RedChalk Group

INNOVATING FOR A SUSTAINABLE FUTURE

GROWING POWER DEMAND REQUIRES A DIVERSIFIED ENERGY STRATEGY

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FEBUARY

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Introduction

The U.S. electrical grid is being pushed to meet growing demand, driven by trends like electrification and data center expansion. This strain is worsened by the variable generation of renewable energy sources. To avoid a power shortage, it is estimated that nearly $2 trillion must be spent to modernize the U.S. grid by 2030. Initiatives include:

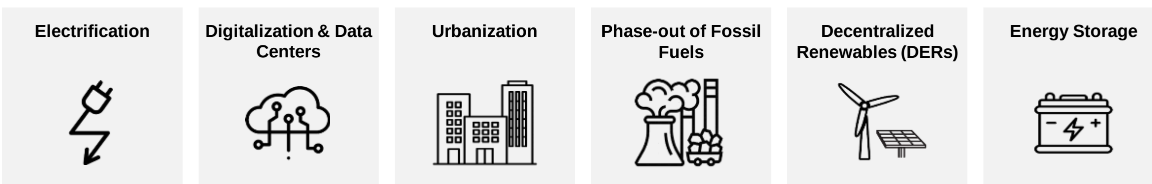
1) Increasing supply through nuclear and renewable energy

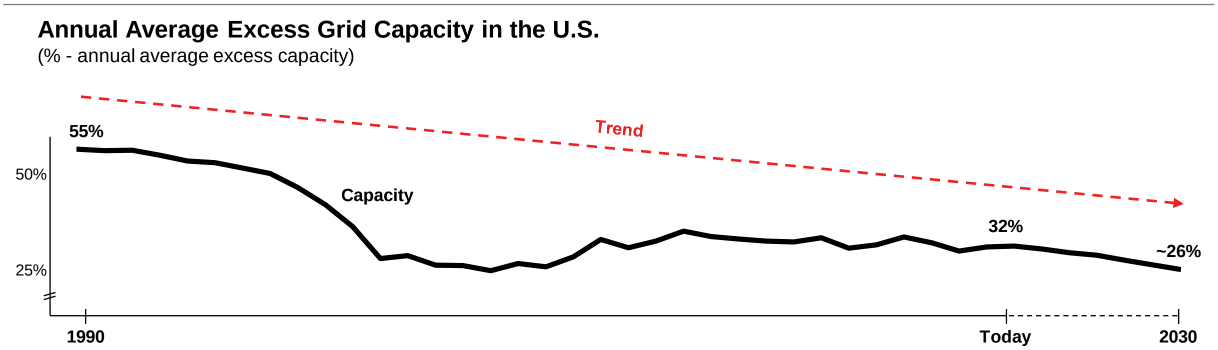
2) Modernizing the grid with smart technologies

3) Reducing demand with energy-efficient practices

Without additional investment, the aging infrastructure of the grid will be unable to supply enough electricity to meet demand in a matter of years. Rolling blackouts in California are already an indication that the grid needs help.

Figure 1: Trends in Electricity Generation and Consumption





The Cost of Modernization

- With growing demand from the electrification, digitalization, and urbanization of the U.S., the grid's ability to continue providing reliable, uninterrupted power is at risk
- The American Society of Civil Engineers predicts the U.S. will need to spend $1.9T on the electrical grid by 2030, $600B above currently expected investments

