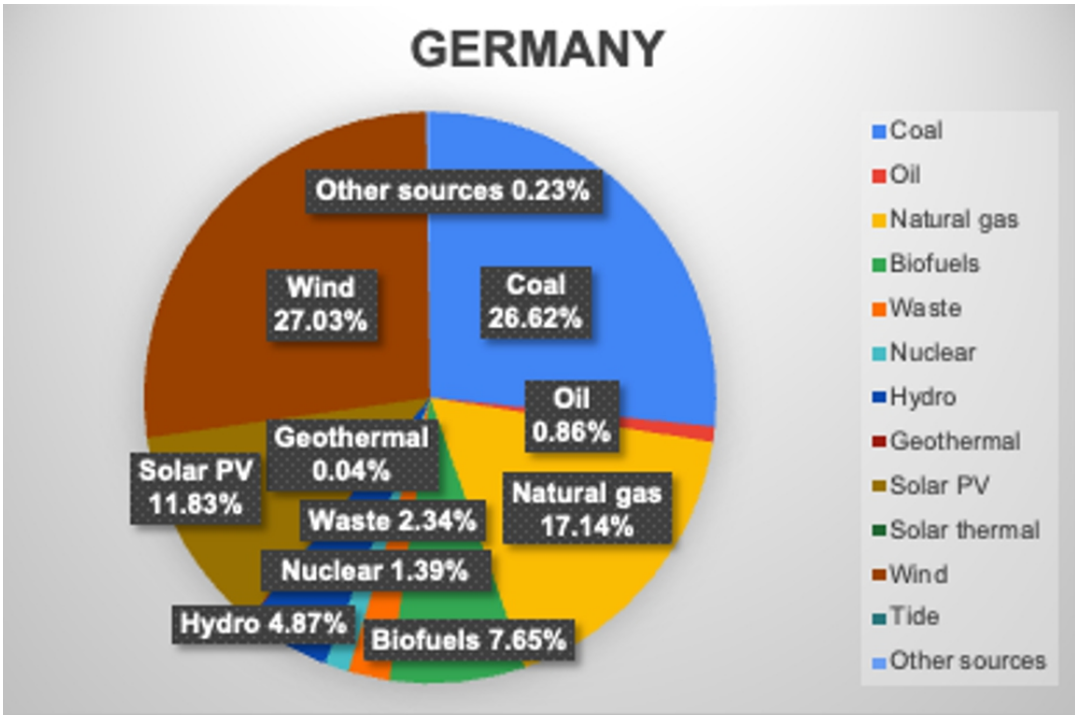
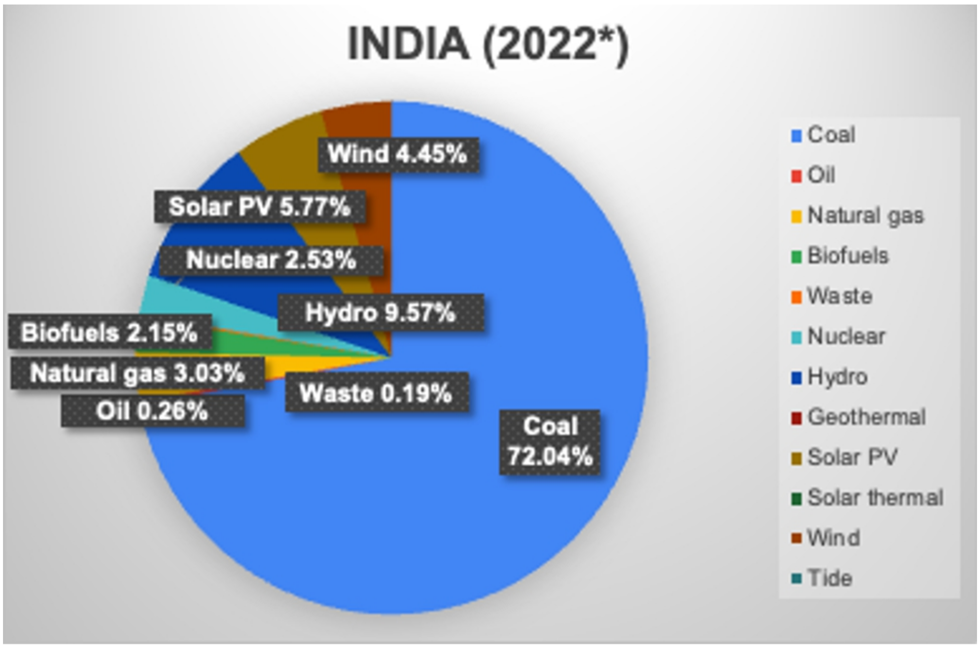
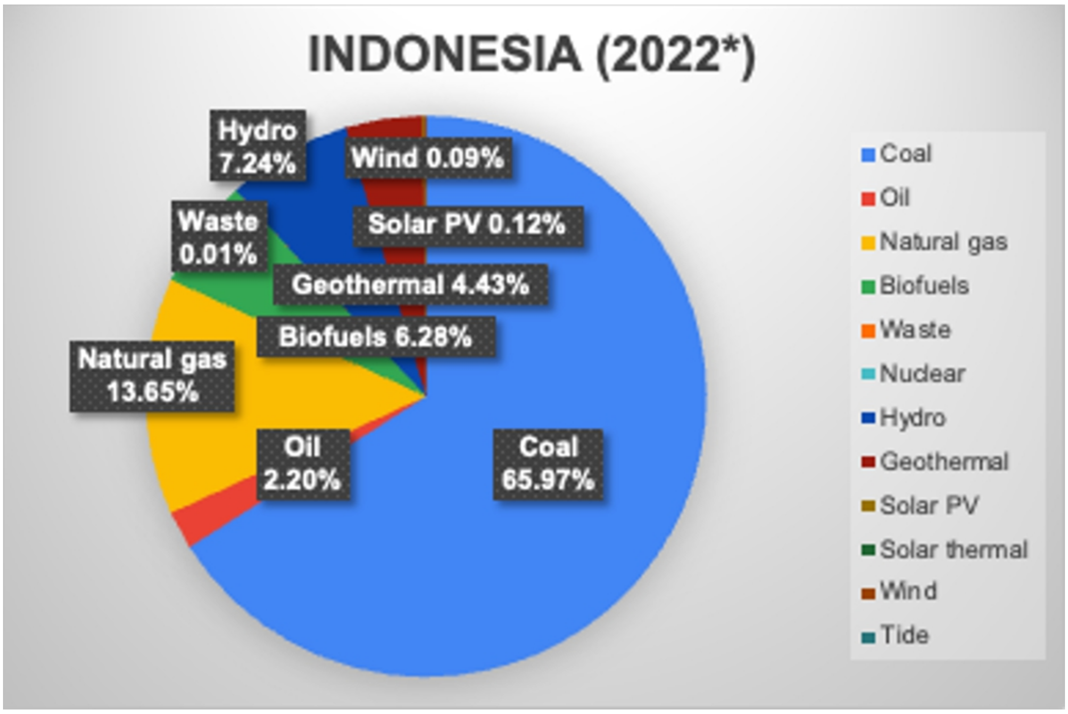
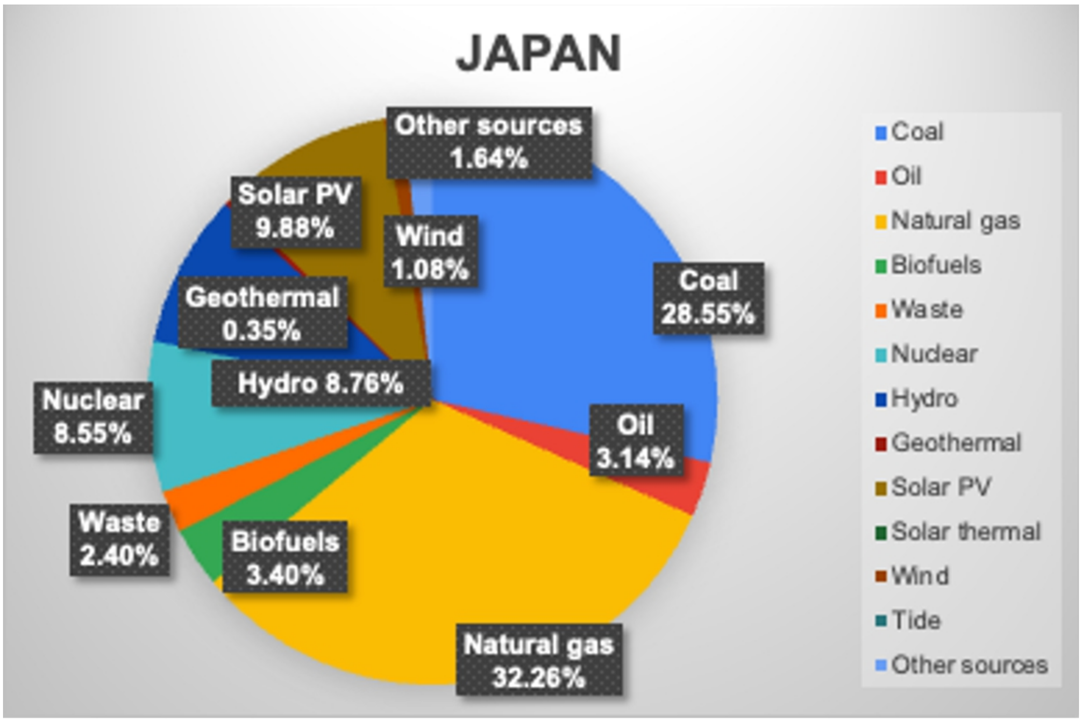
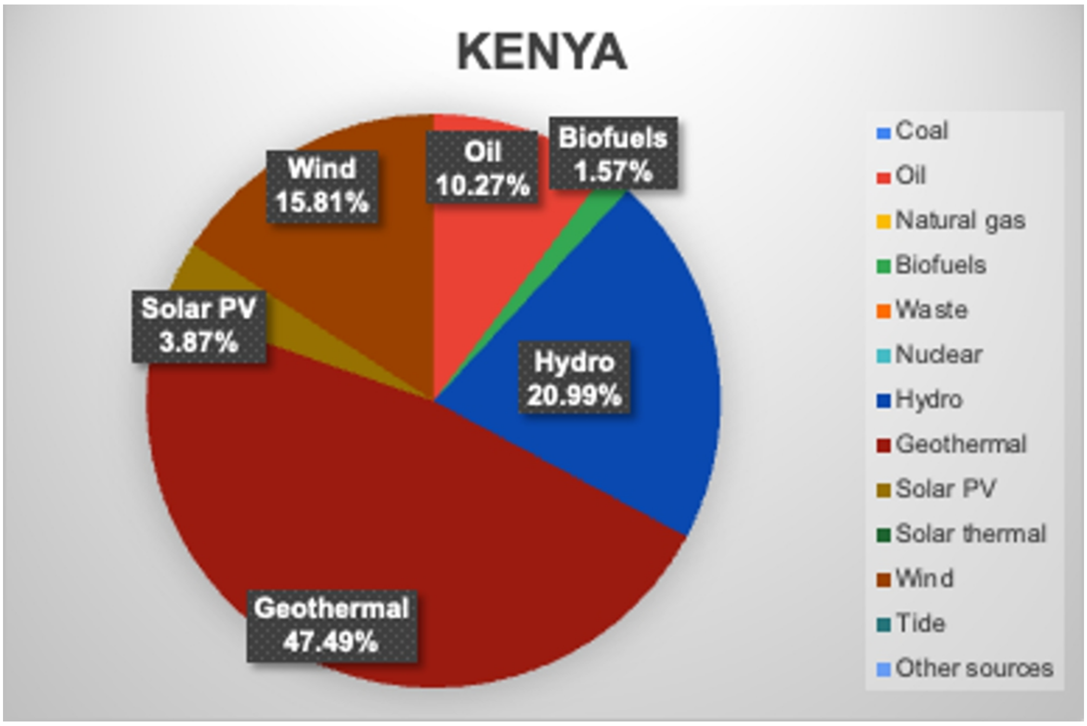
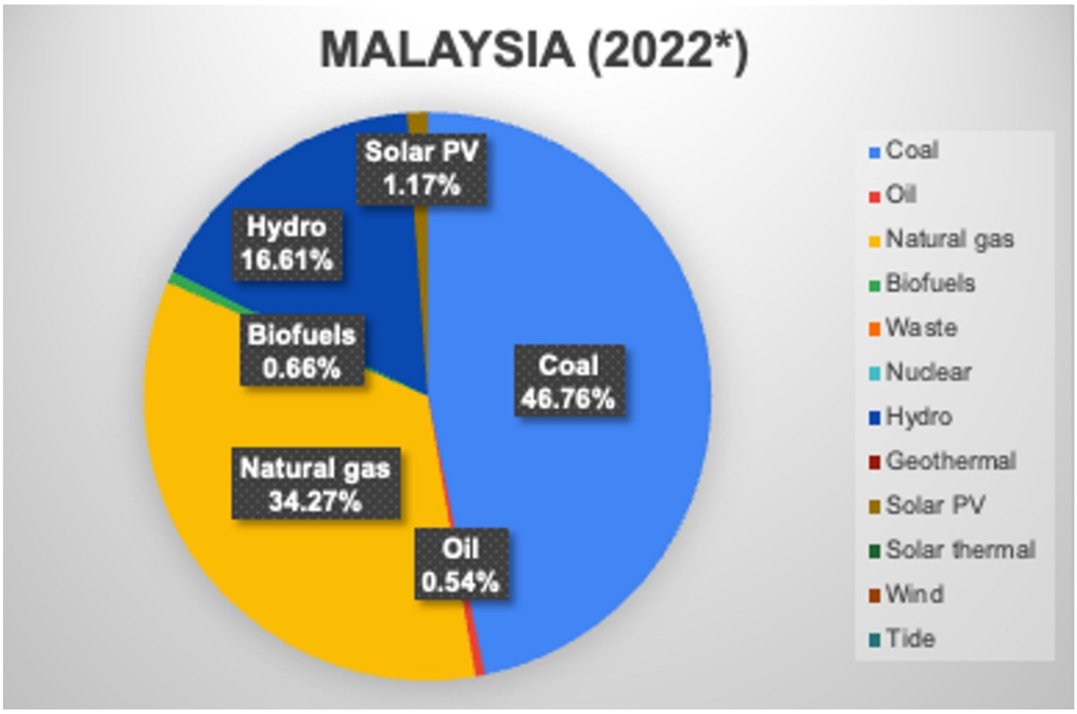
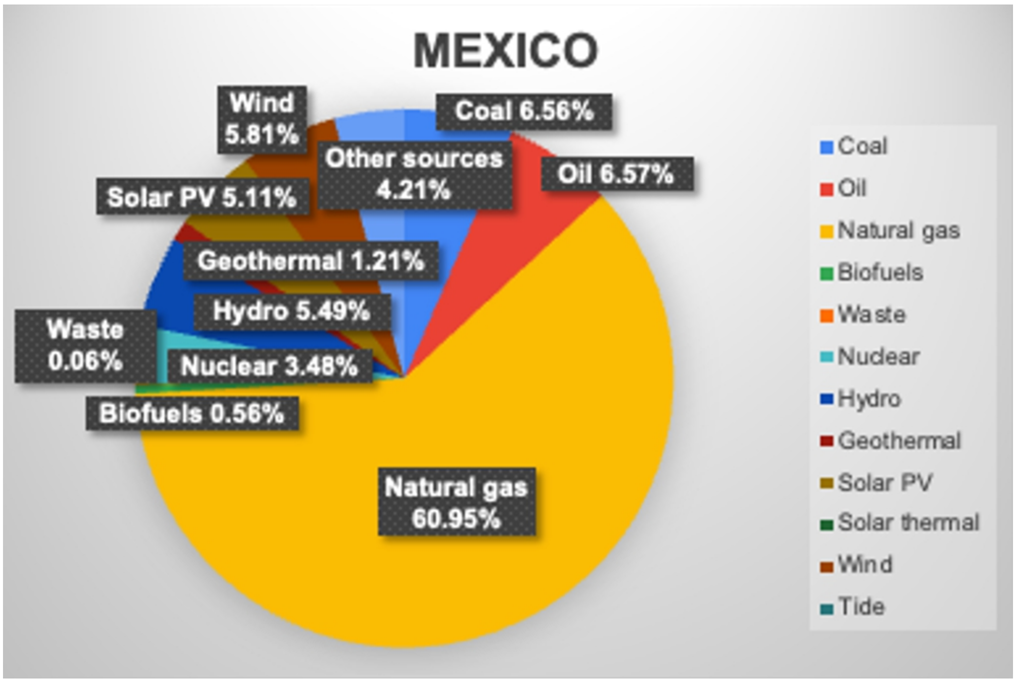
Denmark	Denmark's data center market is projected to reach $3.07 billion USD by 2029, with $2.23 billion expected in 2024. Data centers currently account for approximately 4.5% of Denmark's electricity consumption, with energy use projected to rise sixfold by 2030, reaching nearly 15% of the country's total consumption. By 2040, large-scale data centers could drive electricity demand to 33% of Denmark's 2017 national electricity levels. Denmark's energy system demonstrates a high level of sophistication, incorporating sustainable practices. Excess heat from data centers can be reused as thermal energy within the national grid, offering an efficient energy utilization model. 
Egypt	Egypt's data center market is expected to reach $545.26 million USD in revenue by 2029, growing from $182 million in 2023 at a CAGR of 18.85%. A 2024 revenue projection of $325.07 million highlights rapid growth potential. Despite challenges with a struggling electricity grid, Egypt is attracting data center investments by leveraging its untapped renewable energy resources. Its strategic location at the crossroads of Africa, Asia, and Europe further enhances its appeal for new infrastructure development. By 2029, energy demand from data centers is projected to reach 28 MW, emphasizing the need for reliable power solutions to sustain growth. 

France	France's data center market is projected to reach $15.41 billion USD by 2029, with $11.75 billion forecast for 2024. Annual investments surpass $1.2 billion, driving growth. Data centers use 2.2% of France's electricity, with tax incentives promoting energy efficiency. While Paris has the highest geographical concentration of data centers, cities like Marseille, Lyon, Lille, and Strasbourg are expanding as well, alongside notable growth in rural areas. Energy demands rival Dublin, where 1 megawatt powers 750–1,000 homes. France's growth reflects EU trends, driving regional energy demand through digital infrastructure expansion. 
Germany	Germany's data center industry is expected to reach $25.29 billion USD in revenue by 2029, with $18.71 billion projected for 2024. Frankfurt, alongside London, will see significant growth in data center capacity, with energy consumption comparable to Dublin's, where 1 megawatt powers 750–1,000 homes annually. Data centers account for 3% of Germany's electricity use, with annual consumption projected at 17.9 billion kWh, up from 12.1 billion kWh in 2022. New regulations limit permits in residential areas and mandate renewable energy contributions and waste heat reuse. Rising energy demands are straining power systems, particularly in Frankfurt. 

India	India's data center market is projected to reach $11.59 billion USD by 2029, with a 2024 revenue estimate of $8.64 billion USD. The sector is poised for significant growth, with a CAGR exceeding 50% as forecasted by Jefferies, driven by strong financial services demand, government support, and robust fiber connectivity. Mumbai is the largest data center hub, accounting for over 40% of the nation's capacity at 300 MW. Its inventory is expected to more than double in the next two years, with international players like Blackstone investing heavily. A hyperscale cloud provider has also acquired over 50 acres for expansion. Currently, less than 1% of India's electricity is consumed by data centers, but this figure is expected to rise to 6% by 2030, reflecting the growing energy demand of this booming industry. 
Indonesia	Indonesia's data center market is projected to reach $4.50 billion USD by 2029, with a 2024 estimate of $3.37 billion. Real Estate Asia forecasts the market could hit $3.07 billion by 2026. Following Singapore's moratorium on data centers (2019–2022), Indonesia has experienced a surge in demand. By 2024, the energy capacity of data centers in Indonesia is expected to reach 210 MW, with forecasts suggesting 2.3 GW by 2030—a 44.8% annual growth rate. AI adoption is a key driver, significantly increasing energy consumption per rack from 6 kW to 50 kW. Average household consumption in Jakarta, by comparison, stands at just 3,000 watts. 

Japan	Japan's data center market is projected to reach $29.50 billion USD by 2029, with a 2024 forecast of $20.60 billion USD. Tokyo is a key data center hub in Asia, attracting strong investor and occupier interest due to its strategic location. As of Q1 2023, Tokyo's data center vacancy rates were just above 10%, with demand expected to remain robust as inventory expands by 30% by 2025. The rising energy demand from data centers is presenting challenges for Japan's net-zero emissions goals, as electricity consumption continues to grow. This underscores the need for sustainable energy solutions to support the sector's rapid expansion. 
Kenya	Kenya's data center market is projected to reach $823.70 million USD in revenue by 2029, with a 2024 projection of $589.30 million USD. A $1 billion eco-friendly data center, powered entirely by geothermal energy, is currently under construction, spearheaded by Microsoft and G42. The facility will begin with a capacity of 100 MW, with plans to scale up to 1 GW, showcasing Kenya's commitment to sustainable energy solutions. This project represents a significant milestone for Kenya's data center industry, highlighting its growth potential and alignment with renewable energy practices, while dominating discussions around the nation's digital infrastructure expansion. 

<table>
<tr><td>Malaysia</td><td>Malaysia's data center market is projected to reach $1.51 billion USD by 2029, with a 2024 estimate of $1.20 billion. Microsoft has committed $2.2 billion to expand Malaysian data centers over four years. Electricity demand is expected to surpass 5,000 MW by 2035, with Tenaga Nasional Berhad (TNB) receiving applications for over 11,000 MW—more than 40% of Peninsular Malaysia's current power capacity. With the number of data centers set to almost double from 45 to 89 facilities, Malaysia is emerging as a leading data center hub in Southeast Asia, supported by strong demand and pro-business policies in states like Johor.

</td></tr>
<tr><td>Mexico</td><td>Mexico's data center market is projected to reach $5.07 billion USD by 2029, with a 2024 estimate of $3.87 billion. Limited capacity, construction delays, and power challenges are straining growth, with Querétaro having only 1.2 MW available for lease. Querétaro faces acute resource constraints, particularly with electricity and water, which reflects challenges across LatAm. Energy demand from data centers is expected to grow rapidly, with the Mexican Data Center Association (MEXDC) projecting 1,492 MWh consumption over the next five years. Hitachi Energy estimates demand could exceed 5,000 MWh, driven by the adoption of AI tools and hyperscale operations from firms like Amazon, Apple, and Microsoft.

