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THE STANFORD EMERGING TECHNOLOGY REVIEW 2026

A Report on Ten Key Technologies and Their Policy Implications

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ENERGY TECHNOLOGIES

KEY TAKEAWAYS

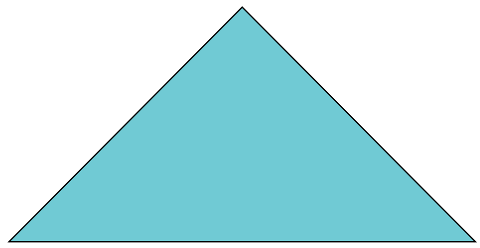
- Although many clean energy technologies are now available and increasingly affordable, scaling them up and building the infrastructure for them will take decades due to infrastructure inertia, stakeholder complexity, and the "energy trilemma," which balances reliability, affordability, and cleanliness.
- The US has shifted from climate urgency to energy dominance, redirecting support from renewables and electric vehicles to fission, coal, and natural gas. Globally, similar trends prevail as nations record peak fossil fuel use and scale back renewable investments, prioritizing energy security over decarbonization.
- Energy innovation is fragmented, diverse, and geopolitically strategic, with progress in technologies like fission, geothermal, fusion, and batteries reshaping the energy frontier. To compete with China, US technology leadership depends on sustained research and development funding, robust supply chains, and strategic industrial policies.

Overview

Energy is the lifeblood of modern society—enabling heating, cooling, light, mobility, information, and the creation of modern materials. Because it touches everything, everywhere, all the time, energy plays out against a complex backdrop of technology, economics, regulation, and consumer behavior. Key elements of this backdrop include the following:

- **Growing demand** As several billion people in the developing world lift themselves out of poverty, global energy consumption is projected to increase by some 50 percent between 2020 and 2050.[1] That increase is not a luxury but is essential to their improved quality of life.
- **The "energy trilemma"** It's not enough that energy systems produce and deliver energy. They need to do so reliably, affordably, and cleanly, with "clean" referring to both local and greenhouse gas

FIGURE 4.1 The energy trilemma



emissions. (Local emissions refer to particulates emitted in the immediate vicinity of a power plant.) Those three dimensions are often expressed as the energy trilemma, as illustrated in figure 4.1.

It is rare to find technologies that simultaneously satisfy all three desiderata. In the US electricity sector, conventional coal is secure and affordable but generally emits greenhouse gases; natural gas is much cleaner locally but still emits carbon dioxide (CO_2); wind and solar are affordable and non-emitting but unreliable; and nuclear power is both clean and reliable but more expensive than alternatives. The trilemma suggests that no single type of energy source will always be right under all circumstances.

- **Opportunities for innovation** The challenge of resolving the energy trilemma has engendered a flurry of technological innovation. That effort has dramatically reduced the costs of onshore wind and solar generation, improved battery performance and economics, surfaced promising geothermal technologies, and rekindled interest in nuclear power, particularly designs for small reactors. Although the many innovations on today's drawing boards will not be impactful for years, they are the foundation for a more affordable, more reliable, and cleaner energy future in the longer term.

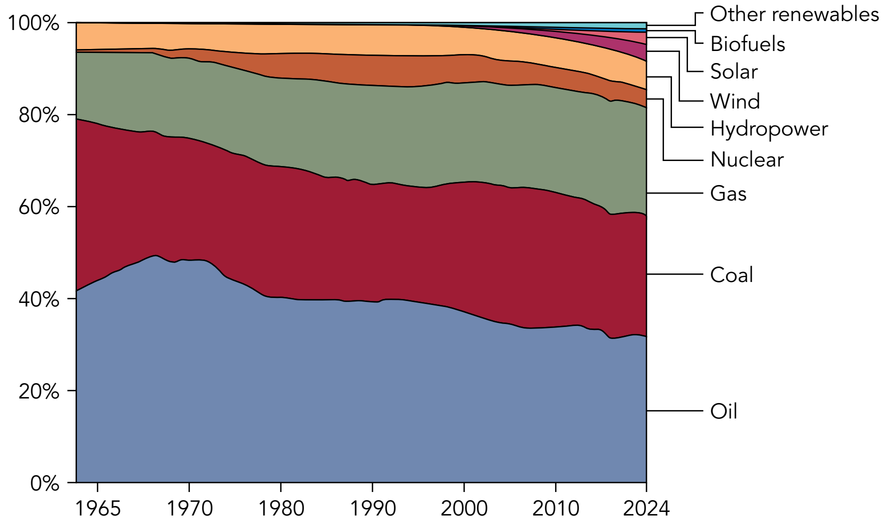
- **Growing electrification** Energy is delivered to end users through carriers, whether they be fuel molecules or electrons. The latter carrier is favored in more advanced countries. This is because electricity is easily moved through wires, is clean at the point of use, and can be employed in many ways, from powering electronics to moving electric vehicles (EVs). Global electricity demand grew 4.3 percent in 2024, almost double the average rate over the prior decade. The rise of data centers, heat pumps, and vehicle electrification is expected to increase US electricity demand by some 25 percent in the next five years, a dramatic acceleration compared with the past two decades, when demand was essentially flat.[2]

