Read the Liftoff reports

How Clean Energy is the Solution to Rising Electricity Demand

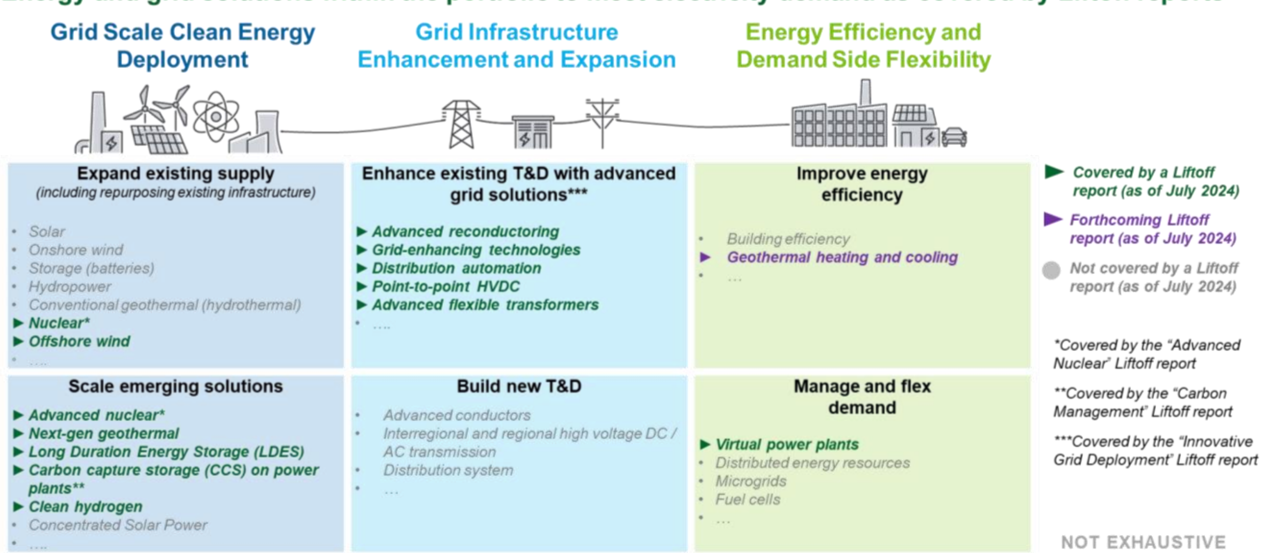
Addressing rising electricity demand requires a portfolio approach to meet near-term demand (3-5 years) with commercially available technologies while paving the way to support long-term (10+ years) growth to stay on the path to a clean energy future.

As outlined in DOE's *Clean Energy Resources to Meet Data Center Electricity Demand*, the United States is returning to a period of rapid electricity demand growth. Electricity demand is expected to grow ~15-20% in the next decade and could double by 2050 to meet net-zero emissions targets – driven by economic development (manufacturing and industrial growth, data center expansion) and beneficial electrification (transport, building, industrial). This level of growth is comparable to historical U.S. demand growth rates that grew rapidly through the mid-2000s. The Department of Energy (DOE) has been anticipating and planning for increasing electricity demand as part of the overall strategy to achieve net-zero emissions targets.

Investing across each segment of the power system – from bulk power generation and storage through the transmission and distribution delivery system and to distributed resources and end-user efficiency – is critical to comprehensively support demand growth. DOE's *2024 Future of Resource Adequacy* report further outlines the portfolio of technology solutions available and necessary enablers (e.g., modernizing interconnection processes, evolving grid market frameworks) to meet electricity demand needs while maintaining a reliable, affordable, and secure grid.

DOE's *Pathways to Commercial Liftoff* series ("Liftoff reports") identifies what it takes to reach commercial deployment at scale for multiple available and emerging energy and grid solutions that are part of this broad portfolio.[1]

Energy and grid solutions within the portfolio to meet electricity demand as covered by Liftoff reports



[1] The Liftoff reports analyze commercialization pathways for clean energy solutions to understand how and when various technologies could reach full-scale adoption. Liftoff reports focus both on emerging and commercially ready but under-deployed solutions and do not evaluate sectors that have already been commercialized at scale (e.g., solar, onshore wind).