$1.9T
Required Investment
Between 2020-2030

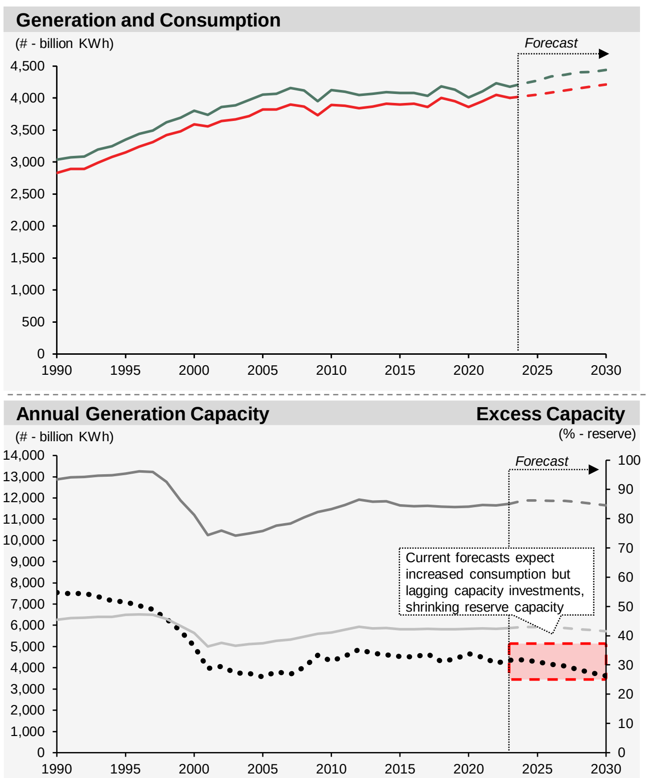
$600B
Shortfall*

*$600B shortfall based on current and expected investments falling short of the $1.9 trillion estimated spend required to modernize the grid

Trends in Consumption and Generation

Starting in the 1990s with the passage of the federal Energy Policy Act and adoption of state renewable portfolio standards, fossil fuel plants (e.g., coal) became an outdated part of the electrical grid. Over decades of phasing out these power plants, the nation's generation capacity has declined as plant closures outpaced current investments in renewables (e.g., solar, wind). Simultaneously, electrification trends (e.g., electric heat pumps, EVs) and the proliferation data centers are straining the grid's ability to meet demand.

Figure 2: U.S. Electricity Generation and Consumption – Annual



Drivers of Consumption

Electrification	• The **shift to electric heating** (e.g., heat pumps) **and cooking** appliances (e.g., electric stoves) and **adoption of electric vehicles** in place of gas-powered products
Digitalization & Data Centers	• Significant **growth in AI and data** is driving construction of energy-intensive data centers *(see the RCG website to learn more about the impact of AI and data centers)*
Urbanization	• Steady **population growth** and the **expansion of cities** increases the need for power infrastructure like streetlights and transportation systems

Generation and Capacity Trends

Phase-out of Fossil Fuels	• The federal Energy Policy Act (1992) and adoption of state renewable portfolio standards led to a **decline in coal** generation and subsequent **investments in natural gas and renewable energy**
Decentralized Generation (DERs)	• Growth in rooftop solar has **transformed end-users from consumers to generators** as electricity no longer only flows from power plants to end-users but is now a complex set of integrated **microgrids**
Energy Storage Expansion	• The development of **battery storage systems** that **store excess generation** that can be used during periods of high demand, thereby **reducing the need for reserve generation capacity**

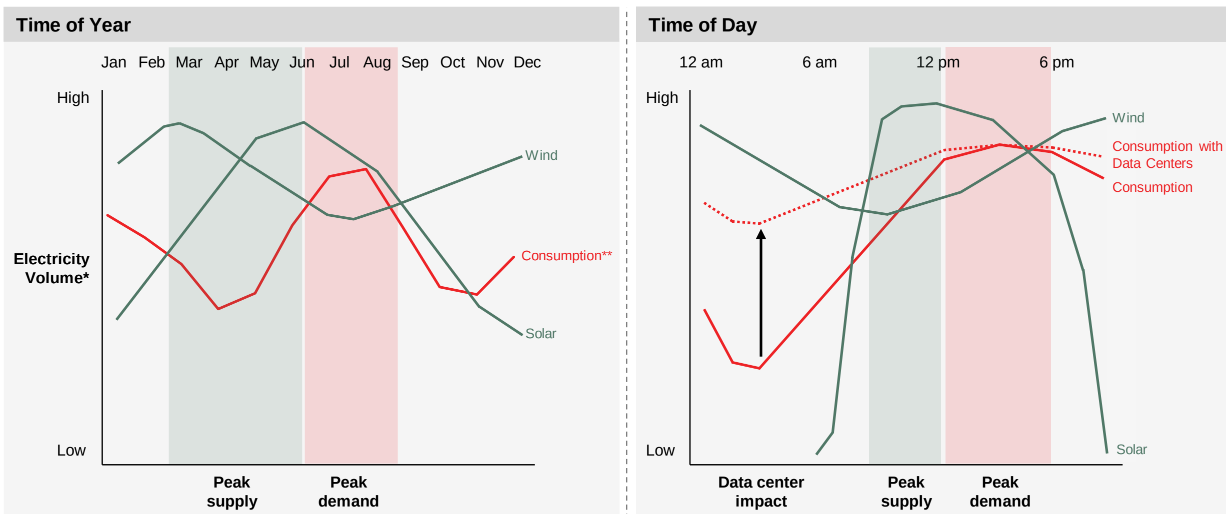
Note: Annual generation capacity is equal to KW capacity times hours per year – realistic capacity is the percent of time generation sources can realistically be in operation (e.g., factoring out maintenance, lack of sun for solar)

