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The U.S. Grid: Revamp Time!

It is no secret that the U.S. electric grid is in dire need of an infrastructure overhaul. America is not only plagued by nearly the highest power outage rate of any developed nation, but its grid is also highly vulnerable and frankly incapable of satisfying growing energy demand. Decades of underinvestment have left the grid antiquated as there have been no major modernization initiatives since its construction during the 1960s. In its latest infrastructure report card, the American Society of Civil Engineers gave the U.S. grid a "C-" grade.

Grid modernization is essential to adequately support economic growth, the proliferation of digitalization, clean energy transition, and improve national security. Next-generation grid enhancing technologies (GETs) will drive the modernization overhaul. GETs fall into two categories: hardware upgrades for the grid itself and software upgrades for the grid's control systems.

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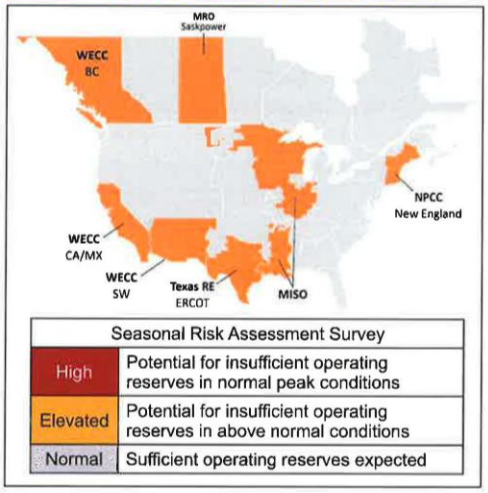
This report argues that the U.S. grid is poised for a significant modernization boom with substantial long-term investment opportunities. We believe that GETs and transmission upgrades are converging to satisfy rising energy demand, enhance grid resiliency, and support decarbonization.

> ***"There is an urgent need to act to ensure the reliability and the affordability of our grid.... We are at a transformational moment for the electric grid."***
> - Willie Phillips, Chairman
> The U.S. Federal Energy Regulatory Commission

America's Grid Layout

America's grid is highly fragmented; therefore, a uniform approach to modernization will fail. The U.S. grid is comprised of three distinct and almost

Chart 1 **Areas Of North American Grid That Are At Elevated Risk This Summer**



Source: North American Electric Reliability Corporation completely isolated sections: Eastern, Western, and Electric Reliability Council of Texas (ERCOT) (**Chart 1**). There are 12 individual "planning regions" that are under the jurisdiction of the Federal Energy Regulatory Commission (FERC), excluding ERCOT. Consequently, the grid's construction lacked standardization, complicating current efforts to address issues and enhance resiliency. If one of the three sections faces extreme weather or needs increased generation, extra capacity cannot simply be "imported" as a stopgap solution. The ERCOT section is the grid's largest single point of failure. Its isolation makes it highly vulnerable, as seen during recent extreme weather events like Hurricane Beryl and the 2021 winter storm Uri, which caused power outages for 4.5 million people.

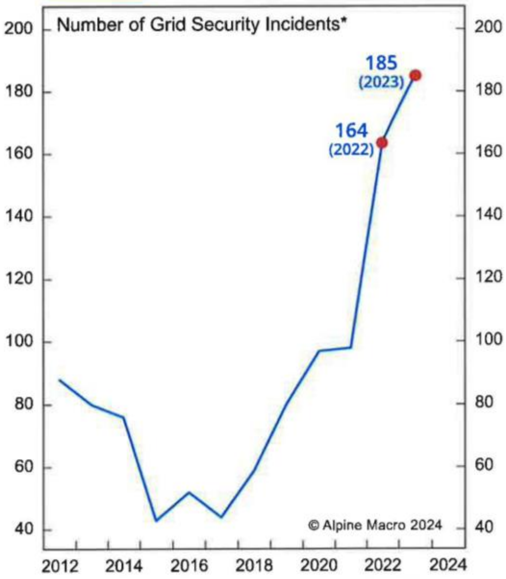
Soaring Demand Meets A Crippled Grid

The U.S. is facing a growing thirst for electricity. U.S. grid planners have nearly doubled their annual load forecast for the next five years, anticipating 4.7% growth each year. During the previous decade, annual load demand growth forecast was just 0.5%. Through 2028, peak demand growth is expected to top 38 gigawatts (GW), notes FERC. In 2022, data center consumption accounted for 2.5% of total U.S. energy demand but is expected to triple to 7.5% (~390 TWh) by 2030. *1

Aside from rising demand, the grid faces emerging vulnerabilities. To form our grid modernization thesis, we broke down the largest threats to grid stability into three distinct buckets:

①
- **Vulnerability to physical attacks steaming from single points of failure.** Last year, U.S. utilities reported 185 instances of mostly physical attacks against critical grid infrastructure, double the reported incidents in 2021 (**Chart 2**). Over 2,800 threats were reported last year – 1,000 more than 2022.

