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Powering a New Era of American Innovation

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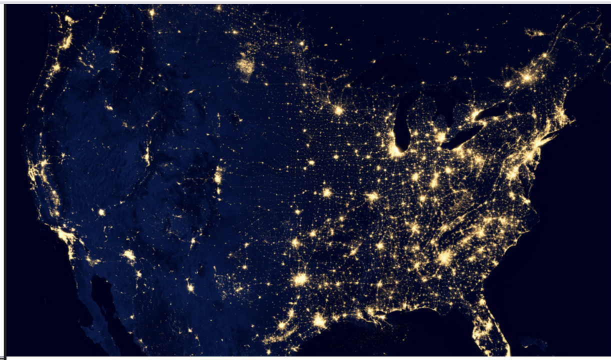
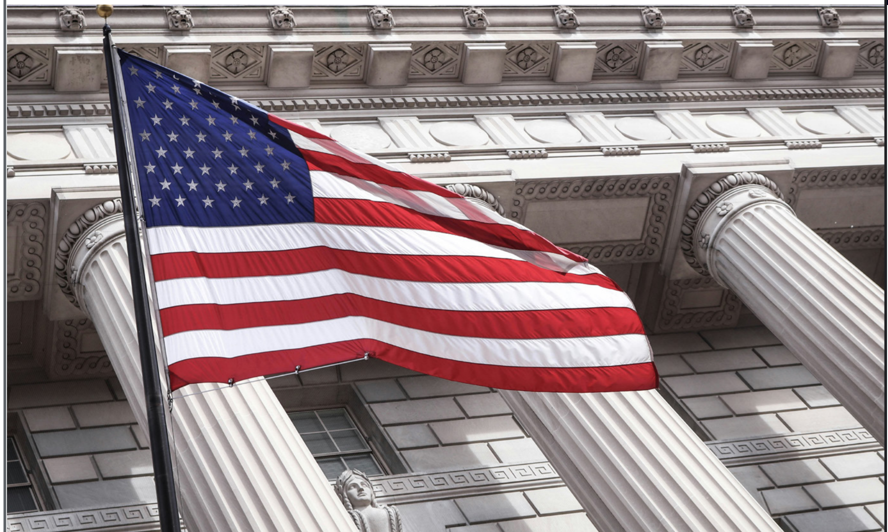




The United States has a generational opportunity to build a new era of American innovation and growth.

The deployment of artificial intelligence (AI) will grow the American economy, create jobs, accelerate scientific advances, improve health and educational outcomes, and strengthen national and global security.

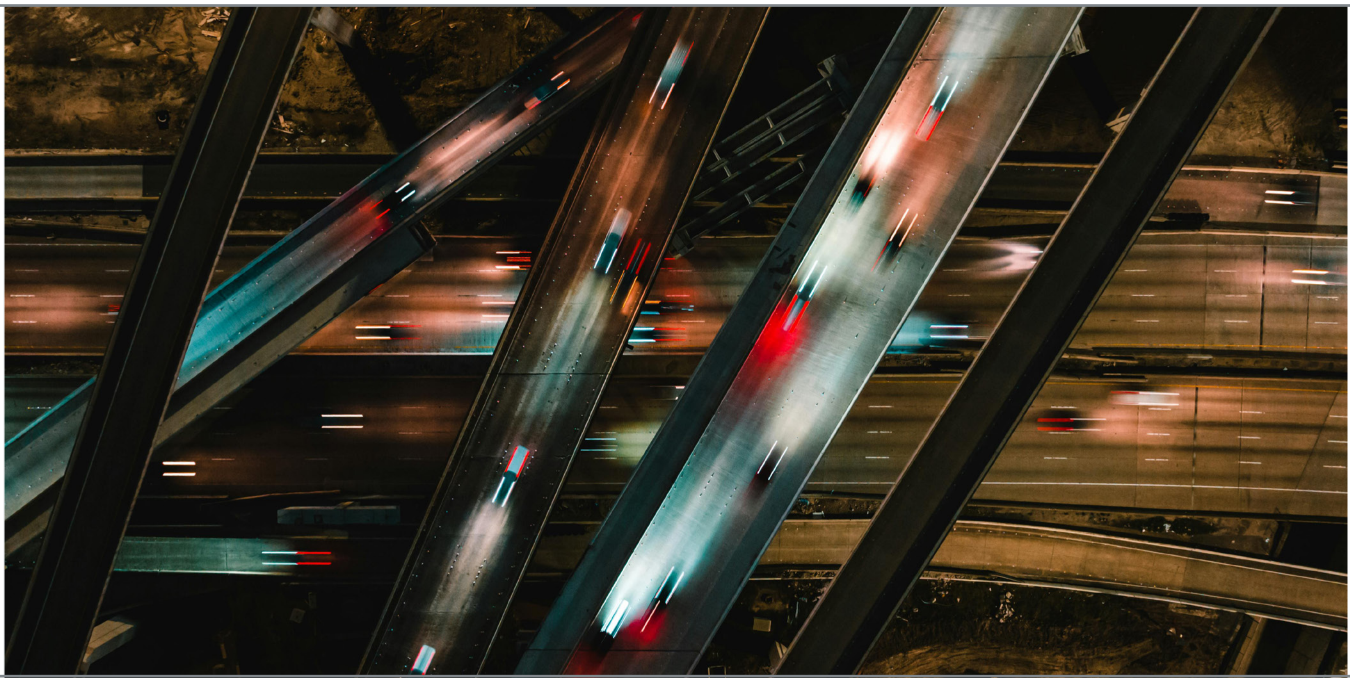
AI presents the United States with a generational opportunity for extraordinary innovation and growth. Fully realizing these opportunities will take a focused, forceful, and expedited effort to increase the capacity of the existing, sometimes antiquated U.S. energy system.