Today, solar PV, land-based wind, battery storage, and energy efficiency solutions are some of the most readily scalable and cost-competitive resources to meet rising demand. In addition to continued investment in these resources and expanding grid delivery infrastructure, scaling other energy and grid solutions – such as those covered by the Liftoff reports (e.g., next-generation geothermal, nuclear, grid-enhancing technologies, virtual power plants) – will also be critically important to ensure a cost-optimal, diverse portfolio of resources are readily available to reliably meet demand over time.

Rising Electricity Demand Elevates the Need for Liftoff

For this subset of energy solutions covered by the Liftoff reports, rising demand today supports three opportunities that industry can pursue to help address power needs in the near term and enable the solutions needed for the long term:

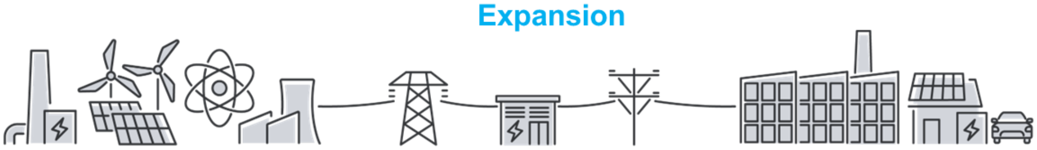
- Invest *now* in clean bulk power generation and storage – including advanced nuclear, next-generation geothermal, offshore wind, power plants with carbon capture, long-duration energy storage, and hydrogen – to ensure expanded availability of these technologies at scale to meet the long-term doubling of demand.
- Enhance the existing transmission and distribution grid *now* by rapidly scaling proven advanced grid solutions (e.g., advanced conductors, grid-enhancing technologies).
- More efficiently serve demand *now* with deployment of virtual power plants and energy efficiency improvements to buildings, industrial plants, and transportation.[2]

Accelerating liftoff for these technologies could collectively add hundreds of gigawatts of capacity on the system to meet demand needs by the mid-2030s.

[2] Note: Energy efficiency solutions are not covered by a Liftoff report (as of July 2024) but are an important demand side management measure. The role of energy efficiency and other available energy and grid solutions are further discussed in DOE's Future of Resource Adequacy report.

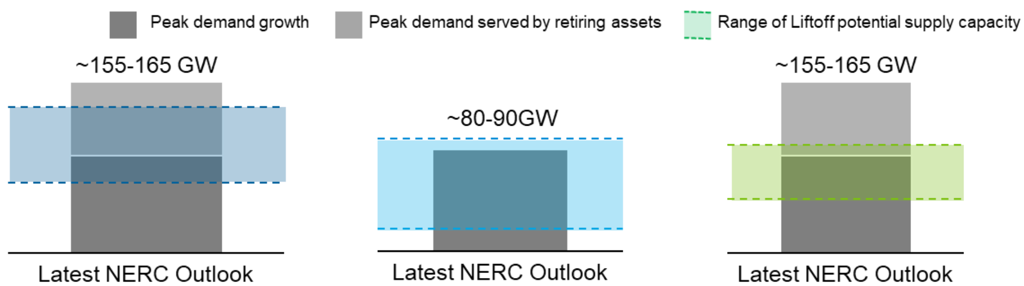
Priority opportunities for liftoff supported by rising electricity demand

Only includes energy and grid solutions covered by the Liftoff reports; does not include all solutions available to serve demand



	Grid Scale Clean Energy Deployment	Grid Infrastructure Enhancement and Expansion	Energy Efficiency and Demand Side Flexibility
Priority opportunities	**Invest *now* in clean bulk power generation and storage** to add baseload supply that complements variable renewables and replaces aging power plants	**Enhance the existing grid *now* with advanced grid solutions** to increase utilization of the existing system	**More efficiently serve demand *now* with Virtual Power Plants** that aggregate distributed resources to serve, shift, and reduce overall demand
Mid-2030s Liftoff deployment potential *(GW)*	**~65-135 GW** Adv. Nuclear, Offshore Wind, Next-Gen Geo., CCS, LDES, Hydrogen*	**>20-100 GW** Advanced Grid Solutions** (*Innovative Grid Deployment*)	**>50-100 GW** Virtual Power Plants