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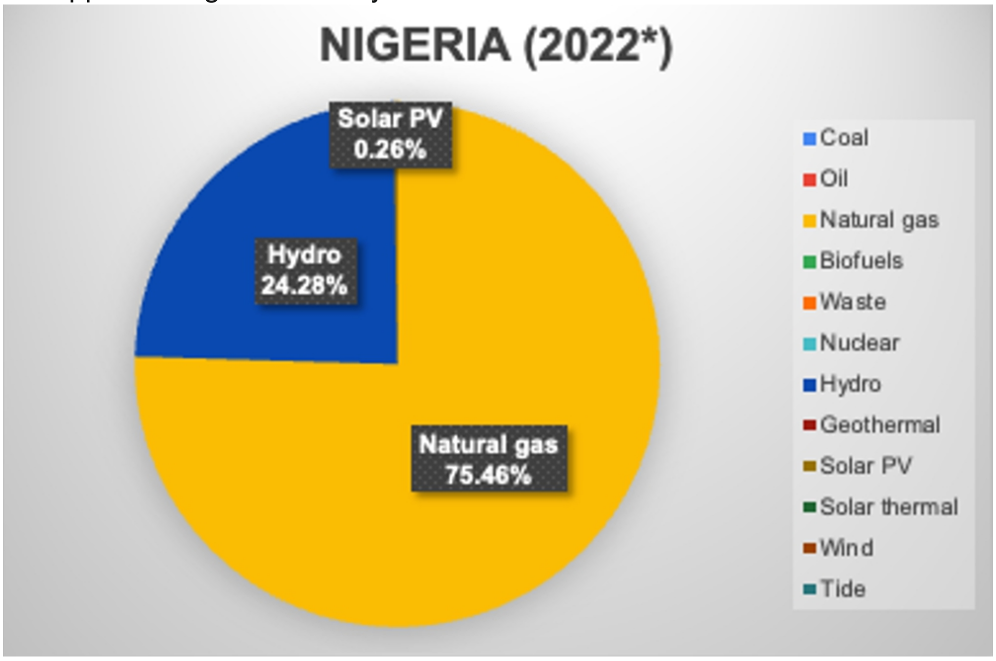
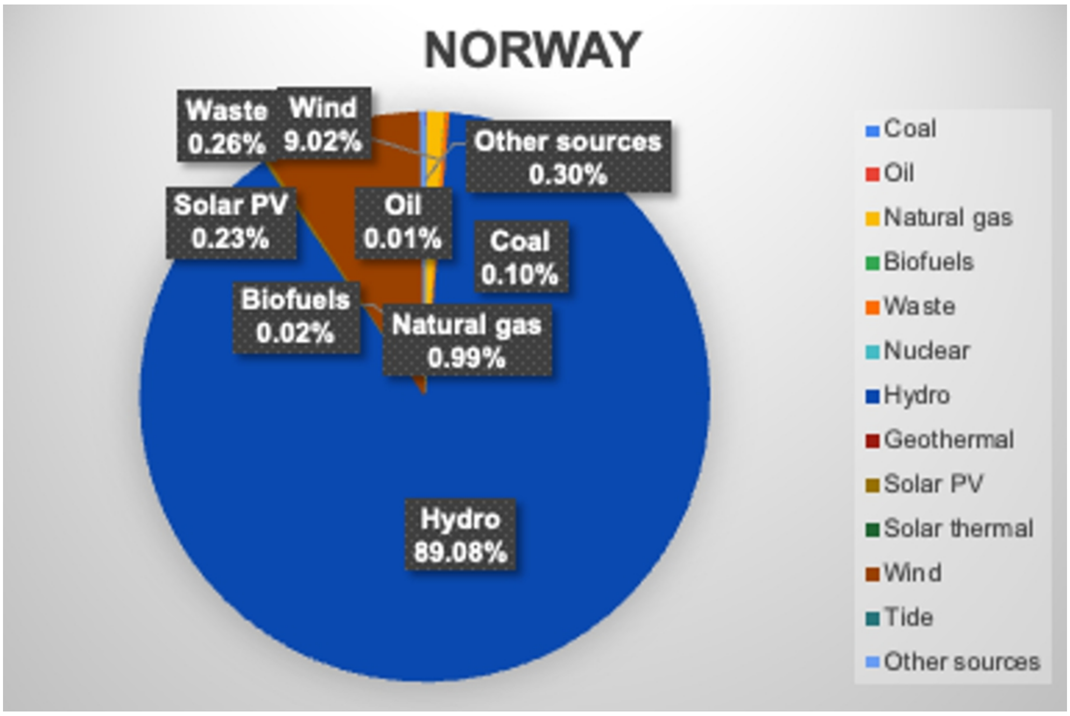
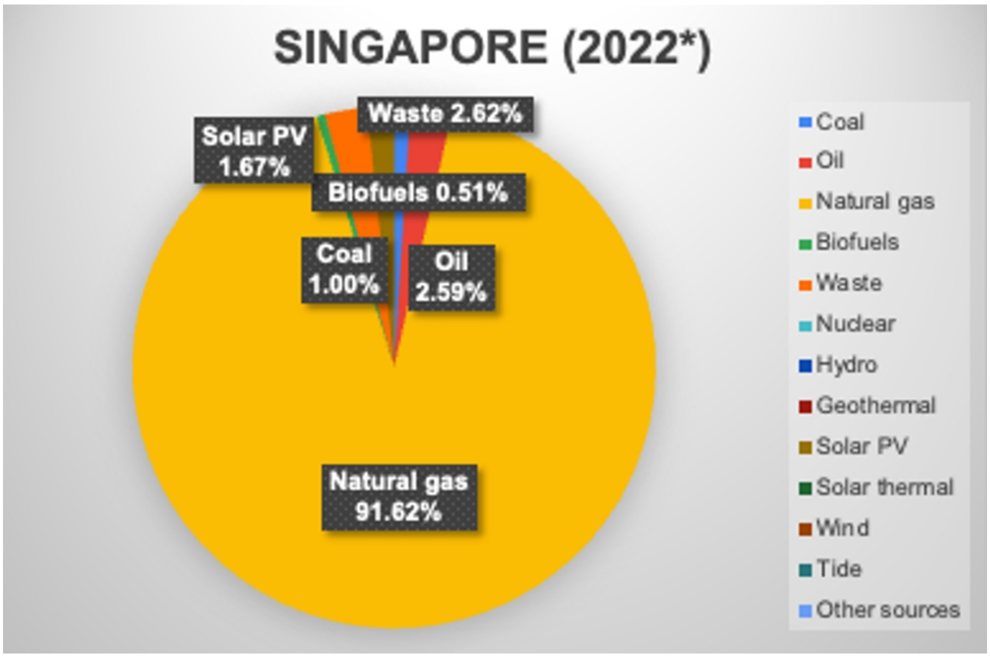
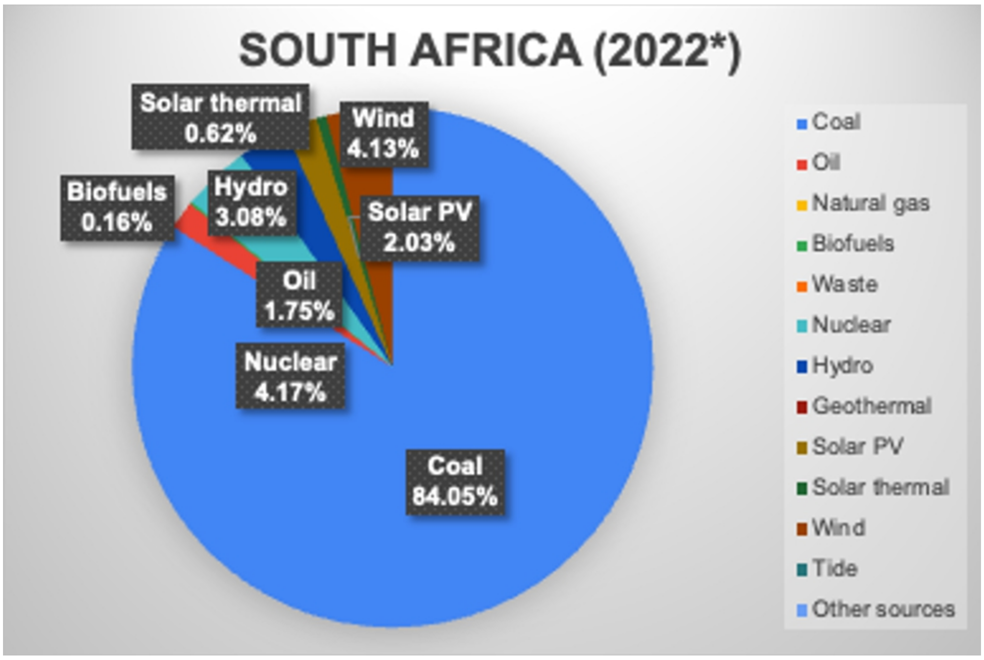
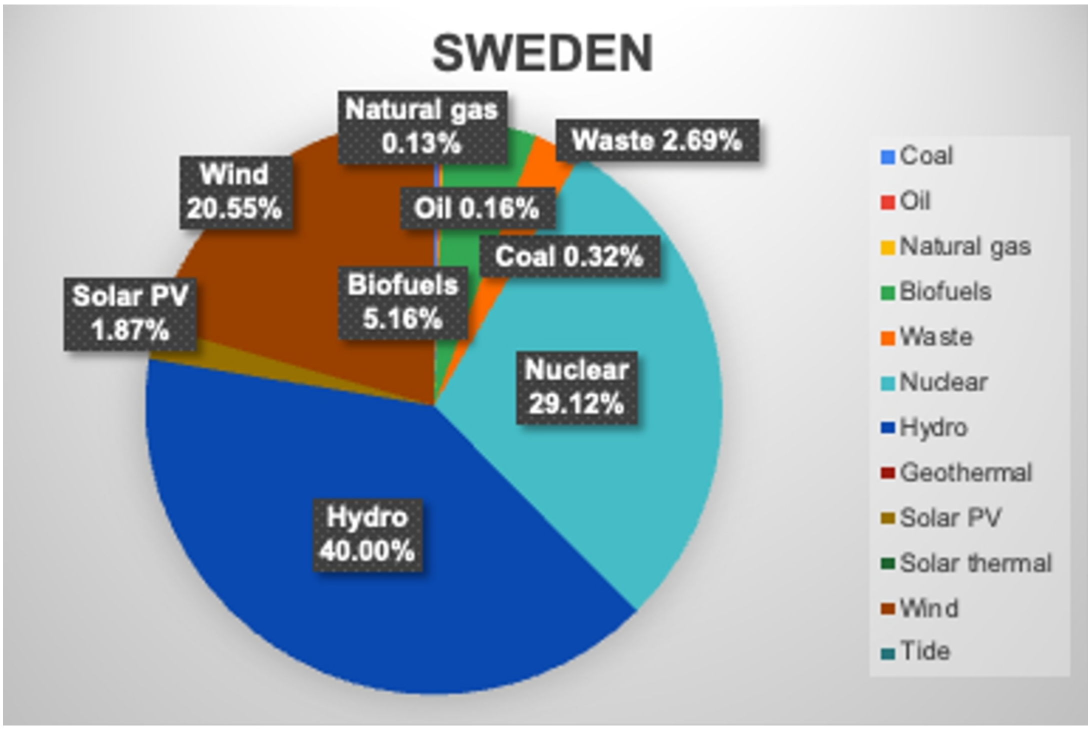
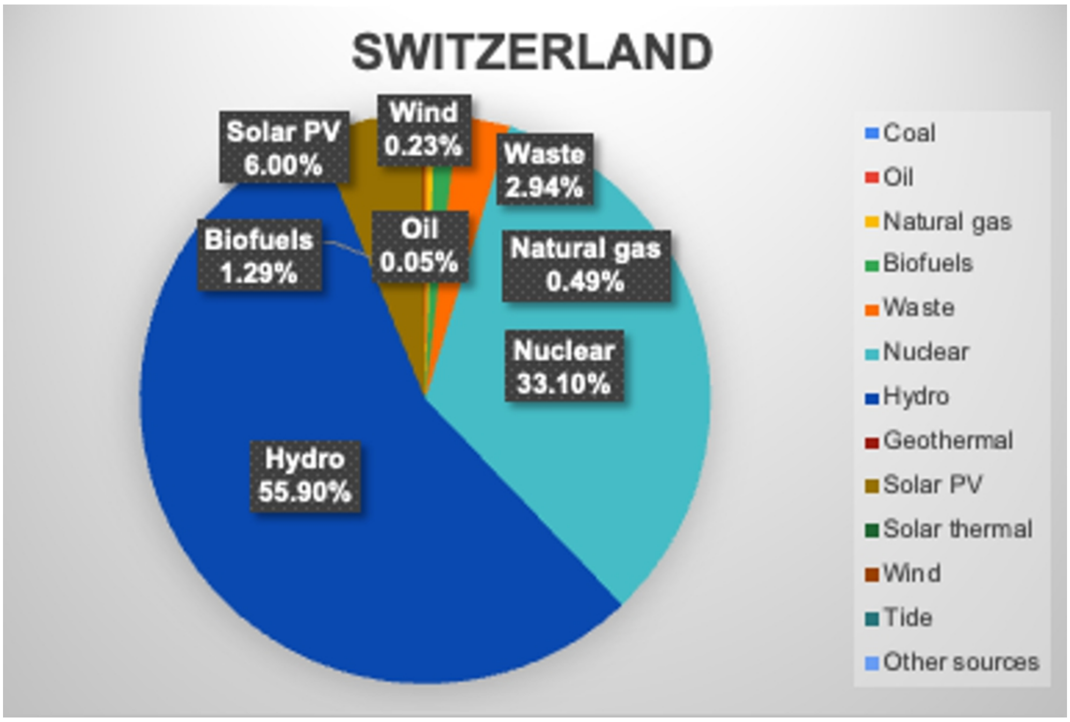
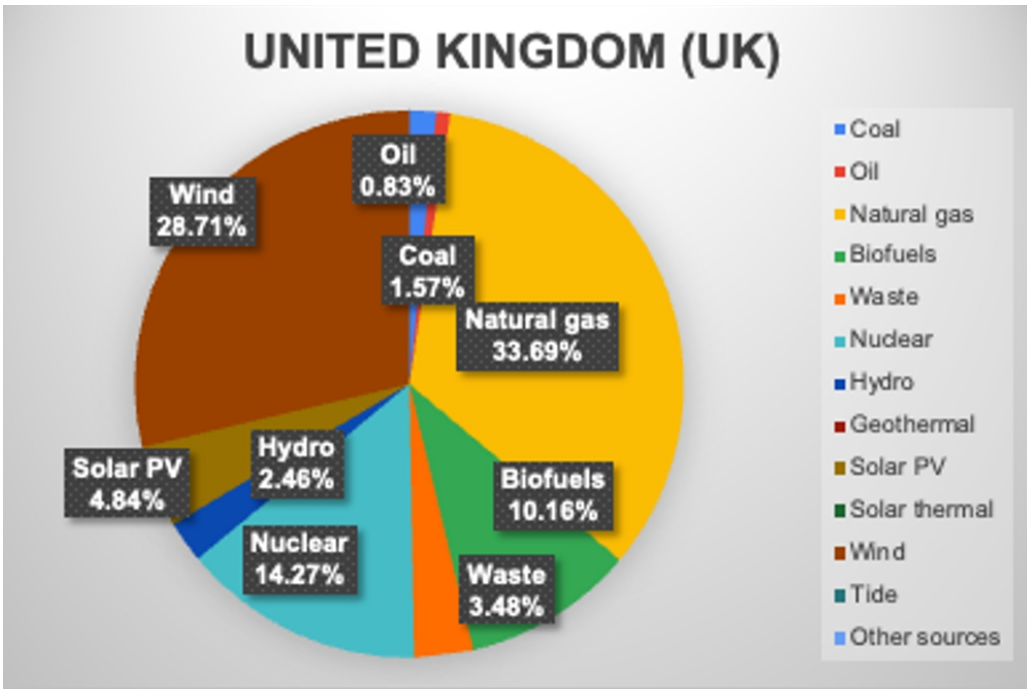
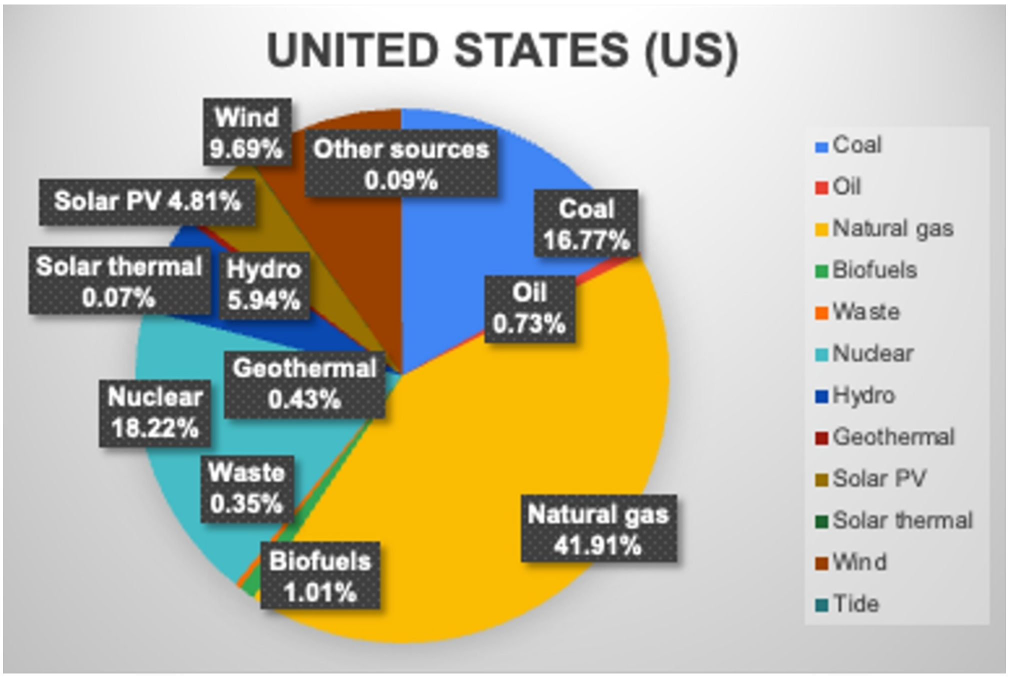
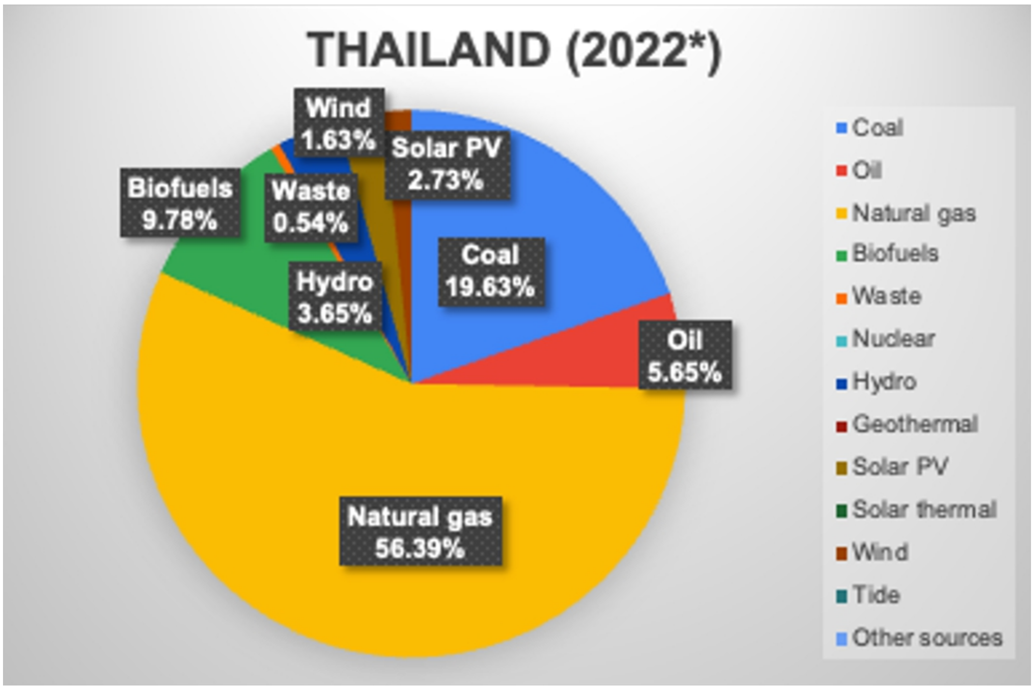
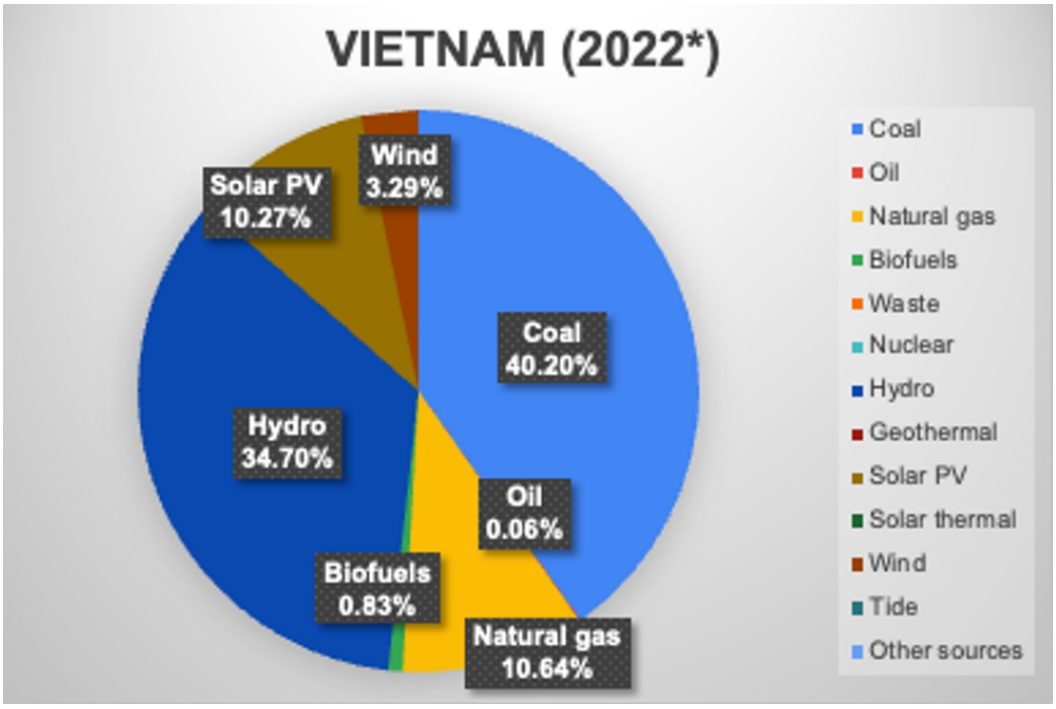
Nigeria	Nigeria's data center market is projected to reach $2.44 billion USD by 2029, with a 2024 estimate of $1.56 billion. Valued at $230 million in 2022, the market is expected to grow to $415 million by 2028. However, the sector faces significant challenges due to soaring energy costs, particularly for diesel fuel, which is critical given the country's unreliable power grid. Nigeria currently has over 11 data centers, far below the estimated demand, leaving a $600 million infrastructure gap. Diesel generators are often the only reliable energy source, but rising costs strain operations and threaten the sustainability of cloud and internet services. Despite having 4% of global GDP, Africa hosts just 1% of global digital infrastructure, underscoring the urgency of addressing Nigeria's data center deficit to support its digital economy. 
Norway	Norway's data center market is expected to generate $2.34 billion USD in revenue by 2029, with $1.70 billion projected for 2024. Electricity demand from data centers is estimated to rise to 4–9 TWh annually by 2040, primarily for cooling, with waste heat expected to be reused. The Norwegian government has positioned the country as a hub for tech companies. A notable example is Google's hyperscale data center, valued at EUR 600 million, set to be operational by 2026. This facility alone will consume 5% of Norway's total electricity and has already secured 240 megawatts, with plans to expand to 840 megawatts, making it the largest consumer of power in the nation. 