The good news is that the steps required to power growth are within our reach. These include:

1. Accelerating innovation and investment in affordable, reliable, and secure energy technologies, including geothermal, advanced nuclear, and natural gas generation with carbon capture (among other sources)
2. Optimizing use of the existing grid and unlocking construction of new transmission infrastructure
3. Developing the labor force needed to construct new infrastructure

Building upon Google's nearly two decades of investing in energy innovation and policy, in this paper we identify and discuss 15 additional policy opportunities that would power a new era of American leadership.

By unlocking advanced electricity resources and grid infrastructure, the United States would enable all sources of electricity to contribute to a more reliable and affordable energy future. Many of these proposals have been incubating in policy circles for some time, reach across a broad base of stakeholders and are drawn from the broader discussion of policy options. They now require constructive public and private collaboration to advance.



Sizing the economic upside and the energy required to power it

History is clear: technological development drives growth and prosperity, and AI is poised to be a central driver of the next wave of expansion. Indeed, AI could be a sizable catalyst to economic growth, with economists estimating that adoption of the technology could contribute trillions of dollars to U.S. GDP over the coming decade.[1]

Beyond economic growth, AI is enabling an acceleration in scientific breakthroughs across many domains and helping people deliver high-quality solutions in health, education, and more.

Leading in AI and digital transformation, however, requires a significant increase in U.S. electricity supply. In 2024, the Federal Energy Regulatory Commission (FERC)'s five-year demand growth forecast more than tripled compared to the same forecast in 2023, with the United States expected to use an additional 128 gigawatts (GW) before the end of the decade.[2] This expansion is driven by data center demand increases, manufacturing onshoring, and continued economic growth.

Economists have long found a direct causal relationship between energy consumption and economic growth.[3]

After limited demand growth rates over the past two decades (average of 0.62% annually during the 2010s and 0.42% in the 2000s), a return to load growth could require electricity sector investment over the next five roughly double the amount invested in the previous five years.[4]

The magnitude of energy demand from AI (estimates range from 15-90 GW of new U.S. data center demand by 2030[5]) will ultimately be driven by the ability of the public and private sector to unlock the economic upsides of AI, as they evolve industrial processes, business models, and operating procedures — as in technological evolutions throughout history.

Efficiency gains in the AI technology stack will help bend the electricity growth curve. Improving efficiency in AI has been and remains a top focus for hyperscalers, continuing a trend seen for decades.

128 GW

FERC's estimate for energy growth before 2030

Notably, energy efficiency gains have historically occurred much faster in data centers than other sectors of the economy.

Between 2010-2018, global data center energy consumption increased by 6% while compute workloads increased 550%, implying energy intensity decreases of ~20% per year.[6] This is achieved with improvements in everything from models and hardware to data centers themselves.