The strain on the electrical grid is more prominent when considering variations in generation and consumption throughout the year and on a daily basis. During the year, demand peaks in the summer as electricity is used for cooling – solar generation is also variable and peaks in the spring and early summer. However, within a day, solar panels are only able to provide electricity during the day, creating a supply shortage during the night that could be exacerbated with the growth in data centers which have IT load that runs nearly 24/7.

Figure 3: U.S. Electricity Generation and Consumption – Seasonal and Daily

Generation
Consumption

ILLUSTRATIVE



	Time of Year	Time of Day
Peak Supply	• Renewable energy sources (e.g., wind, solar) have **peak generation periods in the spring** • **Solar** generation is **highly variable**, lower in the winter	• Solar panels do not generate electricity at night which creates a **need for energy storage solutions to bridge supply-demand mismatches**
Peak Demand	• **Electricity demand is highest in the summer** due to increased cooling needs	• **Daily consumption peaks during mid-day** and drops at night as people sleep
Data Center Impact	• **Data centers are similar to other consumption trends** with increased cooling needs in the summer	• **Data center consumption has limited variability** (near- constant IT needs and increased cooling during the day) • **Solar** generation is **unable** to directly meet **overnight demand**

*The greater the difference in peaks and troughs indicates higher variability - lines represent differences within each segment (e.g., wind) and should not be compared to other lines (wind being above consumption does not mean that total wind generation surpasses total consumption, rather that wind generation is less volatile than consumption)
**Consumption with data centers is similar to time of year overall consumption patterns with increased cooling needs in the summer causing the variance

Potential Grid Solutions

To prevent electricity consumption from exceeding generation and thereby forcing blackouts, there are three solutions: 1) Increase supply / generation capacity, 2) improve grid efficiency, 3) decrease demand / consumption. Supply could be increased with additional investments in nuclear power and renewables, the grid could be modernized to a "smart grid" and incorporate microgrids, and demand can be reduced through demand response programs and use of energy efficient equipment (e.g., low-energy appliances).

