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America's Utility-Scale Electricity Generation Landscape in Transition: A 2025 Analysis of Capacity Growth, Regional Trends, and Energy Resource Dynamics

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ABSTRACT

America's power mix is rapidly shifting. Using over 1.3 TW of utility-scale capacity data (Hitachi Energy Velocity Suite; APPA), this study synthesizes development by fuel, ownership, geography, and status (including cancellations, retirements, and storage). Solar leads: 55% of capacity under development and over 80% of 2024 additions. Wind development fell 22%, while natural-gas projects rose 58%. Grid-scale storage surged 181% in two years, with over 165 GW in development. Coal is phasing out (83 GW retired since 2017, another 56 GW planned by 2029). Non-utility generators hold 88% of new capacity, limiting public-power participation despite serving 9% of load. Texas RE and WECC dominate pipelines, yet ~336 GW of planned projects since 2017 were canceled. Findings inform energy decision-makers.

Keywords: Utility-Scale Generation Capacity, Energy Transition, Renewable Energy Deployment, Grid Planning and Storage, Generation Project Attrition

I. INTRODUCTION

A. Background of the Study

Climate change, new technologies, and changing market conditions are all driving a big change in the structure of the global energy sector. Utility-scale electricity generation capacity has become a major focus of this energy transition in the United States, especially as the focus on decarbonization, distributed generation, and system modernization grows (Qusay Hassan et al., 2024), (Wang, C.et al., 2023), (Yu Yang et al., 2024). The combination of state and federal policy incentives, lower costs for renewable technologies, and more industries becoming electrified has led to big changes in the power generation portfolio. The U.S. electric grid will have around 1.3 terawatts (TW) of installed utility-scale capacity by 2025. Solar energy and battery storage technologies are the main drivers of additional development activities (Horzela-Miś A and Semrau J, 2025), (Njema, George G. et al., 2024). Natural gas is still the biggest source of current capacity, making up around 43% of it. However, renewable energy sources, especially solar and wind, have seen their proportion grow rapidly over the past ten years (EIA (2024)), (IRENA (2023)). Along with this rise, energy storage systems are being put in place quickly. Over the previous two years, their growth rates have been more than 180% due to the problems with variable renewable power (National Renewable Energy Laboratory (NREL). (2024)). The sector is also seeing a big shift in how projects are owned, with non-utility generators being in charge of 88% of new capacity in development. To understand how regional, technological, and regulatory changes are affecting the future of the U.S. power supply, we need to look at them more closely

B. Related Works

A rising number of studies have tried to chart and predict trends in power generation in the US. There have been studies on the techno-economic competitiveness of renewables (Jacobson, M.Z. et al., 2022), (Jesse D. Jenkins et al., 2018), the role of natural gas as a bridging technology (Hausfather, Z., 2025), and the growing importance of utility-scale storage in making grids cleaner (Arbabzadeh, M. et al., 2019). Some other studies have looked at capacity planning when there is uncertainty (Jeffrey Logan et al., 2013), differences in deployment between regions (Bistline JET et al., 2022), and how energy policy frameworks have changed at both the federal and state levels (Carley, S. et al., 2020). Most of the work that has come before this one either involves predictive modeling or just looks at a small number of technology or regional areas. There are not many studies that look at the whole development pipeline in an empirical way, incorporating data from all stages—construction, permits, pending applications, and proposals—along with ownership, fuel type, and regional transmission organization (RTO) classifications (Yan, Y. et al., 2025), (Nyaga Githae, B. et al., 2024), (Ataide, M. et al., 2023). Also, national-scale studies that are already out there do not often include important metrics like project attrition, storage trajectories, and ownership asymmetries, which makes them less useful for planning and policy research.

C. Research Gaps and Aims of the Work

Many federal organizations (including the U.S. EIA and FERC) and industry groups periodically publish snapshots of energy trends. However, the academic literature has not yet put all of these data together into a single framework for judging the future of America's utility-scale generation. In particular, the following research deficiencies are clear:

- There is not a full breakdown of new capacity by development stage (construction, permitted, pending, and proposed) with regional and ownership granularity;

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- Energy storage is not given enough attention as a co-evolving infrastructure asset;
- There is not enough quantitative analysis of cancellations and retirements over time, even though they have a big effect on actual generation outcomes;
- There is not a policy-oriented synthesis that links observed data to planning, regulation, and investment.

The goal of this study is to fill up these gaps by providing a complete, quantitative picture of the U.S. energy production development pipeline as of 2025. The study looks at installed capacity, new capacity additions, project attrition, and regional deployment patterns for all major fuel sources and types of ownership. In this way, it hopes to give politicians, utility planners, and grid operators the real-world information they need to back up plans for infrastructure investment, resilience, and reducing carbon emissions.

D. *Contributions and Novelty of the Study*

This paper adds to our understanding of how the U.S. energy system is changing in a number of important ways. First, it brings together and looks at more than 1.3 TW of utility-scale capacity data, including historical and forward-looking datasets from more than 468 GW of new projects that are now being built. Second, it presents a new way to group development stages and ownership types, which shows how market liberalization is affecting future capacity expansion. Third, the report gives the first precise numbers on canceled projects (336 GW since 2017) along with new initiatives and projects that have been retired. This is important information for understanding the risks of implementation and the real-world problems that come up during the transition process. This work also brings attention to a less well-known but more important part of modern power systems: the rise in energy storage. It gives a unique, detailed look of differences in generation planning among regions and RTOs. These dimensions are mostly missing from other national overviews; therefore, our work is a new, data-rich addition that is useful for both academics and practitioners

E. *Paper Layout*

The remainder of this paper is structured as follows. Section 2 presents the current utility-scale generation capacity in the U.S. as of 2025, disaggregated by fuel type and region. Section 3 analyzes the future development pipeline by stage, ownership, and transmission organization. Section 4 examines additions, retirements, and cancellations, providing a historical context for forward-looking trends. Section 5 offers a regional and ownership breakdown, highlighting disparities and transitions in market participation. Section 6 discusses the broader implications for grid resilience, policy design, and infrastructure investment. Finally, Section 7 concludes the paper and identifies avenues for future research, particularly around distributed energy resources, demand-side flexibility, and decarbonization pathways.

