

The **Global Energy Perspective 2023**, published by McKinsey, provides a comprehensive outlook for energy demand and supply across various sectors, fuels, and geographies. Here are the key points:

1. Pathway and Scenarios:

- The report models a 1.5°C pathway aligned with the Paris Agreement.
- It explores four bottom-up energy transition scenarios, each with varying assumptions about technological progress and policy enforcement.
- Despite significant carbon emission reductions, all scenarios result in warming between 1.6°C and 2.9°C by 2100.
- Achieving net-zero emissions may require course corrections to overcome bottlenecks and align with climate goals.

2. Fossil Fuel Demand:

- Total fossil fuel demand is projected to peak by 2030 across all scenarios.
- Coal demand is expected to decline sharply.
- Natural gas and oil, however, are anticipated to continue as core components of the world's energy mix for decades.
- Natural gas demand is driven by its role in balancing renewables-based power generation until large-scale battery deployment occurs.

U.S. Energy Sector:

The United States has a diverse energy portfolio. Here's an overview of energy consumption and production in the U.S.:

1. Energy Mix:

- The U.S. uses a mix of energy sources, including fossil fuels (petroleum, natural gas, coal), nuclear energy, and renewables.
- In 2022, the breakdown of primary energy consumption was as follows:
 - **Renewable Energy:** 37%
 - Includes geothermal, solar, wind, biomass waste, biofuels, wood, and hydroelectric biomass.
 - **Natural Gas:** 13%
 - **Petroleum:** 33%
 - **Nuclear Electric Power:** 36%
 - **Coal:** 8%

2. End-Use Sectors:

- The U.S. has five energy-use sectors:

- Electric power (37.75 quads)
 - Transportation (27.47 quads)
 - Industrial (23.18 quads)
 - Residential (7.11 quads)
 - Commercial (4.90 quads)
- The electric power sector generates most of the electricity (96%) consumed by other sectors.
 - Petroleum dominates transportation energy consumption, while coal plays a minor role in electricity generation.

3. Renewables vs. Fossil Fuels:

- While fossil fuels remain the primary energy source, renewables have been growing.
- In 2021, about 79% of U.S. energy came from fossil fuels, but renewable energy has been contributing more over the years.

Global Energy Perspective 2023 by McKinsey:

The Global Energy Perspective 2023 provides a detailed demand outlook for various sectors, fuels, and geographies across a 1.5°C pathway. It also includes four bottom-up energy transition scenarios.

Despite significant reductions in carbon emissions, all energy transition scenarios remain above the 1.5°C pathway and result in warming between 1.6°C and 2.9°C.

Fossil fuel demand is projected to peak by 2030 in all scenarios. While coal demand is expected to decline sharply, natural gas and oil are expected to continue as core parts of the world's energy mix for decades¹.

U.S. Energy Sector Analysis:

Over the last 7 days, the Energy industry has dropped by 3.7%, driven by declines in companies like Marathon Petroleum.

However, over the past 12 months, the industry showed an 11% increase. Earnings are expected to grow by 2.7% per annum in the next few years².

World Energy Outlook 2022 by IEA:

Renewables, especially solar PV, and wind are gaining ground and are expected to account for 43% of global electricity generation by 2030 (up from 28% today).

Oil demand is projected to rise by 0.8% per year until 2030 but will peak soon after at around 103 million barrels per day due to electric vehicles (EVs) and efficiency gains.

Initiatives from countries in the energy sector:

1. Solar Photovoltaic (PV) Power Potential:

- The World Bank has assessed the solar PV power potential by country.
- Around 20% of the global population lives in 70 countries with excellent conditions for solar PV.
- These high-potential countries tend to have low seasonality in solar PV output.
- Notably, the difference in average practical potential between countries with the highest potential (e.g., Namibia) and the lowest (e.g., Ireland) is slightly less than a factor of two.

2. Energy Transition Investment:

- China remains a global leader in energy transition investment.
- In 2021, China increased its overall energy transition investment by 60% compared to 2020 levels.
- The country's wind and solar capacity also grew by 19% in 2021, with electrified transport contributing significantly to the investment.

3. Energy Efficiency Potential:

- The top 20 energy-consuming economies globally account for more than 75% of global total primary energy supply (TPES).
- Four countries—China, the United States, India, and the Russian Federation—alone contribute nearly 50% of TPES.

4. Photovoltaic Power Potential by Country:

- In total, 93% of the global population lives in countries where the average daily PV potential ranges between 3.0 and 5.0 kWh/kWp.
- Approximately 20% of the global population resides in countries with excellent solar PV conditions.
- These countries have long-term daily PV output averages exceeding 4.5 kWh/kWp.

1. Sweden:

- **Initiatives:** Sweden has been a role model in sustainable energy. It benefits from diverse energy system structures, stable regulatory frameworks, high investment in research and development, and carbon pricing schemes that incentivize greener solutions.
- **Ranking:** Sweden leads the global rankings in the **Energy Transition Index (ETI)**.



2. Norway:

- **Initiatives:** Norway is a pioneer in net-zero efforts.
- **Ranking:** It closely follows Sweden in the ETI rankings.



3. Denmark:

- **Initiatives:** Denmark is another leader in net-zero goals and renewable energy adoption.
- **Ranking:** It ranks high in the ETI, emphasizing its commitment to clean energy transition.



4. Uruguay:

- **Initiatives:** Uruguay has made significant progress in cleaning up its economy.
- **Improvements:** It climbed from 38th to 26th in the Green Future Index by implementing sustainable policies.
- **Challenges:** Agriculture and forestry account for a substantial portion of its exports and nearly 75% of its CO2 emissions.



5. South Africa:

- **Initiatives:** South Africa's National Treasury advanced a Green Finance Taxonomy and established standards for sustainable economic activities.
- **Progress:** It moved from 31st to 25th place in the Green Future Index, encouraging foreign investment in sustainable practices.



6. **Germany:**

- **Feed-in Tariff (FIT):** Households producing renewable energy at home can sell excess electricity to the national grid through the FIT scheme.
- **Tax Incentives:** Homeowners receive tax incentives for energy-efficient renovations, including replacing inefficient doors/windows and upgrading heating systems and insulation.



7. **United States:**

- **Inflation Reduction Act (IRA):** The US IRA transformed the nation into a global leader in decarbonization investment. It offers federal funding across various sectors, including tax credits for households to decarbonize and invest in renewables.

8. **Global Trends:**

- **Investment:** Global investment in energy transition technologies reached a record \$1.3 trillion in 2022, benefiting both businesses and households.
- **Renewable Growth:** Renewable electricity capacity additions surged, with continuous policy support in over 130 countries driving change.

Threats in these industries:

1. **Policy Uncertainty and Financing Challenges:**

- The pace of economic recovery, pressure on public budgets, and the financial health of the energy sector exacerbate existing policy uncertainties and financing challenges.
- The Covid-19 pandemic has introduced additional uncertainty, affecting government policies, investment decisions, and financing availability for renewable projects.
- Some renewable projects are tied to planned but not finalized government-backed auctions or incentives, which may face delays due to the crisis.

2. **Supply Chain Disruptions and Price Fluctuations:**

- While renewable energy costs have been declining steadily, supply disruptions (e.g., due to the pandemic) can lead to local transitional price fluctuations.
- However, there is no sign that the Covid-19 crisis will change the overall declining cost trends for renewables.
- For instance, solar PV manufacturing overcapacity is expected to reach record levels, further reducing module prices.

3. **Economic Recovery and Public Budgets:**

- The pace of economic recovery affects investment decisions and the financial health of the energy sector.
- Heightened pressure on public budgets may impact funding for renewable projects.
- Balancing economic recovery with sustainable energy transition remains a challenge.

4. Cybersecurity and Physical Threats:

- Malicious actors pose a serious threat to the physical security and resilience of energy infrastructure.
- Attacks on energy facilities, both cyber and physical, can disrupt operations and compromise safety.
- Ensuring robust cybersecurity measures and addressing physical vulnerabilities are critical.

5. Market Forces and Transition Readiness:

- Some countries are making significant progress in their transition to low-carbon energy, while others lag.
- Factors such as carbon emissions reduction, energy transition policies, green society initiatives, clean innovation, and climate policy play a crucial role in determining a country's readiness for energy transition.

Future of the energy sector:

1. A New Energy Economy:

- The emergence of a **new energy economy** is evident. Renewable energy sources like wind and solar PV are growing rapidly, and electric vehicle sales are setting records.
- This transition is fuelled by policy actions, technological innovations, and the urgency to address climate change.
- Electricity is taking a central role in people's lives, powering mobility, cooking, lighting, and more.
- By 2050, electricity is projected to account for around 50% of final energy use in a net-zero emissions scenario.

2. Investment Shifts:

- Investment in the power sector now consistently exceeds that in oil and gas supply.
- Clean energy technologies are becoming cost-effective choices for consumers worldwide.
- Solar PV and wind are often the cheapest sources of new electricity generation.
- The market opportunity for clean technology is growing exponentially, creating a competitive landscape for countries and companies.

3. Global Supply Chains and Investment Opportunities:

- Clean technology markets (wind turbines, solar panels, batteries, fuel cells) offer substantial investment opportunities.
- If the world achieves net-zero emissions by 2050, the annual market opportunity for clean tech manufacturers could reach USD 1.2 trillion by 2050.
- Countries and companies are vying for positions in global supply chains.

4. Digitalization and Decentralization:

- Digital technologies are transforming the energy sector, enabling smarter grids, efficient demand management, and decentralized energy production.
- Decentralized systems (such as rooftop solar) empower consumers to generate and manage their energy locally.

5. Energy Transition Challenges:

- Despite progress, challenges remain. Ensuring a smooth transition and avoiding severe climate impacts require concerted efforts.
- Policy stability, financing, and supply chain resilience are critical areas to address.
- Balancing economic recovery with sustainable energy goals is essential.

Major companies in the US energy sector:

1. Exxon Mobil Corporation (XOM):

- Exxon Mobil is one of the largest international integrated oil companies.
- In 2022, it generated \$413.68 billion in revenue, a 44.83% increase from 2021. Exxon annual revenue for 2021 was \$285.64B, a 57.38% increase from 2020.
- Delivered industry-leading 2023 earnings of \$36.0 billion¹, generated \$55.4 billion of cash flow from operating activities and distributed \$32.4 billion to shareholders.
- Leading industry in compounded annual growth rate for earnings excl. identified items and cash flow since 2019.
- Increased Guyana and Permian production by 18% vs. 2022 and achieved record annual refinery throughput.
- Strengthened portfolio with \$4.1 billion of non-core asset divestments, and two acquisitions; one that accelerates Low Carbon Solutions and one that will transform the Upstream business.
- Launched new Mobil Lithium business with the potential to supply up to one million EVs per year by 2030.

ADVANCING CLIMATE SOLUTIONS

Progress Toward Net Zero

- In the Permian Basin, ExxonMobil made great progress on the plan to achieve net zero GHG emissions by 2030. In 2023, the company electrified all of its drilling fleet and replaced over 6,000 natural-gas-driven pneumatic devices in its unconventional operated assets.

Lithium

- In the fourth quarter, ExxonMobil announced its new Mobil™ Lithium business with plans to become a leading producer and grow U.S.-based supplies of lithium for the global battery and EV markets.
- The company is planning its first production for 2027. By 2030, ExxonMobil aims to produce enough Mobil™ Lithium with the potential to supply approximately one million EVs per year.



2. **Chevron Corporation (CVX):**

- Chevron is another major integrated oil company.
- It reported a revenue of \$295.39 billion in the same year.



3. **ConocoPhillips (COP):**

- ConocoPhillips is a significant player in the energy sector.
- Its revenue reached \$151.52 billion in 2022.



4. **EOG Resources, Inc. (EOG):**

- EOG Resources focuses on exploration and production of oil and natural gas.
- Its market cap stands at \$76.60 billion.



5. **Schlumberger Limited (SLB):**

- Schlumberger provides oilfield services and technology.
- The company's market cap is around \$71.25 billion.



6. Marathon Petroleum Corporation (MPC):

- Marathon Petroleum deals with refining, marketing, and transportation of petroleum products.
- Its market cap is approximately \$70.76 billion.



7. Phillips 66 (PSX):

- Phillips 66 operates in refining, marketing, and chemicals.
- The company's market cap is about \$65.72 billion.



8. Pioneer Natural Resources Company (PXD):

- Pioneer Natural Resources focuses on oil and gas exploration and production.
- Its market cap stands at \$63.15 billion.



9. Enterprise Products Partners L.P. (EPD):

- Enterprise Products Partners is a midstream energy company.
- Its market cap is around \$62.53 billion.



10. Occidental Petroleum Corporation (OXY):

- Occidental Petroleum is involved in oil and gas exploration and production.
- Its market cap is approximately \$59.07 billion.

1. Exxon Mobil Corporation:

- **CEO:** Darren W. Woods
 - Darren Woods holds a Bachelor of Science degree in electrical engineering from Texas A&M University and an MBA from Northwestern's Kellogg School of Management.
 - He joined Exxon Company International in 1992 and has held various roles within the company, including vice president of supply and transportation and president of ExxonMobil Refining and Supply Company.
- **CFO:** Kathryn A. Mikells
- **Chief Legal Officer:** Neil A. Chapman
- **Executive Vice President, Geographies:** Khaled Al Mogharbel
- **Chief People Officer:** Carmen Rando Bejar
- **Chief Technology Officer:** Demosthenis Pafitis
- **Executive Vice President, Core Services & Equipment:** Abdellah Merad.



2. Chevron Corporation:

- **CEO:** Michael K. Wirth
 - Michael K. Wirth is Chairman of the Board and Chief Executive Officer.
- **CFO:** Pierre R. Breber
- **Chief Human Resources Officer:** Rhonda J. Morris
- **Vice Chairman:** R. Hewitt Pate
- **Vice President, Health, Safety and Environment:** Marissa Badenhorst
- **Vice President, General Tax Counsel:** Paul R. Antebi.