- **Hydrocarbon dominance** As figure 4.2 shows, hydrocarbons derived from fossil fuels (coal, oil, and natural gas) supplied 86 percent of the world's primary energy in 2024.[3] (Primary energy refers to energy sources before they have been converted to electricity.) Wind and solar generation, while growing rapidly, accounted for 6.5 percent of primary energy the same year.

- **Limitations of renewable sources** Wind- and solar-generated electricity remain substantially cheaper than electricity generated by fossil fuels and also accounted for more electrical energy in 2024 than in any previous year.[4] However, the

The challenge of resolving the energy trilemma has engendered a flurry of technological innovation.

FIGURE 4.2 Global energy consumption by source (1965–2024)



Source: Adapted from Our World in Data, https://ourworldindata.org/grapher/energy-consumption-by-source-and-region, CC BY-SA 3.0

drawbacks of a renewable-heavy grid are becoming apparent.[5] They include the following:

- The cost of the dispatchable backup generation required to ensure high reliability (dispatchable refers to power sources that can be adjusted up or down on demand)
- The difficulties of synchronizing generators that lack mechanical inertia, which makes it harder to bring them online smoothly[6]
- The fire risks of grid-scale battery storage
- The critical materials required by clean energy technologies—materials that the United States heavily imports from countries whose interests do not always align with theirs (e.g., rare earths from China and cobalt from the Congo)

- **The difficulty of large-scale change in energy infrastructure** Energy is delivered to end users by systems, and those systems are hard to change, for fundamental reasons.[7] They involve large investments in assets that last decades, their parts need to work together (e.g., cars, fuel, and the fueling infrastructure must all be compatible), and there are many stakeholders whose interests often don't align. It also takes time to refine the hardware and operating procedures that ensure high reliability and efficiency. Energy systems are therefore best changed slowly and steadily over decades.

- **Efficiency limitations** Greater efficiency of end use (e.g., more miles per gallon in a vehicle or more lumens per watt in a light-emitting diode, or LED) is often invoked as an energy-saving measure. Yet such savings can be partially, or even totally, offset by direct rebound (i.e., greater efficiency leading to greater use) or indirect rebound (i.e., energy savings redirected to other uses).

- **Pragmatic challenges** Innovation in energy systems differs from other fields covered in the *Stanford Emerging Technology Review* (*SETR*) because many viable energy sources already exist. Any new energy source will be producing a commodity—fuel molecules or moving electrons (i.e., electricity). In this case, the cost of producing and delivering this commodity to the end user is paramount, subject to the other dimensions of the trilemma (reliability and lack of emissions). For large-scale deployment in a market economy, a new energy technology not only needs to work; it must be better than the alternatives. Moreover, in a globalized world, invention, manufacturing, and deployment often occur in different countries, which significantly affects the economic and security impacts of energy innovation.

In the United States, the Department of Energy (DOE) and the private sector have been the most significant funders of energy innovation, with government, academia, and the private sector conducting the research on energy technologies. Academia conducts the bulk of early-stage research on energy technologies, as do the US National Laboratories. However, these organizations don't have the resources to effect later-stage development or large-scale demonstrations, let alone deployments. Such efforts fall primarily to the private sector, which includes both large established companies and start-ups that might partner with academic institutions to take early-stage research to commercialization.

Key Developments

In the past few years, explosive growth in the demand for energy has begun to reshape the US energy economy. Data centers, artificial intelligence (AI) workloads, mining of cryptocurrencies, and industrial reshoring have driven electricity demand up by more than 2 percent annually for three consecutive years—a reversal of two decades of flat consumption. Forecasts suggest demand could rise between 16 and 25 percent over the next five years, straining grid capacity and prompting calls for new generation capacity.