Singapore	Singapore's data center market is projected to reach $1.61 billion USD by 2029, with a 2024 estimate of $1.21 billion. It is among the most power-constrained markets globally, with less than 4 MW of available capacity and a vacancy rate under 2%. High demand has pushed rental rates to $300–$450 per month for 250–500 kW. The Singaporean government recently introduced strict regulations, including a 2019–2022 moratorium on new data centers, to meet environmental goals. Data centers consume 7% of the nation's electricity, projected to rise to 12% by 2030. Despite challenges, Singaporean data centers maintain high energy efficiency, with Power Usage Effectiveness (PUE) scores from 1.20 to 1.90 and total power capacity exceeding 569 MW, supported by diverse rack power options from 1.50 kW to 5.40 kW. 
South Africa	South Africa's data center market is projected to generate $1.51 billion USD in revenue by 2029, with $1.21 billion expected by 2024. The country's high mobile connectivity, at 179.8% of its population in 2022, drives demand for data services, but electricity supply challenges pose significant risks to operations. The government has urged data centers to reduce reliance on the national grid and adopt alternative energy solutions. Companies like Teraco are investing heavily, raising $104 million to construct solar and wind farms, targeting 60% energy self-sufficiency by 2025. However, many operators are forced to rely on costly diesel generators as a stopgap, which increases expenses and highlights the urgency of resolving South Africa's energy crisis to support data center growth. 

Sweden	Sweden's data center market is expected to generate $4.37 billion USD in revenue by 2029, with $3.40 billion projected in 2024. Sweden, along with Finland, is highlighted as an ideal location for data centers due to low electricity costs. In 2023, the average wholesale electricity price in Sweden was EUR 51.70 per MWh, significantly lower than Central Europe's rates, such as EUR 131.62 in Germany and EUR 95.18 in Ireland. Data centers currently account for 2.3% of Sweden's national electricity use. Power demand from data centers is projected to double by the end of the decade and double again by 2040, reflecting rapid growth in the sector. 
Switzerland	Switzerland's data center market is projected to generate $3.70 billion USD in revenue by 2029, with $2.75 billion expected in 2024. Data centers consume nearly 4% of the country's electricity, a figure predicted to increase significantly in the coming years. Some estimates place data center-related consumption at 5% of national electricity demand, with over half attributed to server rooms and data centers used by households and businesses. The rise in digitalization is driving greater demand for data processing, communication, and storage, highlighting the need for efficiency. Opportunities for improving energy usage in server rooms & data centers have been identified. 

United Kingdom	The UK's data center market is expected to generate $23.76 billion USD by 2029, with a projected $17.18 billion in 2024. Demand for electricity is forecast to double by 2050 as electrification of heat, transport, and industry increases, with data center power consumption projected to grow sixfold within a decade. In 2024, 72 new data center projects were identified for construction within the following year, indicating rapid industry growth. London (along with Frankfurt) will lead Europe in new data center supply expansion in 2024. Artificial intelligence is expected to significantly drive energy demands, with consumption rising by 500% in the coming decade. 
United States	The U.S. data center market is projected to reach $212.05 billion USD by 2029, with a 2024 estimate of $123.15 billion. Blackstone, holding a $55 billion data center portfolio and $70 billion in pipeline projects, foresees $1 trillion in U.S. capital expenditures for data centers over five years. Electricity demand is expected to rise 40% in the next decade. Northern Virginia leads globally in data center capacity with 2.1 GW, but power supply constraints persist. Dallas/Ft. Worth is the fastest-growing market, with 324 MW under construction and 88.4% preleased. Inventory rose 17% year-over-year by Q1 2023, surpassing Silicon Valley as the second-largest U.S. colocation market. The U.S. houses one-third of the world's data centers, driving questions on whether supply will keep pace with demand as the boom continues. 

Thailand	Thailand's data center market is projected to reach $2.99 billion USD by 2029, with a 2024 estimate of $2.35 billion. KPMG predicts a 27% market growth between 2019 and 2026, creating opportunities for investors in a rapidly expanding industry. Gulf Energy Development Pcl plans to invest an additional 10 billion baht ($271 million) to expand a data center facility near Bangkok, increasing energy consumption to 50 MW from a previously announced 25 MW. Thailand is also piloting projects to link data centers with renewable energy generators, helping investors manage costs, avoid grid constraints, and reduce carbon footprints, aligning with sustainable growth goals. 
Vietnam	Vietnam's data center market is expected to reach $2.58 billion USD by 2029, with a 2024 projection of $2.16 billion and a CAGR of 8.31% from 2024 to 2032. As of July 2024, the revised Telecommunications Law allows 100% foreign ownership in cloud and data center industries, driving international investment. Reliable power supply is a key challenge for Vietnamese data centers, as current infrastructure struggles to meet demand. Long-term sustainability will require investments in power grid improvements and alternative energy solutions. However, Vietnam offers low commercial energy costs and significant renewable energy potential, providing a competitive edge in attracting new data center projects compared to regional peers. 

Europe

Denmark

Denmark has an extremely reliable grid, and is a true stand-out in terms of making the green transition happen policy-wise. This is of some significance to us because they are extremely reliable despite intermittency challenges.

Capacity

- Domestic production capacity 33,948 GWh (2023)[22]
- 2030 Projection:
- No IEA projections specific to Denmark
- Denmark falls under the IEA's Europe Projections

STEPS

○: 4,707.77 TWh

APS:

○ 4,989.45 Twh

Electricity Generation Sources | Denmark | 2023 [22]			
Source	**Value**	**Units**	**Share**
Coal	2,524	GWh	7.43%
Oil	312	GWh	0.92%
Natural gas	1,000	GWh	2.95%
Biofuels	5,512	GWh	16.24%
Waste	1,679	GWh	4.95%
Hydro	19	GWh	0.06%
Solar PV	3,363	GWh	9.91%
Wind	19,539	GWh	57.56%
Total	**33,948**	GWh	100.00%

Electricity Demand

- 2022: 110,173 TJ (30,604 GWh)[16]

Electricity Consumption by Sector | Denmark | 2022 [22]			
Sector	**Value**	**Unit**	**Share**
Industry	31,662	TJ	28.74%
Transport	3,187	TJ	2.89%
Residential	34,274	TJ	31.11%
Commercial & public services	35,065	TJ	31.83%
Agriculture & forestry	5,985	TJ	5.43%
TOTAL	110,173	TJ	100.00%

Grid Reliability

●Security of grid is 99.99%; and reliability is extremely high – average Danish resident is without power for just 40 minutes per year.[50]
●When outages do happen, results from issues with grid infrastructure itself, never energy (electricity) supply.[50]

Policy

●Denmark is truly a world leader in the green transition, having made huge progress toward complete decarbonization already, with a goals of:[51]
○Using 100% biomethane for heating by 2030 (prioritized after Russian invasion for energy security reasons)[51]
○Stopping all fossil fuel production by 2050
○Achieving NZE by 2045, and 110% emissions reduction by 2050

Data Center Outlook

●Demand Outlook
○Data centers in Denmark currently account for ~4.5% of national electricity consumption[174]
○“In Denmark, data centre energy use is projected to rise six times by 2030 to account for almost 15% of the country's electricity use.”
○“Denmark alone is expected to host several large-scale DCs, whose demand for electricity in 2040 may reach 33% of 2017 national electricity consumption”[178]
○Denmark seems to have an unusually high level of sophistication in its considerations for the impact of data centers on its energy system, how excess electrical demand can be met sustainably, and how the heat from the data centers can actually be fed back into the energy system as thermal energy.[178]
●Financial Outlook (as a proxy)
○Revenue associated with data centers in Denmark is expected to reach $3.07 billion (USD) by 2029[116]
■For comparison, 2024 EOY projection is $2.23 billion USD
■Full data set is here: https://www.statista.com/outlook/tmo/data-center/denmark#revenue

France

France is reputed to have one of the best grids in the world – it is meeting its current challenges well, boasting good reliability, leadership in grid digitalization, and a sizable trade surplus in net energy exports. Political leadership is also meeting the rise of AI quite proactively.

Capacity

●2023 domestic production capacity: **526,993 GWh**[20]
●2030 Projection:
○No IEA projections specific to France
○France falls under the IEA's Europe Projections
STEPS
■: 4,707.77 TWh

APS:
- 4,989.45 Twh

Electricity Generation Sources | France | 2023 [20]

Source	Value	Units	Share
Coal	3,098	GWh	0.59%
Oil	5,834	GWh	1.11%
Natural gas	31,248	GWh	5.93%
Biofuels	7,641	GWh	1.45%
Waste	4,205	GWh	0.80%
Nuclear	338,202	GWh	64.18%
Hydro	60,664	GWh	11.51%
Geothermal	113	GWh	0.02%
Solar PV	22,687	GWh	4.30%
Wind	52,409	GWh	9.94%
Tide	448	GWh	0.09%
Other sources	444	GWh	0.08%
Total	**526,993**	GWh	100.00%

Electricity Demand

●2023: 1,492,918 TJ (414,699 GWh)[16]

Electricity Consumption by Sector | France | 2022 [20]

Sector	Value	Unit	Share
Industry	387,529	TJ	25.96%
Transport	38,963	TJ	2.61%
Residential	559,331	TJ	37.47%
Commercial & public services	474,138	TJ	31.76%
Agriculture & forestry	27,527	TJ	1.84%
Fishing	646	TJ	0.04%
Non-specified	4,784	TJ	0.32%
TOTAL	1,492,918	TJ	100.00%

Grid Reliability

●In 2019, France was considered by many to be the most reliable grid in the world for any country with a population over 5 million, going 10 years straight without a blackout[52]
●Although French grid is quite reliable, shifting energy mix (renewables driving intermittency issues) and shifting European grid connectivity have been driving an increase in issues.[45]
●Despite some speedbumps, outlook is positive, as nuclear provides good baseload capacity, and France is a leader in digitalization / smart grid technology.[46]

Policy

●Like many of its European counter-parents, the French government is pushing the NZE transition hard, which is putting pressure on existing systems.[47]
●Goal to increase electricity output by 10% by 2030, and 55% by 2050[47]
●In 2023, France overtook Sweden as largest net exporter of power – which bodes well for reliability in the face of rising domestic demand[47]
●France is currently seeing heavy investment in low-carbon Hydrogen fuel[47]
●French leadership is taking rise of AI quite seriously, positioning the country for upcoming changes[48]

Data Center Outlook

●Demand Outlook
○Data centers in France currently account for ~2.2% of national electricity consumption[174]
○France is offering tax breaks to operators of data centers that meet certain ambitious thresholds for energy efficiency.[182]
○“Dublin's data centers requiring more than 700 megawatts of capacity. Data center hubs in **Paris** and Frankfurt require nearly as much energy as the Dublin hub. By comparison, 1 megawatt of power is enough to power 750 to 1,000 homes for a year.”[183]
○“Much of the data centre activity in France has been centred in Paris, making it one of the top markets in the EU and the world”, but Marseille, Lyon, Lille, and Strasbourg also have strong markets, and there are even now data centers going into rural areas.[184]
●Financial Outlook (as a proxy)
○Revenue associated with data centers in France is expected to reach $15.41 billion (USD) by 2029[114]
■For comparison, 2024 EOY projection is $11.75 billion USD
■Full data set is here: https://www.statista.com/outlook/tmo/data-center/germany#revenue
○“More than US$1.2 billion is invested in the French data centre industry every year – driving eight times additional investment in related hardware, according to the France Datacenter Association (Association de référence de la filière datacenter en France).”[184]

Germany

Germany is a leader in the green transition, having managed the tricky balance of both (1) high shares of intermittent renewables in their energy mix, and (2) excellent grid reliability.

Capacity

●2023 domestic production capacity: **520,003 GWh**[19]

●2030 Projection:
○No IEA projections specific to Germany
○Germany falls under the IEA's Europe Projections
STEPS
■: 4,707.77 TWh
APS:
■ 4,989.45 Twh

Electricity Generation Sources | Germany | 2023 [19]				
Source	**Value**	**Year**	**Units**	**Share**
Coal	138,403	2023	GWh	26.62%
Oil	4,485	2023	GWh	0.86%
Natural gas	89,122	2023	GWh	17.14%
Biofuels	39,800	2023	GWh	7.65%
Waste	12,164	2023	GWh	2.34%
Nuclear	7,216	2023	GWh	1.39%
Hydro	25,345	2023	GWh	4.87%
Geothermal	206	2023	GWh	0.04%
Solar PV	61,536	2023	GWh	11.83%
Wind	140,538	2023	GWh	27.03%
Other sources	1,188	2023	GWh	0.23%
Total	**520,003**	2023	GWh	100.00%

Electricity Demand

●2023: 1,719,881 TJ (477,745 GWh)[16]

Electricity Consumption by Sector | Germany | 2022 [19]			
Sector	**Value**	**Unit**	**Share**
Industry	747,241	TJ	43.45%
Transport	47,328	TJ	2.75%
Residential	483,361	TJ	28.10%
Commercial & public services	423,221	TJ	24.61%
Agriculture & forestry	18,468	TJ	1.07%
Fishing	262	TJ	0.02%
TOTAL	1,719,881	TJ	100.00%

Grid Reliability

●Despite big increases in the shares of renewable electricity generation sources—which carry with them intermittency issues—Germany's grid is still extremely stable.[42]
●Biggest threat to reliability is extreme weather events, which will be increasing in frequency and severity globally thanks to climate change.[42]

Policy
●The “Energiewende” is Germany's plan to cut emissions to almost net zero by 2045, without relying on Nuclear – it has enjoyed broad support with the German public.[43]
●Destruction of Nord Stream 1 pipeline during Ukraine War has put additional pressure on move away from gas and decreased the chances of Nord Stream 2 coming to full fruition.[44]

Data Center Outlook
●Demand Outlook
○Frankfurt (in addition to London) is set to add the largest increases in data center supply in Europe in 2024[138]
○“Dublin's data centers requiring more than 700 megawatts of capacity. Data center hubs in Paris and **Frankfurt** require nearly as much energy as the Dublin hub. By comparison, 1 megawatt of power is enough to power 750 to 1,000 homes for a year.”[183]
○Germany has “recently introduced curbs that include limiting permits for data centres in residential areas, or requiring them to contribute renewable energy to the grid and reuse waste heat.”[144]
○Data centers in Germany currently account for ~3% of national electricity consumption[174]
○“While Germany benefits from a high level of power supply security, the Borderstep Institute estimates the annual total energy consumption of data centers in Germany to be 17.9 billion kilowatt-hours (kWh), which is expected to rise. To put this into perspective, the city of Berlin consumed approximately 12.1 billion kWh in 2022. High power consumption already led to consequences in Frankfurt.”[185]
●Financial Outlook (as a proxy)
○Revenue associated with data centers in Germany is expected to reach $25.29 billion (USD) by 2029[110]
■2024 EOY projection is $18.71 billion USD
■Full data set is here: https://www.statista.com/outlook/tmo/data-center/germany#revenue

Norway
Norway is something of an energy superpower. Its grid is extremely reliable, and it is a net exporter of all things energy related, especially O&G products, but also electricity.

Capacity
●Domestic production capacity 154,890 GWh (2023)[24]
●2030 Projection:
○No IEA projections specific to Norway
○Norway falls under the IEA's Europe Projections
STEPS
■: 4,707.77 TWh
APS: 4,989.45 TWh

Electricity Generation Sources | Norway | 2023 [24]

Source	Value	Year	Units	Share
Coal	148	2023	GWh	0.10%
Oil	13	2023	GWh	0.01%
Natural gas	1,529	2023	GWh	0.99%
Biofuels	36	2023	GWh	0.02%
Waste	409	2023	GWh	0.26%
Hydro	137,974	2023	GWh	89.08%
Solar PV	357	2023	GWh	0.23%
Wind	13,965	2023	GWh	9.02%
Other sources	459	2023	GWh	0.30%
Total	**154,890**	2023	GWh	100.00%

Electricity Demand

●2022: 414,197 TJ (115,055 GWh)[24]

Electricity Consumption by Sector | Norway | 2022 [24]

Sector	Value	Unit	Share
Industry	172,783	TJ	41.72%
Transport	10,491	TJ	2.53%
Residential	130,851	TJ	31.59%
Commercial & public services	91,830	TJ	22.17%
Agriculture & forestry	7,418	TJ	1.79%
Fishing	824	TJ	0.20%
TOTAL	414,197	TJ	100.00%

Grid Reliability

●Continuity/reliability stands at about 99.99%, and even with extreme weather events has only dropped to 99.96 in any given year since mid-1990s. TL;DR – very good.

●Norwegians experience "…on average about two short interruptions and two longer interruptions per year, where the average duration is less than two minutes for short interruptions and approximately two hours for long interruptions."

Policy

●Norway's grid / electricity supply is already basically clean, thanks in no small part to an abundance of hydropower; it's current NZE focus is decarbonizing more complex sectors, such as transport.[57]

●Being an oil producer, 87% of its energy is exported and it plays an important role in energy security/stability for the world & Europe especially.[58]

●Norway has had a a national AI strategy since 2020.[59]

Data Center Outlook

●Demand Outlook

○"According to NVE's estimates, the demand for electricity in data centres will increase to between 4 and 9 TWh per year in 2040. Most of this electricity will be used for cooling and will be expunged as waste heat."[172]

○Norway's government is taking intentional steps to make itself an attractive location for the big tech firms to build data centers—"Google's recent announcement of the establishment of Norway's first hyperscale data centre, valued at EUR600 million, is a good example that the government's strategy has been successful"[173]

■This data center is expected to be operational by 2026 and will amount to 5% of Norway's total electricity usage.

■"Google has already been granted 240 megawatts for operation of the centre but has applied for access to a total of 840 megawatts. Such power consumption will make the data centre the largest consumer of power in Norway and will demand a significant expansion of the Norwegian power grid"

●Financial Outlook (as a proxy)

○Revenue associated with data centers in Norway is expected to reach $2.34 billion (USD) by 2029[118]

■For comparison, 2024 EOY projection is $1.70 billion USD

■Full data set is here: https://www.statista.com/outlook/tmo/data-center/norway

Sweden

Sweden has an extremely "clean" grid and is a net exporter of electricity. Its power supply is quite reliable, as large portions of its clean mix do not suffer from intermittency issues (nuclear + hydro).

Capacity

●Domestic production capacity 165,822 GWh (2023)[23]

●2030 Projection:

○No IEA projections specific to Sweden

○Sweden falls under the IEA's Europe Projections

STEPS

■: 4,707.77 TWh

APS:

■ 4,989.45 TWh

Electricity Generation Sources | Sweden | 2023 [23]

Source	Value	Year	Units	Share
Coal	526	2023	GWh	0.32%
Oil	259	2023	GWh	0.16%

Natural gas	222	2023	GWh	0.13%
Biofuels	8,556	2023	GWh	5.16%
Waste	4,462	2023	GWh	2.69%
Nuclear	48,289	2023	GWh	29.12%
Hydro	66,336	2023	GWh	40.00%
Solar PV	3,098	2023	GWh	1.87%
Wind	34,074	2023	GWh	20.55%
Total	165,822	2023	GWh	100.00%

Electricity Demand

●2022: 441,965 TJ (122,768 GWh)[23]

Electricity Consumption by Sector | Sweden | 2022 [23]			
Sector	**Value**	**Unit**	**Share**
Industry	163,792	TJ	37.06%
Transport	14,770	TJ	3.34%
Residential	146,289	TJ	33.10%
Commercial & public services	111,383	TJ	25.20%
Agriculture & forestry	5,731	TJ	1.30%
TOTAL	441,965	TJ	100.00%

Grid Reliability

●Sweden's grid has been considered quite reliable, but there is recognition of the need to upgrade to plan for demand challenges in the future. Afry gives a good run-down of these issues that can be addressed.[53]
●The EU has set out a goal for the grids of member countries to reach an interconnectedness threshold of 15% - Sweden is well above this number, which helps contribute to reliability.[55]

Policy

●Target to reach NZE by 2040. [54]
●Sweden has had a national AI strategy since 2018 and aims to be a leader in the space.[56]

Data Center Outlook

●Demand Outlook

○Data centers in Sweden currently account for ~2.3% of national electricity consumption[174]
○"By one official estimate, Sweden could see power demand from data centers roughly double over the course of this decade — and then double again by 2040."[175]

○

●Financial Outlook (as a proxy)
○Revenue associated with data centers in Sweden is expected to reach $4.37 billion (USD) by 2029[117]
■For comparison, 2024 EOY projection is $3.40 billion USD
■Full data set is here: https://www.statista.com/outlook/tmo/data-center/sweden#revenue
○Headline: "Finland and Sweden are the best locations for data centers"[176]
■This is subjective of course, but article makes an interesting case
■"According to the statistics of Finnish Energy (Energiateollisuus ry), the prices of electricity in Finland and Sweden in 2023 were the lowest in Europe. The average wholesale price of electricity was EUR 56.47 per MWH in Finland and EUR 51.70 per MWH in the Stockholm area. Compared to Central Europe, the price difference is significant. The corresponding price of electricity in Germany was EUR 95.18, while in Ireland, which attracts a lot of data centers, it was as high as EUR 131.62."