3. ConocoPhillips:

- **CEO:** Ezra Y. Yacob
 - Ezra Y. Yacob became CEO in October 2021 and Chairman of the Board in October 2022.
- **President:** Lloyd W. "Billy" Helms, Jr.
- **Chief Financial Officer:** Stephane Biguet
- **Chief Legal Officer:** Dianne Ralston
- **Executive Vice President, Geographies:** Khaled Al Mogharbel
- **Chief People Officer:** Carmen Rando Bejar
- **Chief Technology Officer:** Demosthenis Pafitis
- **Executive Vice President, Core Services & Equipment:** Abdellah Merad.

4. EOG Resources, Inc.:

- **CEO and Chairman of the Board:** Ezra Y. Yacob
 - Ezra Y. Yacob became CEO in October 2021 and Chairman of the Board in October 2022.
- **President:** Lloyd W. "Billy" Helms, Jr.
- **Chief Operating Officer:** Jeff Leitzell
- **Chief Financial Officer:** Ann Janssen
- **Chief Technology Officer:** Demosthenis Pafitis
- **Executive Vice President, Lower 48:** Nick Olds.



5. Schlumberger Limited:

- **CEO:** Olivier Le Peuch
 - Olivier Le Peuch has been CEO since August 2019.
- **CFO:** Stephane Biguet
- **Chief Legal Officer:** Dianne Ralston
- **Executive Vice President, Geographies:** Khaled Al Mogharbel
- **Chief People Officer:** Carmen Rando Bejar
- **Chief Technology Officer:** Demosthenis Pafitis
- **Executive Vice President, Core Services & Equipment:** Abdellah Merad.

Electricity consumption

We forecast sales of electricity to U.S. end-use customers will increase by 2% in 2024 compared with 2023 and by 1% in 2025. The expected growth contrasts with a 2% decrease in electricity sales in 2023 compared with 2022. We expect electricity consumption to grow in all major consuming sectors this year, with forecast growth especially strong in the residential sector, where we expect it to increase by 4%. Much of the forecast year-over-year growth in residential electricity occurs this summer. We expect a hotter summer this year, with 7% more forecast cooling degree days in 2Q24 and 3Q24 than the same quarters in 2023.

U.S. electricity sales to non-residential customers in the commercial and industrial sectors grow in the forecast by 2% annually in 2024 and 1% in 2025. In some regions, we expect relatively little growth in non-residential electricity demand because vacancies in office buildings remain high compared with pre-pandemic levels. Areas of the country with concentrations of new large computing customers, such as data centers, have the fastest forecast growth in total non-residential electricity consumption; we expect the West South

Central and West North Central Census Divisions together will contribute 50% of total U.S. non-residential electricity sales growth in 2024 and almost 90% of growth in 2025.

Electricity generation

Generation from renewable energy sources is the main contributor to growth in U.S. electricity generation over the STEO forecast. In particular, the electric power sector added 19 gigawatts (GW) of solar capacity in 2023 (a 27% increase), and we expect 37 GW will be added in 2024 and another 32 GW will be added in 2025. With this new capacity, we expect solar will provide 6% of total U.S. electricity generation in 2024 and 7% in 2025, up from a 4% share in 2023.

The increased generation from solar is likely to slow growth in generation from natural gas-fired power plants, even with relatively low natural gas prices in the forecast. We expect the share of total U.S. natural gas-fired generation in 2024 to average 42%, similar to 2023, before declining to 41% in 2025. We don't expect any new combined-cycle gas turbine plants in 2024, another reason why natural gas-fired generation makes up a smaller portion of electricity generation. Low natural gas prices will continue to reduce coal-fired generation; the forecast U.S. coal generation share falls to 15% in 2024 and 14% in 2025, compared with 17% last year.

Coal markets

After the Port of Baltimore was closed as a result of the collapse of the Francis Scott Key bridge, we reduced our forecast for U.S. coal exports by almost 3 million short tons (MMst)—more than 30%—in April and 2 MMst—about 20%—in May compared with the March STEO. The port is the second-largest export hub for coal in the United States.

We do not expect this event to have a significant long-term impact on U.S. exports coal exports. The price and quality of coal are important factors contributing to international demand for U.S. coal, and we assume some coal previously exported from Baltimore will be shipped from other U.S. ports. However, with the full closure of the port of Baltimore through at least May, as well as uncertainty around when the port will fully open and how long it will take to clear bottlenecks, we expect U.S. coal exports to total 94 MMst in 2024 down 6% relative to the March STEO. We expect exports in 2025 to increase to 105 MMst in 2025, similar to our forecast in the March STEO.

As a result of growth in electricity generation from renewable sources and low natural gas prices we expect coal-fired generation to decline, resulting in the electric power sector's coal consumption to decline by 8% in 2024 and to further decline by 5% in 2025. As exports temporarily drop in 2Q24 and electric power consumption declines, we forecast coal production to be 5% lower in April and 4% lower in May compared with the March STEO. With

exports and consumption both down relative to the March STEO, we have lowered our forecast for coal production in 2024 to about 485 MMst.

In a bifurcated renewable landscape, the solar market brightened in 2023, while wind faced sweeping challenges. The latter bore the brunt of project inputs, labor and capital cost pressures, interconnection and permitting delays, and transmission limitations. Meanwhile, supply chain constraints started easing as historic clean energy and climate laws took effect.

In the United States, utility-scale solar capacity additions outpaced additions from other generation sources between January and August 2023—reaching almost 9 gigawatts (GW), up 36% for the same period in 2022—while small-scale solar generation grew by 20%.¹ Only 2.8 GW of wind capacity came online during the same period, down 57% from last year, resulting in renewables accounting for just over half of capacity added versus two-thirds last year.² However, renewable energy's share of US electricity generation remained level at 22%.³ By the end of 2023, the US Energy Information Administration expects utility-scale solar installations to more than double compared to 2022, to a record-breaking 24 GW, and wind capacity to rise by 8 GW.⁴

2024 energy, resources, & industry outlooks

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The tandem push of federal investments flowing into clean energy and pull of decarbonization demand from public and private entities have never been stronger. Moving into 2024, these forces could enable renewables to overcome hurdles caused by the seismic shifts needed to meet the country's climate targets. The uplift and obstacles shaping the year ahead have set the stage for a variable-speed takeoff across renewable technologies, industries, and markets.

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Federal investment push

Deployment highs. The Energy Information Administration expects renewable deployment to grow by 17% to 42 GW in 2024 and account for almost a quarter of electricity generation.⁵ The estimate falls below the low end of the National Renewable Energy Laboratory's assessment that Inflation Reduction Act (IRA) and Infrastructure Investment and Jobs Act (IIJA) provisions could boost annual wind and solar deployment rates to 44 GW to 93 GW between 2023 and 2030, with cumulative deployment of new utility-scale solar, wind, and storage reaching up to 850 GW by 2030.⁶

Cost lows. A temporary rise in renewable costs could belie their long-term declining trend and relative competitiveness. High financing, balance of plant, labor, and land costs outweighed commodity and freight price falls in 2023, pushing up the levelized costs of energy (LCOEs) for wind and utility-scale solar, especially projects with trackers that account for 80% of installed solar capacity.⁷ Inflation and interest rates disproportionately impacted offshore wind, which saw a 50% rise in its LCOE from 2021 to 2023.⁸ While this equation may prevent LCOEs from resuming historical downward trends in 2024, the IRA investment tax credits and production tax credits have made utility-scale solar and onshore wind, including projects paired with storage, competitive with marginal costs of existing conventional generation.⁹ Projects claiming the maximum available credits could capture the world's lowest solar and wind LCOEs.¹⁰ Renewables collecting production tax credits will likely increase the prevalence of negative prices in wholesale electricity markets.¹¹

Decarbonization demand pull

Most states and utilities. Twenty-nine jurisdictions, representing around half of US electricity retail sales, have mandatory renewable portfolio standards (figure 7); 24 jurisdictions, including two new states in 2023, have zero

greenhouse gas (GHG) emissions or 100% renewable energy goals spanning 2030 through 2050.¹² Renewable portfolio standards and clean energy standard policies are expected to require 300 terawatt hours (TWh) of additional clean electricity by 2030.¹³ Complementary to state goals are the 56 individual and 28 parent utilities with carbon reduction targets that serve 83% of US customer accounts.¹⁴ Twenty-five utilities have further committed to either an 80% carbon reduction or an 80% share of clean generation by 2030.¹⁵ More states, localities, and public utilities are expected to invest in renewables in 2024, as the IRA's direct pay and transferability mechanisms help enable their market participation.¹⁶

Major corporations. In the first 10 months of 2023, 30 companies joined RE100, a global corporate initiative to procure electricity entirely from renewables, growing the membership to 421.¹⁷ Around a quarter of the members are headquartered in the United States, and a bulk of their upcoming commitments have a 2025 target date. Some are also driving decarbonization throughout their supply chains. Following a record-breaking year, corporate renewable procurement saw the number of transacting customers increase by 31% between the first half of 2022 and that of 2023.¹⁸ Big technology companies accounted for most of the procured capacity¹⁹—a trend likely to grow in 2024 as the companies meet and help others meet 24/7 and carbon-matching targets with the help of generative artificial intelligence.²⁰ The training and use of generative AI could increase their data center demand for clean electricity five- to sevenfold.²¹ A growing number of corporations are also expected to support renewables by participating in the nascent tax-credit transfer market in 2024. Coming full circle, corporations are participating in multinational efforts to push governments to address climate change and accelerate the energy transition. Ahead of COP28, 131 companies with close to US\$1 trillion in annual revenue drove a campaign urging governments to phase out fossil fuels by 2035.²²

The impact of unprecedented investment in renewable infrastructure will likely become more apparent in 2024. Regulatory boosts to renewable energy and transmission buildout could help address grid constraints. And boosts to manufacturing could lay the foundations of a domestic clean energy industry with stronger supply chains supporting solar, wind, storage, and green hydrogen deployment. A skilled workforce should be prepared to build, operate, and maintain all these new generation and manufacturing facilities planned over the next few years. As renewables become a larger part of power generation and the portfolio of technologies grows, perceptions could start catching up with the reality that renewables can enhance grid resilience. Deloitte's 2024 renewables industry outlook discusses how these trends could impact the industry in the coming year:

- [**Regulatory boosts and brakes: Historic investment could erode obstacles**](#)
- [**Reshoring clean energy: Supply chains shorten and strengthen**](#)
- [**Reskilling the workforce: Unlocking the talent bottleneck is key to decarbonization**](#)
- [**Renewables as a resilience strategy: Amid widespread misperceptions, renewables can save the day**](#)
- [**Renewable technology, redefined: Underground renewables could surge**](#)

1. Regulatory boosts and brakes: Historic investment could erode obstacles

The IIJA and the IRA have boosted renewables through historic investment in new or expanded programs, grants, and tax credits to accelerate the deployment of established and emerging renewable technologies. Over the past two years, they helped catalyze US\$227 billion of announced public and private investments in utility-scale solar, storage, wind, and hydrogen.²³ To date, US\$100 billion of these investments have materialized, in addition to US\$82 billion in distributed renewables and heat pumps (figure 1). States also offered a record US\$24 billion in tax breaks in 2022 to attract projects.²⁴ The bulk of investment flowed to states with ambitious decarbonization targets and mandates, led by California, as well as states with greater renewable resources and lower permitting and siting costs, led by Texas and Florida.²⁵ An outsize share of clean energy investment also flowed to energy, disadvantaged, and low-income communities identified in the IRA for additional incentives.²⁶

Solar and storage soar

The IIJA and the IRA have had some of the biggest impacts on solar and storage. Utility-scale solar captured the largest share of both announced

investment of US\$92 billion and actual investment of US\$52 billion across 38 states. The month after the IRA passed, a record 72 GW of standalone solar was added to the interconnection queue, more than the preceding 11 monthly additions combined.²⁷ Amid a venture capital (VC) industry slowdown, VC funding for solar and storage increased in the first three quarters of 2023, and the IRA boost blunted higher interest rates as public market and debt financing for solar also grew.²⁸ Solar recorded 34% growth in actual investment over the past year, storage jumped 51%, and distributed renewables, storage, and fuel cells increased 31%.²⁹

IRA tax credits have allowed solar and storage developers to creatively configure projects around siting and grid constraints through standalone or hybrid deployment. In 2024, tax credit adders are expected to shape solar and storage market offerings.³⁰ US Treasury's release of guidance on energy and low-income community adders in the last quarter of 2023 could be particularly relevant to community solar developers.³¹ The guidance may also drive more third-party owned solar and storage projects, which can qualify for these adders unlike customer-owned systems.³² Finally, the impact of US\$7 billion in Greenhouse Gas Reduction Fund grants should be seen through the Solar For All program and the US\$3 billion loan from the Department of Energy's (DOE's) Loans Program Office (LPO), which is the government's largest-ever single commitment to solar.³³ Both programs focus on distributed solar and storage deployment in low-income and disadvantaged communities.

Hydrogen teed up for takeoff

The IIJA and the IRA have teed up the takeoff of a new green hydrogen economy. Clean hydrogen has the largest gap between announced and actual investments—more than US\$50 billion and less than US\$1 billion, respectively.³⁴ The gap reflects in part uncertainty over pending Treasury guidance on tax credits that are expected to make green hydrogen competitive. At stake is whether hourly matching, additionality, and deliverability will be required to qualify for the full US\$3/kg credit.³⁵ Favorable final guidance could open the floodgates on actual investments in 2024 and jumpstart the nascent hourly Renewable Energy Credit (REC) market. Treasury alignment with the European Union's approach to gradually phase in the three requirements could also enable the US industry to serve the 10 million metric tons (MMT) clean hydrogen import market that the EU envisions by 2030.³⁶ Exports could help resolve demand uncertainty reflected in the DOE's reallocation of US\$1 billion in hydrogen hub funds to stimulate demand.³⁷ In 2024, the industry should watch for developments in the seven selected hydrogen hubs as they move into their

design and planning phase, as well as the launch of the country's first end-to-end green hydrogen system.³⁸

Energy efficiency inches up

Investment following the IRA fell short of meeting ambitious targets for energy efficiency, as reflected in heat pump deployments. While heat pumps attracted close to US\$45 billion, investment has only grown 1% over the past year.³⁹ Final DOE guidance on state administration of direct customer rebate programs could unleash growth in 2024. An initiative of the US Climate Alliance of 25 states to install 20 million heat pumps by 2030 could further bolster deployments,⁴⁰ as could utility-funded energy efficiency programs.⁴¹

Wind brakes

Wind investment dropped 35% over the past year as projects bore the brunt of headwinds from higher costs and permitting challenges, which respondents of a Deloitte survey identified as the most significant constraints on renewables (figure 2).⁴² Record curtailments felled wind in most independent system operators (ISOs).⁴³ And of the 55 GW in delayed clean power projects, wind projects are facing the longest delays, stretching out to 16 months.⁴⁴ An increase in local and state restrictions and contestations of renewable projects over the past year also impacted wind more than other sources (see the sidebar titled “Generative AI’s impact on renewable deployment bottlenecks”).⁴⁵

Generative AI’s impact on renewable deployment bottlenecks

While generative AI is being used to generate climate disinformation, fueling some of the opposition to renewables, it is also powering new tools for developers to assess community sentiment toward renewables and automate permitting and siting.⁴⁶ For the latter, generative AI can help select the best locations for renewable energy installations, considering wind patterns, solar exposure, and environmental impact. It can also suggest the best solar panel layout to maximize generation and design the most efficient blades with peak aerodynamics for wind. In 2024, more developers are expected to use generative AI tools to inform and accelerate renewable project decisions, processes, configurations, and community engagement.