II. Current Utility-Scale Generation Capacity in the U.S. (2025)

As of early 2025, the United States has about 1,326,426 megawatts (MW) of utility-scale electrical production capacity installed. This capacity comes from a wide range of fuel sources and is spread out across the country. This number does not include distributed generating, such rooftop solar, but it does include all of the grid-connected capacity that national utilities, transmission operators, and federal agencies keep an eye on (Assia Chadly et al., 2024), (Collins N. Nwagu et al., 2025). Natural gas, coal, and renewables make up most of the national portfolio, and the generation capacity is broken down by fuel type, area, and ownership class.
To technically define generation capacity, let us consider the relation (1) below:

$$C_{total} = \sum_{i=1}^{n} C_i \qquad (1)$$

where C_{total} is the total utility-scale generation capacity and C_i is the nameplate capacity of generation from fuel type i. The national capacity as of 2025 is thus:

$$C_{total} = 1{,}326{,}425.96 \text{ MW} \qquad (2).$$

A. *National Capacity by Fuel Type*

Natural gas continues to be the most important trend, making up 42.7% of total installed capacity, which is 566,692 MW. Coal-fired plants still make up 15.1% of capacity with 200,762 MW, even though their structures are falling apart. Wind power makes up 11.6% (153,878 MW), solar energy makes up 10.1% (134,480 MW), and hydropower makes up 7.6% (100,993 MW). Nuclear energy makes up 7.8% (103,147 MW) of current capacity, even though there has not been any large new development since the 1990s (save for Sections 3 and 4). Figure 1 shows this distribution and emphasizes the 10 fuel types with the largest installed nameplate capacity. The picture shows how important fossil fuels are and how quickly wind and solar electricity are becoming more important.

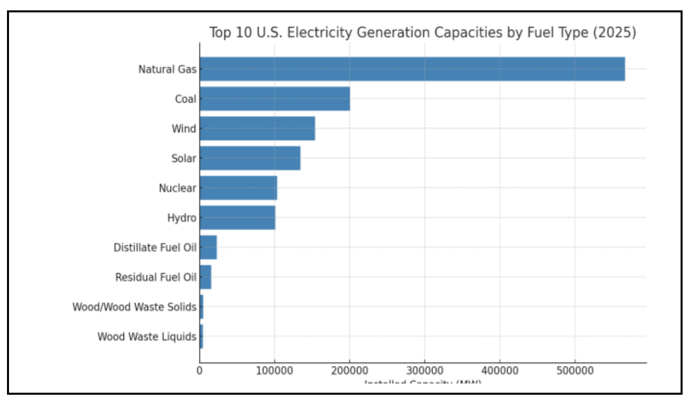


Fig. 1. Top 10 U.S. Electricity Generation Capacities by Fuel Type (2025) (Source: APPA, Hitachi Velocity Suite, 2025)

Fossil fuels still make up a lot of the grid's generating potential, but the rapid increase of renewables, especially solar, shows that people's tastes for technology are changing. It is worth noting that solar capacity has expanded by more than 30,000 MW in 2024, which is a 30% increase in total solar deployment from the previous year.

B. Regional Distribution of Capacity

The infrastructure for generating electricity in the United States is not evenly spread out. Differences in population density, natural resources, policy contexts, and old infrastructure are what cause geographic differences (Flores NM et al., 2023), (Strielkowski, W. et al., 2021). The SERC Reliability Corporation region, which covers much of the Southeast, has the most, with 385,213 MW, or 29% of the total national capacity. The Western Electricity Coordinating Council (WECC) region, which includes California, Arizona, and Washington, comes in second with 270,498 MW (20.4%). The ReliabilityFirst (RF) and Midwest Reliability Organization (MRO) regions come next, with 250,632 MW and 173,591 MW, respectively. The Texas Reliability Entity (Texas RE) runs on its own through ERCOT and is in charge of 152,253 MW, or 11.5% of the total capacity. The Northeast Power Coordinating Council (NPCC) region, which includes densely populated yet transmission-constrained areas like New York and New England, has 86,093 MW. U.S. territories, such Puerto Rico and Guam, add just 8,146 MW. Figure 2 shows the regional distribution of generation capacity, which shows these findings.