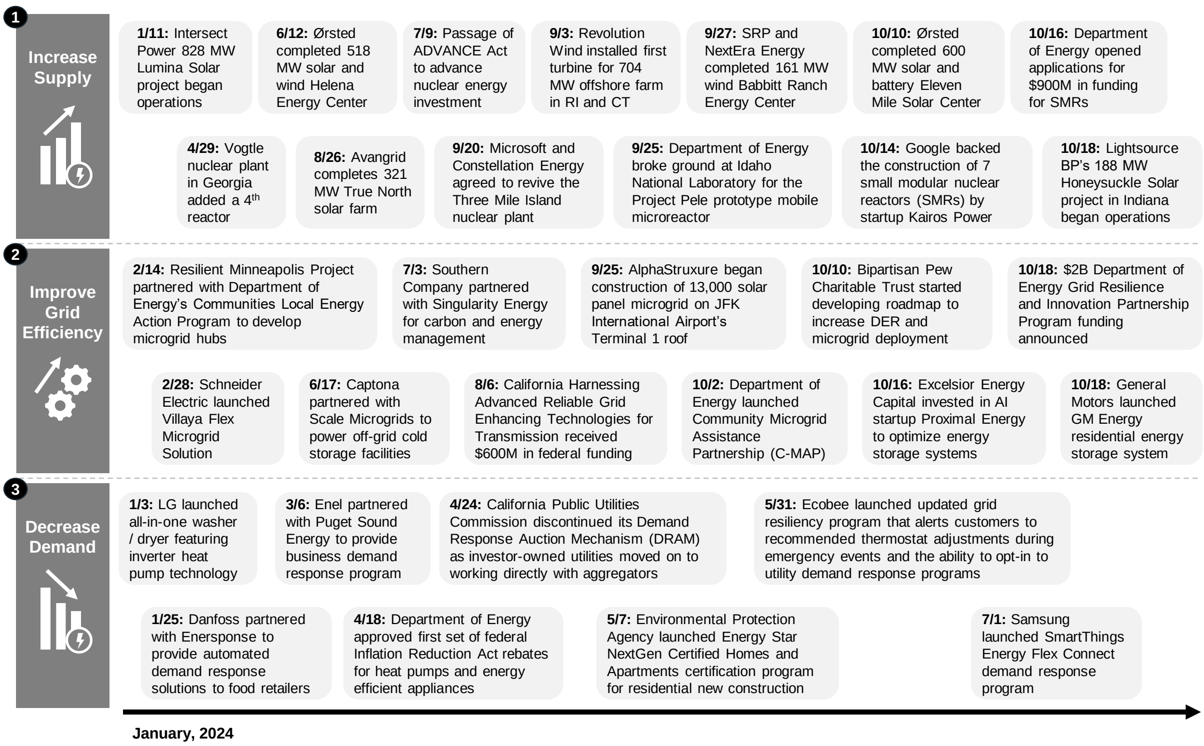
Figure 4: Electricity Supply-Demand Optimization Solutions

		Advantages	Disadvantages	Implications
1 Increase Supply	**Nuclear**	• **Most reliable** form of generation, capable of being in operation 92.7% of the time • **Cheaper to produce than coal** (~19% lower cost per MWh)	• **Negative public perception** (e.g., fear of another Chernobyl) • **High upfront capital requirements** ($3-$9B) • Far away from population centers (~50 miles)	• Nuclear can provide **large-scale**, **reliable power** supply which could be **particularly valuable** in addressing the exponential electrical needs of **data centers**
	Renewables *(e.g., solar, wind)*	• Can be **small-scale / localized** (distributed generation) • Onshore wind and utility solar are the **cheapest forms of electricity** (35%+ discount)	• **Least reliable** form of generation, with solar only operable 24.6% of the time and wind at 34.6%	• Renewables can enable **end-user participation in power generation** though high variability of output **necessitates investments in battery storage solutions**
2 Improve Grid Efficiency	**Grid Modernization**	• 60% of the distribution grid is older than its 50-year lifespan and **needs to be updated anyway** • **Upgrading** existing infrastructure is **cheaper than expanding** the grid	• **High upfront capital requirements** (~$5 trillion to modernize) • Reliance on digital communication / connectivity poses **cybersecurity risks**	• Grid modernization is necessary as the U.S. electrical **grid continues to age** and provides the crucial first step of **identifying vulnerable areas / stress-points** across the grid
	Decentralized / Microgrids	• **Enhanced grid resilience** (independent and local operation) • **Limits power loss** during transmission (~5%)	• **Limited scalability** and may not be sufficient to serve all electrical needs • **Significant complexity** requires advanced control and monitoring capabilities to manage	• Though complex, microgrids can enable the most **efficient allocation of electricity** while **mitigating the risk** of relying on a singular power source which is all the more important as societal electrification continues
3 Decrease Demand	**Demand Response**	• **Lowers costs** to both utilities and end-users • **Lower capital requirements** than investing in new generation capacity	• **Dependent on** end-user **voluntary participation** / reliance on human behavior • **Could disrupt day-to-day operations**, particularly for industrial and commercial buildings	• Demand response presents a **low-cost opportunity** to reduce demand in a way that **benefits both utilities and end-users**, though the feasible amount of demand that can be reduced may not be enough on its own
	Energy Efficient Equipment	• **Lowers costs** to end-users in the long-term • **Ease of installation** (does not disrupt existing grid operations)	• **Reliance on end-user buy-in** which may require regulatory mandates • Can reduce overall demand but a more **limited impact on peak demand**	• Energy efficient equipment can save end-users money on their power bills and **may advance sustainability goals**, but **efficiency gains will diminish over time**

In 2024, many initiatives were undertaken across the three types of solutions. Notably, many data center hyperscalers (e.g., Google, Amazon, Microsoft) made partnerships with energy providers (e.g., Constellation) to invest in nuclear power while the U.S. Department of Energy announced over $2B in funding to modernize the grid.

