From Stranded Power to Sustainable Energy: Innovative Approaches to Recovering and Reusing Unutilized Electrical Capacity

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Abstract

Electricity systems waste a surprising share of the capacity they already have. Wind and solar output is curtailed when grids cannot carry it, transmission and distribution networks sit well below their limits for most hours of the year, and data centers reserve power for redundancy and worst-case peaks that rarely occur. Anioke (2026) describes this unused electricity and capacity as stranded power. At the same time, demand is rising sharply. The International Energy Agency (IEA, 2025) projects that global data center electricity use will more than double from about 415 TWh in 2024 to around 945 TWh in 2030, and estimates that grid constraints could delay about 20% of planned projects. This article reviews innovative approaches for recovering and reusing unutilized electrical capacity. It covers six groups of approaches, from better measurement and analytics to flexible interconnection and storage. The evidence shows that unused capacity is one of the fastest and least costly resources available for meeting new demand sustainably. The article closes with the barriers that remain and recommendations for operators, utilities, and policymakers.

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Introduction

For most of the history of the electricity industry, the answer to growing demand has been to build. New power plants, transmission lines, and substations were added as consumption rose. This approach is now under strain. The rapid growth of data centers, driven largely by artificial intelligence (AI), has created a wave of large new loads that must be connected within a few years. Anioke (2025) shows that data centers raise total electricity demand, create new risks for grid stability, and complicate the transition to sustainable energy. In many regions, new generation and transmission simply cannot be built quickly enough.

There is, however, another source of supply that is often overlooked: capacity that already exists but is not being used. Every power system contains slack. Anioke (2026) describes such unused electricity and capacity as stranded power, and argues that finding productive uses for it can ease grid pressure while supporting sustainability goals. This article builds on that idea, reviewing the main forms of unutilized capacity and six groups of approaches to recovering and reusing it.

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The Many Forms of Unutilized Electrical Capacity

Unutilized capacity appears at every level of the electricity system. Four forms are especially relevant.

Curtailed renewable generation. When wind and solar output exceeds what the local grid can absorb or transmit, operators order generators to reduce output. This energy is lost. Kim et al. (2017) showed that significant stranded power persists in power systems and that it grows as the share of wind generation increases.

Idle grid headroom. Transmission and distribution net-

works are sized for peak demand, which occurs for only a small number of hours each year. For the rest of the time, much of their capacity is unused. Norris et al. (2025) showed that this headroom is large enough to accommodate tens of gigawatts of new load in the United States, provided that load can reduce its demand during the few hours when the system is under stress.

Stranded capacity inside facilities. Data centers are designed for high reliability. Their electrical systems include redundant feeds, backup generators, and uninterruptible power supplies sized to carry the full load if the main supply fails. Power is also allocated to each server based on nameplate ratings or worst-case estimates. Fan et al. (2007), studying large Google server clusters, found a consistent gap between the power provisioned and the power actually consumed, even at peak. This unused headroom is capacity that has been paid for but does no useful work.

Inefficient supporting systems. Cooling and other supporting systems often run with conservative settings that consume more power than necessary. Every unnecessary kilowatt used for cooling is a kilowatt that could otherwise power computing equipment or be returned to the grid.

Anioke (2025) notes that these forms of waste interact with the planning challenges utilities already face. When facilities request more grid capacity than they truly need, and when available capacity sits idle, the system appears more constrained than it really is.

Approach 1: Making Unutilized Capacity Visible

Recovering unused capacity begins with seeing it. Many organizations do not know how much of their provisioned power they actually use, or when and where curtailment occurs on the grid.

On the grid side, the key data sources are curtailment records, market prices, and congestion reports. Locations that frequently experience zero or negative prices, or persistent transmission congestion, are strong signs of stranded power. Grid models can project how curtailment will change as new renewable projects come online, as Kim et al. (2017) demonstrated in their analysis of where flexible data centers could best absorb surplus energy.

Inside facilities, detailed power metering at the rack, row, and room levels shows how actual consumption compares with allocated capacity. Fan et al. (2007) found that modeling the combined power use of large groups of servers gives a far more accurate picture than adding up individual nameplate ratings, and reveals substantial unused headroom.

