Hoover Institution | Stanford University

ENERGY POLICY

Changing the Landscape for New Nuclear Power

John Deutch, William Madia, Steven Koonin, James O. Ellis Jr., and David Fedor

After more than a decade of meetings, studies, and recommendations on the potential for revitalizing the US nuclear power enterprise, today's message from the nuclear community is clear: unexpected new energy demands, and the unconventional business models that come with them, offer the best prospect in decades for delivering on new nuclear's promise. If these new opportunities are cultivated, they could restart a civilian nuclear power enterprise that possibly could compete on cost and at scale with other sources of energy. The incoming presidential administration is well positioned not just to study the problem but also to do something about it, but that will require clear leadership and accountability for the outcomes.

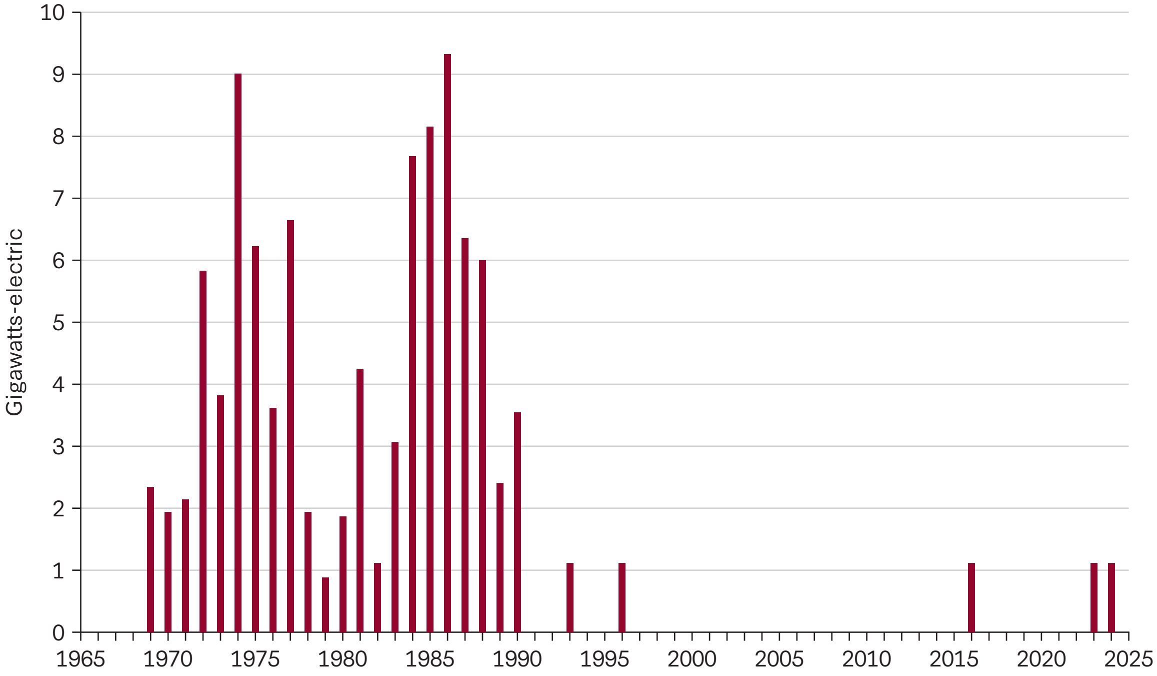
HOW WE GOT HERE

Most nuclear power reactors in the United States were built between 1970 and 1990 by four domestic light-water reactor manufacturers: three that used pressurized water—Westinghouse, Brown and Root, and Combustion Engineering—and General Electric, which used boiling water. The number of US nuclear power reactors peaked at 112 and has since declined, primarily for economic reasons. As of August 2023, the United States had ninety-three operating commercial nuclear reactors at fifty-four nuclear power plants in twenty-eight states.[1] The average age of these nuclear reactors was about forty-two years; almost all operating reactors have received forty-to-sixty-year license extensions from the US Nuclear Regulatory Commission (NRC), and six of those subsequently received sixty-to-eighty-year operating license extensions (sixteen more are similarly under review).[2] The oldest operating reactor began commercial operation in 1969; the newest reactor to enter commercial service, in 2024, is Unit 4 at the Vogtle Electric Generating Plant in Georgia. Only five new reactors have been commissioned since 1990, as shown in figure 1. Nevertheless, even with this decline, the US nuclear fleet has managed to maintain its roughly 19 percent share of total US electricity generation through consistent improvement in its capacity factor (efficiency).[3]