Switzerland

Switzerland's energy supply is extremely reliable, but heavily dependent on imports. They are focused on transitioning away from both fossil fuels and nuclear

Capacity
●Domestic production capacity 73,667 GWh (2023)[1]
●2030 Projection:
○No IEA projections specific to Switzerland
○Switzerland falls under the IEA's Europe Projections
STEPS
■: 4,707.77 TWh
APS:
■ 4,989.45 Twh

Electricity Generation Sources | Switzerland | 2023 [21]				
Source	**Value**	**Year**	**Units**	**Share**
Oil	38	2023	GWh	0.05%
Natural gas	361	2023	GWh	0.49%
Biofuels	951	2023	GWh	1.29%
Waste	2,169	2023	GWh	2.94%
Nuclear	24,384	2023	GWh	33.10%
Hydro	41,187	2023	GWh	55.90%
Solar PV	4,419	2023	GWh	6.00%
Wind	168	2023	GWh	0.23%
Total	73,677	2023	GWh	100.00%

Electricity Demand
●2022: 205,310 TJ (57,031 GWh)[16]

Electricity Consumption by Sector | Switzerland | 2022 [21]			
Sector	**Value**	**Unit**	**Share**
Industry	62,310	TJ	30.35%
Transport	12,850	TJ	6.26%
Residential	69,680	TJ	33.94%
Commercial & public services	57,040	TJ	27.78%
Agriculture & forestry	3,430	TJ	1.67%
TOTAL	205,310	TJ	100.00%

Grid Reliability

●The Swiss grid is among the most reliable in the world, mutually benefiting from connections to its European neighbors.[48]
●Note: Switzerland runs a big trade deficit on energy imports, which makes them dependent on imports to maintain this reliability.[49][179]

Policy

●Because Switzerland has to import most of its power, energy policies are first and foremost focused on energy security.[49]
●The Fukushima nuclear disaster in 2011 brought about strong concerns in regards to Nuclear in Switzerland, so they have been making efforts to get away from this in their energy mix.[49]
●Green transition is a big priority for Switzerland; CO2 taxes have been implemented & energy research is thriving.[49]

Data Center Outlook

●Demand Outlook

○“Data centres in Switzerland use almost 4% of the country's total electricity, and in the coming years their electricity consumption will 'increase massively', predicts Altenburger.”[180]
■Altenburger is a professor of building technology and energy at Lucerne University of Applied Sciences and Arts and co-author of a study on data centres in Switzerland[180]
○Other estimates have data centers at almost 5% of national electricity demand
“More than half of this is accounted for by server rooms (SR) and data centers (DC). Increasing digitalization (households and companies) is leading to a sharp increase in the demand for data processing, including communication and storage. At the same time, significant energy

■efficiency potentials have been identified in the area of server rooms and data centers."[181]

●Financial Outlook (as a proxy)
○Revenue associated with data centers in Switzerland is expected to reach $3.70 billion (USD) by 2029[115]
■For comparison, 2024 EOY projection is $2.75 billion USD
■Full data set is here: https://www.statista.com/outlook/tmo/data-center/switzerland#revenue

United Kingdom

The UK currently has a very stable grid, however controlling for intermittency issues in the planned shift from natural gas to renewables will be key moving forward. Outlook is positive overall.

Capacity
●Domestic production capacity 323,910 GWh[1]
●2030 Projection:
○No IEA projections specific to UK
○The UK falls under the IEA's Europe Projections
STEPS
■: 4,707.77 TWh
APS:
■ 4,989.45 Twh

Electricity Generation Sources | United Kingdom | 2023 [1]

Source	Value	Year	Units	Share
Coal	4,472	2023	GWh	1.57%
Oil	2,360	2023	GWh	0.83%
Natural gas	96,226	2023	GWh	33.69%
Biofuels	29,007	2023	GWh	10.16%
Waste	9,943	2023	GWh	3.48%
Nuclear	40,748	2023	GWh	14.27%
Hydro	7,018	2023	GWh	2.46%
Solar PV	13,826	2023	GWh	4.84%
Wind	81,989	2023	GWh	28.71%
Tide	11	2023	GWh	0.004%
Total	285,600	2023	GWh	100%

Electricity Demand
●Current: 987,338 TJ (274,261 GWh)[15]

Electricity Consumption by Sector | United Kingdom | 2022 [1]

Sector	Value	Unit	Share
Industry	306,372	TJ	31.03%
Transport	30,379	TJ	3.08%
Residential	346,490	TJ	35.09%
Commercial & public services	290,260	TJ	29.40%
Agriculture & forestry	8,558	TJ	0.87%
Fishing	5,279	TJ	0.53%
Total	987,338	TJ	100.00%

Grid Reliability

National Grid reports

● average network reliability of 99.999997%[2]

Policy

●Most recent UK energy strategies drew criticism for over-reliance on Green Hydrogen, which is still largely theoretica

●New Labour government is setting new agenda for electricity sector; goals for 2030 include:[3]

○Fully decarbonize electrical sector

○2x onshore wind capacity

○4x offshore wind capacity

○5x acceleration in construction of new electrical grid infrastructure

Data Center Outlook

●Demand Outlook

○National Grid CEO, John Pettigrew via BBC:[107]

■"Demand on the grid is growing dramatically, and forecast to double by 2050 as heat, transport and industry continue to electrify."

■"…the power those data centres use (will) increase six-fold in the next decade."

○In August 2024, BarbourABI identified 72 data centre projects that were slated to start construction in the UK solely in the next 12 months (i.e. by August 2025)[108]

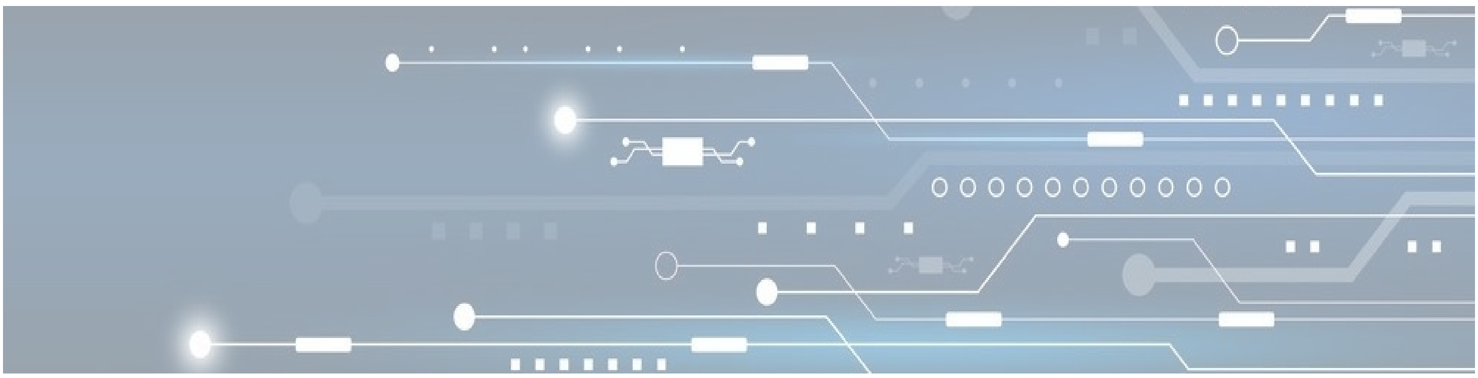
○London (in addition to Frankfurt) is set to add the largest increases in data center supply in Europe in 2024[138]

○"In the UK, AI is expected to suck up 500% more energy over the next decade."[175]

●Financial Outlook (as a proxy)

○Revenue associated with data centers in the UK is expected to reach $23.76 billion (USD) by 2029[119]

■For comparison, 2024 EOY projection is $17.18 billion USD



■ Full data set is here: https://www.statista.com/outlook/tmo/data-center/united-kingdom#revenue

Asia-Pacific

Australia

Australia has a very reliable grid on par with expectations for a western, industrial economy. The current shift to renewables will create challenges with intermittency, but there is a plan in place to manage this.

Capacity

●Domestic production capacity 274,470 GWh (2023)[31]
●2030 Projection:
○No IEA projections specific to Australia
○Australia falls under the IEA's Asia Pacific Projections
STEPS
■: 19,043.30 TWh
APS:
■ 18,899.96 Twh

Electricity Generation Sources | Australia | 2023 [31]				
Source	**Value**	**Year**	**Units**	**Share**
Coal	127,632	2023	GWh	46.50%
Oil	4,864	2023	GWh	1.77%
Natural gas	48,865	2023	GWh	17.80%
Biofuels	3,092	2023	GWh	1.13%
Hydro	16,666	2023	GWh	6.07%
Solar PV	41,964	2023	GWh	15.29%
Solar thermal	3	2023	GWh	0.00%
Wind	31,384	2023	GWh	11.43%
Total	274,470	2023	GWh	100.00%

Electricity Demand

●2022: 711,108 TJ (197,530 GWh)[31]

Electricity Consumption by Sector | Australia | 2022 [31]			
Sector	**Value**	**Unit**	**Share**
Industry	283,067	TJ	35.60%
Transport	24,281	TJ	3.05%
Residential	249,448	TJ	31.38%
Commercial & public services	231,877	TJ	29.17%
TOTAL	795,024	TJ	100.00%

Grid Reliability

●Aussie grid is very reliable, with minimum reliability standard set at 99.998%[79]

●National electricity authority (Aemo) says that the transition to renewables will not impact reliability "if investments in new generation are delivered 'on time and in full'".[79]

Policy

●Australian policy is focused on balancing security with NZE transition, with specific initiatives outlining strategies for hydrogen, wind, EVs, and buildings.[80]

●Australia does have a national action plan & strategy that is specific to AI, but mention of energy implications are mostly absent.[81]

Data Center Outlook

●Demand Outlook

○Headline: "Power-hungry data centres scrambling to find enough electricity to meet demand"[157]

■"Australia is one of the top five data centre hubs in the world. There are 214 data centres spread across the country, according to the Australian Information Industry Association."

■"Morgan Stanley estimates that data centres are currently using 5 per cent (1,050 MW) of the electricity on Australia's power grid and that is expected to grow to 8 per cent (2,500 MW) by 2030. Some estimates even suggest they could require up to 15 per cent of the power on the grid by then."

■"'It's not yet an insurmountable problem, but if the demand continues to escalate at the rate it has, based on the recent developments, I think it is an issue.'"

○Headline: "AI datacentres to strain Australia's energy supply, spike prices without change, expert says"[158]

■Tom Allen, UBS analyst: "We think that current government forecasts are significantly underestimating the load growth in demand,"

■"Datacentres now account for almost a quarter of large industrial power demand in Australia. UBS forecasts that load will increase by 16% a year out to 2030."

■"The Australian Energy Market Operator had so far largely missed the rise of datacentre demand in its forecasts" – but this is expected to change

●Financial Outlook (as a proxy)

○Revenue associated with data centers in Australia is expected to reach $7.06 billion (USD) by 2029[124]

■2024 EOY projection is $5.40 billion USD

■ Full data set is here: https://www.statista.com/outlook/tmo/data-center/australia#revenue
○Interesting anecdote on how data centers will impact the price of electricity[158]
■"Evening peak demand could see wholesale power price spreads as much as 70% higher by 2030. Price spreads between 3.30pm and 8.30pm have averaged $312 per megawatt-hour so far this year in the national energy market, and are projected to reach $525/MWh by the end of the decade, UBS estimates."

India

India's grid is struggling to keep pace with the size of their population; great progress has been made in recent years, but reliability is still an issue outside of major cities. Big investments are being made into renewables, but even bigger ones are being made into fossil fuels in order to address demand.

Capacity

●2021 domestic production capacity: **1,635,165 GWh**[16]
●2030 Projection:[15]
○The IEA does do India-specific projections (for 2050 as well)
STEPS
■: 2,671.79 TWh
APS:
■ 2,580.55 Twh

Electricity Generation Sources | India | 2022 [16]

Source	Value	Year	Units	Share
Coal	1,306,856	2022	GWh	72.04%
Oil	4,746	2022	GWh	0.26%
Natural gas	54,952	2022	GWh	3.03%
Biofuels	39,024	2022	GWh	2.15%
Waste	3,497	2022	GWh	0.19%
Nuclear	45,861	2022	GWh	2.53%
Hydro	173,669	2022	GWh	9.57%
Solar PV	104,739	2022	GWh	5.77%
Wind	80,714	2022	GWh	4.45%
Total	1,814,058	2022	GWh	100.00%

Electricity Demand

●2022: 5,034,974 TJ (1,398,604 GWh)[16]
●2026 Projection: 82 TWh[14]

Electricity Consumption by Sector | India | 2022 [16]

Sector	Value	Unit	Share
Industry	2,124,736	TJ	42.20%
Transport	90,000	TJ	1.79%
Residential	1,303,199	TJ	25.88%
Commercial & public services	378,359	TJ	7.51%
Agriculture & forestry	866,880	TJ	17.22%
Non-specified	271,800	TJ	5.40%
TOTAL	5,034,974	TJ	100.00%

Grid Reliability

●Investment in India's capacity (mostly private sector investment in coal) has created a power surplus (i.e. capacity exceeds demand) but India's distribution infrastructure (i.e. the grid) is still lagging behind.[36]
●In rural and peri-urban areas, power outages are still quite common – however, reliability is better in urban areas thanks to power surplus.[36]

Policy

●Policy specific to grid regulations has made huge improvements in India's reliability – large scale blackouts are now quite rare – but have stalled in addressing issues outside of urban areas.[36]
●Meanwhile, the Indian government is considering granting data centers “infrastructure status”, which would put it in the same category as roads, railways, and the electrical grid.[37]
●India is making big commitments on boosting renewable energy capacity, but these boost alone do not seem to be keeping pace with demand, so there is huge parallel investment in fossil fuels to fill the gap.[38]

Data Center Outlook

●Demand Outlook
○“Mumbai is India's largest data center market at over 300 MW, accounting for over 40% of total capacity”[138]
○“Data center inventory in Mumbai is expected to more than double over the next two years. This strong demand is particularly driven by financial services companies, a good ecosystem of fiber connectivity and government support. Established domestic and global operators are expanding in the market, and a major hyperscale cloud provider recently acquired over 50 acres of land on the city's edge. Other international investors with planned developments in greater Mumbai include Blackstone, Brookfield-Digital Realty and Princeton Digital Group.”
○Current percentage of India's electricity demand coming from data centers is less than 1%, but this is expected to rise to 6% by 2030.[160]
●Financial Outlook (as a proxy)

○Revenue associated with data centers in India is expected to reach $11.59 billion (USD) by 2029[111]
■2024 EOY projection is $8.64 billion USD
■Full data set is here: https://www.statista.com/outlook/tmo/data-center/india#revenue
○"Financial service firm Jefferies has outlined a robust growth trajectory for India's data center sector, forecasting a CAGR of over 50%" [160]

Indonesia

Indonesia has unique challenges, including geography. Its energy mix is mostly fossil fuels, and it suffers from blackouts on a regular basis, even in urban areas.

Capacity

●Domestic production capacity 376,803 GWh (2022)[29]
●2030 Projection:
○No IEA projections specific to Singapore
○Indonesia falls under the IEA's Asia Pacific Projections
STEPS
■: 19,043.30 TWh
APS:
■ 18,899.96 Twh

Electricity Generation Sources | Indonesia | 2022 [29]				
Source	**Value**	**Year**	**Units**	**Share**
Coal	248,576	2022	GWh	65.97%
Oil	8,308	2022	GWh	2.20%
Natural gas	51,425	2022	GWh	13.65%
Biofuels	23,679	2022	GWh	6.28%
Waste	44	2022	GWh	0.01%
Hydro	27,295	2022	GWh	7.24%
Geothermal	16,677	2022	GWh	4.43%
Solar PV	443	2022	GWh	0.12%
Wind	356	2022	GWh	0.09%
Total	376,803	2022	GWh	100.00%

Electricity Demand

●2022: 1,277,850 TJ (354,958 GWh)[29]

Electricity Consumption by Sector | Indonesia | 2022 [29]			
Sector	**Value**	**Unit**	**Share**
Industry	581,664	TJ	45.52%
Transport	1,290	TJ	0.10%

Grid Reliability

●Existing data on grid reliability has been shown to be often inaccurate.[72]

●Blackouts are common enough in Indonesia that ownership of back-up generators is not uncommon.[72]

Policy

●Policy has favored coal but has not done much to prevent miners from selling their product abroad when it is economically advantageous to do so—this has highlighted Indonesia's over-dependence on coal as an energy source as irregularities in supply and demand have frequently resulted in blackouts.[74]

●Green transition goals are not particularly aggressive, with target for renewables by 2025 set at 23%[73]

Data Center Outlook

●Demand Outlook

○"South-east Asian countries like Malaysia and Indonesia have seen a surge in demand for data centres after close neighbour Singapore placed a moratorium on them between 2019 and 2022."[147]

○"Predictions indicate that by 2024, the energy capacity of data centers in Indonesia will surge to 210 megawatts (MW)"[149]

■"Hendra Suryakusuma, Chairman of IDPRO, revealed that the energy capacity of Indonesia's data centers is projected to increase by 44.83% compared to the previous year"

■"…energy capacity of data centers in Indonesia is forecasted to reach approximately 2.3 gigawatts (GW) by 2030. The adoption of Artificial Intelligence (AI) contributes significantly to this growth."

■"'Previously, data processing and analysis primarily relied on CPU models, but now, with the integration of AI, the energy consumption per rack has significantly increased, from an average of 6 kilowatts to up to 50 kilowatts,' he [Hendra Suryakusuma, Chairman of IDPRO] elaborated. In contrast, the average household electricity consumption in Jakarta stands at only about 3,000 watts."

●Financial Outlook (as a proxy)

○Revenue associated with data centers in Indonesia is expected to reach $4.50 billion (USD) by 2029[126]

■2024 EOY projection is $3.37 billion USD

■ Full data set is here: https://www.statista.com/outlook/tmo/data-center/indonesia#revenue
○“Real Estate Asia forecasts that by 2026, the Indonesian data center market could reach a value of up to 3.07 billion US dollars or Rp45.9 trillion.”[149]

Japan

Despite some unique challenges, Japan's grid is extremely reliable. NZE strategy has been tricky without nuclear, but Japan compares favorably in terms of carbon emissions.

Capacity

●Domestic production capacity 1,012,889 GWh (2021)[17]
●2030 Projection:[15]
○The IEA does do Japan-specific projections (for 2050 as well)
STEPS
■: 1,053,62 TWh
APS:
■ 1,083.34 Twh

Electricity Generation Sources | Japan | 2023 [17]				
Source	**Value**	**Year**	**Units**	**Share**
Coal	280,751	2023	GWh	28.55%
Oil	30,867	2023	GWh	3.14%
Natural gas	317,291	2023	GWh	32.26%
Biofuels	33,461	2023	GWh	3.40%
Waste	23,644	2023	GWh	2.40%
Nuclear	84,055	2023	GWh	8.55%
Hydro	86,120	2023	GWh	8.76%
Geothermal	3,406	2023	GWh	0.35%
Solar PV	97,152	2023	GWh	9.88%
Wind	10,592	2023	GWh	1.08%
Other sources	16,121	2023	GWh	1.64%
Total	983,460	2023	GWh	100.00%

Electricity Demand

●2022: 3,264,207 TJ (906,724 GWh)[17]
●2026 Projection: 82 TWh[14]

Electricity Consumption by Sector | Japan | 2022 [17]			
Sector	**Value**	**Unit**	**Share**
Industry	1,143,246	TJ	35.02%
Transport	59,507	TJ	1.82%
Residential	943,956	TJ	28.92%
Commercial & public services	1,104,765	TJ	33.84%

Agriculture & forestry	9,388	TJ	0.29%
Fishing	3,345	TJ	0.10%
Total	3,264,207	TJ	100.00%

Grid Reliability

●Japan has one of the most reliable grids in the world. It's much more reliable than the US, UK or Germany, with blackouts occurring on average just 1x in 5 years, and outages typically lasting less than 30 minutes[39]
●However, Japan is not without challenges – one of them is load sharing across differing frequencies on eastern/western portions of the grid (50 v. 60 hertz)[18]

Policy

●Fukushima was a major disruption to Japan's energy mix, as the government basically shut down nuclear power nationally following the disaster. As a result, fossil fuel usage increased[40] and Japan has been playing catch up on emissions.
●Despite these challenges, their emissions per capita are lower than other comparable countries, such as US & Australia – which, it could be argued, demonstrates policy success.[39]
●Target of 59% non-fossil fuel electricity generation & increasing nuclear back up to 20-22% by 2030.[41]

Data Center Outlook

●Demand Outlook
○Tokyo is one of the most significant data center hubs in the Asian region and the outlook is quite strong[138] (meaning electricity demand is expected to continue to increase here)
○“Tokyo continues to attract significant investor and occupier interest as a key Asia-Pacific data center location. Data center vacancy rates for greater Tokyo stood at just above 10% as of Q1 2023. Demand is expected to remain robust even as new inventory is set to expand around 30% by 2025.”
○Rising energy demand from data centers is challenging Japan's ability to meet net-zero emissions goals[159]
●Financial Outlook (as a proxy)
○Revenue associated with data centers in Japan is expected to reach $29.50 billion (USD) by 2029[112]
○2024 EOY projection is $20.60 billion USD
■Full data set is here: https://www.statista.com/outlook/tmo/data-center/japan#revenue

Malaysia

Malaysia gets the prize for “most improved” of selected ASEAN countries; over the past 20 years, it has gone from regular blackouts to a stable grid, clear policy, and secure energy supply. On paper it seems to be well equipped for increased energy demand, but the transition to renewables will be a factor.