Turning these measurements into decisions requires analytics and automation at the enterprise level. Asuri (2019) examines how embedded analytics and modernized user interfaces within enterprise resource planning (ERP) systems can improve visibility and operational performance. Asuri (2023) describes a framework for integrating large language models with enterprise platforms to enable intelligent automation. Applied to energy management, such tools could bring power, asset, and workload data together in one place, allowing operators to identify stranded capacity and act on it routinely rather than through occasional audits.

Approach 2: Recovering Stranded Capacity Inside Facilities

Once stranded capacity has been identified, the next step is to put it to work.

Power oversubscription. Fan et al. (2007) showed that by measuring actual power use and setting limits on peak consumption, operators can safely deploy substantially more servers within the same provisioned power budget. This practice, called oversubscription, relies on power capping, so that servers can be slowed briefly if total demand approaches the limit. It allows a data center to deliver more computing without asking the grid for more power.

Intelligent cooling. Cooling is one of the largest energy uses in a data center after the computing equipment itself. Lazic et al. (2018), working with Google's data center team, developed a model-predictive control system that learns how a data center floor responds to changes in fans, water flow, and other cooling settings. The learned controller regulated conditions on a real server floor using only a few hours of exploratory data and improved efficiency relative to existing controllers. Power saved on cooling can be redirected to computing, effectively recovering capacity within the same grid connection.

Reusing reserve capacity. Anioke (2026) points to the large amount of power capacity that data centers hold in reserve for redundancy. With careful design, some of this capacity can support lower-priority workloads that can be shut down immediately if a failure occurs. The reserve remains available for emergencies, but no longer sits idle the rest of the time. Anioke (2026) notes that recovering capacity in these ways can defer the need for new grid connections.

Approach 3: Dispatchable Computing to Absorb Curtailed Renewables

The second major resource is the renewable energy that grids cannot absorb. Data centers are unusual among large loads because much of their work can be moved in time or between locations. This makes them well suited to soaking up surplus power.

Kim et al. (2017) examined this idea in detail. They found that simply building data centers next to wind farms did not reliably reduce stranded power and could even increase it in some cases. The benefit appeared when data centers were

treated as dispatchable loads, able to raise or lower their demand in response to grid conditions, and placed optimally across the system. Under this approach, flexible data centers reduced stranded power, lowered system costs, and ran at a large share of their capacity on energy that would otherwise have been wasted.

Anioke (2026) identifies several practical uses for stranded renewable power, including flexible computing placed near wind and solar sites. Suitable workloads include AI model training, scientific simulation, large-scale data processing, and other batch tasks that do not need an immediate result.

Approach 4: Carbon-Aware and Grid-Aware Scheduling

Even without building near renewable sites, data centers can align their demand with the availability of clean and uncongested power through intelligent scheduling.

Radovanović et al. (2023) describe Google's carbon-intelligent computing system, which uses forecasts of next-day grid carbon intensity and of computing demand at each data center cluster. It then sets hourly limits on available capacity, delaying flexible tasks to hours when cleaner power is available. The system operates across Google's global fleet, demonstrating that such scheduling is practical at very large scale.

The same forecasting approach can be extended to target stranded power directly. Grid operators and market data can signal when curtailment or negative prices are likely, and scheduling systems can shift flexible work into those periods.

Approach 5: Flexible Interconnection to Unlock Grid Headroom

The idle headroom in transmission and distribution networks is perhaps the largest form of unutilized capacity. Norris et al. (2025) examined the 22 largest balancing authorities in the United States, which together serve about 95% of national load. They found that existing systems could integrate about 76 GW of new load if that load accepted curtailment for an average of just 0.25% of the year. At 0.5% curtailment, the figure rose to 98 GW, and at 1.0% to 126 GW.

These figures reflect a simple fact: grid stress is concentrated in a small number of peak hours. A new data center or other large load that agrees to reduce its demand during those hours can be connected far sooner, using capacity that would otherwise stay idle. Flexible interconnection agreements formalize this arrangement, allowing grid operators to limit a facility's draw at certain times in exchange for faster access. This approach turns unused grid capacity into a resource for growth.

Approach 6: Storage and Hourly Clean Energy Matching

Energy storage provides a way to move stranded power from the hours when it is abundant to the hours when it is needed. The IEA (2025) notes that many AI data centers are installing large battery systems to smooth the rapid power swings of their workloads, and that these batteries could also support the wider grid if the incentives are right. A battery charged with surplus solar output at midday can supply a facility in the evening, reducing its draw on the grid at peak times.