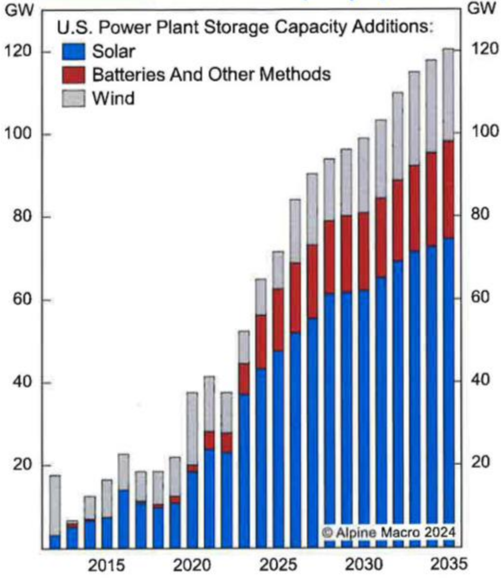
Chart 2 **U.S. Grid Facing Rising Threats**



*Includes cyber attacks, reports of vandalism, suspicious activity, thefts and actual physical attacks; source: Department of Energy

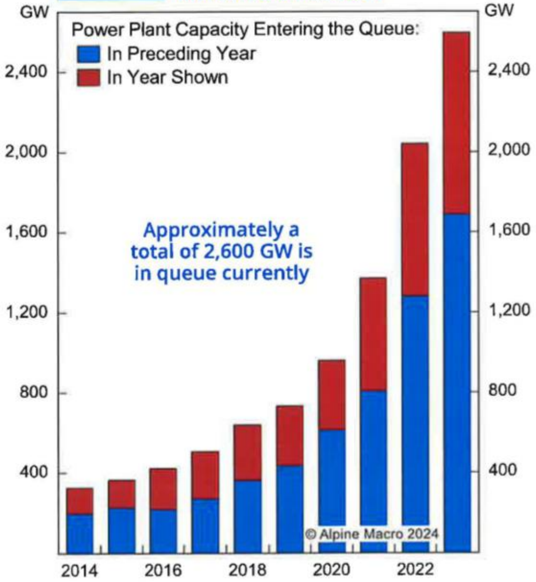
②
- **Susceptibility to adversarial cyber-attacks.** Nationally, the number of points in grid software or hardware that are susceptible to cyber-attacks totals 24,000 unique locations. Yet, the number of susceptible points is increasing by about 60 per day, according to the North American Electric Reliability Corporation (NERC). Over the next year and a half, the grid could have over 50,000 points vulnerable to cyber threats.

Chart 3 Wind And Solar Could Boost Power Plant Capacity By 80%



Note: Data from 2024 onwards are forecasts;
source: BloombergNEF

Chart 4 New Capacity Queues Have Increased Since 2024



Source: Lawrence Berkeley National Laboratory

③
- **Diminishing resilience to extreme weather events.** Over the last decade, severe storm outages have increased by 74% compared to the previous decade. Climate change is increasing grid strain from more frequent excessive heat, flooding, high wind events including hurricanes and wildfires, and sea-level rise.

Interconnection Woes

Aside from threats to the grid, worsening ability to connect new generation capacity is arguably its most debilitating impediment. Grid connection delays are now hampering America's ability to satisfy growing energy demand.

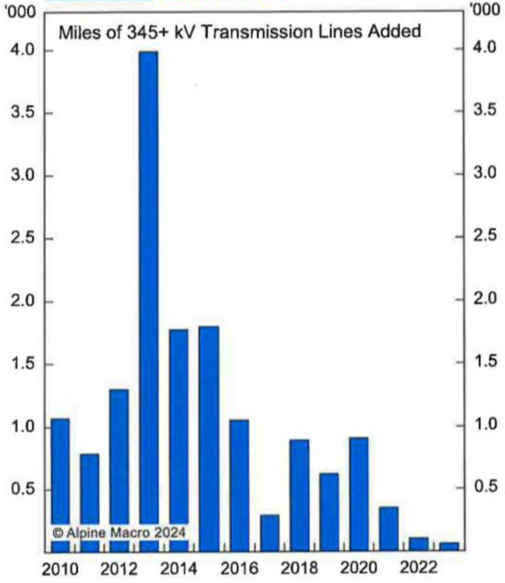
For example, at the conclusion of 2023, approximately 2,600 gigawatts were stuck in the queue, (2x the generation of the current U.S. power plant fleet) (**Chart 3** and **Chart 4**). Interconnection now takes an average of nearly five years.