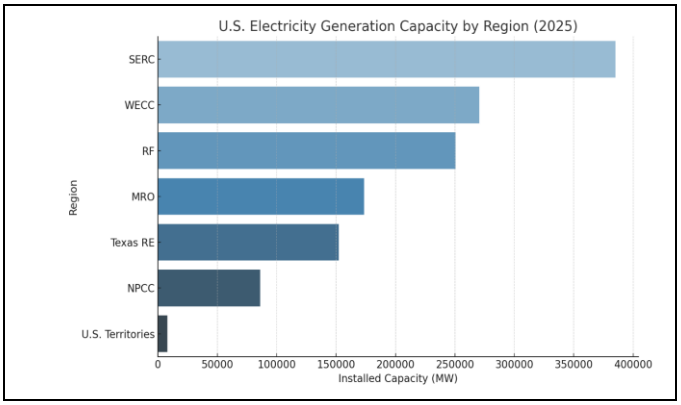


Fig. 2. U.S. Electricity Generation Capacity by Region (2025) (Source: Hitachi Energy Velocity Suite, 2025)

This analysis by area shows that the Southeast and West possess the most overall capacity, but it also shows how important the Midwest and Texas regions are in the continuing energy shifts. Table 1 depicts the U.S. generation capacity by region (2025).

TABLE I. U.S. GENERATION CAPACITY BY REGION (2025)

Region	MW
SERC	385213.44
WECC	270497.71
RF	250631.8
MRO	173591.18
Texas RE	152252.6
NPCC	86092.91
U.S. Territories	8146.32

C. Strategic Implications

The current setup of utility-scale capacity is the structural backbone for long-term resource adequacy, grid reliability, and peaking reserves. But differences in regional energy portfolios could slow down or make the renewable energy transition less fair (Kabeyi MJB and Olanrewaju OA, 2022). For instance, WECC is ahead in deploying wind and hydro power because of its topography, whereas SERC still relies significantly on fossil fuels for baseload generating, especially natural gas and old coal. Also, many areas with a lot of renewable resources have problems with their transmission infrastructure, which makes it harder for projects to get off the ground, especially for wind and solar companies (Seetharaman et al., 2019), (A.G. Olabi et al., 2023). To figure out where future policy and investment incentives should go, you need to know what these capacity numbers mean.

III. FUTURE GENERATION DEVELOPMENT PIPELINE BY STAGE, OWNERSHIP, AND TRANSMISSION ORGANIZATION

The future of electricity generation in the U.S. depends on both installed capacity and the development pipeline. As of early 2025, the utility-scale generating pipeline has 468,582 MW of additional capacity that is currently going through multiple stages of development, including as being built, getting permission, waiting for an application, and being proposed (Seaver Wang et al., 2023), (Gopika Jayadev et al., 2020). This section goes into great detail on this pipeline, breaking it down even more by kind of ownership and membership in regional transmission organizations (RTOs). We define the total pipeline capacity P_{total} is the sum of the capacity at all four stages of development:

$$P_{total} = P_{UC} + P_{PM} + P_{PA} + P_{PR} \quad (3)$$

where P_{UC}, P_{PM}, P_{PA}, and P_{PR} correspond to the capacities under construction, permitted, pending application, and proposed, respectively. Substituting known values (in MW) leads to relation (4):

$$P_{total} = 65{,}207.60 + 78{,}039.37 + 81{,}578.13 + 243{,}757.08 = 468{,}582.18 \text{ MW} \quad (4)$$

Figure 3 shows this breakdown. It shows that the projected stage, even though it is undetermined, makes up more than 52% of the development pipeline. This is followed by pending applications (17.4%), approved capacity (16.6%), and under-construction capacity (13.9%).

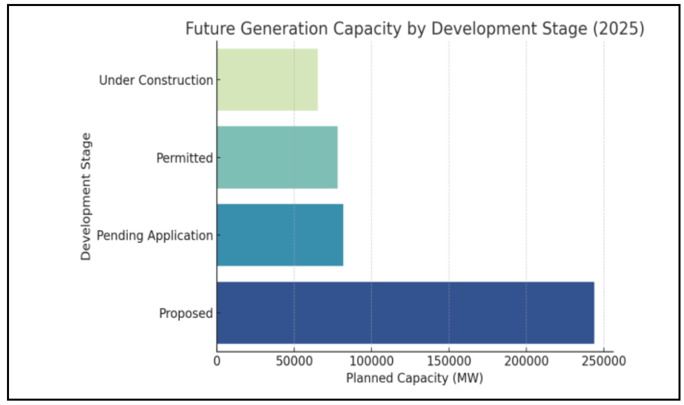


Fig. 3. Future Generation Capacity by Development Stage (2025) (Source: Hitachi Energy Velocity Suite, 2025)

This tiered evolution shows substantial changes in structure. There are 65.2 GW of projects currently under development, which are the most likely additions in the near future. The 243.8 GW of projects in the planned stage, on the other hand, show the market's ambition but have not yet been screened for regulatory, economic, or environmental issues. The ownership structure is a major factor that affects how mature and feasible a project is. Figure 4 shows that non-utility generators are the most important players, owning about 210.3 GW of the proposed generation capacity. This is 86.3% of all proposals. Investor-owned utilities (IOUs) and public power companies provide 19.6 GW and 6.2 GW, respectively. The rest comes from federal and cooperative utilities. This difference in ownership is due to the fact that public power companies have not always had access to tax breaks, whereas independent power producers (IPPs) may quickly raise money in deregulated markets.