Capacity

●Domestic production capacity 187,297 GWh[100]
●2030 Projection:[100]
○No IEA projections specific to Thailand
○Malaysia falls under the IEA's Asia Pacific Projections
STEPS
■: 19,043.30 TWh
APS:
■ 18,899.96 Twh

Electricity Generation Sources | Malaysia | 2022 [100]				
Source	**Value**	**Year**	**Units**	**Share**
Coal	87,584	2022	GWh	46.76%
Oil	1,013	2022	GWh	0.54%
Natural gas	64,180	2022	GWh	34.27%
Biofuels	1,227	2022	GWh	0.66%
Hydro	31,101	2022	GWh	16.61%
Solar PV	2,192	2022	GWh	1.17%
Total	**187,297**	2022	GWh	100.00%

Electricity Demand

●2022: 591,216 TJ (164,227 Gwh)

Electricity Consumption by Sector | Malaysia | 2022 [100]			
Sector	**Value**	**Unit**	**Share**
Industry	288,518	TJ	48.80%
Transport	917	TJ	0.16%
Residential	132,862	TJ	22.47%
Commercial & public services	167,115	TJ	28.27%
Agriculture & forestry	1,804	TJ	0.31%
Total	591,216	TJ	100.00%

Grid Reliability

●Although Malaysia suffered from widespread blackouts as recently as the 2000s, it is now a regional leader in terms of grid reliability.[97]

●They use System Average Interruption Duration Index (SAIDI) to quantify reliability – as of 2019, this was sitting at about 48 minutes per person.[97]
●SAIDI scores since 2019…[99]
○2020: 44.95 (target = 50)
○2021: 45.25 (target = 50)
○2022: 45.06 (target = 50)
○2023: 46.10 (target = 50)

Policy
●Incentive Based Regulation (IBR) was introduced in 2014 and has been quite successful in ensuring a reliable power supply.[98]

Data Center Outlook
●Demand Outlook
○Microsoft is investing heavily in data centers in Malaysia – in May 2024 they announced $2.2 billion in investments to take place over the next 4 years.[145]
○"…potential electricity demand from data centres is expected to hit over 5,000 megawatts (MW) by 2035. Interest in new data centres is even higher, with national electricity utility Tenaga Nasional Berhad (TNB) having received applications for supply exceeding 11,000 MWs. This represents just over 40% of Peninsular Malaysia's existing installed power-generation capacity at 27,000 MWs."[146]
○"Our energy reserves may not be able to handle the data centre growth in 10 years."[147]
■"The number of data centres is expected to double from the existing 45 sites nationwide, with an additional 44 sites in the pipeline"
■"South-east Asian countries like Malaysia and Indonesia have seen a surge in demand for data centres after close neighbour Singapore placed a moratorium on them between 2019 and 2022."
○TENAGA Nasional Bhd's (Malaysia's utility) has seen a big jump in share price, partially in response to data center electricity demand forecasts.[148]
○"When Rangu Salgame looks at Malaysia, he sees the next Virginia 'in the making' (reference to US data center hub). Johor, the southernmost state in peninsular Malaysia, has a policy to speed up clearances for data centers."[175]
●Financial Outlook (as a proxy)
○Revenue associated with data centers in Malaysia is expected to reach $1.51 billion (USD) by 2029[128]
■2024 EOY projection is $1.20 billion USD
■Full data set is here: https://www.statista.com/outlook/tmo/data-center/malaysia#revenue

Singapore

Singapore's grid is very reliable, but also (unsurprisingly) very dependent on imports. Current energy mix skews heavily toward natural gas, which contributes to reliability, but policy focus is on a shift to renewables, which will bring challenges.

Capacity

●Domestic production capacity 57,347 GWh (2022)[28]
●2030 Projection:
○No IEA projections specific to Singapore
○Singapore falls under the IEA's Asia Pacific Projections
STEPS
■: 19,043.30 TWh
APS:
■ 18,899.96 Twh

Electricity Generation Sources | Singapore | 2022 [28]

Source	Value	Year	Units	Share
Coal	571	2022	GWh	1.00%
Oil	1,484	2022	GWh	2.59%
Natural gas	52,543	2022	GWh	91.62%
Biofuels	292	2022	GWh	0.51%
Waste	1,502	2022	GWh	2.62%
Solar PV	955	2022	GWh	1.67%
Total	**57,347**	2023	GWh	100.00%

Electricity Demand

●2022: 608,607 TJ (169,058 GWh)[28]

Electricity Consumption by Sector | Singapore | 2022 [28]

Sector	Value	Unit	Share
Industry	76,331	TJ	38.63%
Transport	10,438	TJ	5.28%
Residential	28,479	TJ	14.41%
Commercial & public services	81,640	TJ	41.32%
Non-specified	694	TJ	0.35%
TOTAL	197,582	TJ	100.00%

Grid Reliability

●Singapore's grid is one of the most reliable in the world, functioning mostly on natural gas imports.[70]
●Unique features of Singapore's grid is that it “is partially smart, and the transmission & distribution system is underground to a large extent.”[70]

Policy

●Heavy focus on “greening” the grid, increasing the share of the energy mix that comes from renewables.
●Smart grids, solar deployment, and BESS are all major areas of focus in Singapore right now to increase resilience and decrease emissions.[70][71]

Data Center Outlook

●Demand Outlook

○“Singapore—the world's most power-constrained data center market—has less than 4 MW of available capacity and a record-low vacancy rate of less than 2%.”[138]
○“The worldwide shortage of available supply is leading to price increases for data center capacity. Singapore has the highest rental rates at $300 to $450 per month for a 250- to 500-kilowatt (kW) requirement” [138]
○In recent years, the Singaporean government has introduced new regulations severely limiting the construction of new data centers "to comply with more stringent environmental requirements”[144]
○Singapore imposed a moratorium on new data centers between 2019 and 2022[147]
○“In Singapore, seven percent of total electricity consumption goes to data centers, and this number is projected to reach 12 percent by 2030.”[156]
■“Amid global energy challenges, Singapore's data center landscape showcases reliable power infrastructure. While the nation's green energy contribution remains at 2 percent, data center enterprises benefit from an array of Power Usage Effectiveness (PUE) scores, ranging between 1.20 and 1.90. The average PUE for Singaporean data centers rests at an enviable 1.47, reflecting the industry's dedication to energy efficiency. In addition, with an aggregate power capacity exceeding 569.18 MW, Singapore's colocation facilities offer a variety of rack power options, spanning from 1.50 kW to 5.40 kW.”
●Financial Outlook (as a proxy)
○Revenue associated with data centers in Singapore is expected to reach $1.61 billion (USD) by 2029[125]
■2024 EOY projection is $1.21 billion USD
■Full data set is here: https://www.statista.com/outlook/tmo/data-center/singapore

Thailand

Thailand has made big improvements in grid infrastructure – reliability is respectably high, regional interconnectedness is growing, and grid access now at 100%. Thailand is a developing country, but seems to be a success story right now—at least by every metric that would inform its ability to meet energy demand from data centers.

Capacity

●Domestic production capacity 185,972 GWh (2022)[30]
●2030 Projection:
○No IEA projections specific to Thailand
○Thailand falls under the IEA's Asia Pacific Projections
STEPS
■: 19,043.30 TWh
APS:
■ 18,899.96 Twh

Electricity Generation Sources | Thailand | 2022 [30]

Source	Value	Year	Units	Share
Coal	36,500	2022	GWh	19.63%
Oil	10,516	2022	GWh	5.65%
Natural gas	104,867	2022	GWh	56.39%
Biofuels	18,187	2022	GWh	9.78%
Waste	1,007	2022	GWh	0.54%
Hydro	6,790	2022	GWh	3.65%
Geothermal	1	2022	GWh	0.00%
Solar PV	5,069	2022	GWh	2.73%
Wind	3,035	2022	GWh	1.63%
Total	**185,972**	2022	GWh	100.00%

Electricity Demand

●2022: 711,108 TJ (197,530 GWh)[30]

Electricity Consumption by Sector | Thailand | 2022 [30]

Sector	Value	Unit	Share
Industry	318,866	TJ	44.84%
Transport	989	TJ	0.14%
Residential	193,489	TJ	27.21%
Commercial & public services	166,726	TJ	23.45%
Agriculture & forestry	1,205	TJ	0.17%
Non-specified	29,833	TJ	4.20%
Total	711,108	TJ	100.00%

Grid Reliability

●Thailand reached 100% grid connection for its population in 2016.[75]

●Minimum reserve margin for electrical system is 20%, but actual numbers tend to be in the low-30s.[75]
●In 2017, average down-time of grid per year was 104 minutes.[76]
●Already there are existing grid connections in place with Malaysia, Cambodia, and Laos—and new one planned with Myanmar.[76]

Policy
●Goal to reach NZE by 2050[77]
●Currently, heavily dependent on imports, so NZE transition is also very much about energy security[78]

Data Center Outlook
●Demand Outlook
○Energy billionaire Sarath Ratanavadi & his company Gulf Energy Development Pcl are set to “spend an additional 10 billion baht ($271 million) to double their outlay on a data center facility in suburban Bangkok. The expansion will increase the center's energy consumption to 50 megawatts from a previously announced 25 megawatts.”[153]
○Thailand is piloting projects aimed at connecting data centers directly with generators of renewable energy in order to help investors manage costs, avoid grid constraints, and manage the carbon footprint of the data centers.[154]
●Financial Outlook (as a proxy)
○Revenue associated with data centers in Thailand is expected to reach $2.99 billion (USD) by 2029[127]
■2024 EOY projection is $2.35 billion USD
■Full data set is here: https://www.statista.com/outlook/tmo/data-center/thailand#revenue
○KPMG “predicts that Thailand's data centre market will grow by 27% between 2019-2026, which it says is 'indicating a potential opportunity for investors to enter a steadily-growing industry.'”[155]

Vietnam
Vietnam's grid is a bit shaky, and extreme heat has been increasingly causing supply shortfalls and blackouts in the summer months. Renewable projects are moving slowly but underway, while the government aims to address blackouts with (among other things) more fossil fuels, including imports.

Capacity
●Domestic production capacity 276,414 GWh[101]
●2030 Projection:[101]
○No IEA projections specific to Vietnam
○Vietnam falls under the IEA's Asia Pacific Projections
STEPS
■: 19,043.30 TWh
APS:
■ 18,899.96 TWh

Electricity Generation Sources | Vietnam | 2022 [101]				
Source	**Value**	**Year**	**Units**	**Share**
Coal	111,113	2022	GWh	40.20%
Oil	179	2022	GWh	0.06%
Natural gas	29,410	2022	GWh	10.64%
Biofuels	2,296	2022	GWh	0.83%
Hydro	95,929	2022	GWh	34.70%
Solar PV	28,397	2022	GWh	10.27%
Wind	9,090	2022	GWh	3.29%
Total	**276,414**	2022	GWh	100.00%

Electricity Demand

●2022: 867,292 TJ (240,914 GWh)[101]

Electricity Consumption by Sector | Vietnam | 2022 [101]			
Sector	**Value**	**Unit**	**Share**
Industry	459,543	TJ	52.99%
Transport	1,732	TJ	0.20%
Residential	274,143	TJ	31.61%
Commercial & public services	101,548	TJ	11.71%
Agriculture & forestry	30,326	TJ	3.50%
Total	867,292	TJ	100.00%

Grid Reliability

●Vietnam faced an energy crisis in the summer of 2023, with blackouts common.[105]

●This set of issues was basically repeated in summer 2024, despite the government having time to plan for it.[106]

●Supply of electricity falls short of demand—especially in the north during the summer—development of new renewables projects has been slow, and the geography is challenging, as its elongated shape makes dispatchable power for load balancing difficult.[106]

Policy

●Vietnam has put forth NZE goals, but there is talk that this was political showmanship that is unlikely to become reality.[105]

●Current government focus is on expanding new dispatchable grid infrastructure and stockpiling fossil fuels.[106]

Data Center Outlook
●Demand Outlook
○One of the “significant challenges” faced by Vietnam's data center industry: Reliable power supply[150]
■”One of the critical challenges is ensuring a reliable power supply. Data centers require consistent and robust energy sources to maintain operations. However, Vietnam's current infrastructure struggles to meet these demands, leading to concerns about the long-term sustainability of data center growth. The government and private sector will need to invest in enhancing the country's power grid and exploring alternative energy solutions to support this burgeoning industry.”
○However, Vietnam also offers low prices for commercial-use energy and favorable amounts of renewables in their energy mix, so—in terms of how it competes with its neighbors in the region to bring in new data centers—energy is touted by some as an advantage here.[152]
●Financial Outlook (as a proxy)
○Revenue associated with data centers in Vietnam is expected to reach $2.58 billion (USD) by 2029[129]
■2024 EOY projection is $2.16 billion USD
■Full data set is here: https://www.statista.com/outlook/tmo/data-center/vietnam#revenue
○As of July 1 2024, “Vietnam's cloud and data center industries are now open to 100 percent foreign ownership through the implementation of the revised Telecommunications Law”[150]
○Estimated CAGR from 2024 to 2032 for data center sector growth in Vietnam is 8.31%.[151]

Africa

Egypt
Egypt's electricity sector is in crisis thanks to the growing regional conflict in the Middle East. In the past their grid had been quite reliable, but today there are rolling blackouts with no immediate solutions. However, as Egypt is a net-importer, longer-term energy projects should help address reliability.

Capacity
●Domestic production capacity **208,738 GWh** (2022)[26]
●2030 Projection:
○No IEA projections specific to Egypt
○Egypt falls under the IEA's Africa Projections
STEPS
■: 1,203.13 Twh
APS: 1,326.69 TWh

Electricity Generation Sources | Egypt | 2022 [26]				
Source	**Value**	**Year**	**Units**	**Share**
Oil	18,006	2022	GWh	8.63%
Natural gas	165,384	2022	GWh	79.23%
Hydro	14,646	2022	GWh	7.02%
Solar PV	4,892	2022	GWh	2.34%
Wind	5,810	2022	GWh	2.78%
Total	**208,738**	2022	GWh	100.00%

Electricity Demand

●2022: 608,607 TJ (169,058 GWh)[26]

Electricity Consumption by Sector | Egypt | 2022 [26]			
Sector	**Value**	**Unit**	**Share**
Industry	170,115	TJ	27.95%
Transport	1,857	TJ	0.31%
Residential	247,351	TJ	40.64%
Commercial & public services	157,874	TJ	25.94%
Agriculture & forestry	31,410	TJ	5.16%
TOTAL	608,607	TJ	100.00%

Grid Reliability

●Egypt's power grid had been quite reliable until just recently:[69]

○In 2023, Egypt instituted rolling black-outs as a cost-cutting measure, telling the public that this measure was temporary

○In 2024, the growing conflict in Israel led to additional energy insecurity, and the decrease in traffic (revenues) through the Suez Canal due to Yemeni piracy has harmed the government's ability to respond. Hence, rolling blackouts continue.

Policy

●The Egyptian government is bringing in foreign developers—for both O&G and renewables—to diversify energy supply & increase independence, but this is not an immediate solution.

●Right now, political leadership is asking the public to make do.

Data Center Outlook

●Demand Outlook
○Egypt, despite their struggling grid, are courting new data center investment—and the untapped potential of the country's renewable energy resources are a selling point.[164]
○Egypt is also viewed as a strategic location for new data center construction because of its “prime location at the crossroads of data links between Africa, Asia and Europe”[166]
○2029 Projection for energy demand from data centers: 28 MW[165]
●Financial Outlook (as a proxy)
○Revenue associated with data centers in Egypt is expected to reach $545.26 million (USD) by 2029[122]
■For comparison, 2024 EOY projection is $325.07 million USD
■Full data set is here: https://www.statista.com/outlook/tmo/data-center/egypt#revenue
○The Egypt data center market size was valued at USD 182 million in 2023 and is expected to reach USD 513 million by 2029, growing at a CAGR of 18.85% during the forecast period.[165]

Kenya

Kenya has a remarkably “clean” electricity supply, with ~68% coming from geothermal and hydro. However, this has not translated to grid reliability, as blackouts are frequent, even in the capital city, and ~50% of the population nationally reports no access to the grid, even though theoretical access should be at ~80%.

Capacity

●Domestic production capacity **12,701 GWh** (2023)[25]
●2030 Projection:
○No IEA projections specific to Kenya
○Kenya falls under the IEA's Africa Projections
STEPS
■: 1,203.13 TWh
APS:
■ 1,326.69 TWhls, making AI development more accessible for a wider range of programmers within a country

Electricity Generation Sources | Kenya | 2023 [25]

Source	Value	Year	Units	Share
Oil	1,305	2023	GWh	10.27%
Biofuels	199	2023	GWh	1.57%
Hydro	2,666	2023	GWh	20.99%
Geothermal	6,032	2023	GWh	47.49%
Solar PV	491	2023	GWh	3.87%
Wind	2,008	2023	GWh	15.81%
Total	12,701	2023	GWh	100.00%

Electricity Demand

●2023: 37,724 TJ (10,479 GWh)[25]

Electricity Consumption by Sector | Kenya | 2023 [25]

Sector	Value	Unit	Share
Industry	19,650	TJ	52.09%
Residential	12,840	TJ	34.04%
Commercial & public services	5,234	TJ	13.87%
TOTAL	37,724	TJ	100.00%

Grid Reliability

●As of 2022, about half of Kenya's population had no access to the electrical grid at all, with another 6% saying that their connection to the grid was only functional about ½ the time. This is especially striking considering that the grid's geographical coverage should serve about 80% of the population.[60][61]

●Still, Kenya has made huge improvements in access to the grid in past years and aims to achieve 100% access by 2030.[62]

●Kenya suffers from frequent blackouts—even in Nairobi—which are highly disruptive to economic activity.[63]

Policy

●Green transition and energy independence are a policy priority in Kenya[64]—both of which are getting more publicity than grid reliability policies.

●Investments are forthcoming to address blackouts, with a recent round of investments from UK & AfDB for ~73 million USD.[65]

Data Center Outlook

●Demand Outlook

○Kenya has a $1 billion data center under construction that will run 100% on geothermal energy via Microsoft and G42 – this is a good example of "eco friendly" data centers.[170]

■Will start at 100 MW, with the potential to expand to 1 GW

■This is pretty much dominating the current news cycle for Kenya

●Financial Outlook (as a proxy)

○Revenue associated with data centers in Kenya is expected to reach $823.70 million (USD) by 2029[120]

■For comparison, 2024 EOY projection is $589.30 million USD

■Full data set is here: https://www.statista.com/outlook/tmo/data-center/kenya#revenue

Nigeria

Of all the countries evaluated in this paper, Nigeria's energy system is likely most ill-equipped to meet an increase in electricity demand, as current capacity and imports do not come close to supporting existing needs, let alone future growth associated with data centers or AI.

Capacity

●Domestic production capacity 37,915 GWh[102]

●2030 Projection:[102]

○No IEA projections specific to Nigeria

○Nigeria falls under the IEA's Africa Projections

STEPS

■: 1,203.13 TWh

APS:

■ 1,326.69 Twh

Electricity Generation Sources | Nigeria | 2022 [102]				
Source	**Value**	**Year**	**Units**	**Share**
Natural gas	28,611	2022	GWh	75.46%
Hydro	9,204	2022	GWh	24.28%
Solar PV	100	2022	GWh	0.26%
Total	37,915	2022	GWh	100.00%

Electricity Demand

●2022: 116,081 TJ (32,245 GWh)[102]

Electricity Consumption by Sector | Nigeria | 2022 [102]			
Sector	**Value**	**Unit**	**Share**
Industry	26,167	TJ	22.54%
Residential	61,416	TJ	52.91%
Commercial & public services	28,498	TJ	24.55%
Total	116,081	TJ	100.00%

Grid Reliability

●“In Nigeria the electrification rate has reached 96%, yet only 18% of these connections function for more than about half of the time”[74]

●“With less than 8,000 megawatts of capacity and an average supply of less than 4,000 megawatts — less than half of what Singapore supplies to just 5.6 million people — power outages are an everyday occurrence in Nigeria.” [96]

●Blackouts can sometimes last weeks.[96]

●Most people & businesses that need regular grid access rely on emergency back-up generators.[103]
●Nigeria's energy grid collapsed 46 times between 2017 and 2023[162]

Policy
●Lots of policy documentation around the green transition – there is a goal to be carbon neutral by 2060.[104]
●Haven't found much on how they plan to improve reliability & access for existing system.

Data Center Outlook
●Demand Outlook
○“The surge in energy costs, particularly diesel, is straining the operations of data centers in Nigeria. This challenge threatens to impact other essential technology services, including internet consumption and cloud services.”[161]
■Nigeria has ”over 11” (not very many) data centers, and "industry experts argue that this is insufficient, estimating a $600 million data center gap.”
■“Ayotunde Coker, chief executive officer of OADC, recently stated, 'We do not have enough data centres. Xalam Analytics shows that Africa has 1 percent of the global digital infrastructure while having 17 percent of the world's population and 4 percent of the global GDP.'”
○In summary, because of Nigeria's highly unreliable grid, use of back-up diesel generators is the only reliable option for data centers, so the current rise in diesel prices is challenging the economics of the sector.[162]
●Financial Outlook (as a proxy)
○Revenue associated with data centers in Nigeria is expected to reach $2.44 billion (USD) by 2029[123]
■For comparison, 2024 EOY projection is $1.56 billion USD
■Full data set is here: https://www.statista.com/outlook/tmo/data-center/nigeria#revenue
○According to an Arizton Advisory and Intelligence report, Nigeria's data centre market was valued at $230 million in 2022 and is expected to reach $415 million by 2028.[161]

South Africa
South Africa's grid overwhelmingly coal-powered, making it quite dirty—and it suffers from black-outs that are both frequent and long-lasting. Motivated organizations maintain continuity via back-up diesel generators, which are far more expensive than the power that should be available through the grid. Data centers operators will need to get creative to acquire a reliable power source.

Capacity
●Domestic production capacity 234,849 GWh (2022)[27]
●2030 Projection:

○No IEA projections specific to South Africa
○South Africa falls under the IEA's Africa Projections
STEPS
■: 1,203.13 TWh
APS:
■ 1,326.69 Twh

Electricity Generation Sources | South Africa | 2022 [27]				
Source	**Value**	**Year**	**Units**	**Share**
Coal	197,401	2022	GWh	84.05%
Oil	4,116	2022	GWh	1.75%
Biofuels	373	2022	GWh	0.16%
Nuclear	9,803	2022	GWh	4.17%
Hydro	7,245	2022	GWh	3.08%
Solar PV	4,777	2022	GWh	2.03%
Solar thermal	1,445	2022	GWh	0.62%
Wind	9,689	2022	GWh	4.13%
Total	**234,849**	2022	GWh	100.00%

Electricity Demand

●2022: 670,525 TJ (186,257 GWh)[27]

Electricity Consumption by Sector | South Africa | 2022 [27]			
Sector	**Value**	**Unit**	**Share**
Industry	351,969	TJ	52.49%
Transport	7,644	TJ	1.14%
Residential	165,188	TJ	24.64%
Commercial & public services	125,960	TJ	18.79%
Agriculture & forestry	17,225	TJ	2.57%
Non-specified	2,539	TJ	0.38%
TOTAL	670,525	TJ	100.00%

Grid Reliability

●~72% of population has access to the electrical grid, and report that it functions some or most of the time / 20% are connected and report it working half the time / 9% have no connection whatsoever.[66]
●South Africa suffers from frequent blackouts – sometimes more than 1x per day, each lasting hours, prompting the use of back-up diesel generators across the country. This makes its emergence as a hub for data centers a bit of a paradox, as this article explores.[67]

Policy

●Being so deeply dependent on coal, South Africa's green transition goals currently focus on "diversification" of energy sources, while the government contends with other pressing economic and social issues.[68]

Data Center Outlook

●Demand Outlook

○"GSMA Intelligence data also showed that there were 108.6 million cellular mobile connections in South Africa at the start of 2022, equivalent to 179.8% of its population"[163]

○Headline: "South African gov't says data centers should reduce reliance on the grid and start self-provisioning energy"[167]

■"South Africa faces electricity supply challenges," the report stated. "Given that data centers operate 24 hours a day and consume vast amounts of electricity, reliance solely on the national grid may be insufficient. Therefore, it is crucial for data center owners and operators to implement additional alternative energy resources to prevent operational disruptions."[167][168]

○Headline: "How data centers are battling South Africa's energy crisis"[169]

■Angus Hay, regional executive for South Africa at Africa Data Centers (ADC): "The general impact of load shedding on data centers is to increase the reliance on using diesel, which increases costs because diesel is more expensive than grid electricity. We can run full-time on our concurrently maintainable diesel generators, although we would not prefer to."