Figure 5: 2024 Notable Announcements and Initiatives

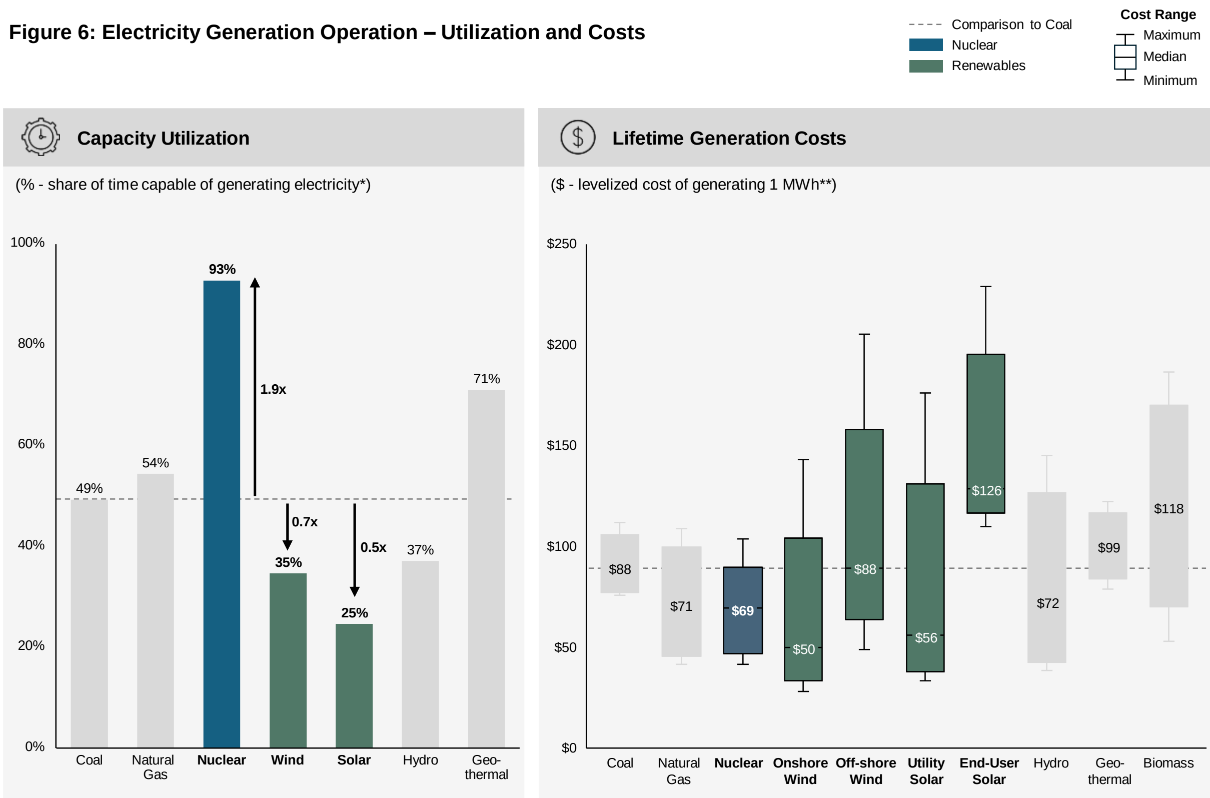
NOT EXHAUSTIVE



Increasing Supply Through Nuclear And Renewable Energy

When it comes to increasing supply in the age of “green” and sustainable energy, nuclear power is capable of generating significant capacity with next to no downtime required. Renewables like solar and wind are more variable in generation (lack of wind or sun limits production) but offer lower-cost electricity than coal and natural gas while solar also enables localized generation (e.g., rooftop solar) that can address specific energy needs.