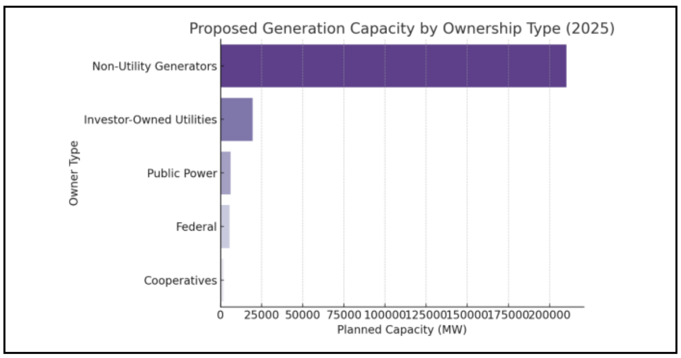


Fig. 4. Proposed Generation Capacity by Ownership Type (2025) (Source: APPA, FERC, 2025)

This distribution has a lot of effects. IPPs have shown that they can efficiently bring together large-scale renewable energy and gas plants, but their dominance raises concerns about how to coordinate the grid, keep prices stable, and plan for resilience, especially in areas that do not have vertically integrated control. Regional Transmission Organizations (RTOs) and Independent System Operators (ISOs) are the main groups that make sure that transmission interconnection and regulatory compliance happen (Ergun, S. et al., 2025), (Muhammad Khalid, 2024), (Talha Bin Nadeem et al., 2023). Figure 5 shows the proposed generation capacity for each RTO region. The biggest part, 32.8% or about 80 GW, is outside of RTO jurisdictions, usually in vertically integrated areas like the Southeast (SERC). PJM ISO and New York ISO stand out among RTOs, nevertheless, with proposed capacity of 47.4 GW and 47.0 GW, respectively. After it, there are Midcontinent ISO (28.9 GW) and California ISO (18.1 GW). ERCOT ISO has the smallest proportion, with only 5.7 GW proposed, even though Texas is a big energy provider. This is probably because its development portfolio is already quite advanced.

This difference between regions shows that developers are making different bets on where to build in the future based on things like market conditions, connectivity queues, regulatory timetables, and governmental regimes. For example, significant interconnection backlogs in PJM have been known to slow down the integration of renewable energy sources, even though there is a lot of market interest (Federal Energy Regulatory Commission (FERC), 2024. The fact that there are so many non-RTO projects in the Southeast shows that vertically integrated utilities with controlled resource planning processes are still in charge. All of these results show how complicated and different the U.S. electrical business is. Even though there are a lot of proposed projects, which shows that there is enough capacity to meet decarbonization goals, the attrition rate for proposed projects is still significant. Since 2017, over 335 GW of projects have been canceled (see Section 6 for more information). So, a realistic future trajectory has to take into account not only aspiration but also practicality, financial closure, grid limits, and regulatory clearance. Finally, the relationship between the type of ownership and the stage of development should be looked at. Non-utility generators are more common in early-stage plans, while IOUs are more common in the allowed and under-construction phases, where it is important to integrate them financially and operationally with existing assets. This gradient shows that different ownership classes have different time frames and levels of risk tolerance when it comes to strategy.

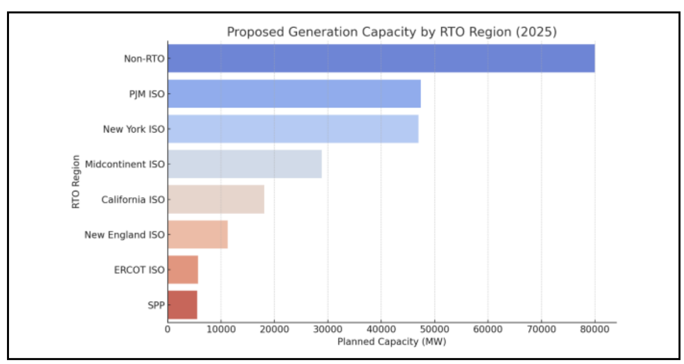


Fig. 5. Proposed Generation Capacity by RTO Region (2025) (Source: FERC, ISO/RTO Council, 2025)

IV. Additions, Retirements, and Cancellations: Historical Trends and Future Outlook

To understand how America's utility-scale power generation capacity has changed over time, we need to look at both proposed and built projects as well as the net effects of actual additions, retirements, and cancellations throughout time (Anna H. Schleifer et al., 2021). These three capacity flow vectors decide how the U.S. energy system will change structurally in a useful way. This part gives a detailed look at those changes from 2017 to 2024, giving us a historical look at how these trends affect and limit future energy transitions. We define the **net realized capacity** (C_{net}) over a given period as:

$$C_{net} = C_{add} - (C_{ret} + C_{can}) \qquad (5)$$

where C_{add}, C_{ret}, and C_{can} denote the cumulative capacities added, retired, and canceled, respectively. For the period 2017–2024, the U.S. utility-scale capacity dynamics are as follows: C_{add} = 265,101 MW, C_{ret} = 135,023 MW, C_{can} = 335,715 MW. Substituting these values into the equation yields to relation (6) below:

$$C_{net} = 265{,}101 - (135{,}023 + 335{,}715) = -205{,}637 \text{ MW} \qquad (6)$$

This negative balance shows a very important structural insight: the U.S. grid has developed, but the number of cancellations has significantly outpaced the number of new capacity additions, especially in the early stages of expansion. Figure 6 shows this, when cancellations are higher than the total of both additions and retirements.