A Hoover Institution Essay

January 2025

FIGURE 1 US Nuclear Capacity Additions, by year commissioned



Source: US NRC and US EIA data, as suggested in US Energy Information Administration, "First New U.S. Nuclear reactor since 2016 Is Now in Operation," *Today in Energy*, August 1, 2023, https://www.eia.gov/todayinenergy/detail.php?id=57280.

Several factors caused the collapse of a US reactor construction enterprise that once produced as many as ten reactors per year. First was public concern about nuclear safety after the 1979 Three Mile Island accident in Pennsylvania and the 1986 accident at the Chernobyl power station in the Soviet Union. Second, and less appreciated, was the unanticipated flattening of the annual rate of electricity demand growth from 5 percent in the 1970s to 2–3 percent in the 1980s.[4] This was compounded by deteriorating financials caused by (1) an increase in the overnight capital cost of building new reactors that put new builds out of reach for most US electric utility balance sheets, alongside (2) the decline in and variability of wholesale electricity rates for baseload power. The changes in wholesale electricity rates stemmed from both policy choices—the desire of regulators and integrated system operators to reduce greenhouse gas emissions by favoring the dispatch of low marginal cost (often subsidized), intermittent wind and solar generation—and the market response to cheap, natural gas–fired power generation resulting from the US fracking boom.[5]

Meanwhile, over the past twenty years, American entrepreneurship—supported by public financial support for research, development and demonstration—has resulted in a variety of promising new nuclear designs and firms, including both Generation III and Generation IV technologies. These new options, however, have encountered the same challenging financial environment in the US marketplace for power, and the hoped-for expansion has not occurred.

Importantly, of these three original structural challenges to nuclear power, the first—societal preferences—has changed dramatically within the past several years. There is now a widespread acknowledgment that nuclear power capacity must expand significantly if global net-zero emission levels are to be reached. At the 2023 COP 28 meeting in Dubai, twenty countries pledged to work to triple global nuclear capacity by 2050, with additional countries signing on to that pledge at the 2024 COP 29 meeting in Baku, Azerbaijan.[6] And in September 2024, the US Department of Energy (DOE) issued its revised *Pathways to Commercial Liftoff: Advanced Nuclear* guidance, which similarly envisioned a tripling of US deployed nuclear capacity from approximately 100 gigawatts-electric in 2024 to 300 gigawatts-electric by 2050.[7] This changing social motivation now balances the public concern about nuclear safety that hastened the demise of the first US civilian nuclear construction enterprise.

Unexpected, the other historically limiting factors are now changing as well.

TODAY'S OPPORTUNITY

The first change that helps reverse these past structural challenges to nuclear is the resumption of broad-based growth in electricity demand in the United States.

Large US industrial and commercial firms, either individually or in association, are looking to take a share in the ownership of nuclear power assets to meet the rapid growth in baseload demand driven by cloud data centers, AI-driven needs, and cryptocurrency.[8] Three major technology companies have recently proposed to dedicate nuclear power plant electricity production to meet their uninterruptible power needs:

1. Microsoft has contracted with Constellation Energy to restart Unit 1 at Three Mile Island (880 megawatts-electric) under a twenty-year power purchase agreement.[9]
2. Alphabet/Google has signed an agreement of up to 500 megawatts-electric for multiple Kairos Gen IV small modular reactors (SMRs).[10] The Kairos SMR system uses two 75 megawatts-electric units with 19.5 percent U_{235} enriched TRISO pebble fuel and molten fluoride coolant. The first engineering test of that system, which has already received an NRC construction license, will be a 35 megawatts-thermal reactor (which will not produce electricity) at Oak Ridge, Tennessee: It is expected to be operational in 2027.[11] A second engineering test of two reactors that are together expected to produce 70 megawatts-thermal, plus a shared power-generation system, received NRC construction approval in November 2024.[12] These test reactors are expected to receive up to $300 million support from DOE on a performance milestone basis.[13]
3. On October 16, 2024, Amazon announced three nuclear energy projects. One, in Washington State, with Energy Northwest (a consortium of state public utilities), will build four advanced SMRs, each with roughly 320 megawatts-electric. Another, in Virginia, has Amazon entering into an agreement with Dominion Energy to explore the development of SMRs at the existing North Anna nuclear station. Finally, Amazon led an investment of $500 million in X-Energy's Gen IV 80 megawatts-electric SMR gas-cooled

> nuclear reactor. The first four-unit 320 megawatts-electric module is scheduled for construction in Washington State, with the option to expand to twelve units (960 megawatts-electric) and an ultimate goal to produce 5 gigawatts-electric.[14]

Second, new efforts to improve the realized value of nuclear energy output in the marketplace are also changing the nuclear landscape. US industry is turning to nuclear power to fill the gap between the anticipated growth in demand for baseload power in electricity markets and the decline in its supply.

The increasing volatility of electricity pricing over the past decade has shifted the nuclear energy paradigm from supplying wholesale power almost exclusively for electricity-generating utilities to a more lucrative multi-use model. One way to achieve even higher capacity factors is for nuclear plants to offer a combination of heat and power. A prominent example is the TerraPower Natrium system that combines a Gen IV 345 megawatts-electric sodium fast reactor with a gigawatt-scale molten salt energy storage system. The Natrium system allows for stable nuclear power operation, with output directed either to electricity production or to high temperature heat for industrial applications, as local market conditions warrant. The initial Natrium plant under construction in Wyoming is estimated to cost $4 billion, with half the funding to be provided by DOE.[15]

“Out-of-market” subsidies and mandates have driven deployment of intermittent renewables across the country, depressing baseload power prices for other generators. To balance these, the nuclear industry plans to take advantage of new investment and production tax credits (ITCs and PTCs) that were extended to nuclear power by the 2022 Infrastructure Recovery Act. Whether those incentives continue or are modified, operators looking forward are expecting parity in the treatment of nuclear and renewables.

The third change, of critical importance, concerns ways to overcome the historical trend of increasing nuclear capital costs—especially for promising new, but not yet commercially demonstrated, technologies.

As usual in the history of US energy policy, the DOE has taken this nuclear energy revival as an opportunity to introduce new technology—Gen IV SMR reactors—as a key part of the goal to develop clean, affordable nuclear energy options. The principal advantages of those reactors are their smaller size, safer design, and purported lower capital cost per megawatt-hour when produced in quantity. Conventional Gen III light-water reactors (LWRs) are typically tenfold larger and constructed on an individual basis (recent Gen III reactors have proven to be very expensive to build, although modular SMR manufacturing has the potential to correct that deficiency as well). However, because there is as yet no Gen IV SMR reactor in operation in the United States, their cost advantage remains to be confirmed.

Gen IV SMR reactors face an additional challenge. Most require fuel enriched between 10 and 20 percent (to achieve higher power densities) compared to the conventional 3 to 5 percent enrichment of Gen III reactors. This high-assay low-enriched uranium (HALEU) fuel is not widely available today. The new enrichment and deconversion plants required to meet the more stringent criticality demands of HALEU fuel will make it more costly to produce.

The overnight unit capital cost of these new Gen IV SMRs is expected to decline from the first-of-a-kind to the nth-of-a-kind article, but there is considerable uncertainty in this "learning curve." That uncertainty is the principal barrier to attracting low-interest infrastructure (as opposed to venture) capital to finance the initial buildout.