Procurement models also influence how much stranded power is used. Many companies have matched their annual electricity consumption with renewable certificates, an approach that can leave many hours of demand served by fossil generation. Riepin and Brown (2024) studied a stricter model, 24/7 carbon-free energy, in which every hour of consumption is matched by clean generation on the same grid. They found that hourly matching allows buyers to eliminate the emissions linked to their electricity use and reduces system-level emissions by up to 572 kg of CO2 per year for each MWh of participating load. Hourly matching also pushes buyers toward storage and flexible demand, the very tools needed to make use of stranded renewable power.

Sustainability Benefits

Recovering and reusing unutilized capacity delivers benefits across environmental, economic, and operational dimensions.

Lower emissions. Using curtailed wind and solar energy displaces fossil generation that would otherwise serve the same demand. Hourly clean energy matching and carbon-aware scheduling further reduce the carbon intensity of electricity use (Radovanović et al., 2023; Riepin & Brown, 2024).

Less new infrastructure. Every megawatt recovered inside a facility, and every megawatt of grid headroom unlocked through flexibility, reduces the generation and transmission that must be built.

Stronger renewable economics. When curtailed power finds a buyer, wind and solar projects earn more revenue. This improves the financial case for new renewable investment and accelerates the energy transition.

Better grid stability. Flexible demand helps operators balance supply and demand, especially in grids with high shares of variable renewable energy. Anioke (2025) argues that this kind of grid-supportive behavior is essential if data center growth is to be sustainable.

Barriers to Wider Adoption

Despite these benefits, several barriers slow the recovery of unutilized capacity.

Data gaps. Many facilities lack detailed power monitoring, and grid data on curtailment and congestion is not avail-

able in every market.

Reliability concerns. Operators of critical facilities are cautious about any measure that might affect uptime. Oversubscription and the use of reserve capacity depend on reliable monitoring and power capping (Fan et al., 2007).

Cost of flexibility. AI data centers are very capital-intensive, so operators are reluctant to leave hardware idle (IEA, 2025). Flexibility is most realistic for workloads that can genuinely wait.

Intermittency and location. Stranded renewable power is available only at certain times and places, and many sites with abundant curtailment are remote from fiber networks and skilled workforces.

Market and regulatory rules. Many interconnection processes offer only firm capacity, and few markets reward flexible demand or allow facilities to buy curtailed power directly.

Organizational silos. Energy, facilities, and IT teams often work separately. Enterprise platforms that integrate analytics and automation across functions, as discussed by Asuri (2019, 2023), may help close these gaps, but organizational change is often slower than technical change.

Recommendations

Seven steps would help turn stranded power into a mainstream sustainable energy resource:

1. **Measure unutilized capacity systematically,** through detailed facility metering, enterprise analytics, and public grid data on curtailment and congestion (Asuri, 2019; Fan et al., 2007).
2. **Recover stranded capacity inside facilities** through power capping, oversubscription, and AI-based cooling control (Fan et al., 2007; Lazic et al., 2018).
3. **Operate data centers as dispatchable loads** and site flexible computing where curtailed renewable power is abundant (Anioke, 2026; Kim et al., 2017).
4. **Adopt carbon-aware and grid-aware scheduling** for flexible workloads (Radovanović et al., 2023).
5. **Offer flexible interconnection agreements** that let new loads connect sooner in exchange for limited curtailment (Norris et al., 2025).
6. **Move toward hourly clean energy matching** and design storage as a grid asset (IEA, 2025; Riepin & Brown, 2024).
7. **Reform markets and tariffs** so that facilities can buy curtailed power and are rewarded for flexibility (Anioke, 2025).

Conclusion

The electricity system holds a large and largely untapped resource: capacity that already exists but goes unused. Curtailed wind and solar power, idle grid headroom, stranded capacity inside data centers, and inefficient supporting systems all represent value that is currently lost. Innovative approaches now make it possible to recover much of this value. Better measurement and enterprise analytics make unused capacity visible. Oversubscription and intelligent cooling recover capacity inside facilities. Dispatchable computing and carbon-aware scheduling allow data centers to absorb surplus renewable energy. Flexible interconnection unlocks grid headroom for new loads, and storage combined with hourly clean energy matching moves clean power to the hours when it is needed most. The barriers are real but manageable. With coordinated action by facility operators, utilities, technology providers, and policymakers, stranded power can become a cornerstone of a more efficient and sustainable energy system.

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