Mid-2030s Liftoff deployment potential vs. peak electricity demand resource needs *(GW)*



Example solutions not covered by Liftoff reports that are also available to meet system needs	*Utility-scale solar, onshore wind, batteries, hydropower*	*New T&D builds, co-location of demand with supply to reduce needs*	*Energy efficiency, micro-grids*

Investment across entire power sector system is needed to meet growing electricity demand; investment in one segment alone is not sufficient to match supply and demand

Average project deployment timeline	**~5-10 years** *(varies by tech)*	**<1-3 years**	**<1-3 years**

*Clean hydrogen as a generation or storage solution is not included in the capacity potential; continued advances in cost reduction and technical performance are necessary to enhance the commercial viability of clean hydrogen as a power solution

***Innovative Grid Deployment* Liftoff report evaluates system capacity impact of deploying individual advanced grid solutions to their full potential overnight. Additional capacity impact is expected to be possible from deploying solutions in combination.

****Virtual Power Plants* Liftoff report evaluates 2030 deployment potential of VPPs at 80-160 GW total (or 50-100 GW capacity additions 2023-30). With continued DER adoption, actual VPP potential by 2035 is likely higher.

Notes: **Liftoff deployment potential:** See footnotes 3, 4, and 7 for additional detail on Liftoff deployment potential.

Resource needs: Resource needs include new peak demand growth (e.g., data centers, electrification, manufacturing) that will need supply resources and replacement of aging assets that are due for retirement and/or that would be retired to meet clean energy goals. The needs of the transmission & distribution grid segment only account for new peak demand growth as it is assumed the new capacity to replace retiring assets could utilize existing T&D infrastructure (note: this is a simplified assumption here; actual T&D need may vary if new resources are not proximate to retiring assets). The resources needs are based on North American Electric Reliability Corporation's (NERC) Long-term Reliability Assessment (LTRA) (Dec 2023) as a proxy for potential trajectory. This outlook represents a ten-year outlook over 2023-2033 and includes all NERC geographies. NERC completed this outlook before 2024 so does not necessarily reflect the latest market developments today as near-term load dynamics evolve. DOE is continuing to monitor load growth developments and will be releasing continued market updates, such as a congressionally mandated report on data center load growth by end of year.

Liftoff Opportunity: Invest now in clean bulk power generation and storage

Investment in continued research, development, demonstration, and deployment of the clean power generation and storage solutions covered by the Liftoff reports must continue and expand in the near term so that these technologies are deployed at scale by 2050 to meet long-term needs. At scale, these technologies can provide essential firm capacity to meet demand and other grid services to integrate variable renewable energy resources.