Among the most promising of today's opportunities for nuclear is, unsurprisingly, a financial innovation that would voluntarily spread the risk of early deployment cost overruns among willing private investors, with the government backstopping a fraction of the overall program deficit. This private–public risk-sharing approach has stimulated much interest among potential buyers of nuclear energy output.[16] One detailed proposal by the Energy Futures Initiative has been discussed extensively at the Hoover Institution as well.[17]

In brief, a group of companies with a common interest in firm power agree to finance the project through a special purpose investment vehicle (SPIV) and a partnership with the government. The SPIV finances construction of ten or more nuclear plants of the same type over a ten-year period, assuming a learning cost curve and constant annual payments by each firm. At the end of that period, the discounted sum of the annual firm payments will equal the target cost, and the government would agree to cover a pre-agreed fraction of any project cost overrun. The agreed-upon number of builds and the duration of the partnership would depend on an engineering judgment that the new reactor system and its supporting fuel cycle and supply chain would be sufficient to achieve steady-state operation.

In sum, there are three new paradigms that offer an unexpected new opportunity for the US nuclear industry to break out of the structural challenges that ended the first US nuclear power construction enterprise:

1. Growing electricity demand from nontraditional, capital-rich energy buyers who "behind the meter" are partnering with nuclear operators to receive a firm fraction of the reactor's electricity output to meet their specific industrial or commercial needs
2. The integration of nuclear power reactors with thermal storage to profitably dispatch more power when needed, and less when not needed, in otherwise challenging wholesale market conditions
3. The creation of special purpose investment vehicles with a government-financed backstop to drive down first-of-a-kind costs, build out the supply chain ecosystem, and spur long-term workforce development

NUCLEAR DIPLOMACY

Changes are also occurring in the global nuclear market. The International Atomic Energy Agency (IAEA) and the recent COP 28 deliberations about nuclear power, share the belief that expansion of nuclear energy globally will take place in "embarking countries" that do not currently have a nuclear infrastructure.[18] The US nuclear construction enterprise of the 1970s benefited from participating in a global nuclear market, so it is worth paying attention to the role that US diplomacy could play in allowing a reinvigorated US nuclear construction enterprise to function effectively beyond the domestic market.

It is unlikely that embarking countries would begin deployment with Gen IV reactor technology or would have the financial capacity or business practice experience for the three new organizational arrangements just discussed. For embarking countries, a different approach would be required to encourage nuclear energy deployment.

Embarking countries and many potential OECD investors will likely be drawn to Gen III reactors because they use lower enrichment fuel and have a more extensive safety, operation, and construction track record—although overnight construction cost remains a prominent concern. For example, the GE-Hitachi LWR boiling water BWRX 300 megawatts-electric reactor has early traction, with interest from the Province of Ontario and Saskatchewan Power in Canada and Tennessee Valley Authority in the United States.[19] Participants in those early projects will be well positioned to share their Gen III experiences with embarking countries.

International nuclear expansion will occur through the efforts of each individual country and of nuclear suppliers, supported by the occasional involvement of international organizations such as the World Bank, IAEA, and the United Nations Framework Convention on Climate Change (UNFCCC), whose support for nuclear power should be more vigorously encouraged by the United States. The United States has an unusual opportunity to participate in the anticipated spread of nuclear reactors to meet growing energy needs in less developed parts of the globe; this participation will be to the benefit of recipient-country security and economic development, while avoiding greenhouse gas emissions and, at the same time, advancing US geopolitical objectives, nuclear supply chain capabilities, and nuclear safety standards.

DOING SOMETHING ABOUT IT

Government and industry should not expect that the emergence of these three new paradigms guarantees that the landscape will bloom with new reactors. The power sector remains fiercely competitive and subject to ratemaking and policy preferences. Even optimistic forecasts of new electricity demand from motivated tech firms show data-center power demand in the United States rising from about 3 to 4 percent of the total in 2023 to 8–9 percent in 2030—which is significant but is still a relatively small fraction of the overall market.[20]

If Gen IV systems become a commercial success, they likely will be pursued through one of these new paradigms and will not follow the typical pattern of integration into electric utilities. Therefore, the policy imperative for the next US presidential administration should be to encourage these new market entrants, in partnership with new reactor vendors and operators, and to help them succeed in their stated ambitions to finance and deploy multiple units of the designs they have chosen.