In response, capital is shifting from intermittent renewables to dispatchable generation—especially natural gas, nuclear, and energy storage. Clean energy sectors are facing headwinds as utility-scale solar and wind projects have slowed due to the loss of federal tax credits and rising interest rates. Wind generation of electricity in the United States declined in 2023 for the first time in twenty-five years,[8] and growth in solar generation capacity slowed despite record installations in 2023.[9] At the same time, natural gas infrastructure is expanding rapidly, albeit constrained by labor and supply chain bottlenecks. Nuclear power is experiencing a renaissance, with new builds, restarts, and uprates underway. (Uprates refer to the process of increasing the maximum power output of an existing nuclear power plant through modifications or improvements.)

In short, aspirations for an accelerated energy transition have collided with scientific and techno-economic realities. These collisions, many of which predate the current US administration, have led to a new pragmatism in energy matters as the transition's costs and challenges become increasingly apparent. There is now more attention on an energy source being affordable and reliable than a single-minded focus on mitigating greenhouse gas emissions.[10]

This pragmatism is reflected in the repeal of most tax subsidies for emissions mitigation in the US Inflation Reduction Act and by the Trump administration's elevation of energy reliability and abundance, if not "energy dominance," over emissions-mitigation efforts. A number of other global developments during the past year reflect this trend as well:

- Global consumption of each of the major fossil fuels (coal, oil, and natural gas) hit a record high in 2024, despite record investments in renewable energy.[11] Total energy-related CO_2 emissions increased by 0.8 percent in 2024, hitting an all-time high of 37.8 gigatons of CO_2.[12]
- The United States began withdrawing from the Paris Agreement, while the European Union

Nuclear power is experiencing a renaissance, with new builds, restarts, and uprates underway.

softened compliance burdens under political pressure, signaling a retreat from an aggressive climate policy.[13]

- Mandates banning internal combustion engine vehicles are facing mounting resistance in Europe.[14] In addition, as Russia curtailed shipments of pipeline gas to Europe in retaliation for European support to Ukraine, Europe increased its imports of liquefied natural gas (LNG) to compensate for the loss.[15] However, LNG has a significantly worse emissions footprint than Russian pipeline gas because of the processing needed to liquify natural gas and the transportation of it from source to destination. Europe's actions therefore suggest a weakening of its commitments to reducing emissions, at least in the short term.

- Established in 2021 to align the financial sector with emissions targets, the Glasgow Financial Alliance for Net Zero unraveled in early 2025 following mass departures by major US banks from its affiliated coalitions, exposing the fragility of voluntary climate finance initiatives.[16] Companies are quietly retreating from public sustainability commitments amid a political backlash.[17] Major carmakers, including General Motors, Mercedes-Benz, and Aston Martin, scaled back EV plans in 2024–25, citing weak demand, high costs, and uncertain policy environments.[18]

The emerging zeitgeist is that all three legs of the trilemma are important—a change that will temper, but not halt, sustainable energy research and development and deployment efforts. In the past year, the two energy technologies that have gained in prominence are nuclear power and coal.

Nuclear Power

In September 2024, the DOE's "Pathways to Commercial Liftoff: Advanced Nuclear" report projected that the United States would need 700–900 gigawatts (GW) of clean firm power by 2050, with nuclear expected to triple its capacity to about 300 GW.[19] Consistent with this theme, the past year has seen a renaissance in the US nuclear power sector, driven by surging electricity demand, emissions concerns, and strategic industrial policy.

The most tangible development has been the completion of Vogtle Units 3 and 4 at the Alvin W. Vogtle Electric Generating Plant, in Georgia, which marked a historic milestone as the first new reactors built in the United States in over three decades (see figure 4.3).[20] These Westinghouse AP1000 pressurized water reactors added 2.2 GW of baseload capacity, making Plant Vogtle the largest nuclear power station in the country. Despite cost overruns and delays, the project demonstrated that large reactors remain viable when paired with federal loan guarantees and tax incentives.