Offshore wind faces high capital requirements, long project development and permitting timelines, and locked-in power sales contracts.⁴⁷ Developers executing agreements signed during low inflation now face higher financing costs and 40% jump in equipment and construction costs over the past year,

while state policymakers may not be willing to provide additional support that could increase consumer costs.⁴⁸ Four contract renegotiations and three cancellations have imperiled half the of the offshore wind pipeline.⁴⁹ Federal and state action to expedite permitting, ease financing, and adjust incentives may be needed to keep projects in the pipeline and on track for meeting targets.

In 2024, the tide is expected to start turning as the industry gets more steel in the water and adapts to the new seascape. Developments to watch include the start of operations at Vineyard Wind in Massachusetts;⁵⁰ the construction of the country's largest offshore wind project in Virginia;⁵¹ the Oregon, Central Atlantic, and second Gulf of Mexico lease sales;⁵² and the pursuit of coordinated procurement in three northeastern states.⁵³ Flexible structures and market participants are expected to reshape agreements. Following Treasury guidance, more developers may seek to improve project economics by siting onshore grid connections in the energy communities that line US coasts and qualify for an adder.⁵⁴ There may also be greater uptake of the adder from the growing pipeline of onshore wind-repowering projects since most are located in energy communities.⁵⁵

Tackling transmission

Transmission is a factor in most constraints on renewable deployment. Regarding the top cost constraint survey respondents identified (figure 2), capturing the full customer benefit of low-cost renewables hinges on transmission. Insufficient capacity drove up congestion costs by 72% in 2022 over the previous year to US\$20.8 billion.⁵⁶ Interregional and regional transmission would need to more than double and quintuple, respectively, to meet high clean energy growth projections by 2035.⁵⁷

IIJA and IRA programs and grants could start tackling transmission issues in 2024. These include the DOE's announced plans to accelerate high-voltage transmission line permitting,⁵⁸ US\$3.9 billion in grants from the Grid Resilience and Innovation Partnerships Program,⁵⁹ and US\$1.3 billion in grants for three interregional grid projects.⁶⁰ At the beginning of the year, we'll be watching for the DOE's release of additional Transmission Facilitation Program funding and US Federal Energy Regulatory Commission interconnection rule compliance plans, as well as complementary ISO initiatives to reduce interconnection queues.⁶¹ We expect to see more corporations participate in Federal Energy Regulatory Commission regulatory filings as transmission constraints jeopardize their renewable targets.⁶² At the same time, IRA and IIJA boosts to renewable development could significantly exacerbate pressure on transmission bottlenecks in 2024.

2. Reshoring clean energy: Supply chains shorten and strengthen

A domestic clean energy manufacturing revival is underway as producers reshore to better capitalize on IRA tax credits and meet demand from renewable developers chasing domestic content adders. Since the IRA passed, companies have announced US\$91 billion of investments in over 200 manufacturing projects, including US\$9.6 billion in 38 solar projects, US\$14.4 billion in 27 storage projects, US\$1.4 billion in 14 wind projects, and US\$54 million in six hydrogen projects, closely tracking investment levels in their respective renewable energy sources.⁶³ These projects' shortened supply chains could increase transparency and resilience while decreasing emissions and exposure to geopolitical vicissitudes.

Solar and storage set to surge downstream and start extending upstream

Announced projects could more than triple this year's solar photovoltaic module capacity in 2024, grow it by an order of magnitude by 2026, and meet US demand before 2030 (figure 3)⁶⁴—a striking reversal from US import dependence for 85% of supply in 2022.⁶⁵ While China currently produces 83% of the cells and polysilicon and 97% of the wafers that go into modules,⁶⁶ new domestic polysilicon capacity and the United States' first cell, wafer, and ingot manufacturing plants are slated to come online in 2024.⁶⁷ This reshoring is premised on balancing domestic panels' 40% price premium⁶⁸ and the 40% tax incentive⁶⁹ for manufacturers that use 40% domestic components.⁷⁰ The latter part of this equation may be at risk because 40 GW of module capacity planned by 2025 may not qualify for a domestic content adder due to lack of sufficient cell capacity.⁷¹ Meanwhile, solar imports more than doubled in the first eight months of 2023 amid global overcapacity that drove prices to record lows, placing half the pipeline at risk of delays or cancellation.⁷² In 2024, the enforcement of trade rules and the Uyghur Forced Labor Prevention Act⁷³ and the expiration of waivers on duties covering solar cell and module imports from Southeast Asia in June⁷⁴ could address overcapacity concerns. And more far-reaching final Treasury guidance on the domestic content adder could encourage upstream investment in wafers, ingots, and polysilicon.

Storage is on a similar trajectory as solar. Announced projects could drive almost eightfold growth in battery manufacturing capacity in 2024. Planned cell production could grow the US share of global capacity from 4% in 2022 to 15% by the end of the decade in a segment where China currently holds a 79% share.⁷⁵ Yet, lithium-ion battery imports also reached a record high in 2023⁷⁶ and the US continues to be fully dependent on imports for some upstream supply chain components.⁷⁷ Companies have announced projects to manufacture copper foils and cathode active materials, 100 GWh for each, but none are expected to come online in 2024.⁷⁸ Expanded Uyghur Forced Labor Prevention Act enforcement on batteries could provide further impetus to domestic supply chain development in 2024.

Wind homes in on offshore gap

The wind supply chain is more domestically rooted and evenly distributed across components than solar and storage, but the little capacity change planned for 2024 may be raising concerns offshore. China leads the global market for wind too: With turbines selling at prices 70% lower than their Western counterparts, Chinese manufacturer exports jumped to 70% of wind turbine orders announced in the first half of 2023.⁷⁹ The greater role of developer relationships, specifications, and incentives in offshore wind has relatively insulated its supply chain from import pressure. On the other hand, infrastructure development and capacity additions have lagged demand from offshore wind developers seeking access to domestic content adders that could improve project economics. Meeting the Biden administration's offshore wind target could require a US\$22.4 billion investment in 34 additional manufacturing facilities, 10 dedicated vessels, and 10 ports.⁸⁰ Whether projects proceed in 2024 hinges on the offshore wind pipeline's solidity. The development of 18 planned component manufacturing facilities⁸¹ and the collaboration between nine East Coast states and federal agencies on offshore wind supply chain buildout are anticipated.⁸²

Hydrogen electrolyzers take root

Electrolytic hydrogen is embryonic at a time when industrial policy is ascendant and the global production landscape is still in flux, providing a major opportunity to reshore renewables. The high-efficiency electrolyzers that dominate the US pipeline are more economic, despite higher upfront costs, but they are exposed to competition from low-cost manufacturing regions.⁸³ China is already expected to account for over half of global capacity in 2023.⁸⁴ In the United States, companies have announced 9 GW of electrolyzer manufacturing capacity, under a quarter of which is expected to

come online in 2024.⁸⁵ Most projects remain at early stages as the market awaits Treasury guidance on green hydrogen that could trigger a burst of electrolyzer demand.⁸⁶ The Department of Energy (DOE) estimates electrolyzer capacity would need to grow at a 20% compound annual growth rate to meet demand through 2050.⁸⁷ In 2024, we will be watching the relative competitiveness of manufacturers focused on scale versus modular approaches, and their ability to keep pace with demand. Gaps could prompt domestic content requirements for electrolyzers.

Critical mineral crimp tightens

The IRA has driven up energy transition demand for the critical minerals that underpin renewable supply chains. By 2035, this demand is expected to rise 15% and 13% higher than pre-IRA numbers for lithium and cobalt, respectively, which are needed for storage; 14% for nickel, which is in storage, wind, and hydrogen supply chains; and 12% for the copper needed across all energy transition technologies.⁸⁸ Meanwhile, domestic and free trade agreement country supply that could qualify for IRA incentives is limited. China refines around half of global copper production, two-thirds of lithium, three-quarters of copper, and four-fifths of nickel.⁸⁹ And Indonesian nickel, which accounts for half of global mining capacity, is mostly Chinese invested.⁹⁰ Underinvestment in mining amid currently low prices, combined with long lead times for new projects that can stretch over a decade, could yield yawning supply gaps. Shortages ranging from 10% to 40% across these minerals are expected by 2030.⁹¹ In 2024, the impact of China's graphite export controls on critical mineral projects should be observed. The beginning of massive shifts in the lithium market from both the supply and demand sides may also become apparent. The discovery of the world's largest known lithium deposit in Nevada at the end of 2023 is a potential game-changer.⁹² And the development of lithium alternatives, such as sodium storage batteries, could accelerate as manufacturers use generative AI to develop new molecules for testing.⁹³

Trends to watch as renewable energy companies reshore in 2024 include the following:

- Companies are pursuing **strategic reshoring joint ventures** to secure a stake in the emerging domestic supply chain. For example, one of the largest renewable developers holds majority ownership and agreement to offtake 40% of output from a new solar panel plant that it is jointly

developing with a solar manufacturer.⁹⁴ And a major solar manufacturer became the largest shareholder of a US polysilicon manufacturer, striking a 10-year take-or-pay agreement that helped restart the plant's production.⁹⁵ Critical mineral mining projects are also seeing direct investments from customers.⁹⁶

- **Supply chain digitalization** is helping companies increase transparency, efficiency, and awareness of competitor demand. It can enable monitoring of environmental, social, and governance practices and compliance with labor and US and free trade agreement content requirements under the IRA and the Uyghur Forced Labor Prevention Act.
- Clean energy manufacturers are developing **end-of-life management and recycling** of solar panels, wind blades, batteries, and electrolyzers to reduce waste and recover critical minerals.⁹⁷ Battery-metal recycling startups raised record funding in 2022.⁹⁸ Since the IRA passed, six companies have announced investments in battery and wind blade recycling.⁹⁹ Two have received Loans Program Office conditional loan commitments. These projects could help address critical mineral shortages.

3. Reskilling the workforce: Unlocking the talent bottleneck is key to decarbonization

Sustaining a record buildout of renewables and domestic supply chain will require growing and (re)training a workforce with the right skills in the right places. Over the past two years, clean energy jobs have grown 10%, at a faster pace than overall US employment.¹⁰⁰ There are currently 3.3 million clean energy jobs, the majority of which are in energy efficiency (68%), followed by renewable generation (16%), clean vehicles (11%), and storage and grid

(5%).¹⁰¹ Looking ahead, wind turbine service technicians and solar photovoltaic installers bookend the projected 15 fastest-growing occupations from 2022 through 2032, when IRA provisions are scheduled to sunset, with 45% and 22% growth, respectively.¹⁰²

The IRA, the IIJA, and the Creating Helpful Incentives to Produce Semiconductors Act are expected to drive massive job creation over their lifetime: 19 million job-years, or around 3 million jobs per year.¹⁰³ Compared to jobs in the overall workforce, a higher share—more than two-thirds—of direct jobs are available to workers without a bachelor's degree. The direct jobs created offer higher-median wages on average, but benefits and unionization rates are lower, and women and other minority groups are underrepresented, according to current data.¹⁰⁴ Announced manufacturing and generation projects across solar, storage, wind, and clean hydrogen plants and their supply chains anticipate the creation of 72,557 annual construction jobs over five years and 24,193 annual operations and maintenance jobs over the lifetime of the plants (figure 4). However, the current half-a-million workforce shortage in the construction sector could constrain the buildout.¹⁰⁵ And while US green job postings grew 20% in 2022, green talent only grew 8.4%, revealing a growing skills gap.¹⁰⁶

Workforce challenges may be greatest in new industries such as clean hydrogen. The seven hydrogen hubs, expected to create 324,280 direct jobs across 16 states, include multiyear workforce plans to address these challenges.¹⁰⁷ More immediately though, the 3.6 GW of currently funded electrolyzer capacity is slated to start coming online in 2024.¹⁰⁸ The new facilities are expected to create around 12,000 infrastructure development jobs over the next two years, as well as 1,600 permanent operational jobs.¹⁰⁹ Deloitte analysis identified skill gaps across core roles and found that there is already a shortage of workers with the required skills, including electrical engineering, manufacturing processes, computer science, tooling, mechanical engineering, automation, and machining.¹¹⁰ And the training pipeline for the relevant workforce of welders, machinists, and engineers across higher education institutions, including two- and four-year colleges, technical, and trade schools, shows potential talent supply challenges in three of the host states.