Additionally, interconnection costs are increasing, often representing 50-100% of the total proposed plant expenses. Although FERC has recently instituted a broad set of reforms to modernize and accelerate the interconnection process, results have largely been disappointing.

Big Cable Challenges

Transmission lines are emerging as the largest grid bottleneck. To avoid delaying the clean energy transition, the world's transmission cable network must double in length to 152 million kilometers by 2050 – nearly the distance between the Earth and

Chart 5 **Slowing U.S. HV Transmission Line Buildout**



Source: Grid Strategies

the Sun. In the U.S. specifically, transmission-line investment must double, or 80% of potential emissions reduction goals in the Inflation Reduction Act will be lost by the end of the decade, notes a Princeton University analysis.

During the first half of the 2010s, the U.S. installed an average of 1,700 miles of new high-voltage (HV) transmission lines yearly. Last year, a mere 250 miles of electricity transmission lines were installed, of which only 55 miles were high-voltage HV transmission lines (**Chart 5**).

To connect renewable power and other new generation, utilities must increase their web of high-voltage transmission lines. Traditional energy generation from coal or gas is often located nearby the areas they supply. Conversely, utility-scale renewable energy generation requires significant space, so they are often situated far from areas where energy demand is concentrated. HV Direct Current lines minimize transmission power loss 30-40% better than alternating current systems. HVDCs primarily use an aluminum conducting core. Already, many Western HVDC cable manufacturers have backlogged order books into the late 2020s.

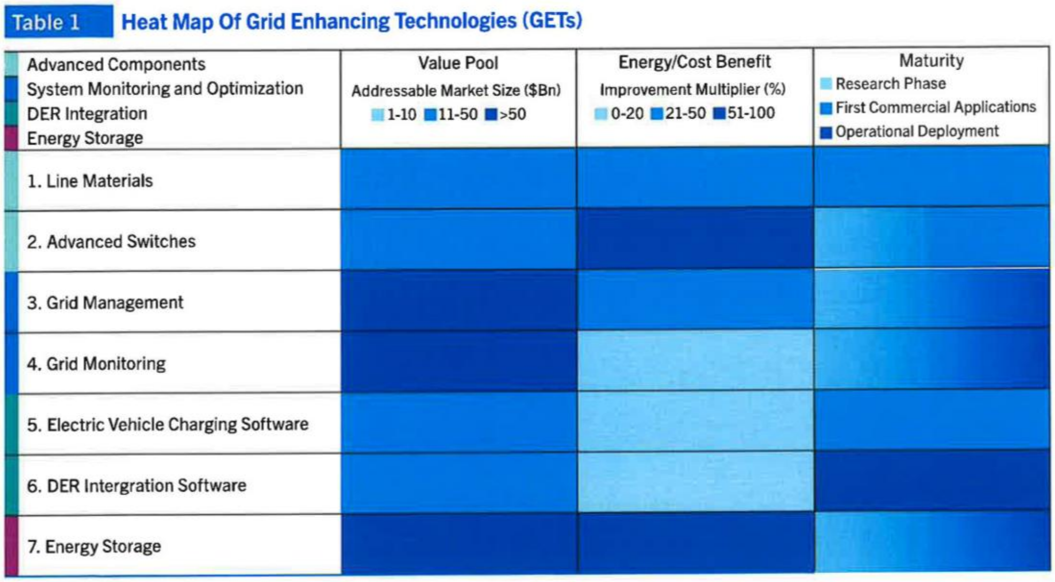
Shorter "link" cables are also essential to connect generating facilities to long-distance lines. These "link" cables need improved energy transmission capabilities and typically rely on copper cores. Global copper scarcity could not only hinder grid scalability but also lead to higher interconnection costs.

Cable Innovation Offers Solutions

Over the past century, cable technology has remained largely unchanged, with most cables still consisting of aluminum wrapped around a steel core. Next-generation cables that use advanced conductors are positioned to provide solutions to cable bottlenecks. In addition, reconductoring, a practice where old transmission lines are replaced with novel conducting technology on existing infrastructure, could be a game changer.