For example, at Google we're seeing advances in:

1. **Model training** - Google has identified tested practices that can reduce the energy required to train an AI model by up to 100x[7] relative to five years ago.
2. **Hardware** - Ironwood, Google's newest Tensor Processing Units (TPU), is nearly 30x more power efficient than our first Cloud TPU from 2018[8].
3. **Data Centers** - Our highly efficient data centers now deliver ~4 times as much computing power[9] per unit of electrical power as they did five years ago.

Given the growth in demand for new and increasingly powerful AI tools, even with these kinds of efficiencies, more power will be needed to unlock the full potential of AI-driven growth.

A path to accelerate innovation, investment, and execution

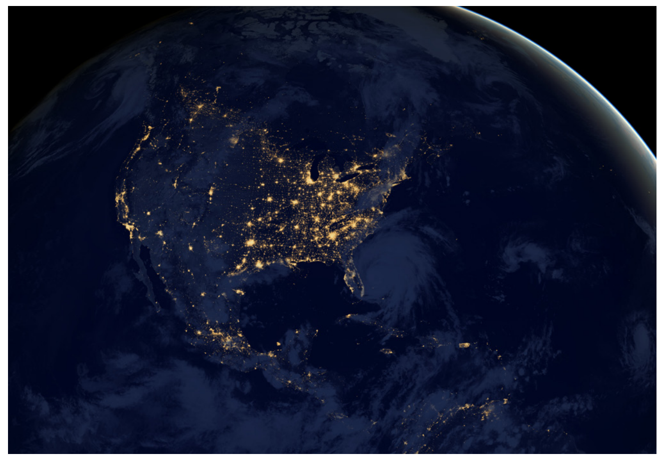
Leaders across business and government should focus on three key areas:

1. Accelerate innovation and investment in advanced energy generation
2. Optimize use of the existing grid and unlock construction of new transmission infrastructure
3. Develop the labor force required to construct new American infrastructure, including training programs for electricians

01

Accelerate innovation and investment in advanced energy generation

Across the country, many different players, from traditional energy providers to startups, are developing and deploying new solutions to increase energy supply.



For example, at Google, we are supporting innovation, development, and deployment of a range of energy resources and technologies, including through the world's first corporate agreements to purchase advanced geothermal[10] and advanced nuclear from small modular reactors[11] (SMRs), among other technologies.

Looking ahead, ushering in an era of abundant growth requires accelerating investment in many sources of energy, including geothermal, advanced nuclear, and natural gas generation with carbon capture and sequestration (CCS), as well as flexible energy resources like demand response (managing facility usage to reduce stress on the grid at peak times of day) and energy storage.

Not only do these technologies offer the promise of diversifying and expanding U.S. energy resources, they also complement the load characteristics of the data centers.

Mature variable energy technologies that are fully developed and currently waiting to interconnect to the grid will also support near-term growth. But advanced energy resources in particular face a variety of market and regulatory challenges:

Advanced nuclear - Construction cost overruns with recent first-of-a-kind advanced nuclear projects have created financial and technological uncertainties that have delayed investment and innovation. Lengthy and complex processes for Nuclear Regulatory Commission licensing pose a hurdle to meeting requests for plant life extensions, restarts, uprates for existing plants, and design certifications and construction of advanced reactors. The United States continues to lack a robust domestic nuclear fuel supply chain, with historically low levels of mining output, no domestic uranium conversion, and only two domestic commercial enrichment facility for fuels needed for advanced reactors.[12]

Advanced geothermal - Lengthy permitting timelines and multiple environmental reviews for geothermal sites prolong development timelines and raise costs. Projects face uncertainty in costs for exploratory drilling and resource development. As geothermal drilling technology advances create access to a wider set of subsurface resources, it will be critical to continue to improve our ability to identify promising locations for geothermal wells.

Demand response - Although demand response offers a flexible, low-cost way to balance the grid and reduce peak load, scaling it to meet the needs of a more electrified and AI-driven economy requires deeper integration of demand response capabilities into regional markets as well as streamlining market participation rules and methodologies nationwide. As AI-related loads expand, demand response frameworks will need to adapt to reflect the unique characteristics of AI load profiles to enable their participation.

Natural gas and carbon capture with sequestration - In most countries throughout the world, a portion of any electricity drawn from the grid comes from natural gas. Limited turbine availability and manufacturing bottlenecks, as well as demand-stimulated price increases, create supply chain headwinds for new natural gas plants. The nascent state of midstream CO2 pipelines, the patchwork of state regulations governing pipeline permitting, and the lack of clear federal permitting authorities pose challenges for sequestration infrastructure development. Above-market costs for capture technologies with a limited track record at commercial scale create investment and cost uncertainties. Emerging efforts to use satellite-based monitoring and tracking of emissions leakage can help measure and verify storage and emissions integrity.