○Teraco "raised $104 million to construct solar and wind farms that will meet 60% of its needs by 2025, reducing reliance on South Africa's coal-dependent grid"[171]

●Financial Outlook (as a proxy)

○Revenue associated with data centers in South Africa is expected to reach $1.51 billion (USD) by 2029[121]

■For comparison, 2024 EOY projection is $1.21 billion USD

■Full data set is here: https://www.statista.com/outlook/tmo/data-center/south-africa#revenue

The Americas

Brazil

Brazil's electrical grid has come a long way in recent years, but is facing new challenges as extreme weather events, economic issues, and political instability threaten its continued reliability.

Capacity

- Domestic production capacity **707,592 GWh** (2023)[32]
- 2030 Projection:
  - The IEA does do Brazil-specific projections (for 2050 as well)

STEPS

- : 779.48 TWh

APS:

- 778.89 Twh

Electricity Generation Sources | Brazil | 2023 [32]				
Source	**Value**	**Year**	**Units**	**Share**
Coal	14,081	2023	GWh	1.99%
Oil	9,083	2023	GWh	1.28%
Natural gas	38,588	2023	GWh	5.45%
Biofuels	57,233	2023	GWh	8.09%
Waste	1,138	2023	GWh	0.16%
Nuclear	14,503	2023	GWh	2.05%
Hydro	425,996	2023	GWh	60.20%
Solar PV	50,632	2023	GWh	7.16%
Wind	95,800	2023	GWh	13.54%
Other sources	538	2023	GWh	0.08%
Total	707,592	2023	GWh	100.00%

Electricity Demand

- 2023: 711,108 TJ (197,530 GWh)[32]

Electricity Consumption by Sector | Brazil | 2023 [32]			
Sector	**Value**	**Unit**	**Share**
Industry	808,088	TJ	38.72%
Transport	8,063	TJ	0.39%
Residential	610,909	TJ	29.27%
Commercial & public services	538,561	TJ	25.80%
Agriculture & forestry	121,620	TJ	5.83%
TOTAL	2,087,241	TJ	100.00%

Grid Reliability

- Frequency of blackouts fell steadily each year between 2010 and 2022.[82]
- However, in 2024, there was a series of outages in São Paulo that left “hundreds of thousands of people without power for consecutive days” and prompted officials to warn of grid “collapse”, citing years of under-investment.[83]
  - Exact narrative here is somewhat murky, with both politics and climate change-related weather events playing a role.
- Climate-related extreme weather events are playing an increasingly large role in reliability issues nationally.[84]

Policy

●Brazil will host COP30[85]
●Policy is strong on balance between transition to renewables & energy strategy[86]

Data Center Outlook

●Demand Outlook
○"The (LatAm) region has experienced significant growth over the past three years, with supply doubling since Q1 2020. Brazil has grown the fastest, with inventory up 127% from 2020 to 2022. It is also the largest, with around 67% of the region's inventory."[138]
○In order for Brazil's electricity sector to meet these increases in demand, "it is essential to solve bottlenecks, especially in the connection with the energy transmission and distribution system"[140]
○Example of climate change playing a role: in 2021, Brazil was experiencing severe droughts, which put a strain on its electricity supply because so much of their energy mix is hydroelectric. In response to this, the federal government actually imposed regulations on how much energy could be consumed by data centers.[141]
●Financial Outlook (as a proxy)
○Revenue associated with data centers in Brazil is expected to reach $7.05 billion (USD) by 2029[131]
■2024 EOY projection is $5.32 billion USD
■Full data set is here: https://www.statista.com/outlook/tmo/data-center/brazil#revenue
○Note – interesting trend line pre-2024:
■2017 revenue was $6.15bn v. 2020 revenue was $4.31bn

Canada

Canada has one of the cleanest grids in the world thanks to hydropower, and there is a credible roadmap to full decarbonization by 2030. Hydro & nuclear should help offset intermittency issues of renewables, but maintaining grid stability and interprovincial connection will be a challenge given climate change.

Capacity

●Domestic production capacity 656,111 GWh[4]
●2030 Projection:[15]
○No IEA projections specific to Canada
○Canada falls under the IEA's North America Projections…
STEPS
■: 5,944.97 TWh
APS:
■ 6,234.54 TWh

Electricity Generation Sources | Canada | 2022 [4]				
Source	**Value**	**Year**	**Units**	**Share**
Coal	27,145	2023	GWh	4.33%
Oil	5,550	2023	GWh	0.89%
Natural gas	85,336	2023	GWh	13.61%
Biofuels	9,194	2023	GWh	1.47%
Waste	309	2023	GWh	0.05%
Nuclear	89,640	2023	GWh	14.30%
Hydro	363,670	2023	GWh	58.02%
Solar PV	8,138	2023	GWh	1.30%
Wind	37,378	2023	GWh	5.96%
Other sources	445	2023	GWh	0.07%
Total	**626,805**	2023	GWh	100.00%

Electricity Demand

●Current: 1,931,430 TJ (536,508 GWh)[15]

Electricity Consumption by Sector | Canada | 2022 [4]			
Sector	**Value**	**Unit**	**Share**
Industry	684,993	TJ	35.47%
Transport	30,416	TJ	1.57%
Residential	644,979	TJ	33.39%
Commercial & public services	532,915	TJ	27.59%
Agriculture & forestry	38,127	TJ	1.97%
TOTAL	1,931,430	TJ	100.00%

Grid Reliability

●In 2023, Electricity Canada reported that the 2022 reliability index for the Canadian electrical grid was 99.98%[6]

●Extreme weather from climate change is a major concern in maintaining stability moving forward[7]

Policy

●Canada already has one of the cleanest grids in the world (thanks largely to hydropower)[5]

●Canadian government has set goals to phase out coal powered electricity generation by 2030[5]

○Hydropower is a key enabler to this transition

○Increased interprovincial connectivity is key to addressing intermittency issues associated with expanding renewables
○Nuclear is recognized as key to baseload capacity moving forward
○Energy efficiency is also a major area of investment

Data Center Outlook

●Demand Outlook
○Canadian utilities are already factoring data centers into their demand forecasts, as the country is an attractive data center construction choice to due to its clean grid, low temperatures, and cheap electricity pricing.[139]
■"Currently the country has 239 operating data centers, the CER said. Ontario leads the country by far with 105 data centers, with Quebec, British Columbia and Alberta following at 57, 35 and 22 centers, respectively."
■"The Alberta Electric System Operator (AESO) recently said it had at least six proposed applications for data centers in its application queue," BRC-Canada said. "If they all went ahead, these facilities would require about 2,000 megawatts (MW) of electricity."
■"At the QScale Q01 data center in Levis, Quebec, nearly 100 MW of energy from waste heat is expected to be redirected to households by the end of 2024," the CER said.
●Financial Outlook (as a proxy)
○Revenue associated with data centers in Canada is expected to reach $10.60 billion (USD) by 2029[130]
■2024 EOY projection is $8.08 billion USD
■Full data set is here: https://www.statista.com/outlook/tmo/data-center/canada#revenue

Chile

Although high-level statistics on reliability are fair, instances of blackouts are not uncommon. Climate change is playing a major role here, with extreme weather often driving outages in major population centers. Chile's energy transition is well under-way, but electricity market regulation is in dire need of updates, which is causing growing pains right now.

Capacity

●Domestic production capacity 87,733 GWh (2023)[35]
●2030 Projection:
○No IEA projections specific to Chile
○Chile falls under the IEA's Central & South America Projections
STEPS
■: 1,646.44 TWh
APS:
■ 1,723.07 TWh

Electricity Generation Sources | Chile | 2023 [35]				
Source	**Value**	**Year**	**Units**	**Share**
Coal	15,164	2023	GWh	17.28%
Oil	2,565	2023	GWh	2.92%
Natural gas	13,488	2023	GWh	15.37%
Biofuels	5,234	2023	GWh	5.97%
Hydro	23,301	2023	GWh	26.56%
Geothermal	466	2023	GWh	0.53%
Solar PV	17,748	2023	GWh	20.23%
Solar thermal	307	2023	GWh	0.35%
Wind	9,460	2023	GWh	10.78%
Total	**87,733**	2023	GWh	100.00%

Electricity Demand

●2022: 285,683 TJ (79,356 GWh)[35]

Electricity Consumption by Sector | Chile | 2022 [35]			
Sector	**Value**	**Unit**	**Share**
Industry	168,837	TJ	59.10%
Transport	5,426	TJ	1.90%
Residential	53,855	TJ	18.85%
Commercial & public services	45,538	TJ	15.94%
Agriculture & forestry	10,828	TJ	3.79%
Fishing	1,199	TJ	0.42%
Total	285,683	TJ	100.00%

Grid Reliability

●National electrification coverage is 99%[93]

●National average for outages is ~15 hours annually, but there are some outlier communities with MUCH higher numbers than this (e.g. 100 hours per year). [93]

●Santiago is increasingly having issues with blackouts, with weather-related blackouts prompting protests this summer.[94]

Policy

●Outdated policies geared toward base-load energy sources are leading to curtailment issues as more renewables are being connected to the grid[95]

“The Chilean government has acknowledged the need for reforms in the electricity market, particularly in areas such as transmission and distribution. However, no short-

●term measures have been implemented to address the current challenges. The lack of immediate action raises questions about whether the renewable energy market in Chile can maintain its diversity and access project financing”[95]

Data Center Outlook

●Demand Outlook

○In September 2024 Google announced that it would halt plans on a $200 million data center, citing environmental concerns:[136]

■This comes “months after a Chilean court partially reversed the center's authorization over water usage concerns, Google announced Tuesday that it would revise the project to comply with more stringent environmental requirements and change its water-intensive cooling system.”

■Important context to this: “Chile is in the midst of a drought, expected to last until 2040.”[135]

○The amount of data centers in Chile is set to increase rapidly, turning Chile into one of LatAm's data center hubs[135]

■“Over the past 12 years, 16 data centers have been approved in Santiago's metropolitan area”

■In May 2024, “Chilean President Gabriel Boric announced the arrival of 28 new data centers in the country”

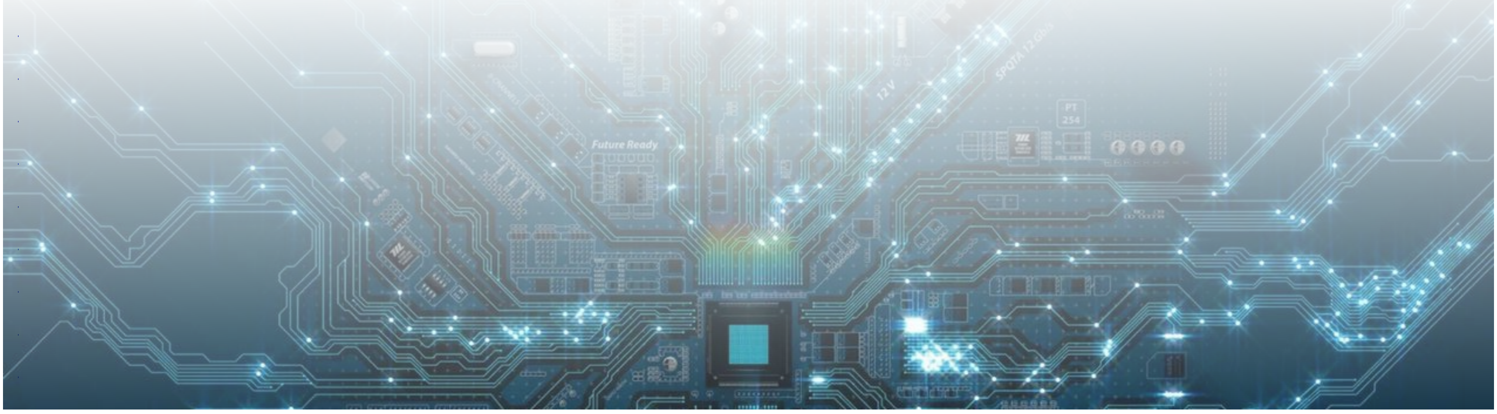
○”Insufficient energy supply in certain areas” is cited as a challenge to the growth of Chile's data center sector[138]

●Financial Outlook (as a proxy)

○Revenue associated with data centers in Chile is expected to reach $1.76 billion (USD) by 2029[134]

■2024 EOY projection is $1.40 billion USD

■Full data set is here: https://www.statista.com/outlook/tmo/data-center/chile#revenue



Colombia

Colombia's grid is relatively reliable but has been pushed to the brink of energy rationing multiple times in recent years due to extreme weather events. So, despite this reliability, Colombia's grid is somewhat precarious right now.

Capacity

●Domestic production capacity 88,878 GWh (2023)[34]

●2030 Projection:

○No IEA projections specific to Colombia

○Colombia falls under the IEA's Central & South America Projections

STEPS

■: 1,646.44 TWh

APS:

■ 1,723.07 TWh

Electricity Generation Sources | Colombia | 2023 [34]				
Source	**Value**	**Year**	**Units**	**Share**
Coal	9,600	2023	GWh	10.80%
Oil	2,808	2023	GWh	3.16%
Natural gas	15,800	2023	GWh	17.78%
Biofuels	2,340	2023	GWh	2.63%
Hydro	57,244	2023	GWh	64.41%
Solar PV	963	2023	GWh	1.08%
Wind	111	2023	GWh	0.12%
Other sources	12	2023	GWh	0.01%
Total	88,878	2023	GWh	100.00%

Electricity Demand

●2022: 252,710 TJ (70,197 GWh)[34]

Electricity Consumption by Sector | Colombia | 2022 [34]			
Sector	**Value**	**Unit**	**Share**
Industry	44,945	TJ	17.79%
Transport	2,206	TJ	0.87%
Residential	140,363	TJ	55.54%
Commercial & public services	61,935	TJ	24.51%
Agriculture & forestry	2,996	TJ	1.19%
Fishing	116	TJ	0.05%
Non-specified	149	TJ	0.06%
Total	252,710	TJ	100.00%

Grid Reliability

●Extreme weather events have raised the threat of energy rationing in Colombia.[91]

○Summary: hydro plays a massive role in dispatchable power supply, so when lakes dry up due to extreme heat, ability to generate power is reduced accordingly

●This almost happened in 2016 as well for the same reason; climate change is playing a role in straining Colombia's grid. [91]

Policy

●Major prioritization being given to change to renewables - "Colombia's energy transition policy making is an inspiring example of a fossil fuel producing country committed to climate action" – IEA[92]

Data Center Outlook

●Demand Outlook

○Colombia has an interesting pilot taking place on “sustainable” data centers[137]

■Assuming 100% utilization rate, these sustainable data centers would consume 5000 kWh per month, which is 20% lower than standard designs

●Financial Outlook (as a proxy)

○Revenue associated with data centers in Colombia is expected to reach $2.07 billion (USD) by 2029[133]

■2024 EOY projection is $1.69 billion USD

■Full data set is here: https://www.statista.com/outlook/tmo/data-center/colombia

Mexico

Currently, reliability of the electrical grid is a problem, causing regular blackouts in the hottest months of the year, and creating substantial economic constraints that must be considered in federal policy.

Capacity

●Domestic production capacity 356,415 GWh (2023)[33]

●2030 Projection:

○No IEA projections specific to Mexico

○Mexico falls under the IEA's North America Projections

STEPS

■: 5,944.97 TWh

APS: 6,234.54 TWh

Electricity Generation Sources | Mexico | 2023 [33]

Source	Value	Year	Units	Share
Coal	23,375	2023	GWh	6.56%
Oil	23,400	2023	GWh	6.57%
Natural gas	217,236	2023	GWh	60.95%
Biofuels	2,008	2023	GWh	0.56%
Waste	210	2023	GWh	0.06%
Nuclear	12,386	2023	GWh	3.48%
Hydro	19,568	2023	GWh	5.49%
Geothermal	4,321	2023	GWh	1.21%
Solar PV	18,211	2023	GWh	5.11%
Wind	20,700	2023	GWh	5.81%
Other sources	15,000	2023	GWh	4.21%
Total	**356,415**	2023	GWh	100.00%

Electricity Demand

●2022: 1,079,981 TJ (299,995 GWh)[33]

Electricity Consumption by Sector | Mexico | 2022 [33]			
Sector	**Value**	**Unit**	**Share**
Industry	637,344	TJ	59.01%
Transport	5,883	TJ	0.54%
Residential	256,244	TJ	23.73%
Commercial & public services	68,108	TJ	6.31%
Agriculture & forestry	48,852	TJ	4.52%
Non-specified	63,550	TJ	5.88%
TOTAL	1,079,981	TJ	100.00%

Grid Reliability

●Blackouts are not uncommon in Mexico, especially during the summer months—they can even last for days in some cases.[87][88][89]

●One blackout in May—as an example—is confirmed to have stemmed from a simple inability to match peak demand (load shedding) during a super hot day during the dinner time "rush", which has obvious implications for the impact of added data centers.[88]

Policy

●AMLO had been largely unfriendly to private investment in Mexico's energy sector but now Sheinbaum may need to re-engage with private enterprise to be successful in pursuing near-shoring strategy to compliment US economy. Currently, reliability of energy supply is a constraint.[90]

Data Center Outlook

●Demand Outlook

○"Large corporations are finding it increasingly difficult to find enough data center capacity. Low supply, construction delays and power challenges are impacting all markets. For example, Querétaro, Mexico, has only 1.2 MW available for lease."[138]

○It is known that energy demand from data centers is expected to grow in Mexico in potentially problematic ways, but the exact scale of this growth is controversial[142]

■"According to the Mexican Data Center Association (MEXDC), this industry is expected to consume approximately 1,492MWh over the next five years.[142]

■However, Hitachi Energy calls this figure "conservative" and estimates that the industry's energy demand could reach up to 5,000MWh." ß And this is still conservative!
●"5,000MWh projection does not take into account the rapid adoption of Generative Artificial Intelligence tools nor hyperscale data center operators like those of Amazon, Apple, Facebook/Meta, Google, IBM, and Microsoft. "Amazon is the largest hyperscale data center operator worldwide and already has expansion plans in Mexico, as do other major industry players. The 5,000MW we estimate are still a conservative figure," he adds.
○Resource constraints (electricity and water) are particularly acute in the province of Querétaro – this (in addition to Chile) would be a good place to look for anecdotes from LatAm.[143]
●Financial Outlook (as a proxy)
○Revenue associated with data centers in Mexico is expected to reach $5.07 billion (USD) by 2029[132]
■2024 EOY projection is $3.87 billion USD
■Full data set is here: https://www.statista.com/outlook/tmo/data-center/mexico#revenue

United States

The US grid might be the most complicated contemplated here because it is not a single grid; it's 3 mostly separated grids, with a patchwork of independent operators beneath them. Grid stability is tied heavily to climate change. From a policy POV, efforts are being made to increase grid connectivity and achieve NZE. However, shifting political landscape plays a major role here.

Capacity

●2022 domestic production capacity: 4,501,876 GWh[8]
●2030 Projection:[15]
○The IEA does do US-specific projections (for 2050 as well)
STEPS
■: 4,805.07 TWh
APS:
■ 5,041.78 TWh

Electricity Generation Sources | United States | 2023 [8]				
Source	**Value**	**Year**	**Units**	**Share**
Coal	744,667	2023	GWh	16.77%
Oil	32,309	2023	GWh	0.73%
Natural gas	1,860,469	2023	GWh	41.91%
Biofuels	44,649	2023	GWh	1.01%
Waste	15,585	2023	GWh	0.35%
Nuclear	808,667	2023	GWh	18.22%
Hydro	263,752	2023	GWh	5.94%
Geothermal	19,013	2023	GWh	0.43%
Solar PV	213,343	2023	GWh	4.81%
Solar thermal	3,096	2023	GWh	0.07%
Wind	430,067	2023	GWh	9.69%
Other sources	3,795	2023	GWh	0.09%
Total	**4,439,412**	2023	GWh	100.00%

Electricity Demand

●Current: 14,422,346 TJ (4,006,207 GWh)[15]

●2026 Projection: 822 TWh[14]

Electricity Consumption by Sector | United States | 2022 [8]			
Sector	**Value**	**Unit**	**Share**
Industry	3,040,890	TJ	21.08%
Transport	60,260	TJ	0.42%
Residential	5,430,907	TJ	37.66%
Commercial & public services	4,847,470	TJ	33.61%
Agriculture & forestry	262,747	TJ	1.82%
Non-specified	780,072	TJ	5.41%
Total	14,422,346	TJ	100.00%

Grid Reliability

●The US power grid is fragmented into multiple grids, primarily Eastern, Western, and ERCOT[9] (although there are additional complexities[11]), making it difficult to speak to stability for the grid overall.

●ERCOT (Texas) consistently suffers from climate related outages.[10]

●Eastern & Western grids face similar problems from wildfires, hurricanes, etc. but information on grid stability is most commonly presented by state.[12]

Policy

●FERC is working to increase connectivity amongst the currently separated regional grids, which should help stability.[9]

●Biden administration aims to reach NZE for electrical grid by 2035[13] but this goal is subject to change depending on the party in power.

Data Center Outlook

●**Demand Outlook**

○Blackstone CEO, Stephen Schwarzman, said the following in July 2024:[109]

■“The need to provide power for these (above) data centers is a major contributor to an expected 40% increase in electricity demand in the United States over the next decade compared to minimal growth in the last decade.”