Fermi America and Westinghouse have also announced plans to construct four AP1000 reactors near Amarillo, Texas, to power a massive AI data center.[21] The AP1000 design, now fully licensed and supported by a trained workforce and mature supply chain, is expected to see reduced costs and construction timelines compared to earlier builds. This proposal reflects a new trend of pairing nuclear power with energy-intensive digital infrastructure, as exemplified by Microsoft's proposed restart of a Three Mile Island unit to power its AI data centers.[22]

FIGURE 4.3 Vogtle Unit 3 under construction in October 2020

Source: US Nuclear Regulatory Commission

Holtec International received regulatory approval to restart the Palisades Nuclear Plant, in Michigan, which has been in decommissioning for three years.[23] Reactivations of a closed US nuclear plant like this could unlock latent capacity at other retired sites.

More technologically advanced reactors will generally use high-assay low-enriched uranium (HALEU), enriched to between 5 and 20 percent uranium-235. Yet domestic supply of this remains severely constrained. Historically, the United States has relied on Russian imports for HALEU, but recent legislation bans such imports after 2027, intensifying pressure to build a domestic supply chain.

Centrus Energy, the only US firm currently producing HALEU, delivered its first batch in late 2023 and aims to scale up its Ohio facility.[24] However, expansion will require billions of dollars in investment and sustained political support. In April 2025, the DOE awarded conditional HALEU supply commitments to five reactor developers by drawing from national stockpiles and DOE reserves.[25] To catalyze long-term supply, the DOE also awarded $2.7 billion in enrichment contracts to four firms, aiming to rebuild domestic enrichment capacity and reduce reliance on foreign sources.[26]

Coal

Coal-fired electricity in the United States has been declining since the 1950s, supplanted by inexpensive natural gas and the deployment of wind and solar generation.[27] Yet coal is garnering renewed attention as an option for powering data centers and AI that addresses reliability and supply chain vulnerability concerns. Coal is a domestically mined resource that can limit US dependence on foreign energy products.[28] In an effort to reinvigorate the industry, the US government designated coal as a critical mineral in April 2025, and President Trump signed an executive order, Reinvigorating America's Beautiful Clean Coal Industry, to expand its mining and use in the United States.[29]

Asia continues to be heavily dependent upon coal. China has pledged to be carbon neutral by 2060, and to that end, installed 365 GW of solar and wind energy capacity in 2024, far outpacing Europe.[30] Yet it also had almost 100 GW of new coal-fired capacity under construction in 2024, the greatest amount in a decade.[31] Coal also continues to dominate in India, accounting for 75 percent of generation.[32]

Over the Horizon

The discussion below provides an overview of technologies that are promising or where policy associated with them or an established area is less developed. It includes some energy technologies not covered in last year's edition of *SETR* and, due to space limitations, provides short descriptions of others. (For more on these technologies, refer to chapter 10 of *SETR* 2025.)

- **Thermal storage** Long-duration energy storage from intermittent sources such as wind and solar is necessary to capture their full value. Storage allows excess energy produced during plentiful times to be used when intermittent sources are unavailable. For example, solar energy is about twice as abundant in summer as in winter. Thermal storage stores excess power in the form of heat, such as by heating a large volume of salts to a very high temperature. When needed, this stored heat can be released to generate power.

- **Renewable combustible hydrocarbons and biodiesel** Research on these technologies aims to create energy sources that do not rely on fossil fuels such as oil, gas, or coal. Renewable fuels include combustible hydrocarbons such as biodiesel, which can be produced from animal fats or vegetable oils; bioethanol produced from corn or algae; hydrogen, which can be produced from many sources; and ammonia produced using green hydrogen (see definition of green hydrogen later in this chapter).

- **Carbon capture and storage (CCS)** CSS reduces CO_2 in the atmosphere by capturing and storing it underground. Carbon capture is usually done at the emission source, like power plant smokestacks, using materials and membranes to extract CO_2 for underground storage or material use. Direct air capture, which removes CO_2 from the atmosphere at much lower concentrations, consumes more energy. However, it is currently progressing through several commercial-scale projects, with research focused on scaling, storage duration, and cost-effectiveness of various removal methods such as biomass storage and mineralization.

- **New grid technologies** These are needed to manage the future electric grid. Compared to today's grid, this future one will be larger, more complex, and more decentralized, integrating varied renewable energy sources and dealing with increased electricity demand. Relevant new technologies include reconductoring (replacing existing power cables with more advanced ones) to boost line capacity, end-use energy management to shift and optimize the timing of electricity consumption, vehicle-to-grid systems that allow EVs to feed energy back to the grid, and second-life battery applications for stationary storage.