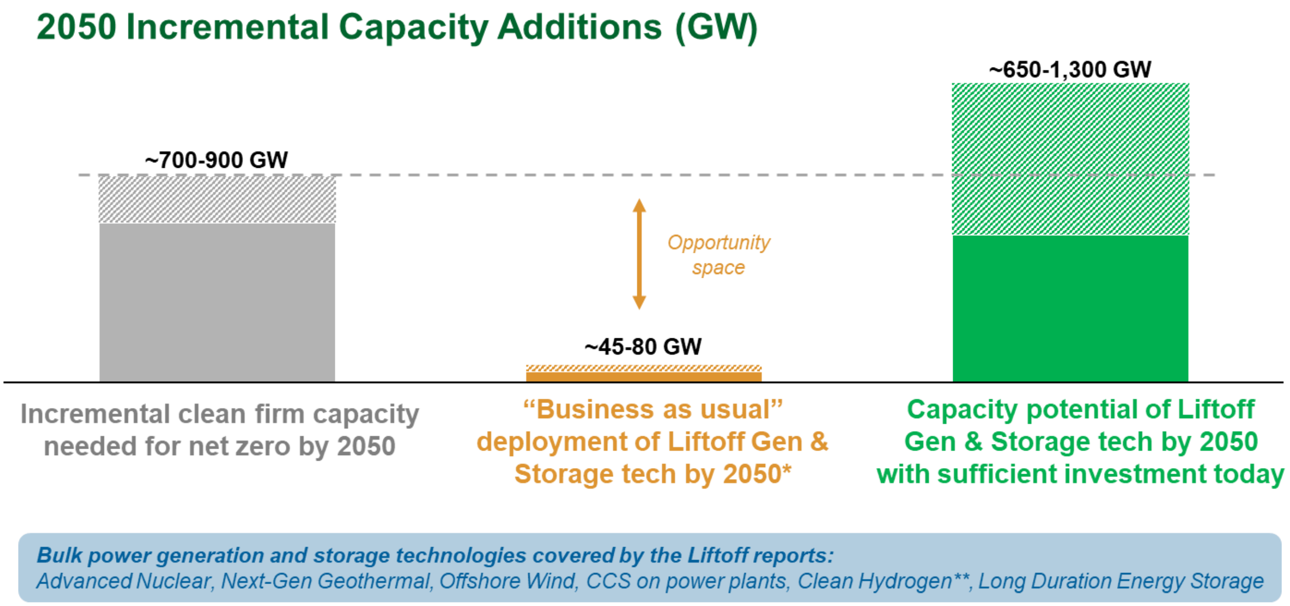
Achieving net-zero in the United States by 2050 requires at least 700–900 GW of additional clean firm capacity, which will enable the increased deployment of variable renewables. Even when priced at a premium per unit of energy, the inclusion of nuclear and other clean firm resources can reduce the system cost of decarbonization by reducing the need for variable generation capacity, energy storage, and transmission. A cost-optimal portfolio includes a diverse mix of clean firm generation, variable renewables, grid expansion and upgrades, and flexible balancing resources, including energy storage of varying durations.

Completing the current pipelines for offshore wind and carbon capture and storage (CCS) projects and significantly investing in other generation and storage solutions (e.g., advanced nuclear, next-generation geothermal, long-duration energy storage (LDES)) could add ~65-135 GW capacity to the grid by the mid-2030s.[3] This is on the order of magnitude of the ~155-165 GW of resources needed by 2033 (including peak demand growth and replacement of retiring assets) based on the North American Electric Reliability Corporation's (NERC) most recent industry outlook. The need for clean firm capacity increases even further if the United States stays on a path to net-zero emissions economy wide by 2050, due to accelerated electrification and the need to replace capacity from existing fossil resources. These early new builds could be co-located and/or deployed in conjunction with new demand growth centers to help meet near-term needs (e.g., co-locating data centers near advanced nuclear or geothermal developments). These solutions could complement continued deployment of other available utility-scale and distributed resources (e.g., land-based wind, solar, virtual power plants, distributed energy resources, microgrids) to meet demand needs.

This early investment is critical so that these technologies are available to deploy at the scale needed to meet 2050 clean energy needs. These technologies could collectively deliver an estimated 650-1,300 GW capacity by 2050, representing ~70-150% of the 700-900 GW of additional clean firm

[3] Mid-2030s Liftoff technology deployment potential assumes Advanced Nuclear = 15 GW operational by 2035 (based on forthcoming Advanced Nuclear Liftoff report update, expected in 2024; includes nuclear uprates, restarts, and new builds); Next-Gen Geothermal = 10-45 GW by ~2035; LDES = 4-13 GW by ~2035; Offshore Wind = 30-50 GW by ~2035; CCS = ~7-10 GW by ~2035 based on currently announced projects. Clean hydrogen as an energy generation or storage solution is not included in the capacity potential but could be a viable capacity source, particularly after the 2030s.

generation needed for net zero emissions by 2050.[4] This indicates that sufficient technical capacity is available to meet future demand needs, providing a pathway for the most cost-effective solutions to be competitively deployed to best meet future system needs. Without sufficient investment in these solutions today to achieve liftoff, only ~45-80 GW of capacity would be added by 2050 under a business-as-usual approach.[5]



*Does not include LDES capacity additions as LDES is not included in NREL's Standard Futures outlook. See footnote 5.