○Northern Virginia is the largest data center market in the world, but power supply is a constraint right now[138]

■It has 2,132 MW (2.1 GW) of supply, increasing 19.5% year-over-year from Q1 2022 to Q1 2023

○Dallas/Ft. Worth is the fastest growing data center market in the US, and ERCOT's independence—though a liability in some circumstances—is proving quite helpful in managing the corresponding spike in power demand.[138]

■“Dallas/Ft. Worth remains one of North America's most popular markets for data center development. Currently, a record setting 323.9 MW are under construction, with 88.4% of capacity pre-leased. Last year saw an 850% increase over the normal leasing activity in Dallas. Also, total inventory rose 17% year-over-year, from Q1 2022 to Q1 2023. This resulted in Dallas/Ft. Worth recently surpassing Silicon Valley as the nation's second-largest colocation data center market.”

■There is some question as to whether or not demand will keep up with supply as the construction boom continues.

○US is home to 1/3rd of all data centers in the world[144]

●**Financial Outlook (as a proxy)**

○Blackstone CEO, Stephen Schwarzman, said the following in July 2024:[109]

■“Current expectations are that there will be approximately $1 trillion of capital expenditures in the United States over the next five years to build and facilitate new data centers, with another $1 trillion of capital expenditures outside the United States”

■On earnings calls, stated that Blackstone has a $55bn data center portfolio currently + $70bn more in the pipeline

○Revenue associated with data centers in the US is expected to reach $212.05 billion (USD) by 2029[113]

■2024 EOY projection is $123.15 billion USD

Full data set is here: https://www.statista.com/outlook/tmo/data-center/united-states#revenue

References

1.International Energy Agency (IEA). "Global EV Outlook 2022: Securing Supplies for an Electric Future." IEA, 2022.

2.U.S. Energy Information Administration (EIA). "Annual Energy Outlook 2023." EIA, 2023.

3.Lawrence Berkeley National Laboratory. "Queueing Up: The Interconnection Bottleneck and its Impact on Renewable Energy Deployment." Berkeley Lab, 2023.

4.PJM Interconnection. "2023 Annual Report on Resource Adequacy." PJM, 2023.

5.The White House. "FACT SHEET: Biden-Harris Administration Launches Federal-State Initiative to Bolster America's Power Grid." The White House, 2024.

6.U.S. Department of Energy (DOE). "Grid Modernization Initiative: Overview." DOE, 2023.

7.Independent Electricity System Operator (IESO). "Annual Planning Outlook and Emissions Update." IESO, 2024.

8.North American Electric Reliability Corporation (NERC). "2023 Long-Term Reliability Assessment." NERC, 2023.

9.Jinjoo Lee. "AI Is About to Boost Power Bills—Who'll Take Heat for That?" The Wall Street Journal, August 12, 2024.

10.World Economic Forum. "AI's Computational Needs and Energy Demands." World Economic Forum, 2023.

11.SemiAnalysis. "The Future of AI and Its Impact on Global Energy Consumption." SemiAnalysis, 2024.

12.Jinjoo Lee. "AI Is About to Boost Power Bills—Who'll Take Heat for That?" The Wall Street Journal, August 12, 2024.

13.MIT Technology Review. "AI and the Energy Crisis: A Looming Challenge." MIT Technology Review, 2024.

14.Nature. "The Environmental Impact of AI: Managing the Growth." Nature, 2023.

15.Morgan Stanley. "AI's Rising Energy Demands and the Global Grid." Morgan Stanley, 2024.

16.Elon Musk. "AI's Energy Demands: The Next Major Hurdle." Interview on AI and Energy, 2024.

17.Markets Insider. "Generative AI and the Rising Strain on Power Grids." Markets Insider, 2024.

18.Fox Business. "AI's Energy Consumption: A Growing Concern for Tech Giants." Fox Business, 2024.

19.Nature. "Legislative Measures for Managing AI's Environmental Impact." Nature, 2024.

20.Markets Insider. "AI's Growing Power Consumption and Grid Challenges." Markets Insider, 2024.

21.Fox Business. "The Future of Energy and AI: Addressing the Growing Demand." Fox Business, 2024.

22.Beth Kindig. “AI Power Consumption Rapidly Becoming Mission Critical”, Forbes, June 2024.

23.Bloomberg News. “Electricity Demand at Data Centers Could Double in Three Years”, Bloomberg News, January 2024.

24.Goldman Sachs. “AI is Poised to Drive 160% Increase in Data Center Power Demand”, Goldman Sachs, May 2024.

25.K. Ramachandran, et al. “As generative AI asks for more power, data centers seek more reliable, cleaner energy solutions.” Deloitte, 2024.

26.K. Pykes. “Understanding TPUs vs GPUs in AI: A Comprehensive Guide.” DataCamp, 2024.
27.United Kingdom - Electricity, International Energy Agency (IEA), www.iea.org/countries/united-kingdom/electricity. Accessed Nov. 2024.
28.“Provide a Safe and Reliable Network.” *National Grid ET*, www.nationalgrid.com/electricity-transmission/who-we-are/riio-t2-performance/safe-and-reliable-network. Accessed Dec. 2024.
29.“New UK Government Plans Big Push on Wind.” *WindEurope*, 9 July 2024, windeurope.org/newsroom/news/new-uk-government-plans-big-push-on-wind/.
30.Canada - Electricity, International Energy Agency (IEA), https://www.iea.org/countries/canada/electricity. Accessed Nov. 2024.
31.International Energy Agency (IEA), 2022, Canada 2022 - Energy Policy Review, https://iea.blob.core.windows.net/assets/7ec2467c-78b4-4c0c-a966-a42b8861ec5a/Canada2022.pdf.
32.“Electricity Reliability in Canada.” *Electricity Canada*, 14 July 2023, www.electricity.ca/knowledge-centre/journal/electricity-reliability-in-canada/.
33.Stephenson, Amanda. “Extreme Weather a Growing Risk to Canada's Electricity Grid: Experts.” *Calgary Herald*, 18 Jan. 2024, https://calgaryherald.com/news/extreme-weather-growing-risk-to-canadas-electricity-grid.
34.United States - Electricity, International Energy Agency (IEA), www.iea.org/countries/united-states/electricity. Accessed Nov. 2024.
35.Einberger, Mathias. “Reality Check: The United States Has the Only Major Power Grid without a Plan.” *RMI*, 1 Jan. 2023, https://rmi.org/the-united-states-has-the-only-major-power-grid-without-a-plan/ .
36.Martinez, Alejandra, and Emily Foxhall. “Why Texas' Mass Power Outages Continue to Happen.” *The Texas Tribune*, 18 July 2024, https://www.texastribune.org/2024/07/18/texas-energy-grid-power-outages-climate-change-infrastructure/.
37.Popovich, Nadja, and Brad Plumer. “Why the U.S. Electric Grid Isn't Ready for the Energy Transition.” *The New York Times*, 12 June 2023, https://www.nytimes.com/interactive/2023/06/12/climate/us-electric-grid-energy-transition.html.
38.“Table 11.3 Reliability Metrics Using Any Method of U.S. Distribution System by State, 2023 and 2022.” U.S. Energy Information Administration (EIA), www.eia.gov/electricity/annual/html/epa_11_03.html. Accessed Nov. 2024.
39.Schmalensee, Richard. “Crossed Wires: Modernizing the US Electric Grid.” Resources for the Future, 16 May 2024, www.resources.org/archives/crossed-wires-modernizing-the-us-electric-grid/.
40.Çam, Eren, et al. International Energy Agency (IEA), 2024, Electricity 2024, https://www.iea.org/reports/electricity-2024/executive-summary.
41.International Energy Agency (IEA), 2024, World Energy Outlook 2023 Extended Dataset, https://www.iea.org/data-and-statistics/data-product/world-energy-outlook-2023-extended-dataset.

42.India - Electricity, International Energy Agency (IEA), https://www.iea.org/countries/india/electricity. Accessed Nov. 2024.
43.Japan - Electricity, International Energy Agency (IEA), https://www.iea.org/countries/japan/electricity. Accessed Nov. 2024.
44.“Japan's Grid Can Handle More Wind and Solar Power than Currently Envisioned by Its Government.” Agora Energiewende, 26 Apr. 2019, www.agora-energiewende.org/news-events/japans-grid-can-handle-more-wind-and-solar-power-than-currently-envisioned-by-its-government.
45.Germany - Electricity, International Energy Agency (IEA), https://www.iea.org/countries/germany/electricity. Accessed Nov. 2024.
46.France - Electricity, International Energy Agency (IEA), https://www.iea.org/countries/france/electricity. Accessed Nov. 2024.
47.Switzerland - Electricity, International Energy Agency (IEA), https://www.iea.org/countries/switzerland/electricity. Accessed Nov. 2024.
48.Denmark - Electricity, International Energy Agency (IEA), https://www.iea.org/countries/denmark/electricity. Accessed Nov. 2024.
49.Sweden - Electricity, International Energy Agency (IEA), https://www.iea.org/countries/sweden/electricity. Accessed Nov. 2024.
50.Norway - Electricity, International Energy Agency (IEA), https://www.iea.org/countries/norway/electricity. Accessed Nov. 2024.
51.Kenya - Electricity, International Energy Agency (IEA), https://www.iea.org/countries/kenya/electricity. Accessed Nov. 2024.
52.Egypt - Electricity, International Energy Agency (IEA), https://www.iea.org/countries/egypt/electricity. Accessed Nov. 2024.
53.South Africa - Electricity, International Energy Agency (IEA), https://www.iea.org/countries/south-africa/electricity. Accessed Nov. 2024.
54.Singapore - Electricity, International Energy Agency (IEA), https://www.iea.org/countries/singapore/electricity. Accessed Nov. 2024.
55.Indonesia - Electricity, International Energy Agency (IEA), https://www.iea.org/countries/indonesia/electricity. Accessed Nov. 2024.
56.Thailand - Electricity, International Energy Agency (IEA), https://www.iea.org/countries/thailand/electricity. Accessed Nov. 2024.
57.Australia - Electricity, International Energy Agency (IEA), https://www.iea.org/countries/australia/electricity. Accessed Nov. 2024.
58.Brazil - Electricity, International Energy Agency (IEA), https://www.iea.org/countries/brazil/electricity. Accessed Nov. 2024.
59.Mexico - Electricity, International Energy Agency (IEA), https://www.iea.org/countries/mexico/electricity. Accessed Nov. 2024.
60.Colombia - Electricity, International Energy Agency (IEA), https://www.iea.org/countries/colombia/electricity. Accessed Nov. 2024.

61.Chile - Electricity, International Energy Agency (IEA), https://www.iea.org/countries/chile/electricity. Accessed Nov. 2024.
62.Athawale, Rasika. “India's Electric Grid Reliability and Its Importance in the Clean Energy Transition.” RAP (Regulatory Asset Protection), 4 May 2021, https://www.raponline.org/blog/indias-electric-grid-reliability-its-importance-in-clean-energy-transition/.
63.Aryan, Aashish. “Govt May Revive Old Data Centre Policy with AI and ML Sops.” The Economic Times, 28 Aug. 2024, https://economictimes.indiatimes.com/tech/technology/govt-to-revive-2020-draft-data-policy/articleshow/112839984.cms?from=mdr.
64.Laan, Tara, et al. “Mapping India's Energy Policy 2023.” International Institute for Sustainable Development, www.iisd.org/story/mapping-india-energy-policy-2023/. Accessed Nov. 2024.
65.Shalfi, Jonathan. “Japanese Energy Policy – Is the Criticism Unfair?” The Japanologist, 28 Aug. 2024, https://www.thejapanologist.com/blog/japanese-energy-policy-is-the-criticism-unfair.
66.Fackler, Martin. “Japan's Nuclear Energy Industry Nears Shutdown, at Least for Now.” The New York Times, 8 Mar. 2012, https://www.nytimes.com/2012/03/09/world/asia/japan-shutting-down-its-nuclear-power-industry.html .
67.“Japan's Energy Policies Aim for Increased Zero-Carbon Electricity Generation.” U.S. Energy Information Administration (EIA), 2 May 2024, www.eia.gov/todayinenergy/detail.php?id=61944.
68.Eriksen, Freja, et al. “Germany's Electricity Grid Stable amid Energy Transition.” Clean Energy Wire, https://www.cleanenergywire.org/factsheets/germanys-electricity-grid-stable-amid-energy-transition.
69.“Germany's Energiewende – The Easy Guide.” Clean Energy Wire, www.cleanenergywire.org/easyguide. Accessed Nov. 2024.
70.Wettengel, Julian. “Nord Stream 2 – Symbol of Failed German Bet on Russian Gas.” Clean Energy Wire, 8 Mar. 2023, https://www.cleanenergywire.org/factsheets/gas-pipeline-nord-stream-2-links-germany-russia-splits-europe .
71.“9. Changes in the Electricity System: Anticipate Rather than Suffer.” IGSNR, EDF, 9 Feb. 2024, igsnr.com/en/9-changes-in-the-electricity-system-anticipate-rather-than-suffer/.
72.Jones, Jonathan Spencer. “How France Is Leading in the Digitalisation of Its Electrical Grid.” Enlit, 29 Dec. 2023, https://www.enlit.world/smart-grids/how-france-is-leading-in-the-digitalisation-of-its-electrical-grid/ .
73.Lafrance, Camille, and Juliette Portala. “CLEW Guide – Government Turmoil Casts Doubt over France's Transition Progress.” Clean Energy Wire, 6 Dec. 2024, https://www.cleanenergywire.org/factsheets/clew-guide-france-moves-action-new-climate-plan-green-industry-makeover.
74.Piquard, Alexandre. “AI Action Plan Outlines How to Place France 'at the Cutting Edge.'” Le Monde, 13 Mar. 2024, https://www.lemonde.fr/en/economy/article/2024/03/13/ai-action-plan-outlines-how-to-place-france-at-the-cutting-edge_6614625_19.html.
75.“Energy Policy.” Eidgenössisches Departement Für Auswärtige Angelegenheiten EDA, 24 Jan. 2023, www.eda.admin.ch/aboutswitzerland/en/home/wirtschaft/energie/energiepolitik.html.
76.Danish Energy Agency (DEA), 2015, SECURITY OF ELECTRICITY SUPPLY IN DENMARK, https://ens.dk/sites/ens.dk/files/Globalcooperation/security_of_electricity_supply_in_denmark.pdf .

77.International Energy Agency (IEA), 2023, Denmark 2023 - Energy Policy Review, https://iea.blob.core.windows.net/assets/9af8f6a2-31e7-4136-94a6-fe3aa518ec7d/Denmark_2023.pdf .
78.“What Makes a Country's Electricity System Stable?” Drax Global, 23 Dec. 2019, www.drax.com/power-generation/what-makes-a-countrys-electricity-system-stable/.
79.Speak, Abigail. “Grid Capacity Challenges in Sweden.” AFRY, 12 Sept. 2019, https://afry.com/en/insight/grid-capacity-challenges-in-sweden.
80.Government Offices of Sweden - Ministry of the Environment and Energy, 2023, Sweden's Draft Integrated National Energy and Climate Plan, https://www.government.se/contentassets/e731726022cd4e0b8ffa0f8229893115/swedens-draft-integrated-national-energy-and-climate-plan/ .
81.European Commission, 2023, Summary of the Commission Assessment of the Draft National Energy and Climate Plan 2021-2030, https://energy.ec.europa.eu/system/files/2019-06/necp_factsheet_se_final_0.pdf .
82.“Sweden - National Approach to AI.” Policy Observatory - OECD.AI, Organisation for Economic Co-Operation and Development (OECD), oecd.ai/en/dashboards/policy-initiatives/http:%2F%2Faipo.oecd.org%2F2021-data-policyInitiatives-24975. Accessed Nov. 2024.
83.“Norway Electricity Security Policy – Analysis.” International Energy Agency (IEA), 5 Oct. 2022, www.iea.org/articles/norway-electricity-security-policy.
84.“Norway 2022 Energy Policy Review - Executive Summary .” International Energy Agency (IEA), June 2022, www.iea.org/reports/norway-2022/executive-summary.
85.“National AI Strategies 2017-2023.” NordForsk, 7 May 2024, www.nordforsk.org/node/1368.
86.Cowling, Natalie. “Kenya: Reliability of the Electricity Supply.” Statista, Apr. 2022, www.statista.com/statistics/1315706/share-of-individuals-with-a-reliable-supply-of-electricity-in-kenya/.
87.Lee, Hee Eun, et al. “Still Lacking Reliable Electricity from the Grid, Many Africans Turn to Other Sources.” Afro Barometer, 8 Apr. 2022, www.afrobarometer.org/wp-content/uploads/2022/04/ad514-pap10-still_lacking_reliable_electricity_from_the_grid-many_africans_turn_to_alternative_sources-afrobarometer-10april22.pdf.
88.75. “Kenya - Energy-Electrical Power Systems.” International Trade Administration | Trade.Gov, 5 July 2024, www.trade.gov/country-commercial-guides/kenya-energy-electrical-power-systems.
89.Wasike, Andrew. “Kenya: A Renewable Energy Hub with Frequent Blackouts.” Deutsche Welle (DW), Jan. 2024, https://www.dw.com/en/kenya-a-renewable-energy-hub-with-frequent-blackouts/a-67875467.
90.Republic of Kenya - Ministry of Energy & Petroleum, 2024, Kenya Energy Transition & Investment Plan 2023 - 2050, https://energy.go.ke/sites/default/files/KAWI/Kenya-ETIP-2050%202.pdf .
91.Koech, Gilbert. “Kenya Gets Sh9.5bn Boost to Address Incessant Blackouts.” The Star, 26 Jan. 2024, www.the-star.co.ke/news/2024-01-26-kenya-gets-sh95bn-boost-to-address-incessant-blackouts.
92.Cowling, Natalie. “South Africa: Reliability of Electricity Supply 2021.” Statista, Apr. 2022, www.statista.com/statistics/1315878/share-of-individuals-with-a-reliable-supply-of-electricity-in-south-africa/.

93.Smolaks, Max. “The Effects of a Failing Power Grid in South Africa.” DCD, 19 May 2023, www.datacenterdynamics.com/en/opinions/the-effects-of-a-failing-power-grid-in-south-africa/.
94.75. “South Africa - Country Commercial Guide.” International Trade Administration | Trade.Gov, 26 Jan. 2024, www.trade.gov/country-commercial-guides/south-africa-energy.
95.Ayoub, Marc. “Egypt's Energy Blackouts: A Growing Crisis Amid War.” The Tahrir Institute for Middle East Policy, 12 Feb. 2024, timep.org/2024/02/12/egypts-energy-blackouts-a-growing-crisis-amid-war/.
96.SPECS Consortium Singapore, Nanyang Technical University Singapore, GRID 2.0, https://www.ntu.edu.sg/docs/librariesprovider60/publications/grid-2-0.pdf?sfvrsn=c1803649_2. Accessed Nov. 2024.
97.“Charging Up Singapore's Grid Resilience.” Energy Market Authority (EMA), 24 Jan. 2024, www.ema.gov.sg/news-events/news/feature-stories/2024/charging-up-singapore-grid-resilience.
98.Kunaifi, Kunaifi, and A. H.M.E. Reinders. “Perceived and Reported Reliability of the Electricity Supply at Three Urban Locations in Indonesia.” Research Gate, MDPI, Jan. 2018, www.researchgate.net/publication/322323216_Perceived_and_Reported_Reliability_of_the_Electricity_Supply_at_Three_Urban_Locations_in_Indonesia.
99.Jong, Hans Nicholas. “As Blackouts Loom, Indonesia's Energy Crisis Highlights Its Addiction to Coal.” Mongabay Environmental News, 8 Jan. 2022, news.mongabay.com/2022/01/as-blackouts-loom-indonesias-energy-crisis-highlights-its-addiction-to-coal/.
100.Falentina, Anna T., and Budy P. Resosudarmo. “The Impact of Blackouts on the Performance of Micro and Small Enterprises: Evidence from Indonesia.” Science Direct, El Sevier, Dec. 2019, www.sciencedirect.com/science/article/abs/pii/S0305750X19302839.
101.Admin. “Thailand Electrical Infrastructure 2023.” Tractus Asia, 6 June 2023, tractus-asia.com/blog/thailands-electrical-infrastructure-status-2023-tractus/.
102.“The Electric Power System - Thailand.” International Council on Large Electric Systems (CIGRE), 2018, www.cigre.org/userfiles/files/Community/NC/2018_National-power-system_Thailand.pdf.
103.“Clean Energy Finance and Investment Roadmap of Thailand.” Organisation for Economic Co-Operation and Development (OECD), 10 June 2024, www.oecd.org/en/publications/clean-energy-finance-and-investment-roadmap-of-thailand_d0cd6ffc-en.html.
104.“Thailand Energy Sector.” ASEAN-German Energy Programme (AGEP), 30 Jan. 2019, agep.aseanenergy.org/country-profiles/thailand/thailand-energy-sector/.
105.“Reliability.” Australian Energy Market Commission (AEMC), www.aemc.gov.au/energy-system/electricity/electricity-system/reliability. Accessed Nov. 2024.
106.“Australia's Energy Strategies and Frameworks.” Australian Government - Department of Climate Change, Energy, the Environment, and Water (DCCEEW), www.dcceew.gov.au/energy/strategies-and-frameworks. Accessed Nov. 2024.
107.“Australia'a AI Action Plan - June 2021.” Organisation for Economic Co-Operation and Development (OECD), June 2021, wp.oecd.ai/app/uploads/2021/12/Australia_AI_Action_Plan_2021.pdf.
108.“Number of Electricity Outages in Brazil 2010-2022.” Statista, 28 Mar. 2024, www.statista.com/statistics/987917/number-electricity-outages-brazil/.