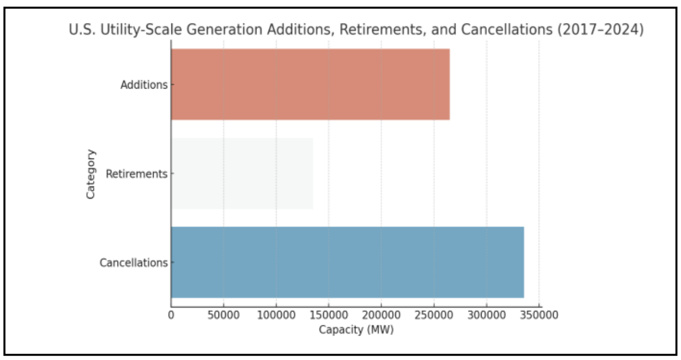


Fig. 6. U.S. Utility-Scale Generation Additions, Retirements, and Cancellations (2017–2024) (Source: Hitachi Energy Velocity Suite, 2025)

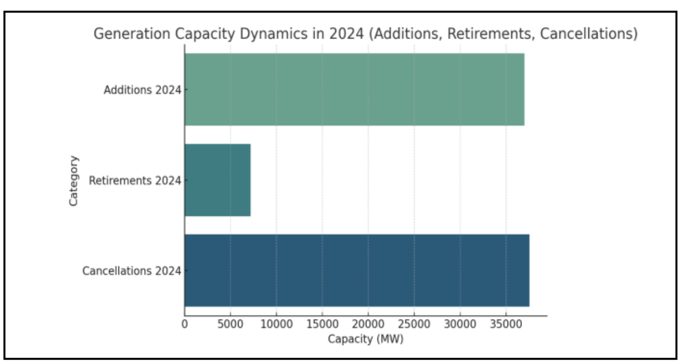


Fig. 7. U.S. Generation Capacity Dynamics in 2024 (Additions, Retirements, Cancellations) (Source: APPA, EIA, 2025)

The year 2024 shows a similar pattern, but the differences are not as big. Figure 7 shows that 37,003 MW of additional capacity were added in 2024. Solar power made up the vast majority of this new capacity (30,290 MW, or 81.9% of the total). At the same time, 7,192 MW of capacity was taken out of service, mostly from coal (49%) and natural gas (41%) plants. At the same time, 37,564 MW of planned capacity were canceled. The majority of these canceled projects were solar (43%) and wind (39%).

The gradual drop in coal is very interesting. The U.S. has shut down more than 83 GW of coal power plants since 2017, and by 2029, another 56 GW will be shut down. This path shows that 69.9% of all announced retirements over the next five years will be from carbon-intensive baseload assets, which is clear evidence that the market is moving away from them. Next is natural gas, which makes up around 24% of impending retirements. This is mostly because peaker units are getting older and low-cost renewables and storage are putting pressure on the economy. Project cancellations also show that there are problems with the way projects are being developed. The huge number of abandoned projects between 2017 and 2024—335.7 GW—shows that there are problems with siting, interconnection delays, regulatory approvals, and financial closures. Most of these cancellations were for wind and solar projects that were still in the planning stages. This shows how fragile speculative development is in a crowded and broken system (Marina Frolova et al., 2025). The yearly trend of cancellations, which in some years is almost equal to yearly additions, also puts grid planners and policy makers at risk. Solar power is the most common type of energy development, but it also has the most abandoned capacity. This split implies that market excitement alone is not enough to turn ambition into reality without simpler permitting, a modernized infrastructure, and ways to lower the risk of financing. We define the retirement replacement ratio (RRR) as the number of new retirees compared to the number of people who leave their jobs over time (Segel-Karpas D et al., 2013), (MacDonald et al., 2011):

$$RRR = C_{add} / C_{ret} \qquad (7)$$

For 2024:

$$RRR = 37{,}003 / 7{,}192 \approx 5.15 \qquad (8)$$

This high RRR means that the economy is growing, with new capacity growing faster than retirements by more than five times. But we need to be careful about how we read this because project cancellations are also going up and the future of anticipated capacity maturation is still unclear. The bigger picture is that while decarbonization and growth are happening, they are happening at different speeds and in different places, and many proposed projects are being dropped before they can be built. So, policymakers and regulators need to look beyond the anticipated capacity numbers and instead focus on the "net realized" contribution of technologies, taking into account both structural retirements and project viability attrition.

V. Regional and Ownership Breakdown: Disparities and Transitions in Market Participation

As the U.S. utility-scale generation industry moves toward a cleaner and more varied energy future, where capacity growth happens and how it happens are very important for making the market fair, strong, and effective (Lawrence Susskind et al., 2022), (Dolf Gielen et al., 2019). This part of the study goes into great detail about future generation capacity, which is defined here as projects that are either being built or have been approved for development. It breaks this information down by region and kind of ownership. These projects are the most likely to happen, and the way they are set up in terms of space and institutions shows big differences in how the energy transition is happening in different parts of the United States. Let G_i be the total planned generation capacity for region or ownership class i, which is defined as:

$$G_i = C_i^{UC} + C_i^{PM} \quad (7)$$

where C_i^{UC} and C_i^{PM} represent the capacity under construction and permitted, respectively.

The Texas Reliability Entity (Texas RE) and the Western Electricity Coordinating Council (WECC) have the most total committed capacity in their regions. Texas RE is building or has permission to build 45,711 MW, and WECC is next with 30,248 MW. The SERC and RF areas also make big contributions, with 26,564 MW and 21,242 MW, respectively. On the other end of the scale, the U.S. Territories only account for 222lr222 Rod, which shows how little infrastructure they do in the utility-scale development story. Figure 8 shows a graphic summary of these distributions, showing where most of the committed utility-scale projects are located.