Ensuring the success of these entrepreneurs is the best opportunity that the United States has to surmount the barrier of moving from high first-of-a-kind levels of cost and risk down to an nth-of-a-kind cost that would unlock a broad set of buyers and revitalize the American nuclear construction and workforce enterprise at scale. Here are four recommendations for industry and government to achieve that goal:

1. If a company or association of companies enters a long-term take-or-pay electricity contract with a generating nuclear utility, it should be considered “behind the meter” to the extent that it does not subject the broader grid to new integration costs. However, to avoid a cost increase to the broader rate base, the facility should be subject to charges for ancillary and transmission services to the extent it retains a call on the utility in the case of a power outage. The president should direct the Federal Energy Regulatory Commission (FERC) to establish rules promptly for these new, promising commercial arrangements.
2. The president should also instruct DOE to apportion a share of its existing loan authority to support financially a pre-agreed fraction of potential cost overrun of a SPIV’s multiyear project that does not achieve its cost goal. The federal funding should be arranged in such a way as to not interfere with the management of the private-sector SPIV and should be limited both in the scope of project coverage and in the total amount of funds available so as to not offload all risk from the private organizers.
3. Congress has provided significant funding and loan guarantees for nuclear reactor demonstration projects. Much of this support has been extended to Gen IV reactors on the assumption that they will be cheaper to construct and operate than Gen III reactors on a per megawatt-hour basis. If supporting evidence from early builds is not available, DOE’s policy should be even-handed between existing and new reactor technologies. If supporting evidence is available, there is no need for long-term preferential DOE treatment because the private sector will naturally select the most economical and safest alternatives.
4. International commercial nuclear partnerships bind countries into decades-long mutually beneficial relationships. Russia has in recent years almost completely dominated the international commercial nuclear reactor construction market in embarking countries, offering them turnkey technology, financing, and fuel-cycle service. China’s domestic nuclear construction supply chain—now approximating the scale of US capabilities in the 1970s—is likely soon to step into tomorrow’s global export markets. To best position US firms for success in a competitive international nuclear supply chain, US industry and government should consider entering joint cooperative bids for international projects with allied partners such as South Korea that have complementary industrial strengths (e.g., low overnight capital LWR costs).

More important than the substance of these recommendations, however, is the system of responsibility—and accountability—that the next administration and Congress will need to implement them. The US energy policy world does not need new analytical reports to establish the value of this technology. Nor does it require yet another blue-ribbon commission to determine the best way to handle the nuclear fuel cycle, or NRC licensing pathways, or workforce development. The authors have participated in numerous such efforts in the past that addressed these important issues, but the truth is that we already have good policy answers for many of them.

Malcolm Gladwell has observed, “Success is not a random act. It arises out of a predictable and powerful set of circumstances and opportunities.” Today we sit at the cusp of an unexpected but very promising opportunity to rekindle the US nuclear enterprise. But the public powers to seize that opportunity are dispersed: research infrastructure and loan authorities at DOE; adaptive but responsible licensing pathways at the NRC; contracting rules and market design at FERC; nuclear diplomacy at the State, Energy, and Commerce departments; the financial authority held by Congress; and the proclivities of individual states. Success in 2030 requires administration leadership today to create a new mechanism that assigns responsibility and authority to a single nuclear champion to see that necessary changes are implemented.

NOTES

1. US Energy Information Administration, “US Nuclear Industry,” *Nuclear Explained*, last modified August 24, 2023, https://www.eia.gov/energyexplained/nuclear/us-nuclear-industry.php.