Generative AI is also reshaping renewable workforce needs. The solar and wind electric power generation industry includes five of the top 10 most AI-intensive occupations—that is, occupations with the largest share of job postings demanding AI skills.¹¹¹ The most significant of these occupations in

the industry are engineering professionals. Talent acquisition for these roles is already challenging, given the competition with other sectors.¹¹² In the administrative segment, generative AI facilitates the submission of daily work orders, supply part requests, asset maintenance, and bidding.¹¹³ The core construction and maintenance workforce segments have the lowest penetration potential, 6% and 4%, respectively.¹¹⁴ Here, AI is enabling full automation of the sector's most arduous work, such as offshore wind turbine inspections, which AI-powered drones could perform on spinning turbines at a lower cost.¹¹⁵ At a broader electric and gas utility level, while most occupations have generative AI exposure, five occupations, including core electrical powerline installers and repairers, have none.¹¹⁶

It is crucial that the core power sector, including power, utilities, and renewable developers, align their decarbonization and workforce planning to ensure the sector is able to continue decarbonizing itself and other sectors such as transportation, buildings, and manufacturing (figure 5). These sectors are helping address some of the bottlenecks constraining the core power sector. For example, transportation electrification, clean fuels, and energy-efficient buildings can help address grid bottlenecks, while domestic clean energy manufacturing should help address supply chain challenges. However, the workforce bottleneck encompasses both the core and broader sectors.

More developers are expected to implement strategies with the following four following elements to help unlock the workforce bottleneck in 2024:

- **Equity:** Upskill the existing workforce in energy communities and help create new, diverse talent pipelines from local, untapped labor pools alongside workplace accommodations to address spatial, identity, and family structure inequities.
- **Quality:** Create purposeful, high-wage, credentialed jobs with portable skills and clear upwardly mobile career paths.
- **Agility:** Continuously assess skills gaps and training timelines (in weeks, months, and years), and proactively align with decarbonization strategy and technology timelines, the pace of domestic supply chain

development, and the pace of digitalization, including the use of AI in the sector.

- **Comity:** Collaborate with ecosystem partners, including educational institutions, trade schools, high school career academies, and technical training groups; local, state, and federal governments; unions; industry associations; and philanthropic organizations to help develop registered apprenticeships, courses, and small business training support.

In 2024, the US Treasury's final guidance on prevailing wage and apprenticeship requirements should take hold and help facilitate a pipeline of renewable energy apprentices that could alleviate shortages. Also anticipated is greater renewable developer and utility uptake of funding from the 54 IIJA and IRA programs that can be deployed for green workforce development.¹¹⁷

4. Renewables as a resilience strategy: Amid widespread misperceptions, renewables can save the day

As the frequency and intensity of extreme weather events, outages, and potential electricity supply shortages rise, renewables have often outshined conventional power sources, generating electricity when the latter could not. Renewables are increasingly becoming a resilience strategy, especially when coupled with storage. This reality does not match with perception, however. More respondents of the Deloitte 2023 power and utilities industry survey were concerned about the resilience of renewables than supply chain challenges and the interconnection queue. Most survey respondents believe that gas, followed by nuclear power, is the most resilient to extreme weather events in their territory, while renewables ranked the lowest (figure 6).

But, in contrast to the surveyed respondents' perception, experience with a record number of extreme weather events and outages over the past year shows that gas poses greater reliability challenges than renewables. For instance, during Winter Storm Elliott, unplanned generation outages reached a record 90.5 GW across the Eastern Interconnection, mainly driven by

natural gas infrastructure reliability issues.^{[118](#)} The impact on the Pennsylvania-New Jersey-Maryland Interconnection (PJM) was especially striking given the grid's historical reliability, familiarity with cold weather, and location atop shale gas basins that directly supply many power plants. A fifth of gas plants, including new ones, failed to ramp up to half capacity during the grid's two emergency calls due to a range of malfunctions across the system, from mechanical problems to frozen transmitters, valves and wells, pipe pressure issues, compressor stations failures, and supply scheduling gaps.^{[119](#)} Gas accounts for 46% of PJM capacity, but drove 70% of forced outages.^{[120](#)} Shifting seasons and states, in the summer, thermal plant outages unexpectedly went above the 11,000 MW red line, which, according to the Electric Reliability Council of Texas (ERCOT), could put its grid at risk.^{[121](#)}

Nuclear also faces increasing reliability concerns as warmer and lower water levels caused by climate change impact operations. Over the past summer—a season when nuclear is most needed to meet power demand—a hot weather alert factored into a shutdown of the nuclear Vogtle plant reactor in July.^{[122](#)} Another nuclear plant shut down later in the summer due to coolant leakage, contributing to a total of 31 unplanned nuclear outages from January through October 2023 and a 25% rise in total nuclear capacity outages in the summer of 2023 versus that of 2022.^{[123](#)}

Meanwhile, renewables paired with storage are taking on the role of gas peakers that can quickly respond to demand spikes and avoid blackouts. During Winter Storm Elliott, strong wind generation helped the Midcontinent Independent System Operator meet demand and continue exports despite 49 GW of forced outages.^{[124](#)} When Texas experienced 10 demand records this summer, batteries discharging in the evening played a key role in avoiding blackouts, while solar and wind generation covered more than a third of demand load in ERCOT during the day and helped prevent power price spikes.^{[125](#)} As a result, ERCOT included storage for the first time as a resource able to meet high net load in its fall Seasonal Assessment of Resource Adequacy for fall 2023.^{[126](#)} Similarly, renewables contributed to a fifth of generation during a heatwave that drove record loads in the Southwest Power Pool.^{[127](#)}

On the distributed renewable front, when the California Independent System Operator called for electricity conservation on August 17, an aggregation of 2,500 residential storage systems were activated for the first time to deliver 16.5 MW of solar power to the grid.^{[128](#)} Some utilities are subsidizing residential battery installations to create such AI-orchestrated aggregations to draw on during peak demand.^{[129](#)} In the aftermath of winter storms and flooding, the Vermont Public Utility Commission lifted caps on programs supporting

residential storage the utility can tap during emergencies.¹³⁰ Meanwhile, generative AI is enabling greater solar photovoltaic module power forecasting and proactive mitigation of extreme weather and cyberattacks.¹³¹ In its latest forecast, the North American Reliability Corporation not only warned about an elevated risk of blackouts across the country this winter,¹³² but also showed that some states rapidly transitioning to renewables are among those at lowest risk of outages.¹³³ The year 2024 may be when perception catches up with reality.

5. Renewable technology, redefined: Underground renewables could resurge

Technologies expected to become more apparent over the next year are transforming renewable capabilities, synergies, and deployment potential. Renewable deployment over the past decade has primarily told a success story for onshore wind, solar, and storage growth amid dramatically falling cost curves. On the flip side, the intermittency and the geographical land use and industrial end-use limitations of renewables are often cited as reasons these resources cannot replace gas as a direct and back-up fuel that can be deployed anywhere and tapped anytime. Yet, renewables that can do just that while supporting grid resilience have made strides this year in moving technological innovation toward commercialization. Two of these renewables are longstanding but often overlooked underground resources: geothermal and renewable natural gas (RNG).

Enhanced geothermal systems (EGS) have expanded the potential to capture the heat of the earth. While the United States is the global leader in geothermal electricity production, geothermal only accounts for 0.4% of US utility-scale generation and is concentrated in Western states, with natural hot water reservoirs in permeable rock at low depths.¹³⁴ EGS could push this share past 6% by 2035, the target date for a 90% cost reduction in EGS, to US\$45/MWh under the DOE's Enhanced Geothermal Earthshot initiative.¹³⁵ EGS uses technology from the oil and gas industry to help create artificial reservoirs and access the omnipresent heat available below the earth's surface. Cost reductions are achieved from advanced sensing and drilling, which accounts for half the cost of geothermal projects.¹³⁶ Developer use of generative AI to assess seismic data and guide drilling has further driven down costs.¹³⁷ EGS can also bring more value by using reservoirs for long-duration storage and direct air capture. This year saw breakthrough announcements from the DOE-funded Frontier Observatory for Research in Geothermal Energy and geothermal energy startups on demonstrating

commercial viability and breaking ground on the world's largest EGS plant. While geothermal accounts for less than 3% of power purchase agreements (PPAs), the megawatt (MW) volume of geothermal PPAs quintupled from 2021, when the world's first corporate geothermal PPA was signed, to 2022; next-gen geothermal accounted for more than half of the MW volume in 2023.¹³⁸ The EGS project pipeline and PPA market are likely to continue strengthening in 2024 to meet demand from the growing number of corporations with 24/7 decarbonization targets.

RNG project development has accelerated recently as well. RNG only accounts for 0.5% of the gas market and mostly serves the transportation sector but could grow tenfold by 2050 as usage expands to power and heat.¹³⁹ Demand has overtaken supply as developers seek to begin construction on RNG facilities before 2025 to qualify for the IRA Section 48-qualified biogas property investment tax credit. The number of operational plants jumped from 230 in 2021 to 300 through the end of July 2023, while the pipeline of plants planned or under construction grew from 172 to 481 for the same period.¹⁴⁰ Landfill and livestock operations are driving most of RNG capacity growth anticipated to come online in 2024.¹⁴¹ These two sources of feedstock account for more than half of US methane emissions, which RNG production can prevent from being vented.¹⁴² Food waste and wastewater treatment projects are also growing. New feedstock streams that could start expanding in 2024 may include forest waste from vegetation management related to wildfire prevention. The use of RNG as a feedstock to produce biohydrogen and sustainable aviation fuels could also take off depending on Treasury guidance on the hydrogen tax credit and carbon accounting. Two major US hydrogen projects are currently using RNG to produce hydrogen.¹⁴³ Also important to consider is US Environmental Protection Agency rulemaking that could grant renewable credits for RNG used in plants generating power to charge electric vehicles. States with supportive policies could further increase RNG demand (figure 7).

In 2024, renewable developers may consider expanding into renewable resources resurging with new technologies. Geothermal and RNG can help developers diversify their renewable portfolios and capitalize on new synergies between intermittent and baseload renewables, and between electrons and molecules.

What to expect in 2024

In 2024, the renewable energy industry could expect to see the historic climate legislation take greater effect as tax credit guidance is finalized, more Loans Program Office loans are issued, and more programs release IRA grant funding, only 10% of which has been disbursed thus far.¹⁴⁴ The massive public and private investment and channeling of capital toward the clean energy transition could propel solar and storage deployments to continue soaring, onshore wind to recover, and residential technologies to pick up speed. Offshore wind and green hydrogen industries could establish a foothold, while underdeveloped renewables could play a greater role in clean energy portfolios. Meanwhile, a clean energy–driven manufacturing renaissance could provide opportunities to develop more resilient renewable supply chains across the country. The surge in renewable projects and domestic manufacturing also calls for a bigger and smarter grid, a skilled workforce to build and operate the plants, and a smooth process to develop both. Challenges in these areas should be addressed in 2024 to help keep the country and corporations on track to achieve their climate goals.

Signposts to watch include the US Treasury's guidance on hydrogen and domestic content adders, the impact of IRA and IIJA funds on workforce development, and Federal Energy Regulatory Commission and DOE actions on grid reform and buildout. This El Niño year may bring more extreme weather events that could call on renewable resources to support the grid. Finally, a quickly expanding range of use cases may grow generative AI's foothold in renewable operations, workforce planning, and distributed aggregations supporting resilience.

From coastal towns and rural farms, to urban centers and Tribal communities, climate change poses an existential threat — not just to our environment, but to our health, our communities, and our economic well-being. At the Department of the Interior, we know that the time to act on climate is now.

Renewable energy — including solar, onshore and offshore wind, geothermal, and wave and tidal energy projects — will help communities across the country be part of the climate solution while creating good-paying union jobs.

The Biden-Harris administration is taking an all-of-government approach toward its ambitious renewable energy goals that will create jobs to support families, boost local economies, and help address environmental injustice.

As directed by President Biden's Executive Order 14008, *Tackling the Climate Crisis at Home and Abroad*, the Interior Department has partnered with other federal agencies

to increase renewable energy production on public lands and waters —including a [commitment to deploy 30 gigawatts](#) of offshore wind by 2030, 15 gigawatts of floating offshore wind by 2035, and a target goal of permitting at least 25 gigawatts of onshore renewable energy by 2025.

To facilitate this transition to clean energy and meet our ambitious goals, the Department [has announced a new offshore wind leasing strategy](#), which includes holding up to seven new offshore wind lease sales by 2025. This strategy provides two crucial ingredients for success: more certainty for industry, and transparency for our stakeholders and ocean users.

Since the start of the Biden-Harris administration, the Department has approved the nation's first eight commercial scale offshore wind projects, held four offshore wind lease auctions – including a record-breaking sale offshore New York and the first-ever sales offshore the Pacific and Gulf Coasts, and advanced the process to access and establish additional Wind Energy Areas in Oregon, Gulf of Maine and the Central Atlantic. The Department has also taken steps to evolve its approach to offshore wind to drive towards union-built projects and a domestic based supply chain.

Onshore, the Biden-Harris administration is expanding renewable energy technologies like wind, solar, and geothermal across public lands while upholding essential regulatory and review processes to avoid adverse human and wildlife impacts. These efforts are bolstered by ongoing updates to the Western Solar Plan, which helps identify where solar resources are high and conflicts are low for accessible and reliable renewable energy for more families across the country.

The demand for renewable energy has never been greater. The technological advances, increased interest, cost effectiveness, and tremendous economic potential make these projects a promising path for diversifying our national energy portfolio while at the same time combatting climate change and investing in communities.

At every step of the way, the Interior Department will undertake these goals with broad engagement, including fishermen, outdoor enthusiasts, sovereign Tribal nations, states, territories, local officials, agricultural and forest landowners, and others to identify strategies and goals that reflect the priorities of all communities.

New U.S. battery manufacturing and supply chain investments announced under President Biden:

- Over **\$120 billion** announced so far
- Over **250** new or expanded minerals, materials processing and manufacturing facilities
- Over **80,000** potential new jobs
- Announced battery cell factories could supply **10 million** new electric vehicles each year

New U.S. electric vehicle component and assembly plant investments announced under President Biden:

- Over **\$35 billion** announced so far
- Over **150** new or expanded sites for EV assembly and EV component or charger manufacturing
- Over **50,000** potential new jobs
- Companies have announced U.S.-made planned production of over **1,000,000** charging stations each year, including **60,000** fast chargers

New U.S. heat pumps and clean HVAC manufacturing announcements under President Biden:

- Over **\$550 million** announced so far
- Nearly **1,800** potential new jobs
- **20** new or upgraded facilities for manufacturing different heat pump technologies and key components, such as compressors and low global warming potential (GWP) refrigerants
- Based on current HVAC market and technology trends, announced investments in new and expanded production facilities could supply over **300,000** heat pumps each year.