Additionally, AI and data-driven systems will optimize grid operations and maintenance by responding dynamically to changes in renewable generation and demand, and by predicting equipment failures.

Of particular interest this year are the following technologies, for which longer descriptions are offered:

Green Hydrogen

Hydrogen is vital to today's energy systems, with important roles in refining and in fertilizer and steel production. Many envision it to be similarly vital in a deeply decarbonized energy future, either as a vehicle fuel itself or as a component of a synthetic fuel, as a form of grid-scale storage, and as an input to industrial processes.

Hydrogen today is produced almost exclusively by steam reforming, in which methane and water are passed over catalysts at suitable temperatures and pressures to yield hydrogen and CO_2.[33] In a decarbonized world, that process would be replaced by the electrolysis of water driven by carbon-free electricity (e.g., from renewables). While there have been initial steps in that direction, progress will depend upon the cost of "green" hydrogen (i.e., hydrogen produced through renewable electricity sources) relative to that produced by steam reforming, the scalability of the technology, and the extent to which the world pursues decarbonization.

Electrolyzer technologies—primarily alkaline, proton exchange membrane, and emerging solid oxide systems—have seen dramatic cost reductions over the past decade. DOE estimates suggest electrolyzer costs have dropped by over 80 percent since 2005, with further reductions expected as manufacturing scales and efficiency improves.[34] Global installed electrolyzer capacity now exceeds 4.5 GW, up from just 0.17 GW in 2021. But despite these advances and a 10 percent annual growth in demand, green hydrogen still accounted for less than 1 percent of the roughly 100 million tons of global hydrogen production in 2024.

While political changes have reduced US prospects and enthusiasm for green hydrogen, global investment is growing. The International Energy Agency projected $7.8 billion in global spending on clean hydrogen in 2025—a 70 percent increase over 2024—with 6 GW allocated to electrolysis projects. Countries like India, China, and Oman are launching giga-scale projects and positioning themselves as future exporters.

The extent to which those investments will pay off depends upon several factors:

- **Cost** Green hydrogen is still expensive and capital-intensive. Today's cost, $3 to $6 per kilogram, remains significantly higher than the $1 to $2 per kilogram cost of steam reforming. Achieving cost parity by 2031 will require breakthroughs in efficiency, materials, and manufacturing.
- **Infrastructure** Pipelines, storage, and refueling stations are limited, especially outside pilot hubs.
- **Offtake uncertainty** Many projects lack firm buyers, creating a mismatch between final investment decisions and market demand.
- **Regulatory fragmentation** Inconsistent standards for emissions accounting, certification, and trade hinder the formation of a global hydrogen market.

Geothermal Energy

Geothermal energy draws upon Earth's internal heat, making it, unlike wind and solar technologies, independent of weather conditions. The most common method of extracting geothermal energy

> **Compared to today's grid, [the] future one will be larger, more complex, and more decentralized.**

FIGURE 4.4 Drone image of the setup for the first demonstration of Quaise Energy's novel drilling technique on a full-scale oil rig

Source: Quaise Energy

is to use steam from naturally occurring geysers to generate electricity. The hot water from geothermal springs can also be used to heat buildings directly.[35] However, there are a limited number of sites where these methods can be deployed.

An alternative method for extracting geothermal energy is to inject water into dry, hot rock deeper down and bring the resulting steam to the surface to generate electricity.[36] Beyond knowing where best to drill, the use of standard drills limits the depths that can be reached and thus the temperatures that can be accessed. And because fracking (which involves injecting liquid at high pressure to expand existing fissures) is required to create channels for steam generation, it is possible to induce seismic events that can damage local infrastructure.[37]

To address these issues, various start-ups are developing safe and efficient drilling techniques that can access greater depths. Quaise Energy, for example, has recently developed a new drill that uses an electromagnetic beam to vaporize rock at great depths (see figure 4.4),[38] thus addressing many of the challenges faced by physical drills.[39] The deepest hole ever drilled was almost eight miles deep, but Quaise wants to push to twelve miles.