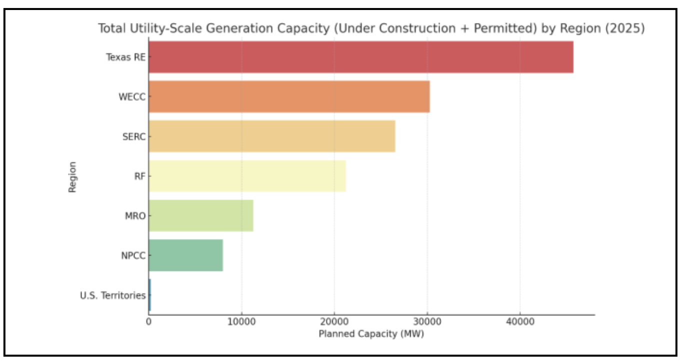


Fig. 8. Total Utility-Scale Generation Capacity (Under Construction + Permitted) by Region (2025) (Source: Hitachi Energy Velocity Suite, 2025)

These geographic patterns are the result of a number of things, including the availability of resources (such solar and wind corridors), the connection to the grid, state-level legislation, and the infrastructure that has been built throughout time. For instance, the Southwest and West Coast benefit from strong solar irradiation and active renewable portfolio criteria. Texas, on the other hand, has a deregulated and very dynamic electricity market with a lot of wind and solar power. On the other hand, the Southeast (SERC) still depends primarily on centralized, vertically integrated utilities and natural gas peaking supplies. Table 2 shows how much power each location can make (2025).

TABLE II. Regional Generation Capacity Breakdown (2025)

Region	Under Construction (MW)	Permitted (MW)	Total MW
WECC	18811.42	11436.33	30247.75
Texas RE	13368.52	32343.22	45711.740000000005
SERC	12993.85	13569.87	26563.72
RF	11270.89	9971.39	21242.28
MRO	4451.21	6816.57	11267.779999999999
NPCC	4089.82	3901.99	7991.8099999999995
U.S. Territories	221.9	0.0	221.9

Ownership structures show even more deep changes in how people participate in the market. Figure 9 shows that non-utility generators (NUGs) make up the vast majority of the generating expansion pipeline. They account for 128,142 MW, or around 89.9% of all capacity that is now being built or has been approved. Investor-owned utilities (IOUs) only make up 11,270 MW of the total, and public power utilities, federal agencies, and cooperatives only make up less than 5% of the total. The fact that public electricity companies have not been able to get federal tax breaks for wind and solar development in the past has made this structural gap even bigger. However, the Inflation Reduction Act's recent modifications are meant to fix this problem.

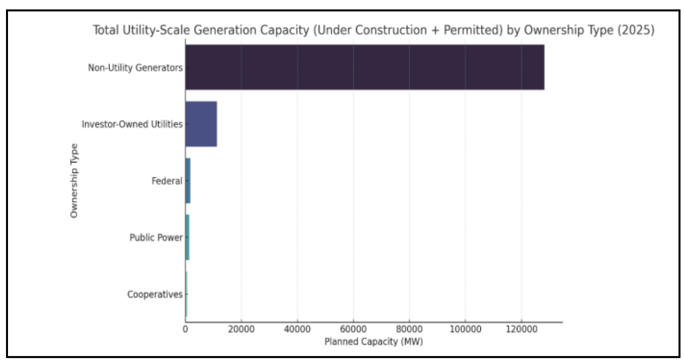


Fig. 9. Total Utility-Scale Generation Capacity (Under Construction + Permitted) by Ownership Type (2025) (Source: FERC, APPA, 2025)

These trends in ownership have strategic effects. NUGs' dominance in capacity development encourages new ideas, lower costs, and faster progress. However, it also makes things harder when it comes to grid integration, coordination, and regulatory monitoring, especially when projects are planned without taking long-term load forecasting or transmission planning into account. On the other side, the fact that only a few public and cooperative utilities are involved may make it harder for energy changes to happen in specific areas, especially in rural or underserved areas. Table 3 shows the breakdown of ownership generation capacity for 2025.

TABLE III. OWNERSHIP GENERATION CAPACITY BREAKDOWN (2025)

Owner Type	Under Construction (MW)	Permitted (MW)	Total MW
Non-Utility Generators	57036.75	71104.92	128141.67
Investor-Owned Utilities	5521.15	5749.3	11270.45
Public Power	1276.7	142.35	1419.05
Federal	759.5	960.0	1719.5
Cooperatives	613.5	82.8	696.3

To assess the relationship between ownership type and regional participation, we define a **market concentration ratio (MCR)** for non-utility actors in each region r:

$$MCR_r = G_r^{NUG} / G_r^{Total} \quad (8)$$

In Texas RE, WECC, and NPCC, this ratio is higher than 0.90, which shows that private actors will have the most influence on future supply portfolios in these areas. On the other hand, SERC and MRO have profiles that are a little more balanced. This is partially because vertically integrated IOUs and regional cooperative associations have been around for a long time. These results show how important it is to make policies and plans that take into account the complicated relationship between regional goals, institutional capability, and private-sector involvement. It's not enough to just raise announced capacity; it also needs to be matched by investments in infrastructure for interconnection, market integration, and ownership models that include everyone so that the energy transformation benefits everyone.