2. Brian W. Smith, *From 40 to 60 to 80 Years—What Is Next for License Renewal in the USA?* (Washington, DC: US Nuclear Regulatory Commission, Division of New and Renewed Licenses), ADAMS Accession No. ML22286A004, https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML22286A004.

3. US Energy Information Administration, “US Nuclear Industry.”

4. US Energy Information Administration, “US Economy and Electricity Demand Growth Are Linked, but Relationship Is Changing,” *Today in Energy*, March 22, 2013, https://www.eia.gov/todayinenergy/detail.php?id=10491.

5. Jeremy Carl and David Fedor, *Keeping the Lights on at America’s Nuclear Power Plants* (Stanford: Hoover Institution Press, 2017).

6. United Nations Framework Convention on Climate Change (UNFCCC), *Conference of the Parties Serving as the Meeting of the Parties to the Paris Agreement, Fifth Session, United Arab Emirates, 30 November to 12 December 2023, Agenda Item 4 (First Global Stocktake)*, FCCC/PA/CMA/2023/L.17 (revised advance version, 13 December 2023), https://unfccc.int/sites/default/files/resource/cma2023_L17_adv.pdf; United Nations Framework Convention on Climate Change (UNFCCC), “COP29: UN Climate Conference Agrees to Triple Finance to Developing Countries, Protecting Lives and Livelihoods,” November 24, 2024, https://unfccc.int/news/cop29-un-climate-conference-agrees-to-triple-finance-to-developing-countries-protecting-lives-and.

7. US Department of Energy, *Pathways to Commercial Liftoff: Advanced Nuclear* (Washington, DC: US Department of Energy, September 2024), https://liftoff.energy.gov/wp-content/uploads/2024/10/LIFTOFF_DOE_AdvNuclear-vX7.pdf.

8. The International Energy Agency estimates such uses could reach 1,000 terawatt-hours by 2026. However, this estimate is still a small fraction of total electricity demand, which in 2024 was about 30,000 terawatt-hours globally and 4,000 terawatt-hours in the United States.

9. Constellation Energy, “Constellation to Launch Crane Clean Energy Center, Restoring Jobs and Carbon-Free Power to the Grid,” September 20, 2024, https://www.constellationenergy.com/newsroom/2024/Constellation-to-Launch-Crane-Clean-Energy-Center-Restoring-Jobs-and-Carbon-Free-Power-to-The-Grid.html.

10. Michael Terrell, “New Nuclear Clean Energy Agreement with Kairos Power,” *The Keyword (Google Blog)*, October 14, 2024, https://blog.google/outreach-initiatives/sustainability/google-kairos-power-nuclear-energy-agreement/.

11. US Nuclear Regulatory Commission, Advisory Committee on Reactor Safeguards, *Safety Evaluation of the Kairos Non-Power Reactor Hermes 2 Construction Permit Application*, letter to Christopher T. Hanson (Chair, US Nuclear Regulatory Commission), July 17, 2024, ADAMS Accession No. ML24197A152, https://www.nrc.gov/docs/ML2419/ML24197A152.pdf.

12. US Nuclear Regulatory Commission, “NRC to Issue Construction Permits for Kairos Hermes 2 Test Facility in Tennessee,” News Release No. 24-081, November 20, 2024, https://www.nrc.gov/cdn/doc-collection-news/2024/24-081.pdf.

13. Kairos Power, “US Department of Energy and Kairos Power Execute Novel Performance-Based, Fixed-Price Milestone Contract,” February 21, 2024, https://kairospower.com/external_updates/u-s-department-of-energy-and-kairos-power-execute-novel-performance-based-fixed-price-milestone-contract-to-enable-investment-in-advanced-reactor-demonstration-project/.

14. “Amazon Signs Agreements for Innovative Nuclear Energy Projects to Address Growing Energy Demands,” About Amazon, October 16, 2024, https://www.aboutamazon.com/news/sustainability/amazon-nuclear-small-modular-reactor-net-carbon-zero.

15. US Government Accountability Office, “Nuclear Energy Projects: DOE Should Institutionalize Oversight Plans for Demonstrations of New Reactor Types,” September, 2022, https://www.gao.gov/assets/gao-22-105394.pdf.