New announcements of electrolyzers and fuel cell manufacturing facilities under President Biden:

- Over **\$2.5 billion** announced so far
- Over **5,500** potential new jobs
- Announced investments in over **15** new or expanded facilities
- Domestic manufacturing capacity for **~12 GW** of electrolyzers per year and **~4 GW** of fuel cells per year

New U.S. land-based wind manufacturing investments announced under President Biden:

- More than **\$400 million** announced manufacturing investments so far
- Investments in **16** manufacturing facilities built in **10** different states
- More than **3,000** new jobs

New U.S. nuclear manufacturing announcements under President Biden:

- Up to **\$8.6 billion** of announced investments so far
- Over **1,600** potential new jobs
- Investments in **29** facilities across **16** states
- Over **three-quarters** of the announcements are to expand domestic uranium production and nuclear fuel fabrication facilities benefiting existing reactors and developing a secure supply chain for advanced reactors

New U.S. offshore wind manufacturing facility, port, and investments announced under President Biden:

- More than **\$6 billion** announced manufacturing and port investments so far
- Investments in **17** manufacturing facilities (7 states), and **15** ports (10 states)
- 26 new vessels being built in 9 different states
- 1 substation in 1 state
- Thousands of new jobs

New U.S. solar manufacturing announcements under President Biden:

- Nearly **\$17 billion** in planned investments announced so far
- **115** new and expanded manufacturing plants announced
- Companies have announced enough solar panel manufacturing capacity to power **18 million** additional homes each year
- Over **35,000** potential new jobs

The Clean Energy Future Is Arriving Faster Than You Think

The United States is pivoting away from fossil fuels and toward wind, solar and other renewable energy, even in areas dominated by the oil and gas industries.

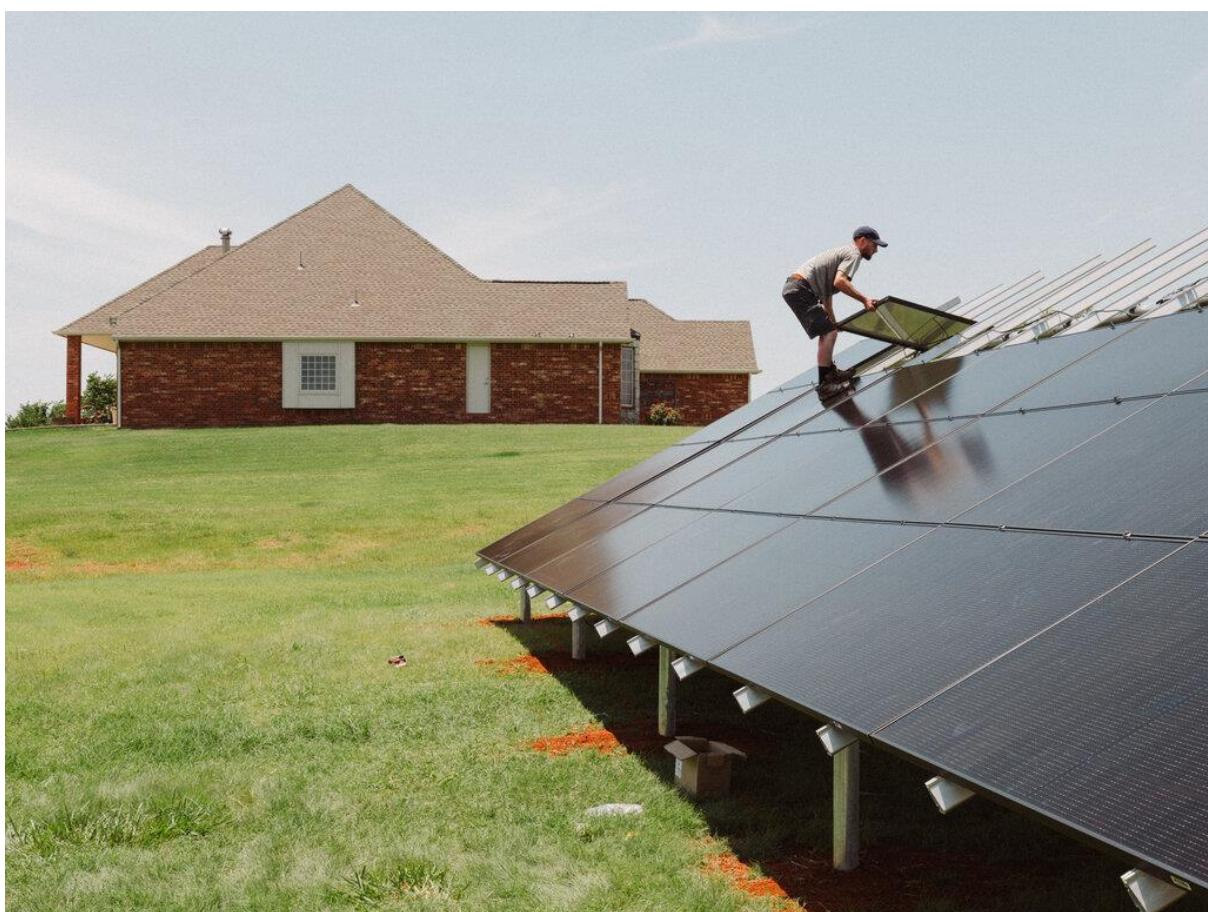
Delivery vans in Pittsburgh. Buses in Milwaukee. Cranes loading freight at the Port of Los Angeles. Every municipal building in Houston. All are powered by electricity derived from the sun, wind or other sources of clean energy.

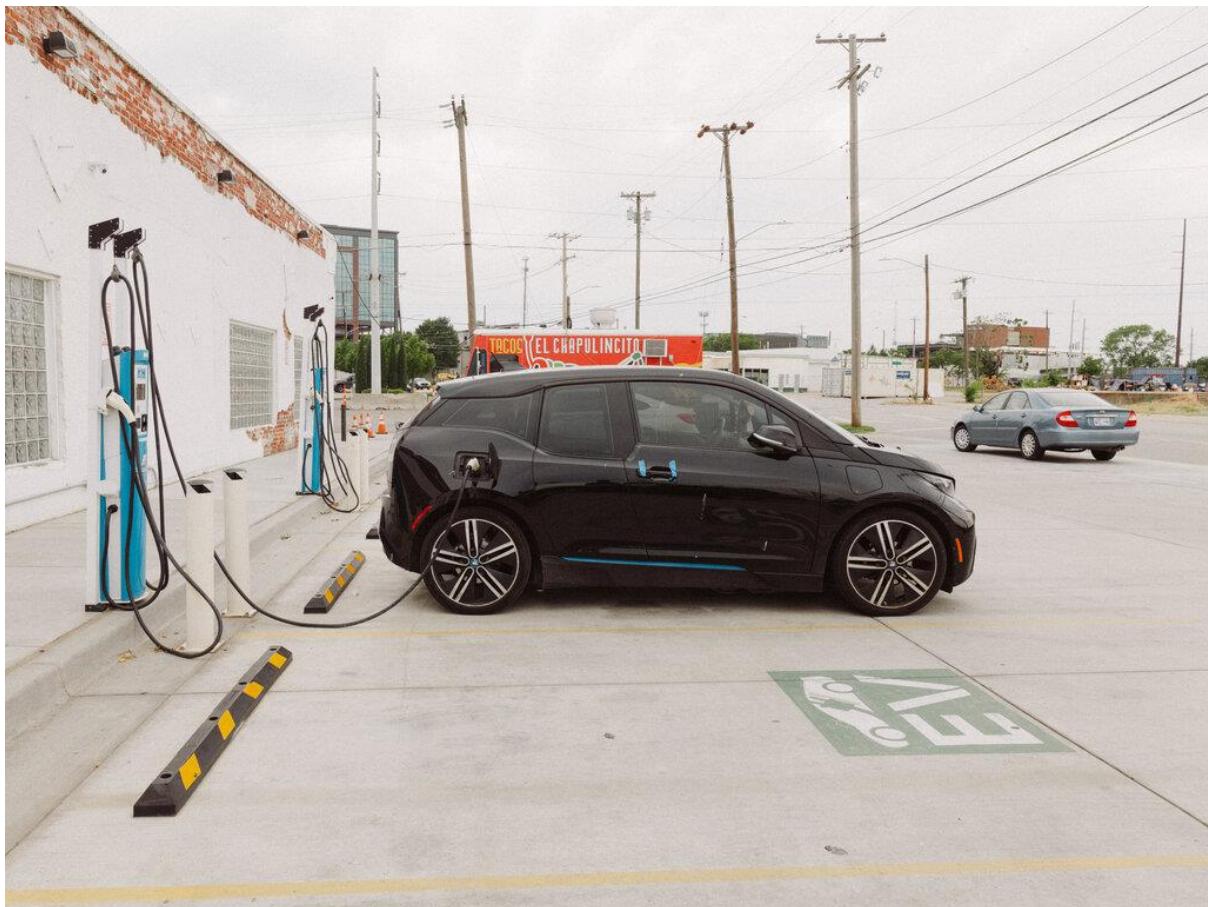
Across the country, a profound shift is taking place that is nearly invisible to most Americans. The nation that burned coal, oil and gas for more than a century to become the richest economy on the planet, as well as historically the most polluting, is rapidly shifting away from fossil fuels.

A similar energy transition is already well underway in Europe and elsewhere. But the United States is catching up, and globally, change is happening at a pace that is surprising even the experts who track it closely.

Wind and solar power are breaking records, and renewables are now expected to overtake coal by 2025 as the world's largest source of electricity. Automakers have made electric vehicles central to their business strategies and are openly talking about an expiration date on the internal combustion engine. Heating, cooling, cooking and some manufacturing are going electric.

As the planet registers the highest temperatures on record, rising in some places to levels incompatible with human life, governments around the world are pouring trillions of dollars into clean energy to cut the carbon pollution that is broiling the planet.





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A big shift in the way America produces energy is already underway.

Continue scrolling

The cost of generating electricity from the sun and wind is falling fast and in many areas is now cheaper than gas, oil or coal. Private investment is flooding into companies that are jockeying for advantage in emerging green industries.

"We look at energy data on a daily basis, and it's astonishing what's happening," said Fatih Birol, the executive director of the International Energy Agency. "Clean energy is moving faster than many people think, and it's become turbocharged lately."

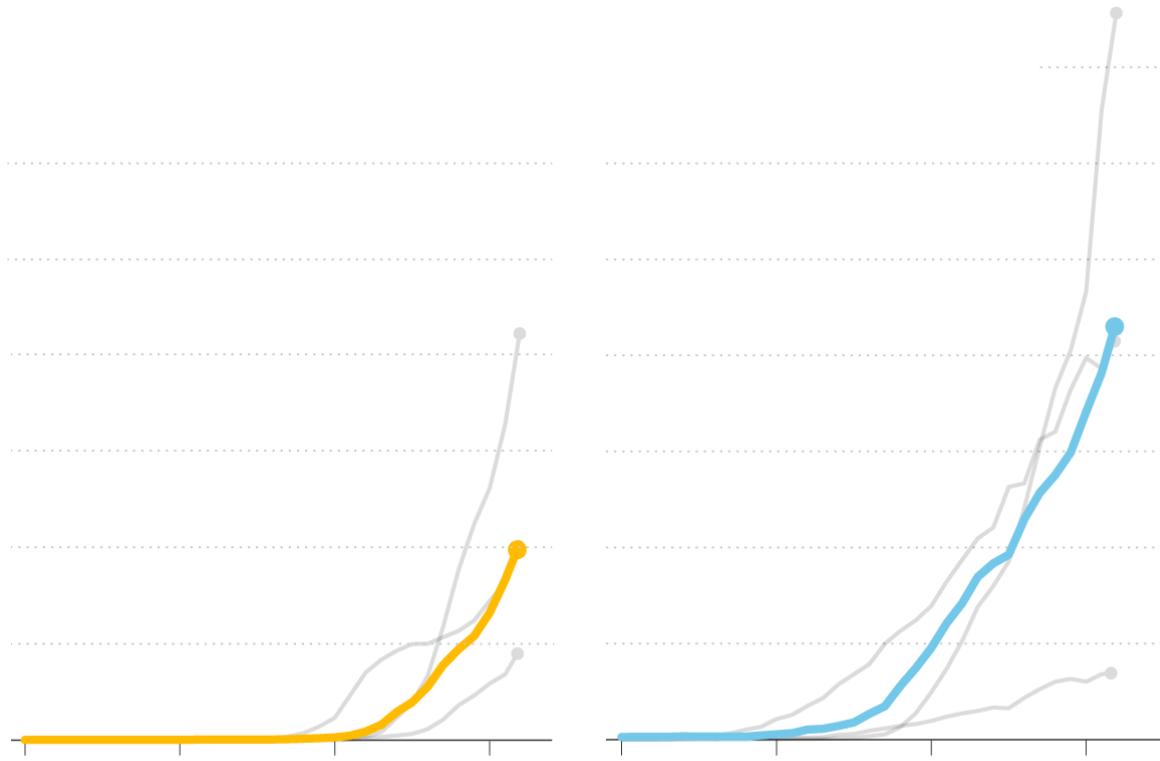
More than \$1.7 trillion worldwide is expected to be invested in technologies such as wind, solar power, electric vehicles and batteries globally this year, according to the I.E.A., compared with just over \$1 trillion in fossil fuels. That is by far the most ever spent on clean energy in a year.

Those investments are driving explosive growth. China, which already leads the world in the sheer amount of electricity produced by wind and solar power, is expected to double its capacity by 2025, five years ahead of schedule. In Britain, roughly one-third of electricity is generated by wind, solar and hydropower. And in the United States, 23 percent of electricity is expected to come from renewable sources this year, up 10 percentage points from a decade ago.

Solar and Wind Power Have Taken Off

Electricity generation per year, in terawatt hours





China
600 TWh
500

SOLAR WIND

U.S.

China

400

E.U.

300

U.S.

200

E.U.

100

India

India

1990

2000

2010

2020

1990

2000

2010

2020

Source: The Energy Institute's 2023 Statistical Review of World Energy

Note: Data reflects generation within country borders.