VI. BROADER IMPLICATIONS FOR GRID RESILIENCE, POLICY DESIGN, AND INFRASTRUCTURE INVESTMENT

The changing structure of America's power generation portfolio, which was shown in the previous sections, has substantial effects that go beyond the numbers for individual projects. It changes the basic ideas behind designing power systems, regulating the economy, and keeping the country safe from energy problems. In this part, we look at the systemic effects of the changes we saw, concentrating on three areas that are all connected: grid resilience, policy and regulatory frameworks, and infrastructure investment. Together, these axes decide how well the U.S. electrical sector can reach a future with a lot of renewable energy, minimal carbon emissions, and fairness for all. Not only does capacity redundancy characterize grid resilience more and more, but so do flexibility, decentralization, and intertemporal adaptability. Solar and wind power are growing at an unprecedented rate, making up more than 65% of all new capacity under development. This adds a lot of variability to the system. The classical way of thinking about power balance—making sure that supply always equals demand—now needs more limits:

$$\sum_{i=1}^{n} P_i(t) + S(t) \geq D(t), \forall\ t \in T \quad (9)$$

$P_i(t)$ is the output from generating source i at time t, S(t) is the dispatchable storage discharge, and D(t) is the instantaneous demand. As the amount of variable renewable energy (VRE) grows, we must rely on fast-ramping capacity, demand response, and grid-scale energy storage. This is made even more difficult by the fact that new projects tend to be built in the same areas (Sections 3 and 5), which might make them more vulnerable to catastrophic weather events or transmission congestion if they are not matched by diversification and infrastructure hardening. The observed rise in energy storage capacity—over 165 GW in the pipeline by 2025—partially helps. But a lot of this capacity is still proposed or waiting to be built, and long connections lineups make it take longer to actually use. So, nameplate capacity alone does not make a resource truly resilient. It needs to be dispatchable, located in the right place, and follow the rules. Policy design has to change so that these systemic needs can be met instead than blocked. As indicated in the ownership study (Section 5), 88% of new capacity is owned by non-utility producers. This means that private companies are the main drivers of infrastructure change in the market. But these people have a lot of trouble with the rules, especially when it comes to siting, permitting, and connecting. For instance, the existing backlog of interconnections in PJM and CAISO has put hundreds of otherwise good projects on hold or stopped them completely (FERC, 2024). So, every policy framework that works must fill in three structural holes:

$$\text{Policy Efficiency} = f(P_{access}, P_{approval}, P_{integration}) \quad (10)$$

where P_{access} relates to equitable market entry, $P_{approval}$ to streamlined permitting timelines, and $P_{integration}$ to coordinated infrastructure planning across regions and technologies.

Another conclusion is that there is an urgent need for investment in infrastructure. There is currently about 468 GW of new power being built, but the current transmission infrastructure can't handle this growth. The American Society of Civil Engineers (ASCE, 2023) gives the current transmission system a C– grade since the lines are old, there aren't enough of them in renewable-rich regions, and they don't work together. This presents a paradox: even if generation grows, grid bottlenecks might limit the efficient use of capacity, as has already happened in places like California and Texas that are prone to curtailment. To make sure that capacity growth matches real delivery potential, strategic capital needs to go to:

- High-voltage transmission corridors that connect resource-rich areas with load centers
- Modernizing substations and distribution systems to support bi-directional power flows;
- Advanced grid management systems made possible by digital twins, AI forecasting, and flexible ramping mechanisms.

Figure 10 shows the conceptual framework that brings together these interdependencies. It shows the feedback loops that connect resilience, policy, and investment

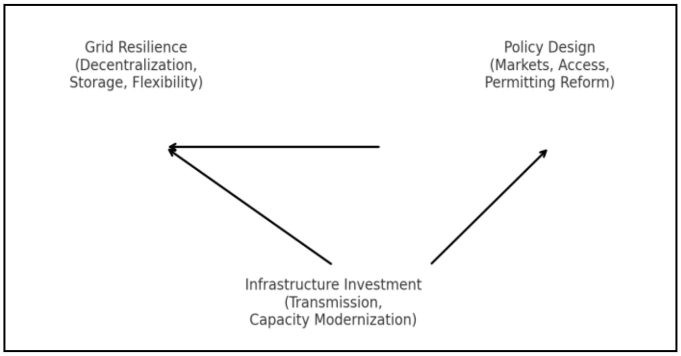


Fig. 10. Conceptual Framework Linking Resilience, Policy, and Investment (Source: Authors, adapted from DOE/NREL frameworks)

Note that the equation is centered. Symbols in your equation have to be defined before or immediately following the equation. Use "Eq. 1" or "Equation 1", not "(1)", especially at the beginning of a sentence: "Equation 1 is . . ." To make your equations more compact, you may use the solidus (/), the exp function, or appropriate exponents. Italicize Roman symbols for quantities and variables, but not Greek symbols. Use a long dash rather than a hyphen for a minus sign. Punctuate equations with commas or periods when they are part of a sentence. The diagram makes it clear that changes in one area are not enough unless they are also made in the others. For instance, making the grid more resilient without speeding up the approval process will slow down project timetables. On the other hand, making it easier for people to get into the market without making sure the grid is stable could cause the system to become unbalanced and make energy less secure.

In general, the data show that the U.S. is on a strong path toward diversifying its generating sources and increasing its capacity. However, for this transition to be successful in the long run, focused reforms must be made to the regulatory framework and the physical infrastructure. The Infrastructure Investment and Jobs Act (IIJA) and the Inflation Reduction Act (IRA) are two new federal programs that offer a lot of funding options. However, there are still major problems with implementation, especially at the state and regional levels. Future grid planning has to move away from a static, supply-focused model and toward a dynamically optimized, resilience-informed strategy that includes social equality, environmental sustainability, and financial accessibility in the core architecture of energy systems.