Liftoff Opportunity: Enhance the existing transmission & distribution grid now with advanced grid solutions

Rapidly scaling commercially available advanced transmission and distribution solutions (e.g., advanced conductors, grid-enhancing technologies, system automation technologies) can increase the flexibility, efficiency and effective capacity of the existing transmission & distribution grid. Full potential deployment of these advanced grid solutions could unlock upwards of ~20-100 GW system capacity on the transmission and distribution system to support rising demand (based on individual technology potential; significant additional capacity is possible if advanced grid solutions are deployed in

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[4] 2050 Liftoff technology deployment potential assumes Advanced Nuclear = 200 GW by 2050; Next-Gen Geothermal = 90-300 GW by 2050; LDES = 225-460 GW by 2050; Offshore Wind = 100-250 GW by 2050; CCS = 40-85 GW by 2050 based on NREL Standard Futures Scenario analysis for decarbonization by 2050. Clean hydrogen as an energy generation or storage solution is not included in the capacity potential but could be a viable capacity source, particularly after the 2030s. Additional clean firm generation capacity needed for net zero by 2050 (700-900 GW) is based on NREL's Examining Supply-Side Options to Achieve 100% Clean Electricity by 2035 (2022).
[5] NREL Standard Futures outlook does not include LDES. Technologies considered include cumulative additions of nuclear, geothermal, gas and coal CCS, and offshore wind capacity. NREL's Standard Futures under current policies scenario is used as a proxy for "business as usual" case, with mid-case, high demand growth, and low demand growth scenarios included. NREL, Standard Scenarios 2023 (Jan 2024).

combination).[6] This represents ~20-110% of the ~90 GW of additional peak demand that is expected to come online in the next decade under current trajectories according to NERC.

Enhancing existing grid capacity can help meet electricity demand by reducing curtailment of existing low-cost resources when transmission lines are constrained, enabling interconnection of new supply, and improving system efficiency. In several cases, given the 7-10+ year timeline to build new transmission, these ready-to-go advanced grid solutions – in combination with virtual power plants (VPPs) discussed below – may be some of the only options available to address near-term demand growth where transmission capacity is a primary constraint.

Liftoff Opportunity: More efficiently serve demand now with Virtual Power Plants

Accelerating deployment of commercially available energy efficiency, distributed energy resources (DERs), and VPPs can support demand growth by more efficiently balancing the timing of demand with available supply and leveraging distributed resources. VPPs are aggregations of DERs such as smart appliances, rooftop solar with batteries, EVs and chargers, and commercial and industrial loads that can provide grid services like a traditional power plant. A wide range of VPP configurations and applications to support demand growth are possible based on local operational dynamics. Most VPPs can be quickly deployed on the grid to meet near-term needs; more sophisticated VPPs (i.e., those that export power back to the grid and/or provide locational benefits) often require additional investments in distribution systems and grid control programs.

In recent years, 30-60 GW of dispatchable distributed capacity has been aggregated into VPPs nationally. By 2030, an additional 50-100 GW of VPP capacity could be added to the grid, with additional capacity potential possible by 2035.[7] This could help meet more than 30-65% of the resources needed to serve peak demand by 2033 based on NERC's latest industry outlook.

Cross-Cutting Adoption Risks and Solutions

Alongside scaling up investment, several cross-cutting adoption risks need to be addressed to accelerate market uptake of these solutions to achieve deployment at scale and effectively meet electricity demand growth.[8] Common adoption risks across multiple sectors can be addressed by building consistent market demand, developing industry supply chains and workforces, establishing repeatable project development models, and continuing to streamline permitting and siting processes.