Figure 6: Electricity Generation Operation – Utilization and Costs



*Capable time factors out generation downtime due to maintenance and other factors that prevent generators from operating non-stop
**Costs are based on a levelized lifetime cost using a discounted cashflow rate of 7% - this does not include transmission and distribution costs

Historically, nuclear power had a negative connotation with thoughts of disasters like Chernobyl creating hesitancy to invest in new reactors. However, recent technological advancements in small modular reactors (SMRs) present an opportunity to create safe and scalable new nuclear plants that can manage large electrical loads (e.g., data centers).

See Red Chalk Group's "Sustainable Power" white paper (here) to learn more about the future of nuclear.

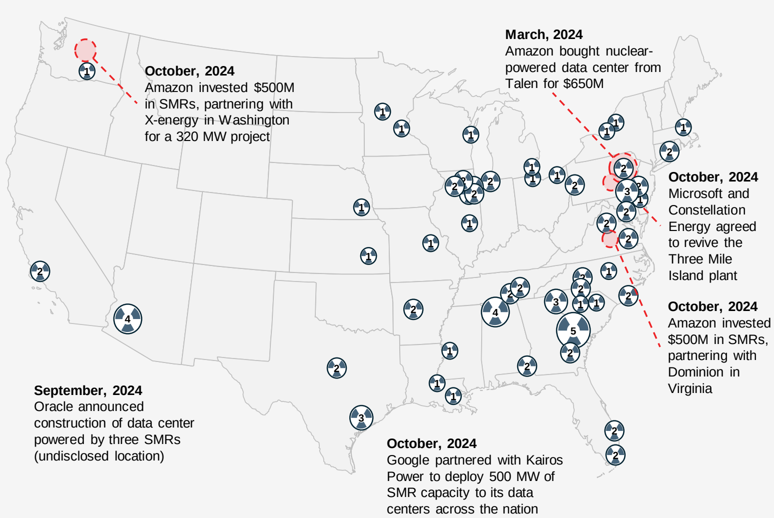
Figure 7: Nuclear Power Trends

Gigawatt (GW) Capacity*

1 GW → 5 GW

Active Traditional Nuclear Power Plants

(# - gigawatt capacity*)



Benefits of SMRs

Modularity
- Limited on-site preparation and assembly required (**shorter construction time** makes them a potential solution in the near-term)
- **Construction** time reduced to under **3 years** (down from 7 years)

Lower Capital Investment
- Factory fabrication can **reduce construction costs** (material and time) while the smaller size reduces spend on unnecessary excess capacity
- Can be **more easily integrated into existing grid infrastructure**

Flexible Deployment
- Can serve smaller electrical markets, isolated areas, and **sites with limited water**
- SMRs can be powered off and on more quickly, allowing them to **adjust to meet demand**

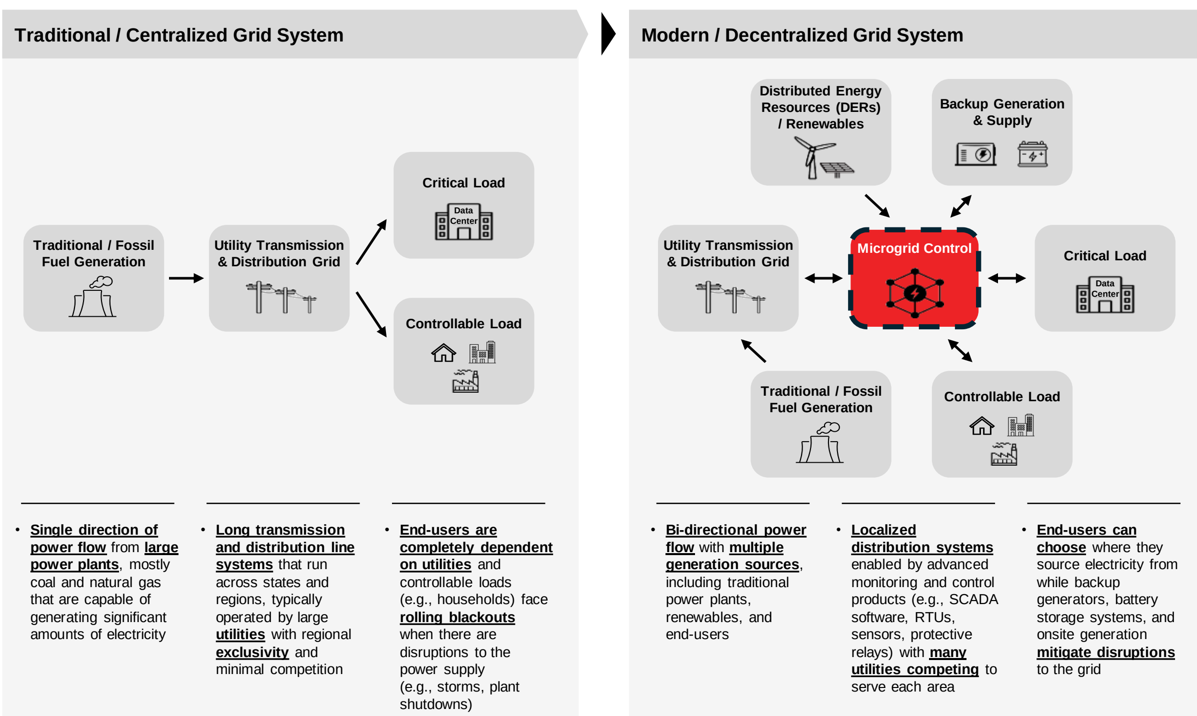
Improved Safety
- Advanced safety measures and passive cooling systems are built into the modular design, **reducing the risk of accidents** and **simplifying regulator processes**
- **Emergency** zone reduced to a **300-meter radius** (down from 10 miles)