16. Advanced Clean Electricity, “Advanced Clean Electricity RFI Overview,” March 19, 2024, https://www.advancedcleanelectricity.com.

17. Ernest J. Moniz, Joseph S. Hezir, Stephen D. Comello, and Jeffrey D. Brown, *A Cost Stabilization Facility for Kickstarting the Commercialization of Small Modular Reactors* (Energy Futures Finance Forum [EF3], October 2023), https://efifoundation.org/wp-content/uploads/sites/3/2023/10/20231011-CSF-FINAL-1.pdf.

18. COP 28, “Joint Statement on Climate & Nature,” December 9, 2023, https://www.cop28.com/en/joint-statement-on-climate-nature.

19. GE Vernova, “GE Hitachi Signs Contract for the First North American Small Modular Reactor,” January 27, 2023, https://www.gevernova.com/news/press-releases/ge-hitachi-signs-contract-for-the-first-north-american-small-modular-reactor.

20. Electric Power Research Institute (EPRI), “Powering Intelligence: Analyzing Artificial Intelligence and Data Center Energy Consumption,” May 28, 2024, https://www.epri.com/research/products/3002028905; Goldman Sachs, “AI is Poised to Drive 160% Increase in Data Center Power Demand,” May 14, 2024, https://www.goldmansachs.com/insights/articles/AI-poised-to-drive-160-increase-in-power-demand.

31 30 29 28 27 26 25 7 6 5 4 3 2 1

Preferred citation: John Deutch, William Madia, Steven Koonin, James O. Ellis Jr., and David Fedor. "Changing the Landscape for New Nuclear Power." George P. Shultz Energy Policy Working Group, Hoover Institution. January 2025.

ABOUT THE AUTHORS

JOHN DEUTCH

John Deutch is a distinguished visiting fellow at the Hoover Institution and an emeritus Institute professor at MIT. He previously served as the deputy secretary of defense and as director of central intelligence.

WILLIAM MADIA

William Madia is a vice president emeritus at Stanford University, where he was responsible for oversight of the SLAC National Accelerator Laboratory. Previously, at Battelle Memorial Institute, he oversaw the management or co-management of six Department of Energy national labs.

STEVEN KOONIN

Steven Koonin is a senior fellow at the Hoover Institution. He was formerly a professor at New York University, under-secretary for science at the Department of Energy, chief scientist at BP, and professor of theoretical physics and provost at Caltech.

JAMES O. ELLIS JR.

Admiral James O. Ellis Jr. (ret.) is an Annenberg Distinguished Visiting Fellow at the Hoover Institution, where he chairs the Shultz Energy Policy Working Group. He completed a distinguished thirty-nine-year US Navy career as commander of US Strategic Command and served as president and CEO of the Institute for Nuclear Power Operations.

DAVID FEDOR

David Fedor is the Stephenson Policy Fellow at the Hoover Institution and research director for its Shultz Energy Policy Working Group.

The George P. Shultz Energy Policy Working Group

Since its founding by the Hon. George P. Shultz and Amb. Thomas F. Stephenson in 2007, the George P. Shultz Energy Policy Working Group has pursued what former secretary of state Shultz called "a balanced approach" toward sustaining the economic, environmental, and security dimensions of energy policy. In today's emerging geopolitical era—arguably the most dangerous since 1962—it convenes energy and national security experts alongside industry practitioners to think afresh about how US energy resources, technologies, and commercial markets can be used as platforms to deepen and reinforce America's critical alliances and partnerships with like-minded nations around the world.

For more information about this Hoover Institution initiative, visit us online at hoover.org/research-teams/energy-working-group.

Hoover Institution, Stanford University
434 Galvez Mall
Stanford, CA 94305-6003
650-723-1754

Hoover Institution in Washington
1399 New York Avenue NW, Suite 500
Washington, DC 20005
202-760-3200

HOOVER INSTITUTION