There are also several recent innovations in dry heat geothermal generation and storage, which increase the flexibility and availability of geothermal energy. For example, Fervo, a start-up based out of Houston, drills horizontally to find heat sources that can warm the water that it injects.[40] Oil and gas companies have become increasingly interested in this form of technology because oil wells can be retrofitted for geothermal energy.[41]

One generic challenge in geothermal applications is depletion of the heat resource because of the long amount of time it takes for the ambient underground heat to replace that which has been extracted. For example, the capacity of the Geysers geothermal plants in California has declined some 65 percent in the past three decades, from 2,000 megawatts (MW) in 1987 to 725 MW today.[42]

The National Renewable Energy Laboratory estimates that geothermal energy on federal lands could support as much as 975 GW of dispatchable generation.[43] The technology has significant bipartisan support. The Geothermal Energy Opportunity Act was introduced in Congress in January 2025 to accelerate approval of geothermal projects.[44] On May 30, 2025, the US Department of the Interior announced emergency permitting procedures to accelerate geothermal projects in support of the Trump administration's goal of energy dominance.[45]

Small Modular Nuclear Reactors

A small modular reactor (SMR) is a compact nuclear fission reactor with an electric power output of up to 300 MW. It is designed for factory fabrication and modular installation to provide a flexible, scalable low-carbon energy source. More than a dozen US start-ups are racing to commercialize advanced SMR designs that promise lower costs, faster deployment, and enhanced safety. These include molten salt, liquid metal, and high-temperature, gas-cooled reactors, many of which operate at atmospheric pressure and use passive safety systems. (Passive safety systems in nuclear reactors enhance safety by relying on natural physical phenomena—such as gravity, natural circulation, and convection—to maintain safe reactor conditions without external power, active controls, or operator intervention.)

Among them are:

- Kairos Power, which is developing the Hermes 2 reactor in Tennessee.[46] This uses molten fluoride salt as coolant and is expected to deliver 50 MW to Google's data centers by 2030, with plans to scale to 500 MW by 2035.
- TerraPower, which broke ground on its Natrium reactor in Wyoming.[47] Using liquid sodium coolant and molten salt energy storage, the plant aims to dispatch 345 MW by 2030 to PacifiCorp, with ramp-up capability to 500 MW.
- Oklo, which is pursuing compact fast reactors cooled by liquid metal.[48] Despite regulatory setbacks, it has secured agreements to supply 12 GW to data center operator Switch by 2044.

Reflecting the urgency to meet AI-driven electricity demand, the DOE recently selected eleven projects for a pilot program to fast-track the development of advanced reactor technologies. Some of these will be intended for use in small modular test reactors, with the aim to bring at least three online by July 4, 2026.[49] One of these, Deep Fission, plans to put an SMR in a one-mile deep borehole that will provide much of the physical safety barriers needed for reactors and thereby reduce construction costs significantly.[50]

Fusion Energy

Like the energy produced by splitting heavy atoms such as uranium or plutonium (fission), energy produced by combining two light atoms (fusion) entails no greenhouse gas emissions. It also has the additional advantages of using abundant fuels and producing minimal long-lived radioactive waste.[51] While it is still some distance from commercial demonstration, nuclear fusion could prove to be a viable long-term energy source for future generations.

The most important among the several technical challenges to realizing fusion energy is to achieve

Many nuclear fusion advances are now driven by start-ups, reflecting the private sector's central role in energy innovation.

"gain"—that is, to confine a plasma of hydrogen isotopes for durations and at temperatures and densities sufficient to produce more energy from fusion than was required to create the plasma. One approach to solving this confinement problem is magnetic confinement fusion, which uses powerful magnets to contain and control a superheated plasma of deuterium and tritium. A second is inertial confinement fusion, which calls for rapidly compressing a deuterium-tritium fuel pellet using lasers to ignite the fusion reaction.

In 2022, the National Ignition Facility, which has the world's largest laser, achieved the first laboratory fusion system with net gain—that is, it produced fusion energy 1.5 times greater than the laser energy that created the hot, dense mass of hydrogen. Subsequent refinement led to an April 2025 experiment that showed a gain of 4.2 times.[52] Although this is a promising milestone, a gain of mid-double-digits magnitude is necessary for a viable power plant.

Beyond sustaining a plasma of sufficient gain, there are two other major technological challenges in making fusion a viable source of energy.

- The walls of whatever vessel contains the plasma must be robust. A fusion plasma produces X-rays and particles that will rapidly degrade wall material. It's therefore important to find material that can resist (or at least slow) this degradation.

- The first fusion reactors will almost certainly be fueled by a mixture of deuterium and tritium. While deuterium is readily available in nature, tritium is radioactive, with a half-life of 12.3 years. This means that tritium must be manufactured. A fusion power plant with a 1 GW output operating for a year would consume at least several times the current global production of tritium. Therefore, a viable fusion reactor must breed its own tritium. Self-manufacture of tritium can be done in principle by exposing ^{6}Li (a particular and relatively rare isotope of lithium) to the neutrons that the reactor produces. However, this process has never been demonstrated at the scale required.