By The New York Times

The Clean Energy Future Is Arriving Faster Than You Think - The New York Times

"The nature of these exponential curves sometimes causes us to underestimate how quickly changes occur once they reach these inflection points and begin accelerating," said former Vice President Al Gore, who called attention to what he termed a "planetary crisis" 17 years ago in his film "An Inconvenient Truth." "The trend is definitely in favor of more and more renewable energy and less fossil energy."

Even as the pace of change in the United States is surprising everyone from energy experts to automobile executives, fossil fuels still dominate energy production at home and abroad.

Corporations are building new coal mines, oil rigs and gas pipelines. The government continues to award leases [for drilling projects](#) on public lands and in federal waters and still subsidizes the industries. After posting record profits last year, leading oil companies are backing away from recent promises to invest more heavily in renewable energy.

The scale of change required to remake the systems that power the United States — all the infrastructure that needs to be removed, re-engineered and replaced — is mind-boggling. There are major challenges involved in adding large amounts of renewable energy to antiquated electric grids and mining enough minerals for clean technologies. Some politicians, including most Republicans, want the country to continue burning fossil fuels, even in the face of overwhelming scientific consensus that their use is endangering life on the planet. Dozens of conservative groups organized by the Heritage Foundation have [created a policy playbook](#), should a Republican win the 2024 presidential election, that would reverse course on lowering emissions. It would shred regulations designed to curb greenhouse gases, dismantle nearly every federal clean energy program and boost the production of fossil fuels.

And while energy systems are changing fast, so is the climate. It is far from certain whether the United States and other polluting countries will do what scientists say is required to avert catastrophe: stop adding greenhouse gases to the atmosphere by 2050. All of the investment so far has slowed the pace at which emissions are growing worldwide, but the amount of carbon dioxide pumped into the atmosphere is at record levels.

And yet, from Beijing to London, Tokyo to Washington, Oslo to Dubai, the energy transition is undeniably racing ahead. Change is here, even in oil country.

'Energy Is Energy'

As the workday begins in Tulsa, Okla., the assembly line at the electric school bus factory rattles to life. Crews fan out across the city to install solar panels on century-old Tudor homes. Teslas and Ford F-150 Lightnings pull up to charging stations powered in part by the country's second-largest wind farm. And at the University of Tulsa's School of Petroleum Engineering, faculty are working on ways to use hydrogen as a clean energy source.

Tulsa, a former boomtown once known as the “Oil Capital of the World” where the minor league baseball team is the Drillers, is immersed in a new energy revolution.

At the port, an Italian company, Enel, is building a \$1 billion solar panel factory. The bus factory is operated by Navistar, one of the biggest commercial vehicle makers in the world. And the city’s main electric utility, Public Service Company of Oklahoma, now harvests more than 28 percent of its power from wind.







Even Tulsa, with its strong links to oil and gas, is embracing clean energy.

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Clean energy entrepreneurs are flocking to Oklahoma, too. Francis Energy, a fast-growing maker of electric vehicle charging stations, is based in Tulsa. Canoo, an electric vehicle start-up, is building a 100,000-square-foot battery factory at a nearby industrial park and a manufacturing plant for its trucks in Oklahoma City, though there are questions about whether the company will have enough funding to realize its plans. And teams from Solar Power of Oklahoma are busy fastening photovoltaic panels to the roofs of homes and businesses around Tulsa.

The city is embracing its shifting identity.

"We have a tremendous sense of pride in our history," said Dewey F. Bartlett Jr., the Republican former mayor of Tulsa who was an oil and gas executive but now helps recruit clean energy companies to the region. "But we also understand that energy is energy, whether it is generated by wind, steam or whatever it might be."

Around the country, clean energy is taking root in unlikely locales.

Houston, home to more than 500 oil and gas companies, also has more than [130 solar-and wind-related companies](#). Some of the country's largest wind and solar farms are in the Texas flatlands outside the city, and a huge wind farm [has been proposed off the coast of Galveston](#).

In Arkansas, a planned solar farm — the state's biggest — is expected to help power a nearby U.S. Steel factory that is undergoing a \$3 billion upgrade. When complete, the plant will use electric furnaces to mold scrap steel into new products. That will result in about 80 percent less greenhouse gases, the company says, and set the pace for an industry that has been a major polluter.

About two-thirds of the new investment in clean energy is in Republican-controlled states, where policymakers have historically resisted renewables. But with each passing month, the politics seem to matter less than the economics.

"We're the reddest state in the country, and we're an oil and gas state," said J.W. Peters, president of Solar Power of Oklahoma. "So it took a lot of time to convince people that this wasn't snake oil."

Mr. Peters was broke six years ago, with less than \$400 in his checking account after his contracting business slowed down. Then he responded to a help-wanted ad looking for workers to install solar panels, which were becoming more popular in Tulsa. He now employs 61 workers and has \$18 million in annual sales. "The environmental benefits are nice," he said, "but most people are doing this for the financial opportunity."

'Something Very Dramatic'

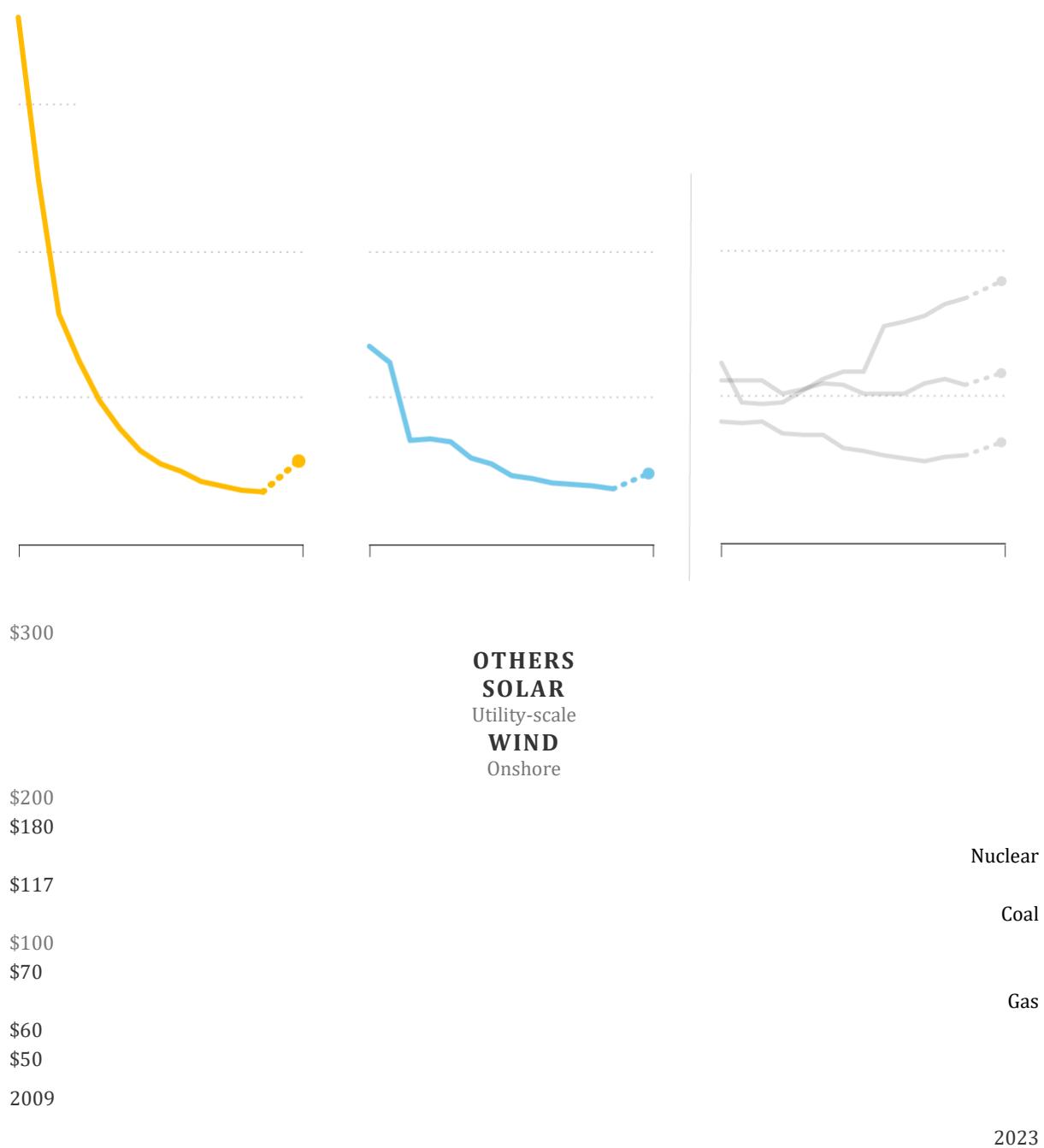
Fifteen years ago, solar panels, wind turbines and battery-powered vehicles were widely viewed as niche technologies, too expensive and unreliable for mainstream use.

But clean energy became cheap far faster than anyone expected. Since 2009, the cost of solar power has plunged by 83 percent, while the cost of producing wind power has fallen by more than half. The price of lithium-ion battery cells fell 97 percent over the past three decades.

Today, solar and wind power are the least expensive new sources of electricity in many markets, generating 12 percent of global electricity and rising. This year, for the first time, global investors are expected to pour more money into solar power — some \$380 billion — than into drilling for oil.

The Cost of Renewable Energy Has Plummeted

Cost of building and running new power plants, in dollars per megawatt hour



2023

2009

2023

2009

2023

Source: [Lazard](#)

Notes: Charts reflect the mean levelized cost of energy, which captures the price of building and running new power plants but excludes other electrical system costs. Lazard did not release data for 2022. In 2023, costs rose because of supply-chain problems, inflation and other issues.