*Capacities are rounded to the nearest whole gigawatt (e.g., 2 = 1.6 to 2.4)

Modernizing The Grid With Smart Technologies

The electrical grid has been around for 50+ years with little change, that is until recently. Now, the traditional power plant to grid to end-user flow is being revamped into modern, decentralized systems that incorporate renewables and battery energy storage and enable bidirectional power flow as end-users participate in generation. Investments in monitoring and control equipment and software could improve the allocation of supply to meet demand at localized levels (thereby preventing broad, state-wide blackouts).

Figure 8: Electrical Grid Systems



Reducing Demand with Energy-Efficient Practices

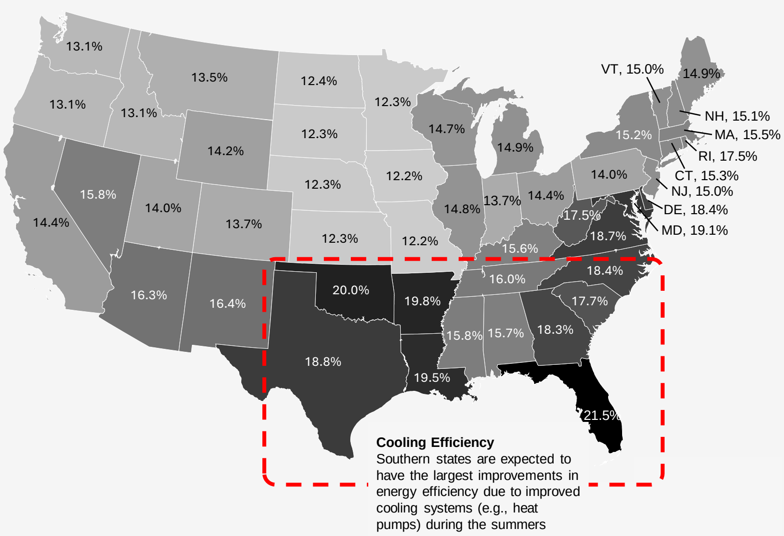
The third solution to addressing the supply / demand imbalance is to reduce demand, but to do so in a way that does not lower our standard of living (reducing electricity consumption does not have to mean using candles and lanterns). Utility demand response programs allow end-users to be compensated for voluntarily reducing their consumption during peak demand periods and energy efficient equipment (e.g., LED bulbs) can allow us to maintain our current usage behaviors while using less electricity than in the past.