Even after these hurdles are surmounted, the cost of electricity generated must be competitive with conventional alternatives. Most knowledgeable observers believe fusion power into the grid won't happen until 2040, at the earliest.

France, Japan, and China are all making progress in their national programs pursuing magnetic confinement fusion.[53] America's national program is dominated by participation in the ITER tokamak international initiative to build a fusion reactor, although the DOE has recently reinvigorated efforts on the alternative stellarator concept. (A tokamak is easier to build and more efficient than a stellarator design, but a tokamak must operate in pulses rather than continuously. A stellarator can operate continuously but is more difficult to build.)

Many nuclear fusion advances are now driven by start-ups, reflecting the private sector's central role in energy innovation.[54] Private companies are pursuing a wider range of fusion technologies than government-backed programs, across both inertial and magnetic confinement approaches. In magnetic confinement, notable examples include Commonwealth Fusion Systems (originating from MIT research)[55] and TAE Technologies (founded at University of California–Irvine),[56] which plan to build their first fusion reactors by the early 2030s. German start-up Proxima Fusion has released open-source plans for a nuclear fusion power plant employing novel containment strategies.[57]

Iron-Air Batteries

Storing energy in large-scale, long-duration batteries is one way of compensating for intermittent wind and solar generation. Unfortunately, lithium-ion (Li-ion) batteries are ill suited for this purpose due to their limited storage capacity and high cost. In *SETR* 2025, we highlighted novel batteries that are emerging to meet future energy reliability needs, including redox flow, Ni-H_2 gas, and Zn-MnO_2. In the past year, Form Energy's iron-air batteries have also emerged as a promising alternative.[58]

Iron-air batteries can deliver up to one hundred hours of utility-scale storage, compared to four hours from Li-ion batteries. (The time of utility-scale storage refers to the period over which a battery can sustain its full rated power output.) This improvement stems from a reversible rusting process. To discharge an iron-air battery, iron oxidizes (i.e., it rusts by combining with oxygen), causing a flow of electrons (electricity). To charge the battery, electricity is used to reverse the rusting process, releasing oxygen.[59] While the chemical processes in Li-ion batteries allow for rapid charge and discharge cycles, they also lead to faster battery degradation. In contrast, the reversible rusting process enables extended energy release, making iron-air batteries ideal for long-duration storage.

Because iron is one of the most abundant metals on Earth, the batteries are significantly cheaper than Li-ion or redox flow batteries. They are also safer, with no flammable materials.[60] But they are less efficient than traditional batteries, releasing only 50 to 60 percent of the stored energy compared to 80 to 90 percent for Li-ion batteries.[61] Even so, many utility companies plan to use this novel energy storage technology. PacifiCorp, for example, noted in its 2025 integrated resource plan that "100-hour iron-air storage has a low capital cost with a low round trip efficiency," making it "a valuable asset in its portfolio."[62]

Iron-air batteries are not intended to completely replace Li-ion batteries but rather serve as a complementary form of long-duration energy storage. They will also contribute to national security goals by reducing US dependence on Chinese-dominated Li-ion batteries.[63]

Transportation Electrification

The One Big Beautiful Bill that passed in 2025 eliminated the tax incentives for EVs and the associated charging infrastructure that had been in place under the 2022 Inflation Reduction Act. This will slow EV adoption in the United States. Nevertheless, the electrification of light-duty transport continues apace in other parts of the world.[64] (Light-duty transport refers to vehicles designed primarily for the transportation of passengers or cargo and weighing less than 8,500 pounds. It typically includes passenger cars, small vans, SUVs, and pickup trucks.)

Certain EV technologies, such as batteries, are currently dominated by Chinese suppliers, who lead the global market. For example, Contemporary Amperex Technology Co., Limited (CATL), supplies 35 percent of the world's Li-ion EV batteries, serving major companies including Tesla, BMW, and Volkswagen. In early May 2025, CATL raised $4.6 billion in a Hong Kong IPO, notably excluding American investors.[65]

Range is one of the greatest challenges facing EVs, making improving battery technology key to their adoption. Currently, EVs with fast charging speeds and long ranges, such as the Tesla Model Y and Mercedes-Benz EQS, take roughly 30 minutes to charge to a range of 280 miles. However, in April 2025, CATL announced that its latest EV battery could add 323 miles of driving range with 5 minutes of charging, marking a significant improvement in EV battery range and charging speed.[66] However, the implications for charging infrastructure should not be underestimated—assuming a nominal 3 miles per kWh, adding 300 miles of range in 5 minutes requires 1.2 MW of power at the charging station, or about 1,000 times the average power draw of an American household.