A recent analysis by GridLab reveals that replacing old cables with new conductive materials cuts replacement costs by half and doubles the capacity compared to constructing entirely new lines with legacy cables for the same capacity. Additionally, updated materials could reduce costs by 3-4%,

Table 1 **Heat Map Of Grid Enhancing Technologies (GETs)**



Advanced Components System Monitoring and Optimization DER Integration Energy Storage	Value Pool Addressable Market Size ($Bn) ░ 1-10 ▒ 11-50 █ >50	Energy/Cost Benefit Improvement Multiplier (%) ░ 0-20 ▒ 21-50 █ 51-100	Maturity ░ Research Phase ▒ First Commercial Applications █ Operational Deployment
1. Line Materials	▒	▒	▒
2. Advanced Switches	▒	█	░→▒
3. Grid Management	█	▒	░→█
4. Grid Monitoring	█	░	░→█
5. Electric Vehicle Charging Software	▒	░	▒
6. DER Intergration Software	▒	░	█
7. Energy Storage	█	█	░→█

Source: McKinsey

potentially saving customers over $180 billion by 2050. Moreover, reconductoring projects typically take 18 months to three years on average, significantly faster than greenfield projects, which can span 5-15 years. Approximately 98% of U.S. lines are run for less than 50 miles, making them ideal for reconductoring.

Cable innovation is flourishing. TS Conductor, a California-based startup, replaces steel with carbon fiber in its cable cores. This strengthens cables, while also making them lighter and less prone to sagging. Pound for pound, these new cables can increase electricity capacity by 250% and cut line losses by 50%. NanoAL, another cable innovator, has developed an aluminum-alloy core cable with improved strength and conductivity compared to copper alternatives.

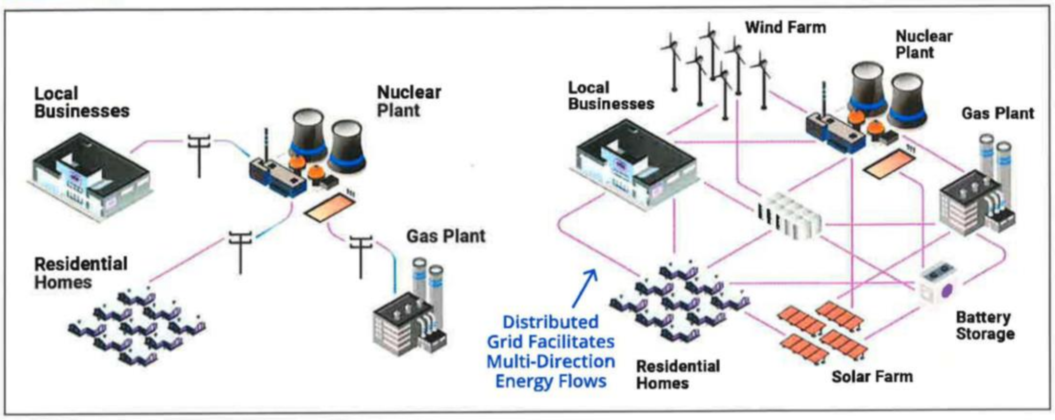
The Grid's Tech-Based Modernization Revival

The deployment of GETs is happening rapidly. GETs combine next-generation hardware and software. Examples include advanced sensors, power flow control devices, and analytical tools. Sensors and control devices are at the forefront of the GET transformation. Sensor-critical products, such as smart meters, automated control systems, and advanced monitoring tools are at the forefront of use cases.

When integrated throughout the grid, these tools can deliver real-time data on energy flow, equipment health, and grid stability. Critically, these sensors can improve operators' ability to proactively detect and anticipate equipment failures (**Table 1**).

The investment surge to upgrade the grid from 1960s infrastructure using GETs is already underway. The

Chart 6 **Conventional Grid Vs Distributed Grid**



Source: WTS Energy

Bipartisan Infrastructure Law has earmarked $13 billion for modernizing the grid and the Inflation Reduction Act guarantees up to $250 billion in loans for projects that reduce greenhouse gas emissions from existing energy infrastructure. This legislation equipped the DOE to allocate $10.5 billion through the Grid Resilience and Innovation Partnerships (GRIP) Program. GRIP strives to strengthen electric grid resilience and reliability. Over 66% of grid digitization projects started last year are already in mature stages, noted BNEF. Digitization could account for roughly 25% of all grid expenditures through 2050.