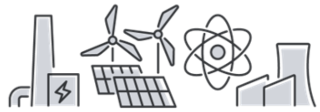
[6] Deployment potential based on Innovative Grid Deployment Liftoff (Apr 2024). 20-100 GW value represents potential incremental peak demand that could be supported from deployment of individual grid technologies to their full potential on the existing T&D grid; greater capacity impact is potentially possible when technologies are deployed in combination. Peak demand growth based on NERC Long Term Reliability Assessment (Dec 2023).
[7] Deployment potential based on Virtual Power Plant Liftoff report (Sept 2023). For the current state, most of the 30-60 GW of VPP capacity today is in demand response programs that are used when bulk power supply is limited; these programs turn off or decrease consumption from DERs such as smart thermostats, water heaters, and commercial and industrial equipment.
[8] Challenges represented in ARL figure are based on respective Liftoff reports for each technology.

Key adoption risks to be mitigated for sector liftoff

Only includes energy and grid solutions covered by the Liftoff reports; does not include all solutions available to serve demand
Indicates key adoption risks for each technology; not for comparison across technology sectors (between columns)

- ● *Primary adoption risk*
- ○ *Secondary adoption risk*

Grid Scale Clean Energy



Grid Infrastructure | **Demand Side Flexibility**

Adoption Readiness Levels Risk Dimensions *(not exhaustive)* ▼	Offshore Wind	Next-gen Geothermal	Advanced Nuclear	CCS	LDES	Hydrogen*	Advanced Grid Solutions	Virtual Power Plants
Value Proposition								
Functional Performance (perceived & actual operational risks)		●			●		○	○
Ease of Use / Complexity (operational switching costs)							●	●
Market Acceptance								
Demand maturity (barriers to entry with incumbent solutions advantaged and/or off-take is not easy/standardized and does not meet the solution's needs)		○	●	●	●		●	●
Downstream value chain (non-existent, highly fragmented, or split incentives across value chain)							●	●
Resource Maturity								
Manufacturing & supply chain (new or expanded supply chain necessary for deployments)	●		●		●	●	○ (some tech)	
Workforce (workforce is limited and/or significant training is required)	○	○	●	○	●	○	●	○
Capital flow (significant capital needed, esp. from high-risk taking investors)		●	●					
Project development (need to build repeatable project execution processes)	○		●			●	●	●
Infrastructure (significant investment in foundational systems necessary)	○			●			○ (some tech)	○
License to Operate								
Regulatory and policy (regulatory and/or policy changes necessary to enable adoption)					○	●	●	●
Permitting and siting (complex and time-consuming process, with multiple overlapping jurisdictions in play)	●	●	●	●		○		
Community perception (perception risks that could slow deployment)	○	○	○	○		○		

*Hydrogen column is focused on power generation and storage applications; not inclusive of other hydrogen applications.
Note: Adoption Readiness Level (ARL) risk dimensions shown are a subset; see the ARL Framework developed by DOE's Office of Technology Transitions for a complete list of ARL dimensions.

Near-term electricity demand growth is a major opportunity, particularly for early movers in the investment and technology communities, to both accelerate and benefit from the scale-up and broad commercial deployment of these energy solutions covered by the Liftoff reports.

Industry momentum is building to further deploy these tools to address demand growth and grid needs – including in ways that mitigate costs to ratepayers. For example, to serve local manufacturing and data center demand needs, Duke Energy recently announced an agreement with Amazon, Google, Microsoft, and Nucor to explore innovative financing structures that can support deployment of new carbon-free energy generation (such as advanced nuclear) in the Carolinas. Google also announced a new "Clean Transition Tariff" with NV Energy in Nevada to spur development of next-generation geothermal and other clean generation. California's Public Utility Commission mandated procurement of 1 GW of clean, firm power by 2026, which has driven 262 MW of new geothermal power purchase agreements. In July 2024, the Electric Power Research Institute (EPRI) launched the GET SET initiative to support utilities with the deployment of grid-enhancing technologies. The Federal Energy Regulatory Commission (FERC) now requires the consideration of advanced transmission technologies in upgrades to existing and new transmission as part of its transmission planning rule (Order No. 1920).[9] To improve demand management, Colorado policymakers signed a bill requiring the local utility (Xcel Energy) to create a VPP program by February 2025, building on Xcel's existing distributed energy resource programs.