Policy Issues

The past year has seen dramatic changes in US energy policy, regulation, and economics, driven by surging electricity demand, shifting political priorities, and global market pressures. Federal and state governments have enacted sweeping reforms, regulatory agencies are reorienting their frameworks, and economic forces are reshaping investment flows. The following are some of the key policy-related trends:

From Decarbonization to Energy Dominance

The Trump administration has emphasized energy abundance and industrial competitiveness over greenhouse gas mitigation, reversing many of the clean energy priorities of previous years. This shift is embodied in legislation that eliminates tax credits for new wind and solar projects—including the Production Tax Credit and Investment Tax Credit, which had catalyzed renewable deployment for decades. New legislation has also expanded federal support for nuclear power, geothermal, and natural gas infrastructure, including fast-track permitting and loan guarantees.

At the same time, the administration issued four executive orders aimed at "unleashing American energy," including mandates to accelerate fossil fuel leasing on federal lands, streamline pipeline approvals, and sunset outdated regulations.[67] These moves signal a realignment toward energy security, grid reliability, and domestic production.

Regulatory Overhaul

Regulatory agencies have undergone significant restructuring. The DOE launched the largest deregulatory effort in its history, proposing to eliminate or modify forty-seven regulations, ranging from appliance-efficiency standards to environmental review procedures. According to the DOE,[68] these changes are expected to save consumers an estimated $11 billion and reduce regulatory text by over 125,000 words.

The Federal Energy Regulatory Commission was directed to implement "conditional sunset clauses" for all energy-related regulations, requiring periodic review and expiration of such regulations unless reauthorized. This introduces uncertainty into long-standing rules governing transmission planning, interconnection (i.e., links between local grids), and wholesale market operations.

The Environmental Protection Agency (EPA) scaled back enforcement of greenhouse gas emissions standards for power plants and vehicles. While previous rules aimed to reduce emissions through 2032, new guidance allows states greater flexibility and delays compliance timelines. More importantly, the EPA has also proposed rescinding the Endangerment Finding that underpins its regulation of greenhouse gas emissions.[69] As noted earlier, nuclear power is enjoying a revival that spans large-scale reactor projects, a host of SMR start-ups, renewed attention to advanced designs and advanced fuels, and federal initiatives aimed at rebuilding domestic capacity and global leadership. For example, the Nuclear Regulatory Commission (NRC) has accelerated licensing pathways for SMRs and microreactors (i.e., advanced reactors generating no more than about a tenth of the power of an SMR and designed for mobility, fast deployment, and minimal onsite staffing), reflecting bipartisan support for advanced nuclear technologies. Additionally, in May 2025 the White House issued four executive orders to reinvigorate the nuclear industrial base, streamline reactor licensing, reform the NRC, and deploy advanced reactors for national security.[70] These orders mandate:

- Accelerated licensing for SMRs and microreactors
- Funding to restart closed plants and uprate existing reactors
- Support for ten new large reactor designs under construction by 2030
- Expansion of HALEU enrichment and deconversion infrastructure
- Workforce development and supply chain localization

Congress has also passed the Accelerating Deployment of Versatile, Advanced Nuclear for Clean Energy (ADVANCE) Act, which facilitates reactor deployment and strengthens export capabilities.[71] The latter is needed to compete with aggressive Chinese and Russian expansion of their nuclear exports.

Supply Chain Issues

Access to lithium and other critical minerals poses a challenge to the long-term success of domestic Li-ion EV battery production. China currently produces 90 percent of the world's permanent rare-earth magnets, which are critical components in EV motors. Since December 2025, China has imposed regulations on exporting various critical minerals, which could gravely impact American access to the materials necessary to build EVs and many other sustainable technologies.[72] Many companies are also concerned about the long-term availability of these materials, and some, like CATL, are looking into more efficient ways to recycle old Li-ion batteries.[73] The battery recycling market is predicted to grow at a compound annual growth rate of 40 percent.

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