Importantly, GETs enable bidirectional energy flow. Legacy grid hardware was designed for one-way flow from central power stations to consumers. It is essential to modernize the grid to accommodate electrical flows in diverse ways, as energy is produced, stored, and released based on demand and baseload requirements at varying times and under different conditions.

The Rise Of Distributed Energy Resources

Currently, America's grid draws power from about 12,000 individual power plants. Yet, the grid is beginning to embark on a transformational shift to incorporate millions of small energy-generation and storage resources to improve resiliency.

Known as distributed energy resources (DERs), this approach significantly enhances grid resilience when combined with the GETs. DERs are often controlled by individual entities, not utility companies. The integration of these technologies is the driving force behind the transformation of the U.S. grid.

By 2028, U.S. DER capacity is expected to top 217 GW, equivalent to 70% of anticipated bulk generation additions during the period, notes Wood Mackenzie (**Chart 6**). Specific DERs set to revolutionize the grid include:

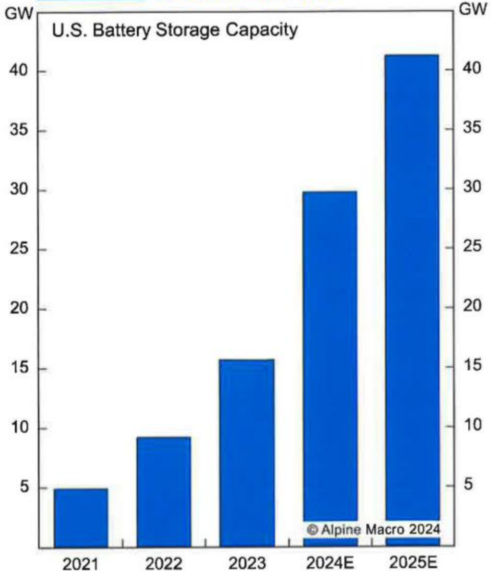
- **Microgrid:** Localized energy systems capable of operating independently or in tandem with the main power grid. They incorporate DERs like solar panels, wind turbines, and batteries to provide reliable power to a specific area. They boast advanced control systems that manage energy production, distribution, and consumption. During grid disturbances or outages, a microgrid can disconnect and function autonomously, maintaining power supply.

- **Distributed energy storage systems:** Decentralized storage units, including batteries, thermal energy storage, and compressed air energy storage that are installed at different locations throughout the grid. These systems store excess energy generated and release it when needed. This helps balance supply and demand, enhance grid stability, and improve energy efficiency (**Chart 7**).

- **Electric vehicle systems:** Mobile energy storage units that can connect to the grid. This integration allows EVs to contribute to grid stability by charging during periods of low demand and discharging stored energy back to the grid during peak times.

- **Virtual power plants (VPPs):** Networks of decentralized, flexible power generation units aggregated and managed through advanced software to function as a single power plant. By leveraging real-time data and sophisticated algorithms, a VPP can optimize energy production, distribution, and consumption by responding dynamically to fluctuations in demand and supply. By tripling U.S. VPP deployment from the current level of 30GW, 10-20% of total peak load demand could be alleviated by the end of the decade, notes the DOE.

Chart 7 **U.S. Battery Storage Expected To Double This Year**



Source: U.S. EIA

Bipartisan Support

Finally, policymakers on both sides of the aisle support grid modernization initiatives, recognizing the importance of federal funding from Washington. As a result, regardless of the outcomes of the coming election cycle, infrastructure spending for the grid will receive support. This is crucial to avoid placing the substantial costs of grid modernization on state utilities, which would ultimately pass these expenses onto consumers. Historically, the primary obstacle to modernizing the grid has been the financial burden placed on utilities.

Investment Considerations

U.S. grid modernization provides long term investors with a unique opportunity to participate in arguably the largest critical infrastructure overhaul in a generation. It is our view that both "pick and shovel" providers of hardware and services, as well as leaders in smart grid software, are well-positioned to outperform.

While a Trump presidency would pose obstacles to the renewable energy transition, the urgent need for infrastructure modernization and digitalization of the grid remains essential, irrespective of the electricity generation source. Companies offering leading hardware and software solutions include: Quanta (PWR), Hitachi (6501, JP), ABB (ABBN, SW), MYR Group (MYRG), Landis+Gyr (LAND, SW), MasTec (MTZ).

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