Building on this momentum, actions that mitigate cross-cutting challenges can unlock progress across multiple sectors at once. These key actions include:

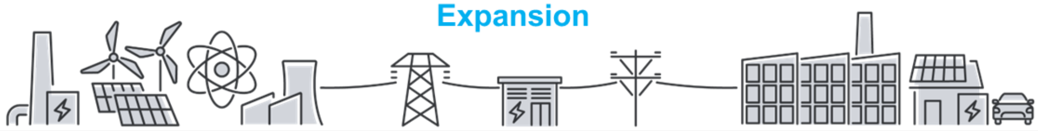
- **Establishing forward-looking, committed orderbooks** to spur deployment of new generation resources (e.g., new offtake models for next-generation geothermal that include upfront capital investment; several committed orderbooks for one advanced nuclear reactor type to benefit from economies of scale).
- **Evaluating virtual power plants and advanced grid solutions as options to address near-term electricity demand hotspots** and rapidly deploying identified, cost-effective solutions to meet needs. Transparently sharing the outcomes of these deployments can support broader awareness and execution know-how to drive industry-wide uptake.
- **Standardizing and simplifying project development processes** to streamline deployments, reduce costs, and accelerate timelines (e.g., customer enrollment for VPPs; permitting for generation & storage; interoperability and operational processes for advanced grid solutions).
- **Revamping grid planning and market structures** to fairly integrate and compensate new energy solutions for their system value (e.g., aligning utility incentives; high-value PPAs for clean, firm generation).
- **Engaging local communities and labor groups** early, frequently, and transparently to de-risk deployments, overcoming adoption challenges while distributing benefits equitably.

[9] The advanced transmission technologies included advanced conductors, dynamic line rating, advanced power control, and transmission switching/topology optimization. Order No. 1920 built off of previous rulings, such as FERC Order No. 2023, which required consideration of several advanced grid solutions (e.g., dynamic line rating) in upgrades to interconnect new supply.

Key actions to advance deployment of solutions covered by the Liftoff reports

Only includes energy and grid solutions covered by the Liftoff reports; does not include all solutions available to serve demand

	Grid Scale Clean Energy Deployment	Grid Infrastructure Enhancement and Expansion	Energy Efficiency and Demand Side Flexibility



Priority Opportunities	**Invest *now* in clean bulk power generation and storage**	**Enhance the existing grid *now* with rapid deployment of advanced grid solutions**	**Better manage demand *now* with rapid deployment of VPPs**

Key Actions *& stakeholders*

Establish forward-looking committed orderbooks (Grid Scale Clean Energy Deployment)
- *Grid operators*
- *Off-takers*
- *Tech. providers & developers*

Evaluate as options to address near-term demand needs (Grid Infrastructure Enhancement and Expansion; Energy Efficiency and Demand Side Flexibility)
- *Grid operators*
- *Off-takers*
- *Regulators & policymakers*
- *Technology providers & developers*

Standardize and simplify project development processes
- *Grid operators*
- *Technology providers & developers*
- *Industry ecosystem (trade associations, consultants etc.)*
- *Community & labor groups*

Revamp grid planning and market reforms
- *Grid operators*
- *Regulators & policymakers*
- *Off-takers*

Engage local communities and labor groups to de-risk deployments
- *Grid operators*
- *Regulators & policymakers*
- *Technology providers & developers*
- *Industry ecosystem (trade associations, consultants etc.)*
- *Community & labor groups*

KEY STAKEHOLDERS IDENTIFIED ARE NOT EXHAUSTIVE

Industry – including utilities, grid operators, and large-load customers (e.g., data centers, manufacturers) – with support from federal and state policymakers and regulators can proactively prioritize these technologies to ensure investment flows toward improved energy solutions. This can ensure a cost-optimal portfolio of a diverse mix of clean firm generation, variable renewables, grid solutions, and flexible balancing resources is available over time. Unprecedented levels of federal funding and technical resources in combination with private sector capital can scale the ready-to-go technologies to help meet near-term demand and continue expanding investment in emerging sectors to support long-term needs.

Want to learn more about DOE resources relevant and available to support rising electricity demand?

Visit **energy.gov/electricitydemand** to learn more about DOE's research, funding opportunities, technical assistance programs, and other resources relevant to electricity demand growth.