Figure 9: Electricity Demand Reduction – Lower Consumption and Improved Efficiency

2023-2035 Reduction
(Assuming no increase in consumption*)
10% >20%

Potential Electricity Consumption Reduction

(% - change in consumption by 2035 from 2023 base)



Demand Reduction Strategies

Demand Response

- Demand response programs allow end-users to **opt into temporary power supply reductions** during peak load times – future programs could allow end-users to generate and sell electricity back to the grid
- Advances in **smart meter technology** could enable more **efficient power allocation**
- **End-user solar generation** and battery storage systems can reduce demand on the broader electrical grid

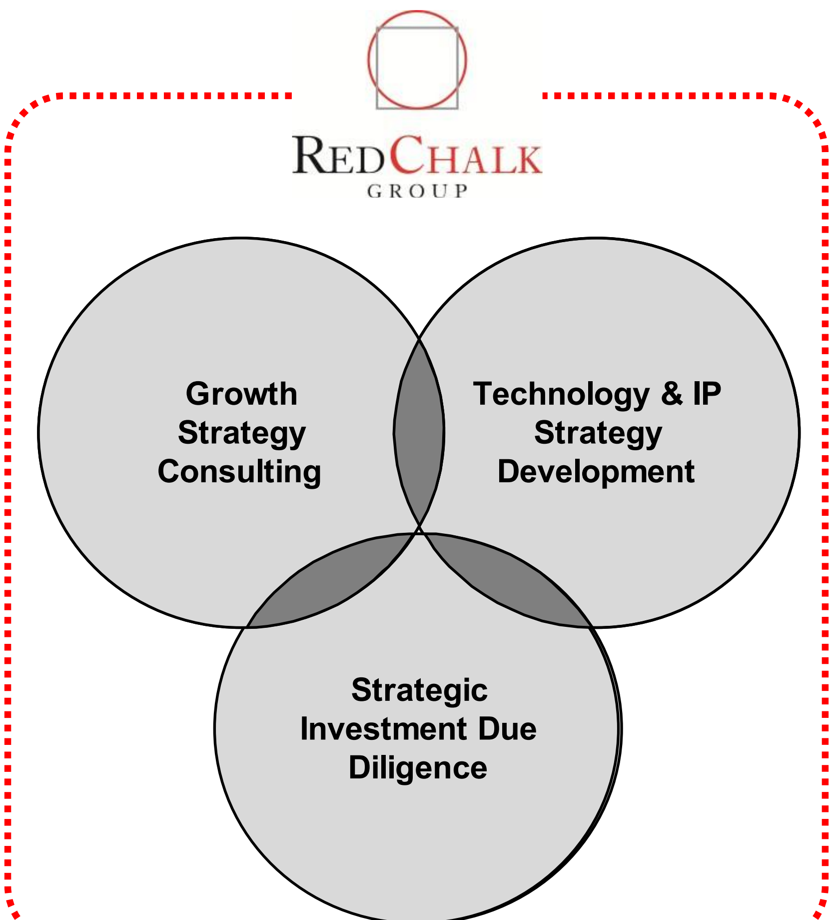
Energy Efficient Equipment

- **Adoption of smart thermostats** and broader **smart-home product ecosystems** can improve end-user usage behaviors
- Manufacturers are creating energy efficient products, (e.g., **LEDs**, **low-energy intensity appliances**) that reduce consumption while maintaining standards of living
- **Federal programs** (e.g., Energy Star) and **tax credits** can incentivize end-users to purchase energy efficient products even if upfront costs may be higher

*Reduction percentages do not incorporate any increases of consumption during the time period and only represent a percent decrease from 2023 consumption levels assuming no increase in future consumption (note: consumption will likely increase due to electrification trends and population growth which could offset reductions due to efficiency gains)

About Red Chalk Group

Red Chalk Group is a boutique professional services firm focusing on advising senior management on issues related to top-line growth, disruptive technology, key mega-trends, and related intellectual property. Our firm delivers strategies related to new revenue platforms, emerging and disruptive technologies, industry & competitive analysis, merger & acquisition/investment support, and IP analysis and transaction services. Red Chalk Group has helped business leaders address their greatest challenges, issues, and opportunities at the most senior levels.



Sources:

1. ASCE, “Report Card for America’s Infrastructure”
2. U.S. Energy Information Administration, “Annual Energy Outlook”
3. Congressional Research Service, “Variable Renewable Energy”
4. International Energy Agency, “Projected Costs of Generating Electricity”
5. World Nuclear Association, “Nuclear Reactors in the United States of America”
6. U.S. Department of Energy, “Energy Efficiency Potential”

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