By The New York Times

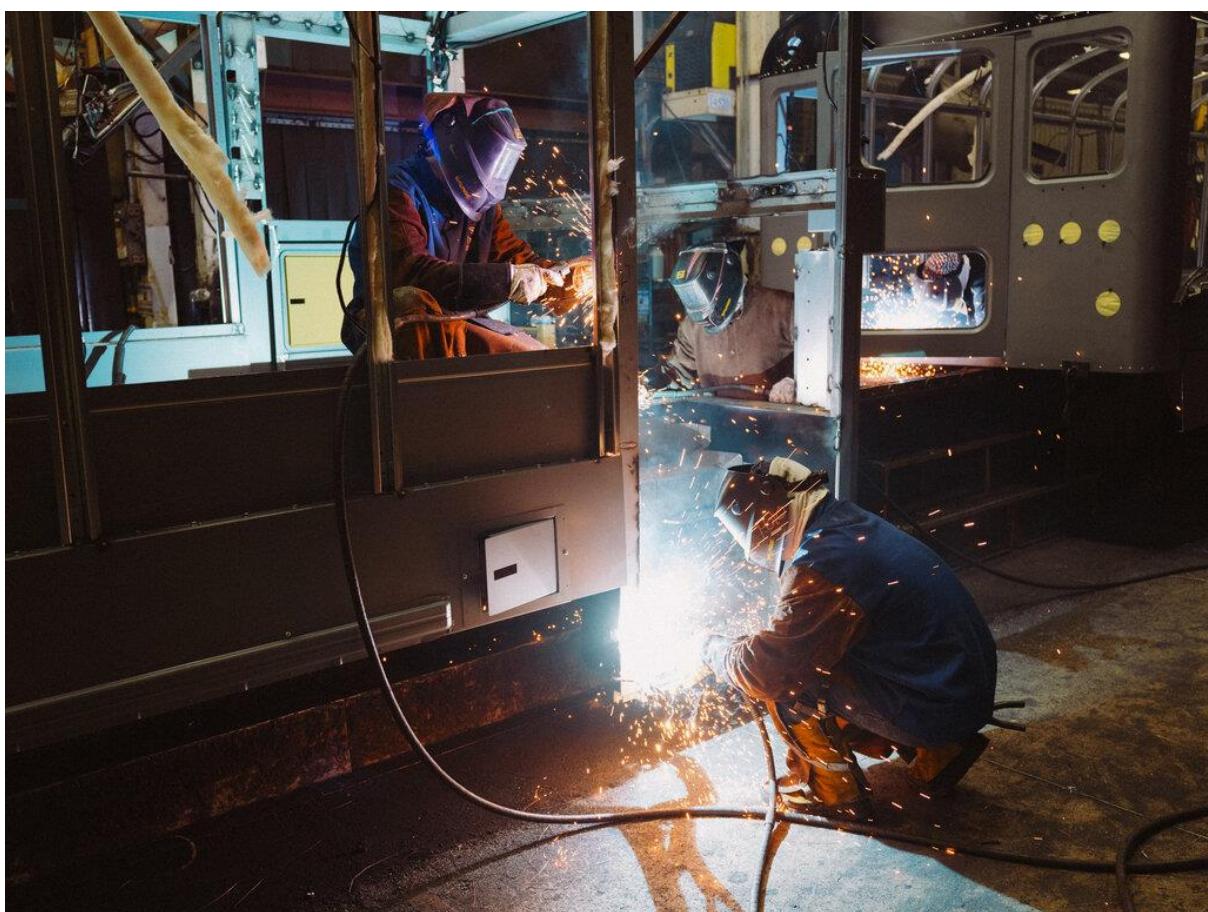
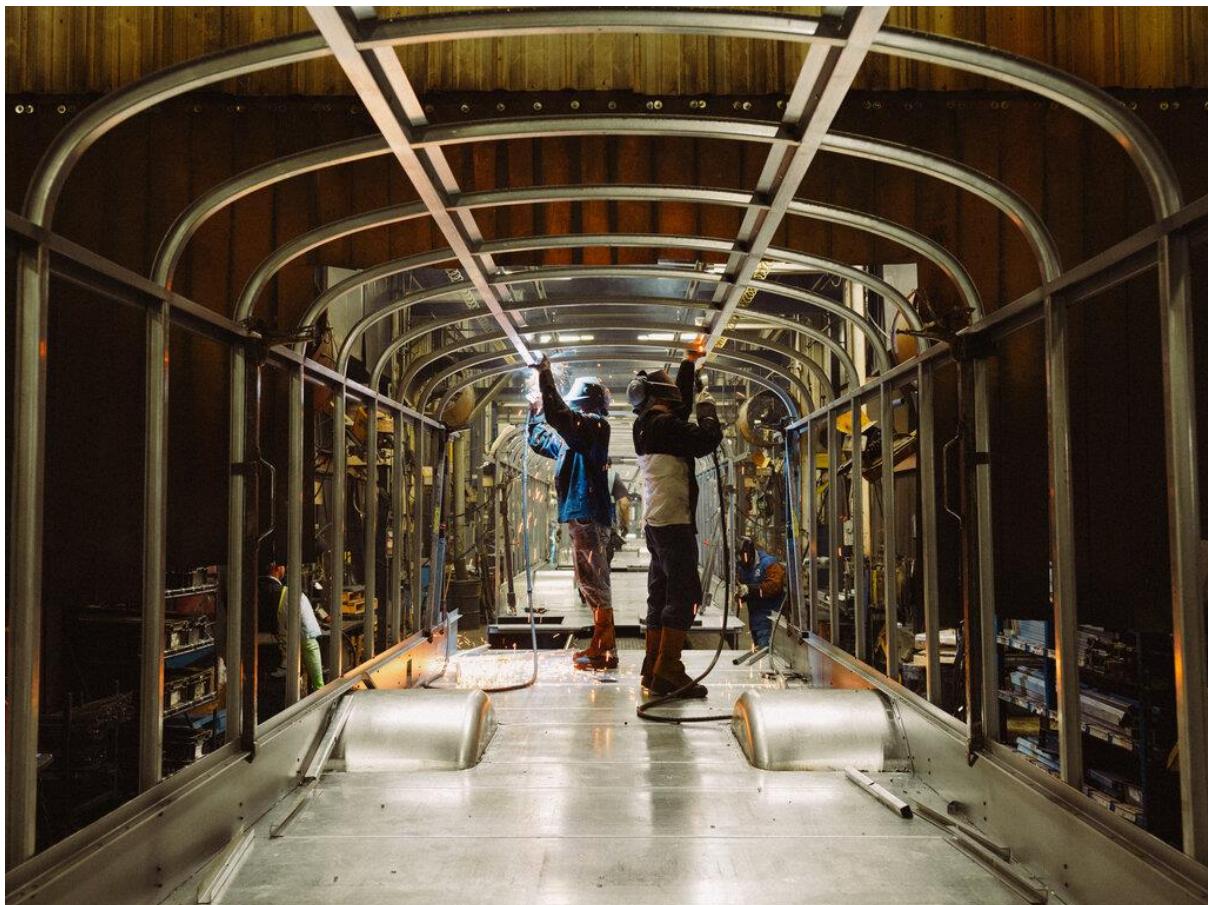
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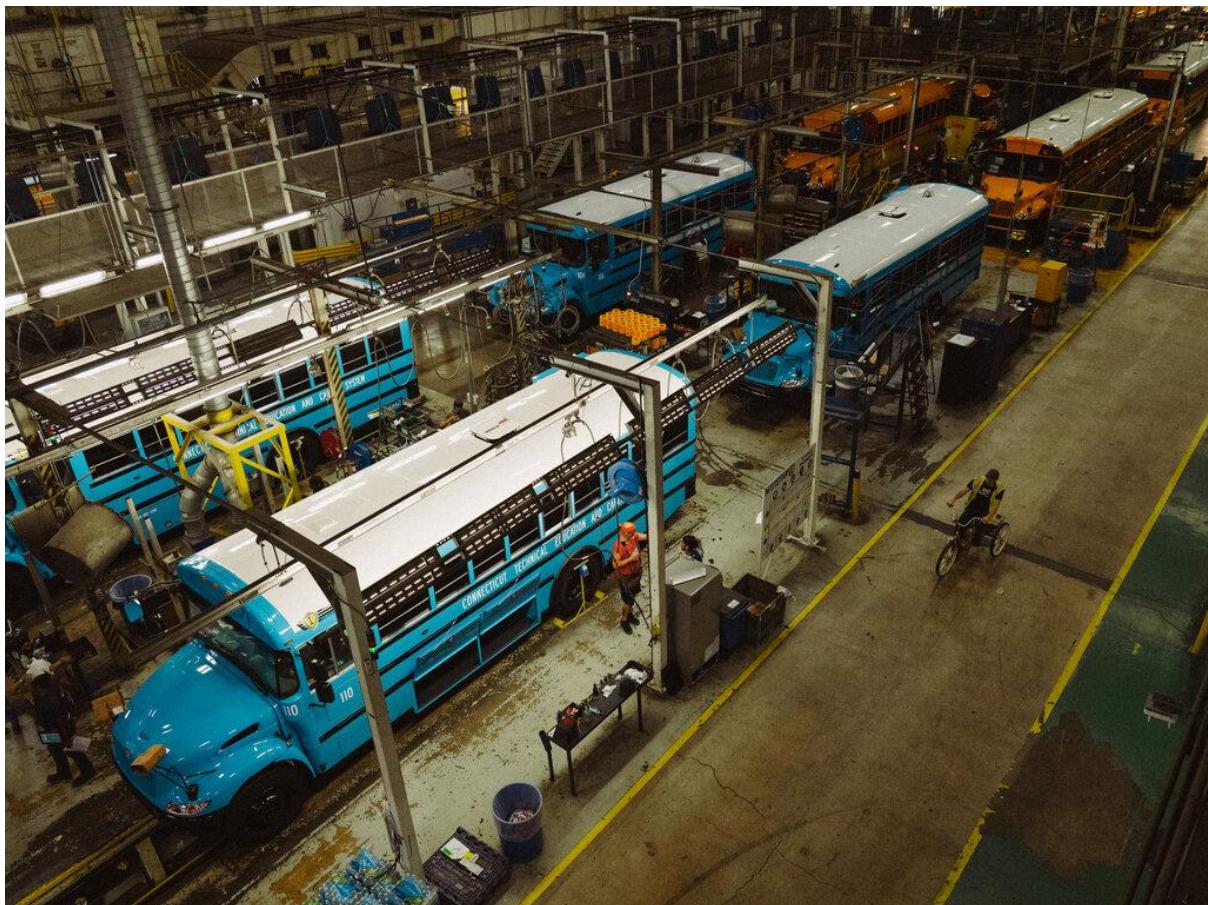
The rapid [drop in costs for solar energy, wind power and batteries](#) can be traced to early government investment and steady improvements over time by hundreds of researchers, engineers and entrepreneurs around the world.

"The world has produced nearly three billion solar panels at this point, and every one of those has been an opportunity for people to try to improve the process," said Gregory Nemet, a solar power expert at the University of Wisconsin-Madison. "And all of those incremental improvements add up to something very dramatic."

An equally potent force, along with the technological advances, has been an influx of money — in particular, a gusher since 2020 of government subsidies.

In the United States, President Biden signed a trio of laws during his first two years in office that allocated unprecedented funds for clean energy: A \$1 trillion bipartisan infrastructure law provided money to enhance the power grid, buy electric buses for schools and build a national network of electric vehicle chargers. The bipartisan CHIPS and Science Act set aside billions of dollars for semiconductors vital to car manufacturing. And the Inflation Reduction Act, which marks its first anniversary on Aug. 16, is by far the most ambitious attempt to fight climate change in American history.







The United States is ramping up its capacity to produce electric vehicles, batteries, solar panels and wind turbines.

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That landmark law provided tax breaks related to electric vehicles, [heat pumps and energy efficiency upgrades](#), solar panel and wind turbine manufacturing and clean hydrogen production. The government is also investing in efforts to capture carbon emissions and store them before they can reach the atmosphere, as well as technology that can remove them directly from the air.

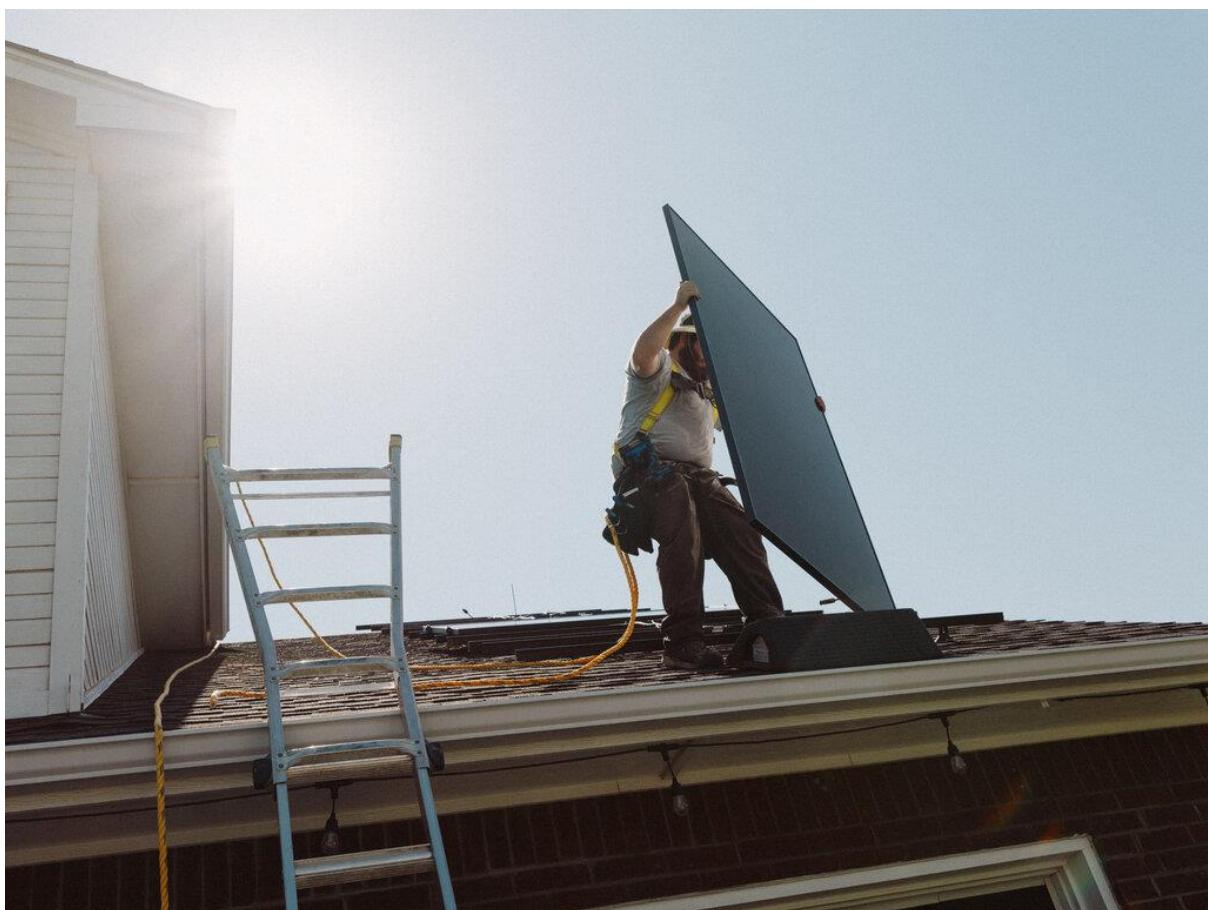
Originally estimated to cost roughly [\\$391 billion between 2022 and 2031](#), the tax breaks are proving so popular with manufacturers and consumers that estimates now put the cost [as high as \\$1.2 trillion](#) over the next decade.

Combined, the three laws have prompted companies to announce [at least \\$230 billion in manufacturing investments](#) so far. In Georgia, a Korean solar manufacturer, Qcells, is building a \$2.5 billion plant. In Nevada, Tesla is building a new \$3.6 billion electric truck factory. And in Oklahoma, the Enel and Canoo facilities are primed to benefit from the Inflation Reduction Act, as is a new \$4.4 billion battery factory being considered by Panasonic, the Japanese conglomerate.

"There's a lot of appetite to invest in the United States thanks to that law," said Giovanni Bertolino, an executive at Enel, adding that the plant his company is building in Tulsa would not exist without the Inflation Reduction Act.

Regulations are also hastening the energy transition. Mr. Biden has proposed tough new federal pollution limits on tailpipes and smokestacks, but several states are acting on their own. California, with market muscle that influences the entire auto industry, plans to halt sales of new gas-powered cars by 2035 and [new diesel-powered trucks](#) by 2036 — and a handful of states are following suit. In May, New York became the [first state to ban gas hookups](#) in most new buildings, requiring all-electric heating and cooking starting in 2026. Several cities, including New York and San Francisco, have similar prohibitions, although some Republican-controlled states have blocked their municipalities from banning gas.

Heavy investment by the United States has [spurred a spirited reaction](#) from other wealthy nations. Countries that initially complained that the United States was unfairly subsidizing clean energy manufacturers have since engaged in a sort of friendly subsidy race.





Clean energy investments are generating thousands of new jobs.

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Canada, South Korea and others have pushed for their companies to have better access to the American incentives, while offering similar subsidies to their domestic manufacturers. After Russia invaded Ukraine last year, the European Union moved to lessen its dependence on Russian oil and gas. In May, for the first time ever, wind and solar power in the E.U. [generated more electricity](#) than fossil fuels.

And in China, which is currently both the world's top polluter and the global leader for renewable power, the government continues to invest in every stage of clean energy production, from solar cells to batteries, wind turbines and more. Like the United States, China provides subsidies to buyers of electric vehicles. Last year it [spent \\$546 billion on clean energy](#), far more than any other country in the world.

With costs falling fast, manufacturing has picked up and installations of solar and wind projects have increased. The U.S. solar industry installed a record 6.1 gigawatts of capacity in the first quarter of 2023, a 47 percent increase over the same period last year.

And those low costs have led many of the United States' biggest corporations, such as Alphabet, Amazon and General Motors, to purchase large amounts of wind and solar power, because it burnishes their reputations and because it makes good economic sense.

"We're seeing the nonlinear change happen before us," said Jon Creyts, chief executive of RMI, a nonprofit organization that promotes the energy transition. "And that's important, because we're facing a climate crisis right now."