To address these challenges, we see eight policy opportunities where government and industry can work together:

1. **Manage nuclear cost uncertainties** - Building on recently introduced legislation, Congress can advance federal legislation to mitigate the risks of uncertain costs by expanding Department of Energy Loan Program Office authorities or establishing advanced nuclear cost-overrun mitigation solutions.

2. **Accelerate nuclear permitting** - The NRC can implement ADVANCE Act reforms[13] by accelerating pre-licensing diligence and engagement with nuclear project developers and by establishing reasonable timelines for processing license amendment requests.

3. **Create a domestic nuclear fuel supply** - The Administration can accelerate implementation of the Nuclear Fuel Security Act[14], which requires the Department of Energy to increase production of advanced nuclear fuels, for example, by establishing benchmarks for progress.

4. **Streamline National Environmental Policy Act (NEPA) requirements for key energy resources** - Congress can help speed permitting for energy resources like advanced nuclear, geothermal, and carbon capture by expanding categorical exclusions for these resources and reforming the judicial review process, amongst other measures. As one example, legislation can help expedite NEPA approvals for geothermal on lands that have been previously developed.

5. **Expedite permitting approvals for advanced geothermal** - Congress can institute processing deadlines for federal leasing and drilling permits to speed site development. States can increase their capacity to manage geothermal project permitting for drilling outside of federal lands. The Administration can continue to enhance U.S. Geological Survey subsurface resource characterization to identify promising locations for geothermal wells.

6. **Streamline CCS regulatory requirements** - Congress can establish federal authorities for permitting and siting of CO2 pipeline infrastructure. The Environmental Protection Agency (EPA) can continue to expedite permitting processes for Class VI wells, including further development of state primacy programs.

7. **Enable voluntary data center participation in demand response frameworks** - FERC can work with grid operators, utilities, and data centers to identify frameworks to incentivize data centers to be flexible in response to dynamic real-time grid conditions, building on recent efforts like Order 2222. Congress can set direction by providing clear statutory guidance on this topic to FERC.

8. **Maintain carbon capture and technology-neutral energy tax incentives and transferability** - Congress can maintain key programs that provide important support to help de-risk new energy projects and speed deployment of advanced energy technologies, including:
   - The 45Q tax credit which helps accelerate development of carbon capture and removal solutions, including by offering a financial incentive for fossil-fuel fired power plants that capture and sequester carbon emissions,
   - The technology-neutral 48E investment tax credit and 45Y production tax credit, each of which support deployment of new energy resources like advanced nuclear and geothermal, and
   - The 6418 provision for the transfer of credits to partners with tax liability who can monetize these credits, which deepens the pool of capital market participants who can support project development.

02

Optimize use of the existing grid and unlock construction of new transmission infrastructure

Today's grid often provides as much of a barrier to the delivery of abundant energy as the energy supply itself.

That's what motivated the incubation and development of the Alphabet company Tapestry[15], which develops AI tools to help grid planners do large-scale, hour-by-hour grid simulations up to 20 years into the future. Tapestry recently announced a partnership[16] with grid operator PJM to use Google DeepMind's AI tools to optimize interconnection of new energy resources.

In addition, Google has developed technology to shift power consumption at our data centers[17] as needed to provide valuable flexibility to help local grids operate reliably and efficiently.

Today's electricity grid is too often underutilized because of misaligned utility incentives that discourage optimization of transmission capacity.

Further, a variety of challenges constrain efforts to build new transmission infrastructure, in particular, permitting bureaucracy, narrow utility grid planning, and fragmentation of physical grids and markets, especially in the West:

Misaligned incentives for optimizing grid capacity - The traditional utility regulatory compact in most U.S. states provides a fixed return for every dollar invested, which incentivizes ever-higher capital expenditures and disincentivizes optimization of returns on invested capital. This discourages use of grid-enhancing technologies (GETs) that can get more capacity out of existing infrastructure by using the grid more efficiently. Studies estimate that these tools could unlock up to 100 GW of additional transmission capacity.[18]

Lengthy transmission project permitting timelines - Planning and permitting a new large transmission line can take a decade or more. A new interstate transmission project needs rights of way from landowners and approvals from each state public utility commission along its route. But states often disagree over how to determine who benefits from — and thus who pays for — a transmission line.