VII. Conclusions and Future Works

This study has given a full, data-driven look at the current and future utility-scale power generation scenario in the United States as of 2025. We looked at the distribution, fuel mix, ownership patterns, and regional dynamics that affect the changing structure of the national grid. We did this using a large dataset that included over 1.3 terawatts of existing capacity and more than 468 gigawatts of capacity that is now being developed. The results show that the system is changing quickly, with solar and storage taking over, coal continuing to drop, non-utility generating participation rising, and big differences in capacity expansion and investment between regions. In terms of numbers, solar makes up 55% of new capacity being built, and energy storage has grown by 181% in just two years. At the same time, project attrition is still a big problem, with more than 335 GW of projects terminated since 2017. This difference between ambition and reality shows how difficult it is to get permits, connect to the grid, and get funding. These issues need to be fixed for the transition to accomplish its policy and climate goals. The analysis makes three main points from a policy and infrastructure point of view: making the grid more resilient by using flexible and dispatchable resources; making it easier for businesses to get the permits they need to install new technologies; and making sure that capital investments are in line with the real-world availability of renewable resources and the growth of load. We came up with a conceptual framework that connects these three pillars. We stressed that the success of the energy transition depended on the simultaneous progress of technical, regulatory, and financial systems. This article shows that the utility-scale industry represents the structural backbone of the national energy supply, but it also shows where further research and innovation are needed. One important area for future research is how to include distributed energy resources (DERs), such as rooftop solar panels, behind-the-meter batteries, and electric cars, in both planning and operations. As DER use grows, especially in cities and suburbs, their overall effect on net load, voltage stability, and system balance needs to be taken very seriously. Demand-side flexibility is another important area of research. As supply becomes more unpredictable, demand response, time-of-use pricing, and dynamic load shifting can all help keep the grid in balance. To make programs that are both technically sound and socially acceptable, we need quantitative models that link consumer behavior with real-time grid signals.

Lastly, long-term research needs to look at solutions to decarbonize several sectors. Electrifying transportation, buildings, and industry will greatly increase the need for electricity and change how people use it. To find the best paths while keeping emissions, dependability, and cost in mind, we need integrated energy system models that connect the electricity, hydrogen, thermal, and transportation sectors.

In conclusion, this paper shows what the current and near-future utility-scale capacity landscape looks like. However, the energy transition will only be successful if centralized and distributed assets, technological and behavioral changes, and federal and local governance mechanisms are all used together. Future research needs to look at more than just how to make technology work better. It also needs to look at the social, institutional, and environmental aspects of a fair and strong energy future.

Highlights

1. Solar accounts for 55% of all new utility-scale capacity under development in the U.S. as of 2025.

2. Energy storage capacity has grown by 181% in two years, reaching over 165,000 MW in the development pipeline.

3. Coal-fired generation continues to decline, with 83 GW retired since 2017 and 56 GW more planned by 2029.

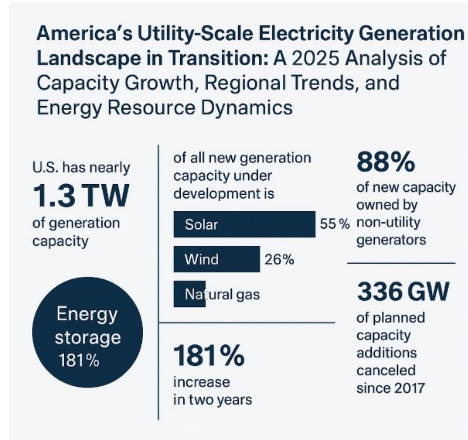
4. Non-utility generators dominate the future energy landscape, owning 88% of planned new capacity.

5. Over 335 GW of planned capacity additions have been canceled since 2017, signaling major execution risks.

Executive Summary

Due to decarbonization, technology, and investment changes, the US power generation environment is changing rapidly. This study analyzes utility-scale electricity generation capacity in all 50 U.S. states and territories using 2025 Hitachi Energy Velocity Suite and American Public Power Association data. Due to rising solar deployment, energy storage, and coal-fired power reduction, the U.S. grid is positioned for a rapid energy transformation with about 1.33 TW of installed generation capacity. The analysis found that solar energy accounts for 55% of new capacity under development and over 80% of additions in 2024. Wind energy development has dropped 22% in the project pipeline compared to last year. Natural gas projects rose 58%, suggesting flexible, dispatchable power sources would continue to balance intermittent renewables. With approximately 11 GW added in 2024 and 165 GW in development, energy storage deployment has surged 181% in two years. Storage technologies are becoming increasingly important for grid flexibility, dependability, and renewable integration. Over 83 GW of coal capacity has been retired since 2017, with 56 GW expected for retirement by 2029. This shows a structural phase-out of carbon-intensive generating. Meanwhile, project attrition remains a major issue: Since 2017, about 336 GW of proposed generating projects have been canceled, more than the capacity added, creating siting, permitting, and market viability issues. Despite providing 9% of the national load, public power utilities own only 2% of new capacity under development, while non-utility generators own 88%. Regional analysis shows that Texas RE, WECC, and SERC dominate new generation activities, while permitted, projected, and constructed capacity differ greatly. Current operational data, development-stage insights, ownership dynamics, and historical cancellation and retirement patterns are unique to this research. It gives policymakers, grid operators, and investors a roadmap for managing a complicated and changing energy sector. The findings highlight the need to align infrastructure planning, regulatory reform, and financial instruments with project execution and grid decarbonization targets.

Graphical Abstract



Availability of Data and Materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Author Contributions

W.F.M.; A.H.: Methodology, Conceptualization, Original Paper Writing; I.D.; P.J.: Resources, Investigation, Software; P.T.: Paper Editing and Final Review, Data Acquisition, Formal Analysis.

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Authors stated that no conflict of Interest.

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Declaration of competing interest

The authors declare that they have no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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