109.Harris, Bryan, and Beatriz Langella. “Blackouts Spark Fears of Grid 'collapse' in Brazil's Biggest City.” Financial Times, 7 Apr. 2024, www.ft.com/content/6c1356e6-bd9e-45e0-95fd-7b083384f5da.
110.“Brazil State Faces Power Outages after Record Flood.” Argus, 6 May 2024, www.argusmedia.com/en/news-and-insights/latest-market-news/2565599-brazil-state-faces-power-outages-after-record-flood.
111.“UN Confirms Belém to Host the COP 30 Climate Conference.” Www.Gov.Br, 28 May 2023, www.gov.br/planalto/en/latest-news/2023/05/un-confirms-belem-is-to-host-the-cop-30-climate-conference.
112.dos Santos, Marcos Eduardo Melo, et al. “SWOT Analysis of Brazilian Energy Policy: A Comparative Panel Data Analysis of the Twenty Largest Economies.” Science Direct, Elsevier, 19 Aug. 2024, www.sciencedirect.com/science/article/abs/pii/S0301421524001927.
113.“Dealing with Electricity Power Cuts in Mexico.” Mexperience, 11 Oct. 2024, www.mexperience.com/when-the-lights-go-out/.
114.“Mexico Hit by Hours of Rolling Blackouts Due to High Temperatures and Low Power Generation.” AP News, 8 May 2024, apnews.com/article/mexico-blackouts-demand-heat-wave-electricity-1a1808e9825c79ee05ce08d7afcb252a.
115.Mega, Emiliano Rodríguez, and John Yoon. “Rolling Blackouts Hit Several Cities as Heat Wave Scorches Mexico.” The New York Times, 8 May 2024, www.nytimes.com/2024/05/08/world/americas/mexico-blackout-heat-wave.html.
116.Morales, Isidro. “Mexico's Next Leader Has an Energy Problem.” Foreign Policy, 29 May 2024, foreignpolicy.com/2024/05/29/mexico-presidential-election-economy-energy-pemex-cfe-amlo-sheinbaum-usmca/.
117.Velez, Juan. “Colombia Is on the Brink of Energy Rationing.” FrontierView, FiscalNote, 18 Apr. 2024, frontierview.com/insights/colombia-is-on-the-brink-of-energy-rationing/.
118.“Energy Policy Review - Colombia 2023.” International Energy Agency (IEA), Sept. 2023, www.iea.org/reports/colombia-2023.
119.Bustos-Salvagno, Javier. The International Association for Energy Economics (IAEE), Reasons For Electricity Outages in Chile: Regulatory Implications, https://iaee2021online.org/download/contribution/abstract/446/446_abstract_20200123_222723.pdf . Accessed Nov. 2024.
120.Ammachchi, Narayan. “Chile's Capital Hit by Frequent Blackouts; Blame Is Being Put on an Italian Company.” Nearshore Americas, Aug. 2024, nearshoreamericas.com/chiles-capital-hit-by-frequent-blackouts-blame-is-being-put-on-an-italian-company/.
121.“The Renewable Energy Paradox: An Update on the Chilean Renewable Market.” Vector Renewables, 27 June 2023, www.vectorenewables.com/en/blog/the-renewable-energy-paradox-an-update-on-the-chilean-renewable-market.
122. Adebayo, Taiwo. “Millions in Nigeria Have Little or No Electricity. It's Straining Businesses and Public Services.” Los Angeles Times, 3 July 2024, www.latimes.com/world-nation/story/2024-07-03/millions-in-nigeria-have-little-or-no-electricity-its-straining-businesses-and-public-services.

123.Thambirajah, Saravanan. “A Brighter Future for Reliable Power in Malaysia.” Energy Watch, 10 June 2021, www.energywatch.com.my/blog/2021/06/11/a-brighter-future-for-reliable-power-in-malaysia/.
124.“Incentivising Opportunity with Malaysia's Electricity Tariff Framework.” Energy Watch, 8 July 2020, www.energywatch.com.my/blog/2020/05/06/incentivising-opportunity-with-malaysias-electricity-tariff-framework/.
125.“Supply Reliability.” Tenaga Nasional Berhad, www.tnb.com.my/smart-grid/supply-reliability. Accessed Nov. 2024.
126.Malaysia - Electricity, International Energy Agency (IEA), https://www.iea.org/countries/malaysia/electricity. Accessed 19 Nov. 2024.
127.Viet Nam - Electricity, International Energy Agency (IEA), https://www.iea.org/countries/vietnam/electricity. Accessed 19 Nov. 2024.
128.Nigeria - Electricity, International Energy Agency (IEA), https://www.iea.org/countries/nigeria/electricity. Accessed 19 Nov. 2024.
129.“Consultation on Energy Policy in Nigeria.” GIZ (Deutsche Gesellschaft Für Internationale Zusammenarbeit), www.giz.de/en/worldwide/143177.html. Accessed Nov. 2024.
130.“Nigeria's Pathway to Achieve Carbon Neutrality by 2060.” Nigeria Energy Transition Plan, www.energytransition.gov.ng/. Accessed Nov. 2024.
131.Takahashi, Toru. “Will Vietnam Face Another Power Crisis This Year?” Nikkei Asia, Nikkei Asia, 25 May 2024, asia.nikkei.com/Spotlight/Comment/Will-Vietnam-face-another-power-crisis-this-year.
132.“Why Is Vietnam Stuck in Power Shortages, and How Are They Dealing with Them?” Reccessary, 4 June 2024, www.reccessary.com/en/news/vn-market/why-is-vietnam-stuck-in-power-shortages-and-how-are-they-dealing-with-them.
133.“Data Centre Power Use 'to Surge Six-Fold in 10 Years.'” BBC News, 26 Mar. 2024, www.bbc.co.uk/news/technology-68664182.amp.
134.Pounds, Megan. “Data Centre Construction Projects: The Surge in the UK.” Barbour ABI, 16 Aug. 2024, barbour-abi.com/whats-driving-the-surge-in-data-centre-construction-projects-in-the-uk/#:~:text=The%20600MW%20London%20Data%20Centre,development%20on%20the%20green%20belt.
135.Moss, Sebastian. “Blackstone Has $70bn in Prospective Data Center Pipeline, on Top of $55bn Portfolio.” DCD, 24 July 2024, www.datacenterdynamics.com/en/news/blackstone-has-70bn-in-prospective-data-center-pipeline-on-top-of-55bn-portfolio/.
136.“Data Center - Germany: Statista Market Forecast.” Statista, Statista Market Insights, July 2024, www.statista.com/outlook/tmo/data-center/germany#revenue.
137.“Data Center - India: Statista Market Forecast.” Statista, Statista Market Insights, July 2024, www.statista.com/outlook/tmo/data-center/india#revenue.
138.“Data Center - Japan: Statista Market Forecast.” Statista, Statista Market Insights, July 2024, www.statista.com/outlook/tmo/data-center/japan#revenue.
139.“Data Center - United States: Statista Market Forecast.” Statista, Statista Market Insights, July 2024, www.statista.com/outlook/tmo/data-center/united-states#revenue.
140.“Data Center - France: Statista Market Forecast.” Statista, Statista Market Insights, July 2024, www.statista.com/outlook/tmo/data-center/france#revenue.

141.“Data Center - Switzerland: Statista Market Forecast.” Statista, Statista Market Insights, July 2024, www.statista.com/outlook/tmo/data-center/switzerland#revenue.
142.“Data Center - Denmark: Statista Market Forecast.” Statista, Statista Market Insights, July 2024, www.statista.com/outlook/tmo/data-center/denmark#revenue.
143.“Data Center - Sweden: Statista Market Forecast.” Statista, Statista Market Insights, July 2024, www.statista.com/outlook/tmo/data-center/sweden#revenue.
144.“Data Center - Norway: Statista Market Forecast.” Statista, Statista Market Insights, July 2024, www.statista.com/outlook/tmo/data-center/norway#revenue.
145.“Data Center - United Kingdom: Statista Market Forecast.” Statista, Statista Market Insights, July 2024, www.statista.com/outlook/tmo/data-center/united-kingdom#revenue.
146.“Data Center - Kenya: Statista Market Forecast.” Statista, Statista Market Insights, July 2024, www.statista.com/outlook/tmo/data-center/kenya#revenue.
147.“Data Center - South Africa: Statista Market Forecast.” Statista, Statista Market Insights, July 2024, www.statista.com/outlook/tmo/data-center/south-africa#revenue.
148.“Data Center - Egypt: Statista Market Forecast.” Statista, Statista Market Insights, July 2024, www.statista.com/outlook/tmo/data-center/egypt#revenue.
149.“Data Center - Nigeria: Statista Market Forecast.” Statista, Statista Market Insights, July 2024, www.statista.com/outlook/tmo/data-center/nigeria#revenue.
150.“Data Center - Australia: Statista Market Forecast.” Statista, Statista Market Insights, July 2024, www.statista.com/outlook/tmo/data-center/australia#revenue.
151.“Data Center - Singapore: Statista Market Forecast.” Statista, Statista Market Insights, July 2024, www.statista.com/outlook/tmo/data-center/singapore#revenue.
152.“Data Center - Indonesia: Statista Market Forecast.” Statista, Statista Market Insights, July 2024, www.statista.com/outlook/tmo/data-center/indonesia#revenue.
153.“Data Center - Thailand: Statista Market Forecast.” Statista, Statista Market Insights, July 2024, www.statista.com/outlook/tmo/data-center/thailand#revenue.
154.“Data Center - Malaysia: Statista Market Forecast.” Statista, Statista Market Insights, July 2024, www.statista.com/outlook/tmo/data-center/malaysia#revenue.
155.“Data Center - Vietnam: Statista Market Forecast.” Statista, Statista Market Insights, July 2024, www.statista.com/outlook/tmo/data-center/vietnam#revenue.
156.“Data Center - Canada: Statista Market Forecast.” Statista, Statista Market Insights, July 2024, www.statista.com/outlook/tmo/data-center/canada#revenue.
157.“Data Center - Brazil: Statista Market Forecast.” Statista, Statista Market Insights, July 2024, www.statista.com/outlook/tmo/data-center/brazil#revenue.
158.“Data Center - Mexico: Statista Market Forecast.” Statista, Statista Market Insights, July 2024, www.statista.com/outlook/tmo/data-center/mexico#revenue.
159.“Data Center - Colombia: Statista Market Forecast.” Statista, Statista Market Insights, July 2024, www.statista.com/outlook/tmo/data-center/colombia#revenue.
160.“Data Center - Chile: Statista Market Forecast.” Statista, Statista Market Insights, July 2024, www.statista.com/outlook/tmo/data-center/chile#revenue.
161.Urquieta, Claudia, and Daniela Dib. “U.S Tech Giants Are Building Dozens of Data Centers in Chile. Locals Are Fighting Back.” Rest of World, 31 May 2024, restofworld.org/2024/data-centers-environmental-issues/.

162.“Google Says It Will Rethink Its Plans for a Big Data Center in Chile over Water Worries.” AP News, 17 Sept. 2024, apnews.com/article/chile-google-data-center-water-drought-environment-d1c6a7a8e8e6e45257ac84fb750b2162.
163.“In Colombia Is the First Environmentally Sustainable Datacenter.” AVI Latinoamérica, 7 Apr. 2023, www.avilatinoamerica.com/en/2023040722886/news/enterprises/in-colombia-is-the-first-environmentally-sustainable-datacenter.html.
164.“Global Data Center Trends 2023.” CBRE, 14 July 2023, www.cbre.com/insights/reports/global-data-center-trends-2023.
165.Weeks, Daniel. “Canada Prepares for Increased Electric Loads as Country Attracts Data Centers.” S&P Global Commodity Insights, 2 Oct. 2024, www.spglobal.com/commodityinsights/en/market-insights/latest-news/energy-transition/100224-canada-prepares-for-increased-electric-loads-as-country-attracts-data-centers.
166.“Experts Discuss Opportunities and Challenges in the Supply of Energy to Data Centers at an Event Promoted by the Law Firm Veirano Advogados in Partnership with PSR " PSR.” PSR, 5 Sept. 2024, www.psr-inc.com/en/news/experts-discuss-opportunities-and-challenges-in-the-supply-of-energy-to-data-centers-at-an-event-promoted-by-the-law-firm-veirano-advogados-in-partnership-with-psr/.
167.Swinhoe, Dan. “Brazilian Government Mandates Federal Data Centers Should Use Less Energy.” DCD, 27 Aug. 2021, www.datacenterdynamics.com/en/news/brazilian-government-mandates-federal-data-centers-should-use-less-energy/.
168.Taborga, Sergio. “Mexico's Data Centers Face Soaring Energy Needs.” Mexico Business, 19 Aug. 2024, mexicobusiness.news/energy/news/mexicos-data-centers-face-soaring-energy-needs.
169.Graham, Thomas. “Mexico's Datacentre Industry Is Booming – but Are More Drought and Blackouts the Price Communities Must Pay?” The Guardian, 25 Sept. 2024, www.theguardian.com/global-development/2024/sep/25/mexico-datacentre-amazon-google-queretaro-water-electricity.
170.Bryan, Kenza. “Data Centres Curbed as Pressure Grows on Electricity Grids.” Financial Times, 12 Feb. 2024, www.ft.com/content/53accefd-eca7-47f2-a51e-c32f3ab51ad5.
171.“Microsoft Announces US$2.2 Billion Investment to Fuel Malaysia's Cloud and Ai Transformation.” Microsoft, 2 May 2024, news.microsoft.com/apac/2024/05/02/microsoft-announces-us2-2-billion-investment-to-fuel-malaysias-cloud-and-ai-transformation/.
172.“Malaysia's Digital Crossroads – Balancing Data Centre Growth and Sustainability.” Energy Watch, 29 Aug. 2024, www.energywatch.com.my/blog/2024/08/29/malaysias-digital-crossroads-balancing-data-centre-growth-and-sustainability/.
173.Saieed, Zunaira. “Malaysia's Push for Data Centres Could Strain Power and Water Supplies, Warn Experts.” The Straits Times, 9 June 2024, www.straitstimes.com/asia/se-asia/malaysia-s-push-for-data-centres-could-strain-power-and-water-supplies-warn-experts.
174.Azhar, Kamarul. “Energy-Guzzling Data Centres a Boon for Tenaga.” The Edge Malaysia, 1 July 2024, theedgemalaysia.com/node/716529.
175.“By 2024, The Energy Capacity of Indonesia's Data Centers Predicted to Reach 210 MW.” Expat Life in Indonesia, 22 Apr. 2024, expatlifeindonesia.com/indonesias-data-centers-predicted-to-reach-210/.

176.Medina, Ayman Falak. “Vietnam's Data Center Market: A New Frontier for Global Investors.” ASEAN Business News, 14 Aug. 2024, www.aseanbriefing.com/news/vietnams-data-center-market-a-new-frontier-for-global-investors/.
177.“Vietnam Data Center Market Size, Share and Forecast 2032.” Credence Research, 16 Sept. 2024, www.credenceresearch.com/report/vietnam-data-center-market.
178.“Vietnam Boasts Strong Status for Data Centre Progress.” Vietnam Investment Review (VIR), 13 June 2024, vir.com.vn/vietnam-boasts-strong-status-for-data-centre-progress-111844.html.
179.Nguyen, Anuchit. “Thai Energy Billionaire Steps Up Data Center Push to Tap AI Boom.” Yahoo! Finance, 27 June 2024, finance.yahoo.com/news/thai-energy-billionaire-steps-data-080522947.html.
180.Zabeu, Sheila. “Thailand Studies Direct Purchase of Clean Energy by Datacenters.” Network King, 11 July 2024, network-king.net/thailand-studies-direct-purchase-of-clean-energy-by-data-centres/.
181.Derrick, Maya. “Thailand Growing as a Data Centre Colocation Powerhouse.” Data Centre Magazine, 13 Aug. 2023, datacentremagazine.com/articles/thailand-growing-as-a-data-centre-colocation-powerhouse.
182.Interesse, Giulia. “Singapore's Data Center Sector: Regulations, Incentives, and Investment Prospects.” ASEAN Business News, 1 Sept. 2023, www.aseanbriefing.com/news/singapores-data-center-sector-regulations-incentives-and-investment-prospects/.
183.Yang, Samuel. “Power-Hungry Data Centres Scrambling to Find Enough Electricity to Meet Demand.” ABC News, ABC News, 25 July 2024, www.abc.net.au/news/2024-07-26/data-centre-electricity-grid-demand/104140808.
184.Hannam, Peter. “AI Datacentres to Strain Australia's Energy Supply, Spike Prices without Change, Expert Says.” The Guardian, 10 July 2024, www.theguardian.com/australia-news/article/2024/jul/10/ai-datacentres-to-strain-australias-energy-supply-spike-prices-without-change-expert-says.
185.Take, Sayumi. “Boom in Data Centers Challenges Clean Power Goals in Asia.” Nikkei Asia, Nikkei Asia, 4 May 2024, asia.nikkei.com/Business/Energy/Boom-in-data-centers-challenges-clean-power-goals-in-Asia.
186.Anand, Saurav. “Data Centers to Push India's Power Generation Needs, $280 Billion Investment Expected - ET Energyworld.” Economic Times - Energyworld, 12 July 2024, energy.economictimes.indiatimes.com/news/power/data-centers-to-push-indias-power-generation-needs-280-billion-investment-expected/111673992.
187.Jaiyeola, Temitayo. “Rising Energy Costs Hamper Data Center Growth in Nigeria.” Business Day NG, 9 Sept. 2024, businessday.ng/technology/article/rising-energy-costs-hamper-data-center-growth-in-nigeria/.
188.Hutchinson, Ella. “Solar plus Storage Is a Win-Win for Nigeria's Booming Data Centre Market and Residents.” Intelligent Data Centres, 3 Sept. 2024, www.intelligentdatacentres.com/2024/09/03/solar-plus-storage-is-a-win-win-for-nigerias-booming-data-centre-market-and-residents/.
189.Hutchinson, Ella. “Navigating Africa's Data Centre Boom amidst Grid Challenges and Environmental Opportunities.” Intelligent Data Centres, 11 Dec. 2023, www.intelligentdatacentres.com/2023/12/11/navigating-africas-data-centre-boom-amidst-grid-challenges-and-environmental-opportunities/.

190.“How Has Egypt Become a Hub for Green Data Centers and What Could Be Done to Draw More Investments to the Sector?” Enterprise, 14 May 2024, enterprise.news/egypt/en/news/story/947fb33e-1145-44d1-a6f7-1b06a44e76da/how-has-egypt-become-a-hub-for-green-data-centers-and-what-could-be-done-to-draw-more-investments-to-the-sector%3F.
191.“Egypt Data Center Market: Investment Analysis & Growth Opportunities 2024-2029.” Arizton Advisory & Intelligence, Apr. 2024, www.arizton.com/market-reports/egypt-data-center-market.
192.“Egypt: An Attractive Country for Data Centers.” Inpro Group, www.inprord.com/en/egypt-data-centers/. Accessed Nov. 2024.
193.Swinhoe, Dan. “South African Gov't Says Data Centers Should Reduce Reliance on the Grid and Start Self-Provisioning Energy.” DCD, 11 June 2024, www.datacenterdynamics.com/en/news/south-african-govt-says-data-centers-should-reduce-reliance-on-the-grid-and-start-self-provisioning-energy/.
194.Republic of South Africa: Department of Communications & Digital Technology, 2024, National Policy on Data and Cloud, https://mybroadband.co.za/news/wp-content/uploads/2024/06/South_Africa_s_National_Cloud_and_Data_Policy_2024_1717231222.pdf.
195.Ndlovu, Nkosinathi. “How Data Centres Are Battling South Africa's Energy Crisis.” TechCentral, 19 Feb. 2024, techcentral.co.za/data-centres-south-africa-energy-crisis/239869/.
196.Payton, Ben. “Kenya Powers up Data Centre with Geothermal Energy Alone.” African Business, 12 Mar. 2024, african.business/2024/03/resources/kenya-powers-up-data-centre-with-geothermal-energy-alone.
197.Prinsloo, Loni, and Mpho Hlakudi. “African Data Center Firm Teraco to Build out Giant Power Plant.” Bloomberg UK, Bloomberg, 28 Feb. 2024, www.bloomberg.com/news/articles/2024-02-28/african-data-center-firm-teraco-to-build-out-giant-power-plant.
198.“Norwegian Data Centres - Sustainable, Digital Powerhouses.” Government.No, www.regjeringen.no/en/dokumenter/norwegian-data-centres-sustainable-digital-powerhouses/id2867155/?ch=4.
199.Ruud, Ingrid Elise, and Johan André Eikrem. “Construction of Google's EUR600 Million Hyperscale Data Centre in Norway.” DLA Piper, www.dlapiper.com/en-es/insights/publications/2024/05/construction-of-googles-eur600-million-hyperscale-data-centre-in-norway. Accessed Nov. 2024.
200.Kamiya, G., and P. Bertoldi. “Energy Consumption in Data Centres and Broadband Communication Networks in the EU.” European Commission, 2024, interactdc.com/static/images/documents/JRC135926_01.pdf.
201.“AI Is Already Wreaking Havoc on Global Power Systems.” Bloomberg, Bloomberg, 21 June 2024, www.bloomberg.com/graphics/2024-ai-data-centers-power-grids/.
202.“Finland and Sweden Are the Best Locations for Data Centers.” Granlund, 6 June 2024, www.granlundgroup.com/stories/finland-and-sweden-are-the-best-countries-for-data-centres/.
203.Iea. “Data Centres and Data Transmission Networks.” International Energy Agency (IEA), www.iea.org/energy-system/buildings/data-centres-and-data-transmission-networks. Accessed Nov. 2024.

204.Petrović, Stefan, et al. Technical University of Denmark, 2020, The Role of Data Centres in the Future Danish Energy System, https://backend.orbit.dtu.dk/ws/portalfiles/portal/236202284/The_role_of_data_centres_in_the_future_DES_clean_version.pdf.

205.“Swiss Transmission Grid.” Swissgrid, www.swissgrid.ch/en/home/operation/power-grid/swiss-power-grid.html. Accessed Nov. 2024.

206.Jorio, Luigi. “A Swiss Label Wants to Make Data Centres Greener.” SWI Swissinfo.Ch, www.swissinfo.ch, 16 July 2024, www.swissinfo.ch/eng/climate-change/a-swiss-label-wants-to-make-data-centres-greener/83240040.

207.“Data Centers in Switzerland - Electricity Consumption and Efficiency Potential.” TEP Energy, www.tep-energy.ch/en/projects/detail/p1108.php. Accessed Nov. 2024.

208.“France Offers Reduced Energy Tax for Data Centers That Meet Efficiency Criteria.” SDIA (Sustainable Digital Infrastructure Alliance), knowledge.sdialliance.org/policies/france-offers-reduced-energy-tax-for-data-centers-that-meet-efficiency-criteria. Accessed Nov. 2024.

209.“EU Moves toward Regulating Data Center Energy and Water Use.” CIO, 15 May 2024, www.cio.com/article/2100517/eu-moves-toward-regulating-data-center-energy-and-water-use.html.

210.“France Data Centre Market: A Tour De Force in the Global Landscape.” Techerati, 18 May 2023, www.techerati.com/features-hub/france-data-centre-market-overview/.

211.“German Data Center Market: Addressing Rising Demand While Navigating Regulation, Location and Energy Challenges.” JLL, 23 Sept. 2024, www.jll.de/en/trends-and-insights/investor/german-data-center-market-addressing-rising-demand.