Lengthy NEPA permitting - NEPA environmental impact statements (EIS) for infrastructure projects take an average of three years to complete, run to more than 1,200 pages, and are often subject to pre-development litigation.[19] For infrastructure projects like nuclear, geothermal, carbon capture, or transmission that frequently require an EIS, the lengthy process and exposure to litigation can raise costs and delay projects.

Narrow grid planning - A carryover from the 2010s when U.S. electricity consumption stayed relatively flat,[20] transmission system planning is often focused on local reliability needs, without sufficiently anticipating demand-growth scenarios across broad, regional footprints.

1,200

Average number of pages of NEPA environmental impact statements

Fragmented electricity grids and markets - In the Western United States there are 38 separate "balancing authorities" that act largely as independently planned and operated grids.[21] This fragmentation results in higher costs, reduced market competition, and less customer choice relative to large regional electricity markets in other areas of the country.

Transmission infrastructure supply chain bottlenecks - The power demand for data centers, new generation, and replacement of aging infrastructure has increased demand for power transformers - equipment critical for both data centers and power generation stations. Supply of transformers remains constrained, driven by a consolidated manufacturing sector and reluctance to invest in production expansion given long break-even timeframes. This supply-demand mismatch has increased wait times for new equipment to 36-48 months.[22]

Optimizing the grid and unlocking new construction will take concerted policy solutions. Here are six suggestions:

1. **Encourage use of Grid-Enhancing Technologies in grid planning** - State legislatures and Congress can pass bills that require consideration of GETs in utility transmission and resource planning. States like Colorado, California, and Virginia have already adopted new ways of working with utilities to get more energy out of the existing grid.

2. **Align utility incentives for grid optimization** - Shared-savings mechanism can give utilities deploying GETs part of the savings (avoided grid-congestion costs) from new transmission system capacity.

3. **Streamline Transmission Permitting** - Congress can pass a permitting reform bill to expedite construction of new transmission lines, such as the transmission provisions in the bipartisan Energy Permitting Reform Act of 2024[23]. That bill would create standardized cost-allocation processes and streamline permitting approval for large transmission lines determined to be in the National Interest.

4. **Ensure comprehensive grid planning** - Legislators and regulators can help ensure that grid planners and utilities take a long-term view of electricity system planning. FERC Order 1920A, which was finalized in 2024 and which grid operators are now preparing to meet, already requires 20-year grid planning that considers seven specific factors in scenario modeling, with updates every five years. Congress can ensure durability of these measures by giving additional statutory guidance to the FERC.

5. **Establish regional electricity markets in the West** - Given growing momentum in Western states, legislatures can advance bills that opt their state electricity system into a regional market. FERC can continue to support regional electricity market expansion, building on its approvals of two proposals in 2023[24] and 2025[25] that would enable a western-region-wide energy market.

6. **Defense Production Act Reauthorization and Title III Appropriations** - Congress can reauthorize the Defense Production Act authorities to support energy infrastructure supply chains. Following reauthorization, Congress can appropriate funds for investment in new manufacturing capacity for electrical transformers to meet demand growth and shorten wait times.

03

Invest in the labor force to build an energy abundant future

Google has long been focused on providing digital skilling opportunities. Since 2017, Grow with Google[26] has trained more than 12 million Americans in digital skills, issuing 400,000 certificates in the United States (and over 1 million globally) in critical areas such as cybersecurity and data analytics, to ensure that everyone has the opportunity to develop the skills necessary to take advantage of the opportunities presented by AI.

Modern workforce development must address the need for workers to build and maintain the investments necessary for an energy abundant future.

In particular, a shortage of electricians may constrain America's ability to build the infrastructure needed to support AI, advanced manufacturing, and a shift to clean-energy. McKinsey estimates that 130,000 additional electricians will be needed by 2030 to build out data centers and manufacturing facilities in the coming years.[27] But we're going in the wrong direction: Nearly 10,000 American electricians either retire or change careers each year while only about 7,000 new entrants join the field.