'A National Phenomenon'

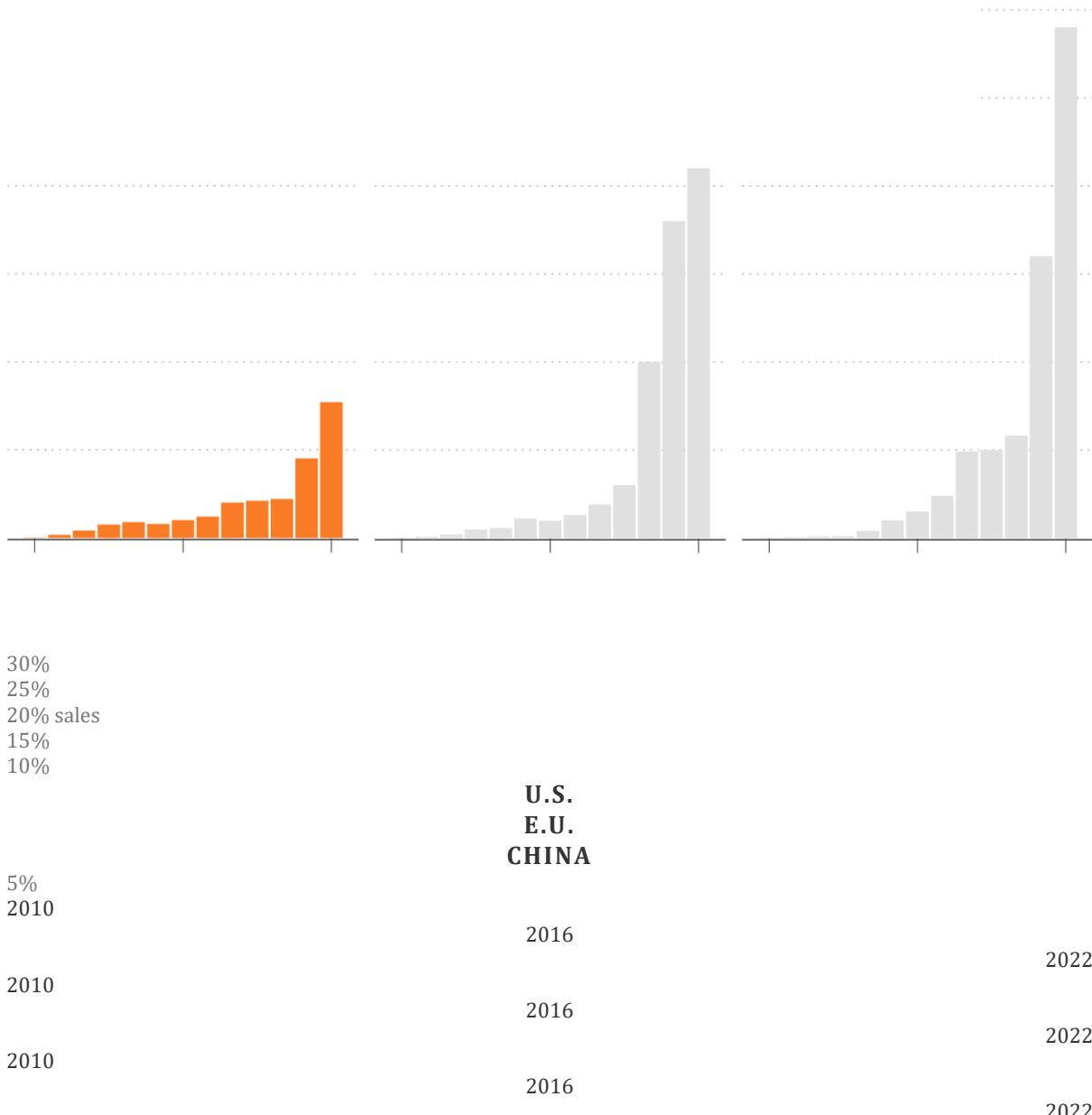
Steve Uerling's Tulsa home is a model of energy efficiency. He replaced all his incandescent light bulbs with LEDs. He installed a heat pump and rooftop solar panels this year. And he drives a plug-in hybrid Ford Fusion and a Tesla Model 3.

Mr. Uerling, a mechanical engineer, said he wanted to see renewable power take off in Oklahoma and was trying to do his part. But he was also driven by his wallet.

"My fuel cost is equivalent to getting 200 miles a gallon on gasoline," he said. "We charge at night, when we get a much cheaper rate on our electricity."

Electric Cars Are Gaining Momentum

Electric models as percentage of total passenger vehicle sales



Source: [International Energy Agency](#)

Note: Sales share of battery electric vehicles excludes plug-in hybrids.

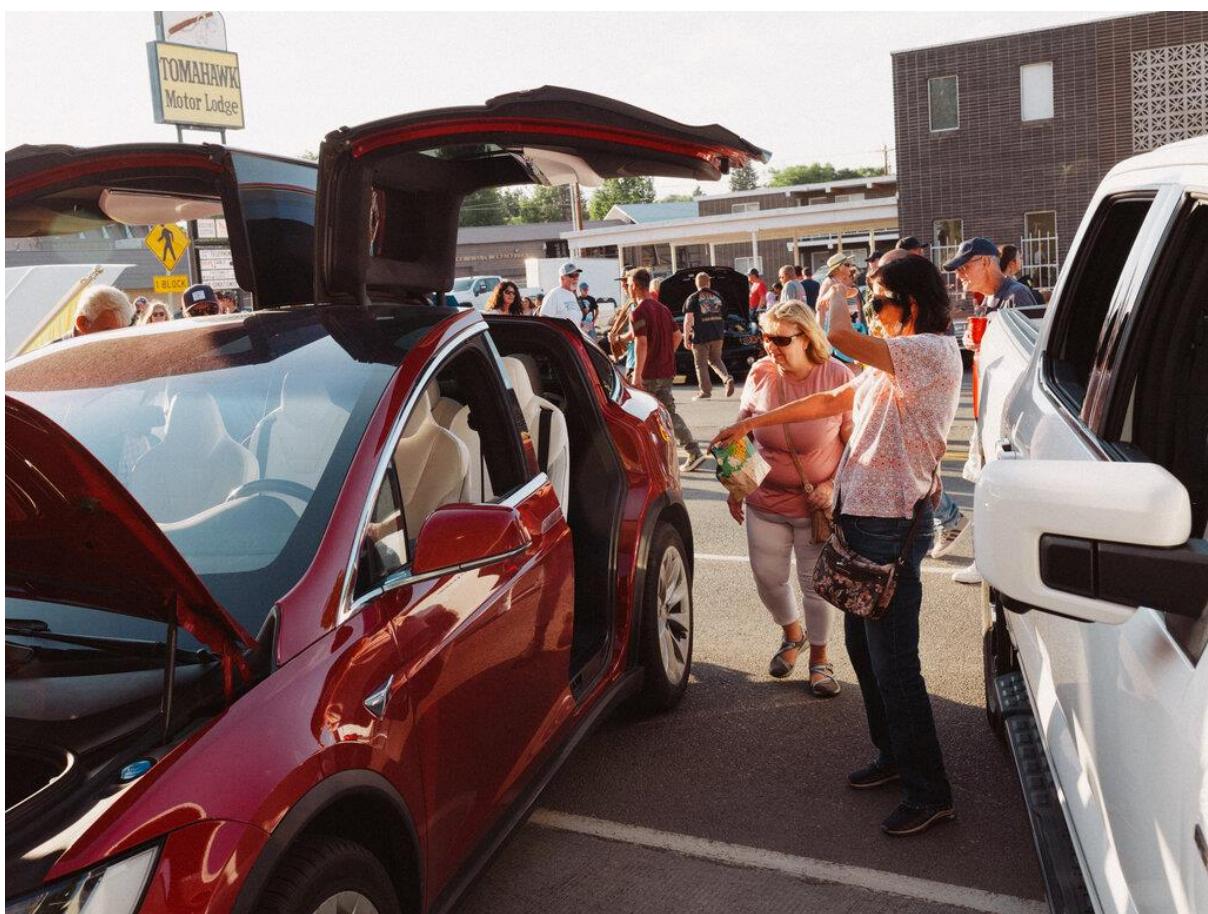
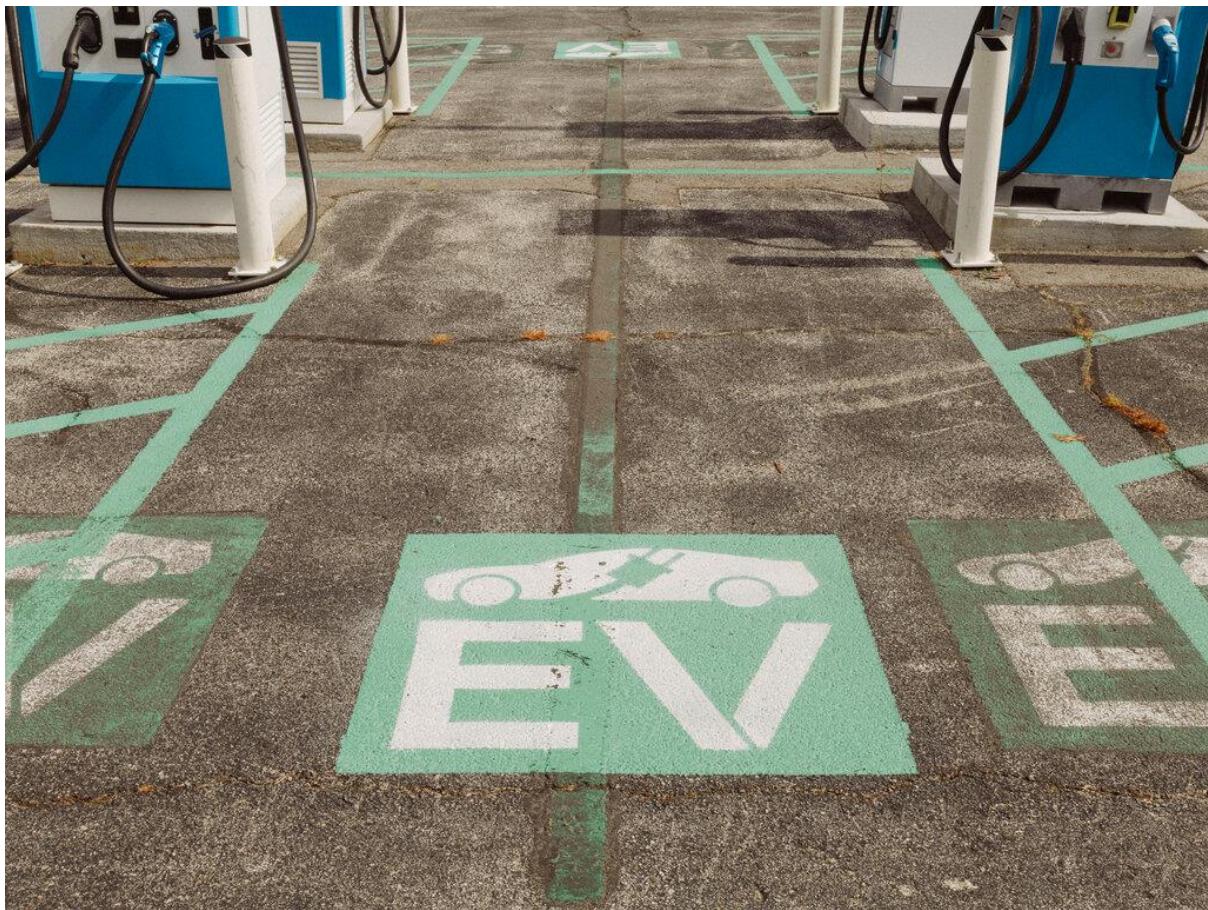
By The New York Times

Millions of people around the country are making similar calculations. Electric vehicles are by far the fastest-growing segment of the auto industry, with record sales of 300,000 in the second quarter of 2023, a 48 percent increase from a year earlier. Teslas are now among the best-selling cars in the country, and Ford has expanded its production of the F-150 Lightning, the electric version of its popular pickup truck, after a surge of initial demand created a waiting list.

Concerns among consumers about the availability of charging stations as well as the cost of some models have helped to cool sales somewhat, [leading some automakers to slash prices](#). Still, federal tax credits of up to \$7,500 have made the least expensive electric vehicles competitive with gas-powered cars. And about two dozen states offer additional tax credits, rebates or reduced fees, further pushing down their cost.

Government action is also helping heavier vehicles go electric. Sales of electric school buses are soaring, largely because of \$5 billion in federal grants that can cover 100 percent of the cost for low-income communities. The Postal Service plans to spend [nearly \\$10 billion to purchase 66,000 electric mail trucks](#) — roughly 30 percent of its fleet — over the next five years.





Electric vehicles sales are growing quickly, but consumers are still concerned about high upfront costs and charging availability.

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In the private sector, Amazon has ordered 100,000 electric delivery trucks from Rivian. Tesla has an electric semitruck, as do several other manufacturers, including Peterbilt.

Companies that provide charging stations are springing up to meet the demand. Francis Energy has more than 400 chargers across Oklahoma and is expanding nationwide. EVgo, which has one of the largest fast-charging networks in the United States, plans to more than double the 3,000 charging stalls it operates.

“It is not a red-state, blue-state thing,” said Cathy Zoi, EVgo’s chief executive. “It is a national phenomenon.”

In an unusual move, seven carmakers — BMW Group, General Motors, Honda, Hyundai, Kia, Mercedes-Benz Group and Stellantis — are spending \$1 billion in a joint venture to build 30,000 charging ports on major highways and other locations in the United States and Canada.

The shift is happening so quickly that some of America’s most iconic automakers are preparing for a world beyond gasoline-powered cars and trucks.

General Motors, which has the largest market share of any carmaker in the United States, has committed to selling only zero-emissions vehicles by 2035. It’s a “once-in-a-generation inflection point” for the 114-year-old automaker, according to Mary Barra, G.M.’s chief executive.

In an interview, Ms. Barra said her company began to consider an all-electric future in 2020. “We started to see this happening with the consumer research we did,” said Ms. Barra, who has subsequently bet billions on G.M.’s efforts to reorient its engineering, overhaul its manufacturing facilities and processes and build new battery plants.

As the cost of batteries comes down, and the number of charging stations nationwide goes up, Ms. Barra expects exponential growth. “I think it’s going to be definitely an upward trajectory,” she said. “It’ll be a little bumpy, but bumpy growing.”