This moment calls for a national focus on workforce development—not just to meet the AI opportunity, but to train the next generation of electricians, technicians, and skilled workers who will power the future.[28]

Google's longstanding commitments to workforce development and the deep partnerships forged between our Grow with Google program and community colleges throughout the U.S. help us begin to meet this demand and, hopefully, catalyze additional investments by others. Building on a grant by Google.org in partnership with key industry players like the International Brotherhood of Electrical Workers and the National Electrical Contractors Association, Google is supporting the Electrical Training Alliance to integrate advanced technologies into their training curriculums to help 100,000 electricians strengthen their skills while training 30,000 new apprentices — potentially a 70% increase in the electrical workforce pipeline by 2030.

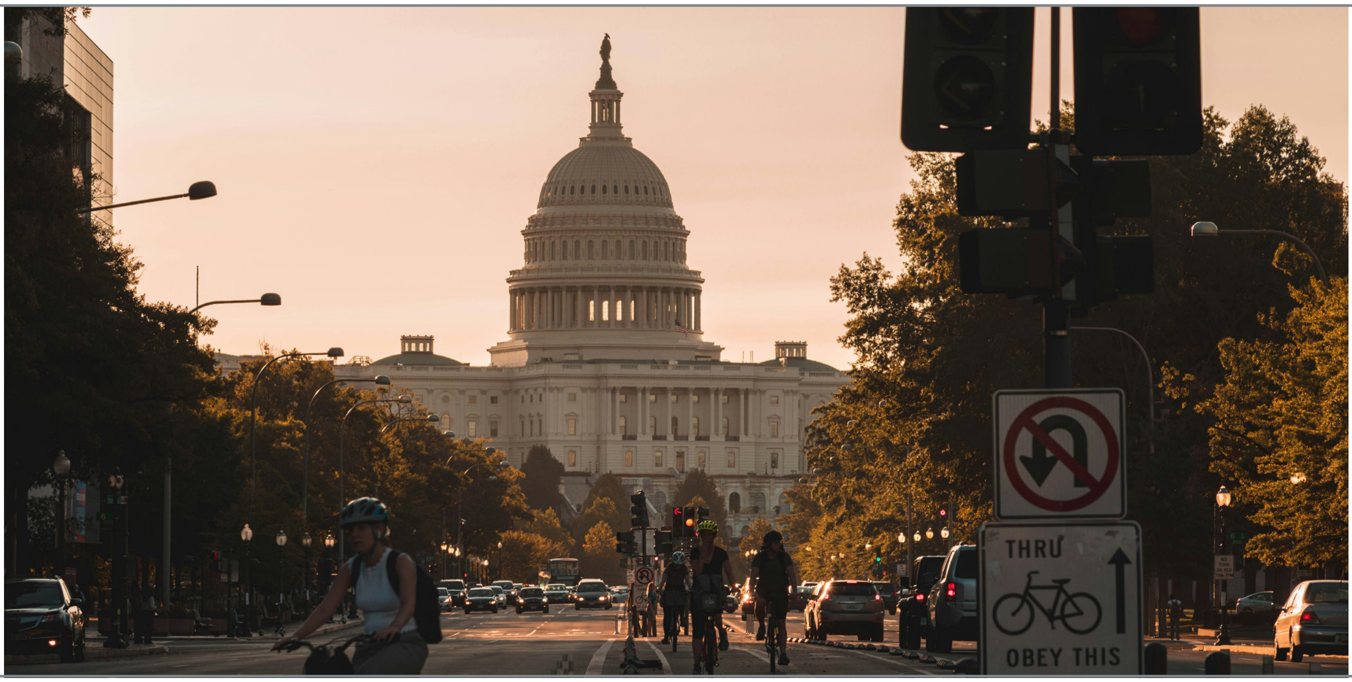
Of course, no single company can fix the expected shortfall alone, but we hope that a shared public and private commitment to introduce and support training programs like this new Google.org supported program suggests a model to develop the workforce required.

70%

Potential increase in the electrical workforce pipeline by 2030

In addition, governments can advance electrical workforce development programs by, among other steps:

- Reviewing electrician state-licensing requirements and enabling greater reciprocity between states
- Promoting registered electrical apprenticeship programs to provide a pathway to employment
- Encouraging more community colleges and universities to develop education initiatives that benefit registered apprenticeship training programs
- Coordinating partnerships between employers, educational institutions, and government agencies to scale successful educational practices and training programs.



The time to act is now

America is a nation with extraordinary talent, unmatched innovation, abundant resources, and an ability to rise and meet any challenge. It is essential to meld those strengths if we are to realize the great economic growth opportunities presented by AI.

The above solutions offer a roadmap for the United States to both power and capture AI's generational opportunity.

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